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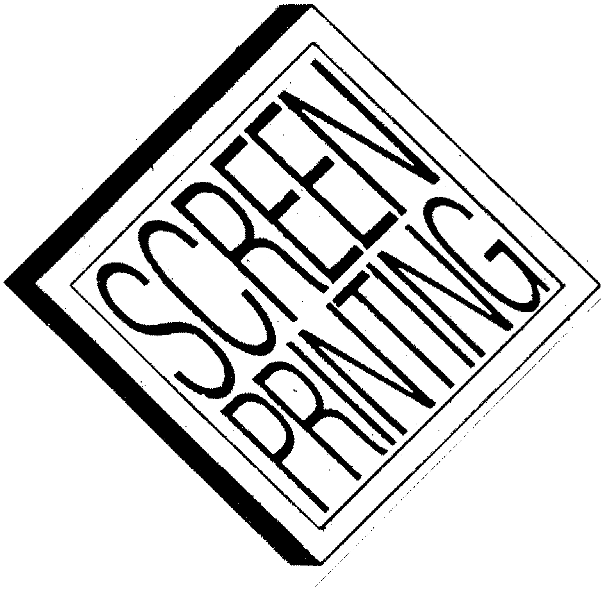
Cleaner Technologies Substitutes Assessment

Industry: Screen Printing

DRAFT Use Cluster: Screen Reclamation



Developed in Cooperation with the Screen Printing Association International and the University of Tennessee Center for Clean Products and Clean Technologies

(2/12/98)

Cleaner Technologies Substitutes Assessment

Executive Summary

Industry: Screen Printing
Use Cluster: Screen Reclamation

United States Environmental Protection Agency
Office of Pollution Prevention and Toxics
Design for the Environment Program

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The performance demonstration was successful due to the voluntary participation and cooperation of the following screen printing facilities. We appreciate your valuable efforts.

Action Graphics, Louisville, KY
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Gillespie Decals Inc., Wilsonville, OR
Identification Products, Bridgeport, CT
Ivey-Seright International, Inc., Seattle, WA
Karagraphic, Kent, WA
Leading Edge Graphics, Minnetonka, MN
M&M Displays Inc., Philadelphia, PA
Masterscreen Products Inc., Portland, OR
Mobius, Inc., Eugene, OR
Modagraphics, Rolling Meadows, IL
Morrison & Burke, Inc., Santa Ana, CA
Nameplate & Panel Technology, Carol Stream, IL
Paramount Screen Printing, Milwaukee, WI
Philadelphia Decal, Philadelphia, PA
Phillips Plastics Co., Fredonia, WI
Quantum Graphics, Redmond, WA
Royal Label, Boston, MA
Screen Process Specialists, Plymouth, WI

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Executive Summary

The Design for the Environment (DfE) Program in EPA's Office of Pollution Prevention and Toxics (OPPT) is a voluntary, cooperative program that works in partnership with industry to develop and distribute pollution prevention and environmental and human health risk information on alternative products, processes, and technologies. The DfE Program develops technical information as well as information products such as case studies, video-conferences, training videos, and software to help industries and the public make cleaner choices in their business practices. All of the technical information developed by industry and the DfE Program is assembled in a document called a Cleaner Technologies Substitutes Assessment (CTSA). The CTSA forms the basis for subsequent information products and serves as a repository for all of the technical information (environmental and human health, exposure and risk, performance, and cost) that is developed in a DfE industry project. In the development of the CTSA, the DfE Program harnesses the expertise for which OPPT is best known: comparative and multi-media risk analysis, methods for evaluating alternatives for risk reduction, and outreach to industry and the public on pollution prevention topics.

The DfE Program uses a new approach to compare the risk, performance and cost trade-offs of alternatives in a decision focused evaluation. The approach evaluates a "use cluster," that is, a set of chemicals, processes and technologies that can substitute for one another in performing a particular function. This method is different from traditional pollution prevention approaches in that it does not focus strictly on waste minimization. Instead, the use cluster approach explicitly arrays alternative chemicals, products and processes allowing comparison of the risk management issues along with performance and cost in a systematic way. During the process of identifying alternatives, attention is focused on finding newer, cleaner substitutes as well as comparing traditional ones.

The DfE Program has been working with the screen printing industry to reduce risk and prevent pollution in the use cluster of screen reclamation. Partners in this effort include the Screen Printing Association International (SPAI) and the University of Tennessee's Center for Clean Products and Clean Technologies. Through a process of collecting information on currently existing screen reclamation alternatives and through a search for other promising options, the DfE Program and the screen printing industry have compared alternative and traditional screen reclamation products, technologies, and processes in terms of environmental and human health exposure and risk, performance, and cost. The results of this comparative assessment are contained in the Screen Reclamation Products Cleaner Technologies Substitutes Assessment.

Specifically, the Cleaner Technologies Substitutes Assessment (CTSA) is an analytical tool developed by the DfE Program for use by industry. The CTSA is intended to provide a flexible format for systematically comparing the trade-off issues associated with a use cluster. In the CTSA, traditional trade-off information such as cost and performance are brought together with environmental trade-off information including comparisons of environmental releases, human health and environmental exposures and risk, energy impacts, and resource conservation. The goal of the CTSA is to offer a complete picture of the environmental and human health impacts, cost and performance issues associated with traditional and alternative products, processes, and technologies so that businesses can make more informed decisions that fit their particular situation. Data contained in the CTSA will be used as the basis for information products designed to reach individual printers and suppliers who may not have the resources to utilize this information on their own.

Structure of the CTSA

The CTSA for Screen Printing Screen Reclamation focuses on the use cluster of screen reclamation. Screen reclamation is a process (to clean a screen a printer must remove the ink, the emulsion, and the haze from the screen) rather than a specific set of chemicals or technologies. Therefore, the CTSA is structured to evaluate screen reclamation systems. Systems typically include combinations of products designed to perform three functions: remove ink, emulsion, and haze and are typically sold as a system (see figure ES-1). Within any given screen reclamation system, the CTSA defines and evaluates the products used in the system and the chemicals that make up the products that are used in that system. The DfE Screen Printing Project has identified five individual methods and technologies through which screen reclamation can be performed.

Profile of Screen Reclamation Use Cluster

To develop comparative information on screen reclamation products and technologies, an array of different kinds of information about the industry is necessary. For example, in order to develop exposure estimates, information about the work practices, the number of employees, the chemicals used by employees, etc., is required. Chapter 1 in the CTSA provides background information, including market information, on the screen printing industry, and the screen reclamation process, in particular. It also describes some of the alternative cleaning technologies that could be applicable to the screen printing industry.

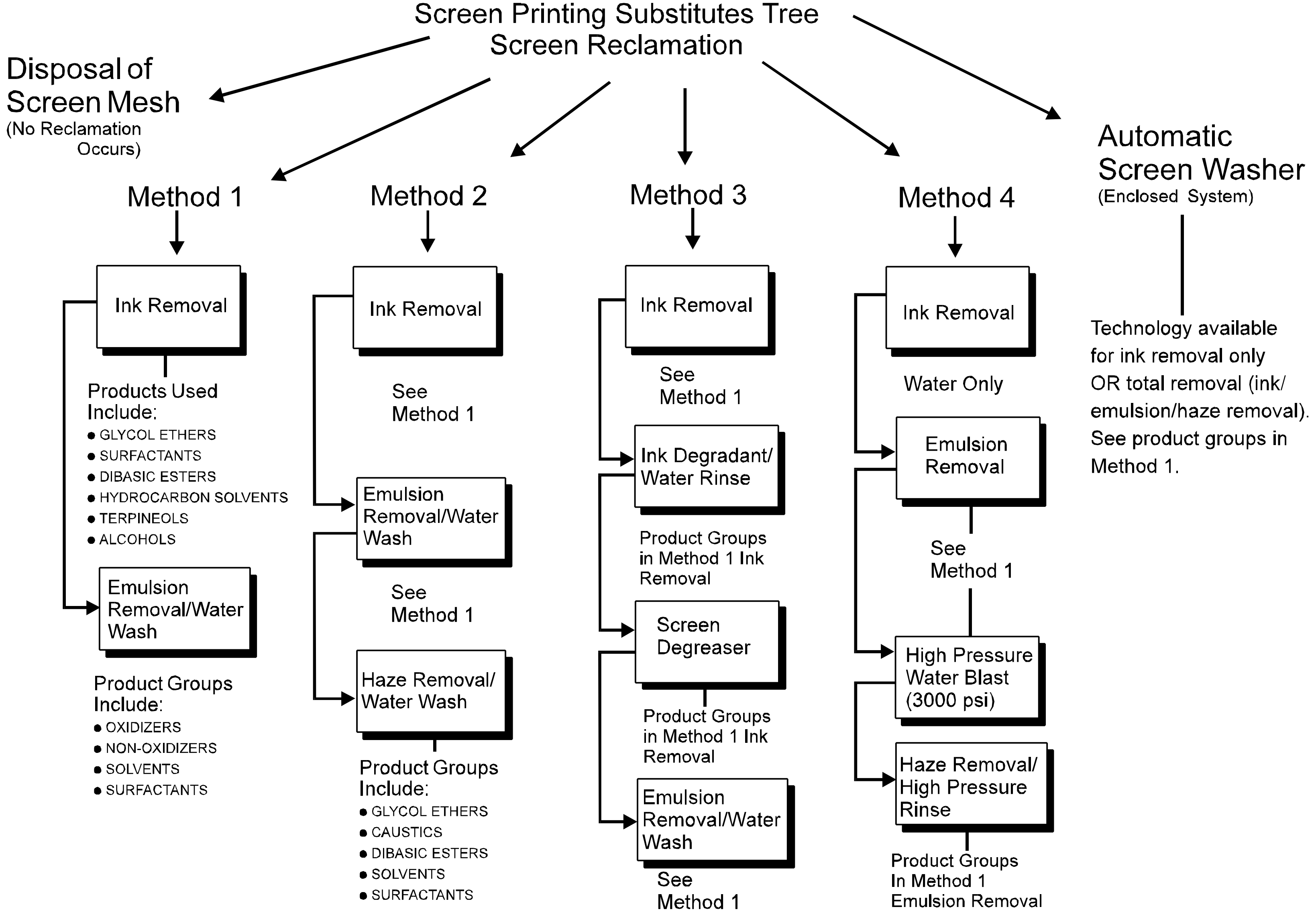
The screen printing industry is characterized by small businesses employing an average of 15 people or fewer. While screen printers can print on a variety of substrates, this effort focuses on the approximately 20,000 facilities who print graphic arts materials, such as fine art prints, billboard advertisements, point-of-purchase displays, posters, plastic banner wall hangings, original equipment manufacturing, and electronic equipment.

The screen printing process involves stretching a porous mesh material over a frame to form a screen. Part of the screen mesh is blocked by a stencil to define the image. A rubber-type blade (squeegee) is swept across the surface of the screen, pressing ink through the uncovered mesh to print the image defined by the stencil. After the screen has been used to print numerous images, it needs to be cleaned for future use. Many screen printing facilities reclaim their screens for reuse because the screen material is valuable and costly to replace. While screen reclamation techniques may vary significantly from one screen printer to another, two basic functions must be performed in order to restore a used screen to a condition where it can be reused: removal of ink and removal of emulsion (stencil). A third step, removing any remaining "ghost image" or haze, may also be required. (See Figure ES-1).

Screen Reclamation Methods

A variety of commercial products have been developed to perform each of these functions and a complementary series of products (e.g., a particular brand of ink remover product, emulsion remover product, and haze remover product) are often sold by manufacturers and distributors as a package. For the purposes of this project, the trade-off issues associated with

Figure ES - 1
Screen Printing Substitutes Tree
Screen Reclamation



a particular product system, consisting of an ink remover, emulsion remover and haze remover, are frequently assessed. Screen printers use these product systems in a variety of methods to reclaim screens.

DfE and SPAI identified five methods of undertaking screen reclamation; these are exhibited in Figure ES-1. Method 1 illustrates how screen reclamation is performed with products from the functional groups of ink removal and emulsion removal only. Under each functional group, some of the categories of chemicals that might be found in these products are listed. Some screen printers may use only products from these functional groups when reclaiming screens. More common among screen printers is the additional use of a haze remover in the screen reclamation process, as depicted in Method 2. Method 3 was developed by technical staff at SPAI and is currently taught at SPAI in workshop classes; it is referred to by the name "SPAI Workshop Process." It differs from Method 1 in that screen degreasers and ink degradants are used in the screen reclamation process. It also differs from Method 2 in that no haze remover is necessary. Method 4 employs both mechanical and chemical technologies to reclaim a screen. The use of a high-pressure water blaster eliminates the need for an ink remover in this method; however, emulsion and haze removers are still used. Method 5 involves the use of an automatic screen washer, an enclosed system that can be used for ink removal only, or as a complete system for screen cleaning.

Alternative Cleaning Processes

Because the Screen Reclamation CTSA is designed to be as comprehensive as possible, it presents information on the fullest consideration of cleaning alternatives. Some of these alternatives may be new or esoteric, others have been used in a cleaning function in other industries and are discussed in the Screen Reclamation CTSA because they may have the potential to be used in screen printing, perhaps with slight modifications. Some of these technologies include blasting methods, stripping methods, and methods that involve pulse light energy. Water-soluble stencils/emulsions also represent a product change that may affect other aspects of the printing and reclamation process (e.g., inks used).

The descriptions of the technologies that are highlighted in the CTSA are not exhaustive, but are intended to promote discussion of the use of potential alternative technologies in the screen reclamation process. Currently, some of these technologies are used in high-tech applications, and may not be economically feasible for the average screen printing establishment. However, further research into these technologies, and their continued development, may result in more cost-effective, easy-to-use applications in the screen printing industry.

One alternative technology evaluated for its potential in screen reclamation was a pressurized baking soda (sodium bicarbonate) spray. The pressurized baking soda spray, when combined with water, could remove solvent and water-based ink from a screen; the spray was ineffective in removing UV-curable ink. Emulsion could also be removed, with only a light haze remaining on the screen. Issues such as potential damage to the screen mesh and cost-effectiveness warrant further investigation, but equipment modifications could make the technology feasible for use in screen reclamation.

Chemical Profiles

Another set of information that is required to complete the comparative analysis of traditional and alternative screen reclamation products and technologies is chemical data. The screen printing industry identified seventy-two chemicals that are in use in screen reclamation. These chemicals comprise the screen reclamation use cluster and range from hydrocarbon solvents and glycol ethers, to surfactants, caustics and oxidizers. Specific information on each chemical was developed to support the risk assessment of screen reclamation products. Each chemical profile includes physical/chemical properties, industrial synthesis, aquatic toxicity, environmental fate, and a hazard summary. The regulatory status of each chemical is also provided as a ready reference, although the discussion of federal environmental regulations is intended for information purposes only and should not be used as a guide for compliance. Market profile information on each chemical, such as total U.S. production and total use in screen reclamation, was also developed. Included in this section is a generic categorization of some of the screen reclamation chemicals; this was developed in order to protect the proprietary nature of the alternative screen reclamation products submitted by manufacturers.

Methodologies

Because the Screen Reclamation CTSA is the DfE Program's first CTSA and will serve as a model for CTSA's developed for other DfE industry projects, it presents a full discussion of the methodologies that are used to develop the comparative environmental and human health risk information. The methodologies presented include: Environmental Releases and Occupational Exposure Assessment, Population Exposure Assessment, Risk Assessment, Performance Demonstration, Screen Reclamation Chemical Usage, and Cost Analysis. By presenting this information in its entirety, the DfE Program hopes to make the evaluation process completely visible so that others will be able to conduct some of these analyses independently.

Most of the methodologies that are applied in this analysis are standard methodologies that the Office of Pollution Prevention and Toxics' (OPPT) Existing Chemicals Program uses, except for the Performance Demonstration, Chemical Usage, and the Cost Analysis Methodologies that will be discussed in more detail later in this section. The human health hazard information was drawn from both literature searches and from public databases such as the Integrated Risk Information System (IRIS). Hazard information including carcinogenicity, chronic health hazard and developmental toxicity was compiled when available. Aquatic toxicity data were taken from literature when available but otherwise structure activity relationships were used to estimate six types of aquatic toxicity. Release and exposure estimates were based on values derived from product usage and work practices information obtained from the Workplace Practices Questionnaire completed as part of the DfE project as well as industry sources.

Performance Demonstration Methodology

To collect performance and cost information on alternative screen reclamation products, EPA's Office of Research and Development and the DfE Program conducted a demonstration of the performance of alternative screen reclamation products.
This type of analysis is not usually part of the work done by the Office of Pollution Prevention and Toxics' Existing Chemicals Program. The performance demonstration methodology summarizes how performance information was collected during both laboratory and production run demonstrations with alternative screen reclamation products. The methodology was developed jointly by EPA, screen printers, and product manufacturers and it governs the demonstration of products in the laboratory and in the field.

Performance data were collected for 11 alternative screen reclamation product systems and one alternative technology. First, performance data were collected for the alternative product systems in a laboratory setting at The Screen Printing Technical Foundation (SPTF). Then, in thirty-day production runs at 23 volunteer facilities field performance information was collected on alternative screen reclamation systems, including information on the time spent on ink removal, volume of products used, and appearance of the screen following each step in the reclamation process. It should be noted that the performance demonstrations are not rigorous scientific investigations. Instead, a large portion of the performance information outlinesthe printers' experiences with and opinions of these products as they were used in production runs at their facilities. The DfE Program will be developing four performance demonstration case studies for distribution to industry based on the more effective demonstrations.

Chemical Usage Methodology

Since there was no resource available providing specific screen reclamation chemical volumes or cost information, the DfE Program worked with industry to develop techniques to estimate both the chemical volume and basic cost information for the methods evaluated. Chemical volume information is necessary to complete both the cumulative exposure estimates and the basic cost comparisons.

The methodology for determining chemical usage summarizes the assumptions and calculations used to estimate the annual national totals of chemicals used in screen reclamation. *The Use Cluster Analysis of the Printing Industry* and The Workplace Practices Questionnaire for Screen Printers developed as part of the DfE Printing Project, the *Screen Printing Association International 1990 Industry Profile Study* and expert opinion estimates, were used to develop an estimate of the chemical volumes. The information needed to develop the estimates included the average screen size, the per screen volume of each type of reclamation product, market shares, the number of screens cleaned yearly, and the number of screen printing operations. The screen size, in conjunction with the amount of product used or purchased and the number of screens cleaned, was used to determine the per screen product usage. Typical formulations were then used to determine the chemical breakdown of the reclamation products. Combining this information resulted in estimates of the volumes for each of the chemicals involved in screen reclamation.

Cost Analysis Methodology

A cost methodology was developed to estimate the costs of baseline screen reclamation, as well as the cost of six alternative chemical, technological and work practice substitutes. The cost estimation methodology is intended to reflect standard industry practices and uses representative data for the given screen reclamation substitutes. For each substitute method, annual facility costs and per screen costs were estimated for individual facilities (those involved in the performance demonstrations) whose operations were characteristic of the given substitute method. For the hypothetical baseline facility, the total annual cost and per screen cost were estimated for reclaiming six screens (2,127 in^2 or 14.7 ft^2) per day. In addition, each facility's costs were normalized to allow cross-facility comparisons, particularly with the baseline scenario. Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario.

Functional Groups in Screen Reclamation

The Screen Reclamation CTSA devotes two chapters to the subject of comparative risk. Chapter 4, focuses on screen reclamation *products*, while Chapter 5 focuses on screen reclamation *systems*. Chapter 4 presents cost and risk information by functional group (i.e., different ink removal product formulations) where the products evaluated might be simply substituted for one another. The evaluations in Chapter 5 focus on systems of products comparing both the formulations of the products within those systems and the changes in the methods used to clean screens.

In Chapter 4, information on the characteristics associated with each of the ink remover, emulsion remover and haze remover products is presented in a format that would allow comparison of several types of products within each functional group. For example, 13 different formulations were evaluated for ink removers.

For each type of product (ink removers, emulsion removers and haze removers), several pieces of information are provided: chemical properties (flash point, percent VOC, vapor pressure), hazard summary (health effects description and aquatic hazard rankings), purchase cost, occupational exposures and risk conclusions, environmental releases and population exposure conclusions. A process safety hazard evaluation was not included but could be an important consideration. For example, when substituting one product for another to avoid a health concern, the new product might have fire hazard issues. A safety hazard evaluation should be included in future CTSAs.

Information on total cost and product performance is not provided on product basis but rather on a system basis. These products are typically sold as a system and more complete cost and performance information is provided in Chapter 5 where systems of products are evaluated.

One of the more important inputs required to conduct a comparative risk assessment is product chemical formulation information. Since EPA is not developing specifications or labeling standards for products, the DfE Screen Printing Project did not believe it was necessary to give product names or to release proprietary formulation information to other product manufacturers or to the public. To make the CTSA usable and flexible, the DfE Program, in conjunction with the screen printing manufacturers and the Screen Printing Association International devised a standard format that includes generic product formulations and product names. The generic formulations and names allow the users of the CTSA to compare chemical constituents in product systems in a range of volumes while protecting the proprietary nature of the product formulations. Therefore, the chemical formulations for the products in the functional groups are not all-inclusive and other formulations may be available commercially.

Substitute Comparative Assessment of Screen Reclamation Systems

Chapter 5 in the CTSA compiles comparative risk, cost and performance data on complete screen reclamation product systems. This comprehensive assessment details four screen reclamation methods and the automatic screen washer and serves as the backbone of the CTSA. Information is provided for each method and technology on occupational exposure and risk, population exposure and risk, performance of traditional and alternative systems, and the analysis of cost of traditional and alternative product systems when available. Table ES-1 summarizes the cost and risk trade-offs for the methods evaluated.

Method 1

Method 1 encompasses the use of only ink removal and emulsion removal products to reclaim screens. The action of these two products can eliminate the use of a haze remover; some screen printers are able to reclaim screens without the need for a haze remover. Eliminating the haze remover achieves the highest priority in the pollution prevention hierarchy, source reduction. Six systems were assessed that can be used with this method. Many of these systems can also be used with a haze remover and are also included under method 2.

Method 2

In a typical screen printing facility, ink remover, emulsion remover and haze remover are all used in the process of screen reclamation. Method 2 incorporates the most common practices in screen reclamation. For the purposes of determining occupational exposure to the haze remover, it was assumed that screen reclaimers only used haze remover on 1-2 screens of the estimated six screens reclaimed daily in the average small/medium screen printing facility. Because Method 2 is the most representative of current screen reclamation practices, 14 systems are assessed that use this method including four traditional systems and ten alternative systems.

Method 3

Method 3 was developed by technical staff at SPAI and is currently taught at SPAI in workshop classes; it is referred to by the name "SPAI Workshop Process." It differs from Method 1 in that screen degreasers and ink degradants are used in the screen reclamation process. Method 3 also differs from Method 2 in that no haze remover is necessary. Technical staff at SPAI developed this method specifically to avoid the use of haze removers, which can damage the screen meshes well as contribute to human health and environmental risks. Only one system was assessed using this method. Due to resource limitations, no performance demonstration was completed for this method. However a cost assessment was completed and issummarized table ES-1.

Method 4

Method 4 is currently in use in screen printing facilities as an alternative to traditional screen reclamation. Method 4 utilizes the action of a high-pressure water blaster (3000 psi) so that the need for ink removal chemicals is eliminated. Emulsion and haze remover chemicals are still applied to the screen, and the water blaster also aids in removal of stencil and haze. Because an ink remover is not used in screen reclamation in Method 4, source reduction, the highest priority in the pollution prevention hierarchy, is achieved. Again, only one system was evaluated using this method.

Automatic Screen Washer

Automatic screen washers are commercially available technologies that remove ink, or in some cases, ink, emulsion and haze, by focusing appropriate reclamation products on a screen mesh surface within a fully enclosed unit. The system can be selective, in that it can be used to remove ink only, or to completely reclaim screens. These units employ facets of the washout booth, pressurized sprayer/applicator, and filtration system to effectively remove ink. Because these systems have a fully enclosed cleaning area, the amount of occupational exposure to the chemical reclamation system in use can be minimized if used properly.

Due to the lack of manufacturer participation, the demonstration of the performance of an automatic screen washer was not undertaken. However, a risk assessment was developed for an automatic screen washing system used by a facility that participated in the performance demonstration; this screen washer only removed ink. Experimental parameters used in the occupational exposure and population exposure calculations were drawn from the data available from this single site. The risk assessment could not be undertaken for the actual solvents used in the screen washer as the composition of the ink remover was unknown. Instead, two typical ink remover formulations were substituted to complete the assessment of releases and risk. Also two cost estimates were developed to reflect different facility operations and size. One estimate reflects a large enclosed system with automated movement of screens through the cleaning process. The other estimate was conducted for a smaller piece of equipment requiring manual loading and unloading of screens, as well as water rinsing of residual ink remover.

Screen Disposal as a Method of Pollution Prevention

During the course of the assessment of various screen reclamation methods, it was proposed that disposal of imaged screens, rather than reclamation might be a feasible alternative. It was known that some screen printers with long production runs and extremely small screens, such as those used to print on medicine bottles, simply cut the screen mesh out of the frame after completion of the production run. By simply disposing of the screens, printers could eliminate the high cost of reclamation chemicals and labor time associated with screen reclamation, as well as reduce the risk associated with occupational and population exposure to these chemicals. Conversely, printers would have to dispose of more screens, with the potential for some screens to be designated as hazardous waste due to the chemicals applied to them during imaging and printing. Due to the different types of source reduction involved in these two options, they are difficult to directly compare in terms of pollution prevention. To determine whether screen disposal was a cost-effective option, a cost estimate was developed to reflect the baseline facility's operations and size. It was estimated that the total cost per year of disposing of the screens, instead of reclaiming them, would be $74,141. The baseline cost of reclaiming screens for a year was estimated at $9,399. Based on this analysis, it is clear that screen disposal is not a cost-effective option for a majority of screen printing facilities. However, printers should not view this cost estimate as a final analysis, because the operations of any one facility can be different from the assumptions used in generating this analysis. It should be noted that screen disposal would be more cost-effective under two circumstances that were not included in the baseline facility estimates: where production runs approach the useful life of a screen and where the size of the screen is relatively small.

Summary of Risk Conclusions

The general conclusions for estimated risks from screen reclamation are outlined below. As presented, the risk conclusions are for all of the methods, unless stated otherwise.

- Estimated worker dermal exposures to traditional and alternative screen reclamation products can be high if proper protective clothing is not worn.
- All of the traditional products presented clear concerns for both inhalation exposures and unprotected dermal exposures to workers.
- Only one of the alternative products (mu) presented a clear concern for inhalation exposures to workers. In general, the alternative products are much less volatile than the traditional products, and, therefore, have fewer releases to air.
- Health risks to the general population from ambient air and drinking water exposures are estimated to be very low for all of the products evaluated due to low quantities of releases from individual sites.
- The major health impact on the general population for screen reclamation products is probably its release of volatile organic compounds that contribute to the formation of photochemical smog in the ambient air. The traditional products, because of their volatility, are likely to have a much greater impact than the alternative products on ambient air quality.
- Use of an automatic screen washer for ink removal may significantly reduce air emissions of certain volatile ink remover components, although the amount of reduction depends on the specific components of the formulation. However, the automatic screen washer is expensive and is probably unaffordable for most screen printers.

Performance and Cost Summary

In Chapter 5, immediately following the risk assessment of each product system, is a detailed performance summary. It includes a general summary of product performance, a description of the product application method, results from the evaluation at the Screen Printing Technical Foundations (SPTF), details of product performance reported separately for each volunteer printing facility, and facility background information. For each product system, a table is also included which provides certain summary statistics from the performance demonstrations at the volunteer printing facilities and at SPTF (for three ink types). For a quick summary of the results, the table providing summary statistics (Chapter 5) is very helpful.

In general, the alternative products performed similarly to traditional products but with generally lower costs and generally more risk reduction than the traditional products. Three systems/technologies consistently met the expectations of printers: Epsilon, Chi and Theta. Delta, Mu and Phi also received mostly favorable reviews. Product Systems Alpha and Omicron AF, as well as ink remover Beta, received mixed reviews, with performance documented as acceptable at some facilities and unacceptable at others. Performance of Gamma, Omicron AE, and Zeta was deemed unacceptable at the facilities that used these product systems. A performance assessment of one traditional system, Traditional System 3, was also conducted; this evaluation was only completed at SPTF. The performance of the products varied greatly with the different ink types; the lacquer thinner removed the ink on screens printed with UV-curable and solvent-based inks, but was completely incompatible with water-based ink. In the case of the screen printed with solvent-based ink, the sodium hypochlorite (bleach) solution used as an emulsion remover caused the screen mesh to rip.

Table ES-1 summarizes the cost and hazard issues by method and system for the alternative systems. Summaries for the baseline method used in the cost estimates is given followed by the four major methods of screen reclamation, automatic screen washer and simple disposal of the screens without reclamation. Within the four primary screen reclamation methods the various systems that can be used with those methods (e.g., alpha, chi, delta, etc.) are listed with the cost and risk summaries. This table presents summaries only, for a more complete description of the costs and exposure and hazard issues consult Chapter 5.

Overall Pollution Prevention Opportunities in Screen Reclamation

Pollution prevention, or source reduction, is the reduction of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment. Pollution prevention can be accomplished through activities such as material substitution, process improvements, changes in workplace practices and in-process recycling. The primary focus of the CTSA through Chapter 5 is on material substitution, Chapter 6 lists ways to achieve pollution prevention and risk reduction through improved workplace practices and equipment modifications.

Pollution Prevention Through Improved Workplace Practices

In an effort to help industry think of pollution prevention options that might be available to them and that do not require changing chemical products, the Screen Reclamation CTSA provides information on improved workplace practices. The basic framework for pollution prevention through improved workplace practices involves:

- raising employee awareness;
- materials management and inventory control;
- process improvement; and
- periodic, in-house audits.

Table ES-1
Costs and Risk Trade-offs of Screen Reclamation Substitutes

System Evaluated		Cost/Screen	Cost/Facility	Risk Trade-offs
Baseline for Method 1 (Traditional System 4 - Haze Remover)		$3.63	$5,446	Clear concern for worker dermal risks and worker inhalation risks
Method 1: Chemical substitutes for ink removal and emulsion removal. No haze removal required.	Chi (no haze remover)	$1.95-2.83	$2,918-4,245	Moderate concern for worker dermal risks and very low concern for inhalation risks
	Beta	$7.97	$11,958	
Baseline for All Other Methods (Traditional System 4)		$6.27	$9,399	Clear concern for worker dermal risks and worker inhalation risks
Method 2: Chemical substitutes for ink removal, emulsion removal and haze removal.	Alpha	$5.92-9.37	$8,886-14,062	Moderate concern for worker dermal risks and low concern for inhalation risks
	Chi	$3.25-3.89	$4,879-5,829	
	Delta	$3.28-7.66	$4,917-11,489	
	Epsilon	$3.08-5.29	$4,624-7,930	
	Gamma	$5.06-5.61	$7,590-8,417	
	Mu	$4.79-9.33	$7,185-13,997	
	Phi	$6.10-7.82	$9,233-11,728	
	Omicron-AE	$5.49-10.85	$8,240-16,278	
	Omicron-AF	$3.89-4.45	$5,836-6,675	
	Zeta	$5.39-8.99	$8,080-13,479	
Method 3: Chemical substitutes for ink removal, degreasing and emulsion removal. No haze removal required.	Omicron	$5.57	$8,358	Moderate concern for worker dermal risks and very low concern for inhalation risks
Method 4: Technology substitute of screen disposal in lieu of reclamation.	Theta	$4.53	$6,797	Marginal concerns for worker dermal risks and very low concerns for worker inhalation risks
Technology Substitute	Automatic Screen Washer	$4.13-10.14	6,198-15,213	Moderate concern for worker dermal risks and very low concern for inhalation risks
Work Practice Substitute	Screen Disposal	$49.43	$74,141	No risks associated with screen reclamation products

Note: Costs presented are normalized costs. Ranges are presented when there was more than one facility using the method and system in the performance demonstration.

Raising employee awareness may be the best way to get employees to actively participate in a pollution prevention program. Materials management and inventory control means understanding how chemicals and materials. With this information opportunities for pollution prevention can be identified. Process improvement through workplace practices requires re-evaluating the day-to-day operations that make up the printing and screen reclamation processes with the goal of waste minimization and pollution prevention. Finally, in-house audits can be used to collect real-time data on the effectiveness of a pollution prevention program. These efforts can give both operators and managers the incentive to strive for continuous improvement. Table ES-2 lists some workplace practices that prevent pollution and describes the benefits associated with them.

Pollution Prevention Through Equipment Modifications

In addition to workplace practices, several types of equipment can be used in screen reclamation to prevent pollution. Such equipment includes sprayer/applicator systems, washout booths, filtration systems, recirculation systems and distillation units. Illustrative examples of each of these systems, as well as explanatory text, are outlined in Chapter 6 of the CTSA.

The use of sprayer/application systems to apply screen reclamation chemicals to the used screen may reduce losses and potential exposures with more effective application. A washout booth can also minimize exposures and waste by containing the reclamation process in a confined area and collecting spent chemicals for proper reuse or disposal. Filtration systems can be used to remove specific substances from the waste stream facilitating compliance and allowing the reuse of some chemicals. Recirculation systems are generally required to reuse captured chemicals. Typically, recirculation systems are used in conjunction with filtration systems, washout booths and/or sprayer application systems. Distillation devices can provide an effective means of recycling and reusing spent solvents.

Many of these systems can save money as well as facilitate compliance and prevent pollution by reducing the amount of chemicals used in screen reclamation. Each printer would need to examine his or her particular process to determine the applicability of any or all of the above equipment modifications. In addition printers should consult applicable water and waste disposal regulations to ensure compliance before making equipment changes.

Social Cost/Benefits of Alternative Screen Reclamation Processes

A summary of various macroeconomic considerations, including energy and natural resource considerations and a social costs/benefits analysis complete the Screen Reclamation CTSA. These considerations allow printers to put into perspective their contributions to environmental problems by discussing the aggregate impact issues.

Table ES-2: Workplace Practices and Their Benefits

Workplace Practices	Benefits
Keep chemicals in safety cans or covered containers between uses	Reduces materials loss; increases worker safety; reduces worker exposure
Use plunger cans, squeeze bottles or specialized spraying equipment to apply chemicals to the screen	Reduces potential for accidental spills; reduces materials use; reduces worker exposure
Consider manual, spot-application of chemicals, where applicable	Reduces materials use; reduces worker exposure if aerosol mists are avoided
Use a pump to transfer cleaning solutions from large containers to the smaller containers used at the work station	Reduces potential for accidental spills; reduces worker exposure
Reduce the size of the towel or wipe used during clean-up	More efficient use of the towel; reduces solvent use; reduces worker exposure
Reuse shop towels on the first pass with ink remover	Reduces material (shop towel and ink remover) use; reduces worker exposure
Evaluate alternative chemical: water dilution ratios (increase the amount of water)	Reduces chemical usage with no loss of efficiency; reduced worker exposure
Only apply chemicals where necessary	Reduces chemical usage; reduces worker exposure
Avoid delays in cleaning and reclaiming the screen	Simplify ink and emulsion removal; less potential for haze on the screen
Gravity-drain, wring, or centrifuge excess solvent from rags	Recovers solvent for reuse
Place catch basins around the screen during the screen cleaning/reclamation process	Captures chemical overspray for recovery and reuse
Use appropriate personal protective equipment (gloves, barrier cream, respirator, etc.)	Reduces worker exposure

Energy and Natural Resource Considerations

When designing products or processes with the environment in mind, conservation of energy and natural resources (e.g., materials) should also be a goal. The Screen Reclamation CTSA identifies the areas where energy and materials are consumed as a result of the screen reclamation process. For screen cleaning and reclamation chemicals, the DfE Screen Printing Project elected to focus on energy and natural resource consumption during the use stage, when printers are actually cleaning and reclaiming their screens. The data collected during the performance demonstration did not allow for clearcut extrapolation because of the variety of conditions present in screen printing shops. As a result, quantitative analysis was not possible. Summarized below are some of the areas where energy and natural resources may be consumed as a result of the screen reclamation process.

- ○ During a water wash, the rate of energy use may be dependent on type of equipment used to apply the water. High-pressure spray washes may require more energy than a non-pressurized water wash.

- ○ Also during a water wash, the use of hot or warm water washes are much more energy intensive than those conducted at ambient water temperatures.

- ○ Another source of resource consumption is disposable shop towels. In addition to the consumption of resources, they also generate solid, potentially hazardous, waste and increased disposal cost.

Social Costs/Benefits Analysis

There are a variety of issues that need to be considered when assessing the overall cost to society that screen reclamation imposes. Many of the issues cannot be quantified but they ought to be included in the decision-making process. The social cost/benefits section in the Screen Reclamation CTSA offers a qualitative discussion of these issues.

The risk assessment conducted as a part of the CTSA analyzed the risk of both traditional and alternative screen reclamation systems using four different methods. Automatic screen washing and simple disposal of the used screens was also examined. A cost analysis was performed to estimate the cost of each alternative screen reclamation method, technology, and work practice evaluated in the CTSA. The social cost/benefits analysis compares in general terms the costs and benefits (in terms of reduced human health risks) of switching to alternative screen reclamation products, technologies, and work practices. In addition, this analysis looks beyond just the costs (material, labor, etc.) and benefits (reduced worker health risks) to printing operations of switching to alternative product systems and considers the potential for benefits to society as a whole. Specifically, it considers the possibility that the use of screen reclamation substitutes could result in reduced health risks to the general population, lower health insurance and liability costs for the printing industry and society, and decreased adverse impacts to the environment. Based on this analysis, the following conclusions were drawn.

- ○ The population of workers exposed to screen reclamation products in the graphics section of the screen printing industry is estimated to be as low as 20,000 or as high as 60,000 depending on how many workers at each facility spend part of their time reclaiming screens.

- ○ The major benefit identified for switching from traditional screen reclamation methods to alternative methods is a significant reduction in inhalation risks to workers.

- ○ Among the chemical substitutes evaluated, labor was the largest portion of the reclamation cost. For the technology and work practice substitutes, equipment and materials constituted the largest portion of the reclamation cost. Alternative products, however, did not necessarily have greater labor costs as compared to traditional products. Rather the labor costs tended to depend on the mix of chemicals and technologies (i.e., high pressure sprays) selected.

- ○ The estimated cost associated with using the baseline traditional screen reclamation system equaled $3.63/screen for method 1 and $6.27/screen for all other methods.

- ○ Under the alternative systems, estimated costs range from $1.95/screen ($2,918 per year) for Method 1 to $10.85/screen (Omicron-AE, Method 2).

- ○ For all systems overall, alternative products are estimated to be less costly than traditional systems depending on the technologies used (see table ES-1).

- ○ The social benefit of switching to alternative screen reclamation products includes the benefit to society of reduced risk from exposure to such hazardous wastes during transport to landfills and in the event of migration of contaminants from the landfill into groundwater. Printers may also receive benefits in the form of reduced hazardous waste disposal costs since for most of the alternative product systems, there might not be any hazardous waste. It should be noted that determination of hazardous wastes was based on ignitability of chemical constituents; toxicity testing could result in a different classification of the wastes as hazardous.

A more complete discussion of the social costs and benefits is included in Chapter 7 of the CTSA.

Conclusion

The appendices include a glossary of terms used in the environmental fate summaries. Also included is a sample questionnaire from the Workplace Practices Questionnaire and the basic results of the survey. The evaluation sheets for both the observers and the participants in the performance demonstration are also included. Finally, general methodology data and a description of some of the models used are included in the appendices.

The draft of the Screen Reclamation Cleaner Technologies Substitutes Assessment is being released for public review and comment for 90 days. After which, comments will be incorporated and a final version of the Cleaner Technologies Substitutes Assessment will be released in the spring of 1995.

Chapter I
Profile of Screen Reclamation Use Cluster

Profile of Screen Printing

Overview of Screen Printing

Screen printing is probably the most versatile of the printing techniques, since it can place relatively heavy deposits of ink onto practically any type of surface with few limitations on the size and shape of the object being printed. The ability to print variable thicknesses of ink with a high quantity of pigment allows for brilliant colors, back lighting effects, and durable products which are able to withstand harsh outdoor weather conditions and laundering. Unlike many other printing methods, substrates for screen printing can include all types of plastics, fabric, metals, papers, as well as exotic substrates such as leather, masonite, glass, ceramics, wood, and electronic circuit boards.[1] While screen printing does compete with other printing techniques for some products (especially for small paper substrate products), it has a specialized market niche for many graphic art materials and textile printing applications. Comparatively low equipment investment costs allow for low cost short production runs.

The screen printing process involves stretching a porous mesh material over a frame to form a screen. Part of the screen mesh is blocked by a stencil to define the image. A rubber-type blade (squeegee) is swept across the surface of the screen, pressing ink through the uncovered mesh to print the image defined by the stencil. The substrate is then either manually placed onto drying racks or placed onto a conveyor transport system for conveyance into a drying unit. The screen and its stencil can be used repeatedly to print the same image multiple times.

The screen printing process differs in many ways from the other printing methods of lithography, gravure, flexography, and letterpress. Because screen printing utilizes various materials in a printing process that differs greatly from other printing methods, it presents environmental challenges that are unique in the printing industry.

Products Printed

The majority of screen printers do not restrict their operations to printing on one substrate or to the production of one end product. Textile products, however, are the most common products in production. Surveys conducted by the Screen Printing Association International (SPAI) show that approximately 54 percent of screen printers produce imprinted textile garments.[2] Perhaps the most well known example is T-shirts. Textile printing also includes the markings and patterns on towels, comforters, caps, visors, aprons, drapes, carpet, sheets, flags, and the basic patterned material that is made into pants, dresses, and other clothing.

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[1] Types of plastics used as substrates include acrylic, epoxies, vinyl, topcoated and nontopcoated polyester, and polycarbonate, while fabric substrates can be either natural or synthetic. Metals used as substrates include aluminum, brass, copper, lacquer-coated metals and steels. Paper substrates range from uncoated, coated and corrugated coated fiberboard to poster and cardboard.

[2] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 9.

Another major category of screen printed products includes graphic arts materials with products as diverse as fine art prints, billboard advertisements, point-of-purchase displays (such as those displayed in supermarkets), posters, plastic banner wallhangings, wallpaper, and decals. Large banners, durable outdoor displays, and short poster runs are specialty products of many commercial screen printing establishments.

Other applications include original equipment manufacturing (for example, the soft keypad on cash registers at some fast food restaurants or the heating controls in a car), printing on electronic equipment such as circuit boards, and product identification markings on products like wine bottles, fire extinguishers, cosmetic compact covers, insulated beverage and food containers, and aerosol spray cans.

Market Information on the Screen Printing Industry

Number of Screen Printing Facilities

The number of American screen printers and the quantity of their sales is difficult to determine because parts of the screen printing industry are "captive in-plant screen departments" within a separate manufacturing industry. For example, one step in toothpaste production is screen printing product identification markings on the tube.

There are three major categories of screen printing facilities:

- ○ Commercial Screen Printing Facilities (garments, signs, posters, decals, etc.)
- ○ Industrial Screen Printing Facilities (panel fronts, circuits, glassware, original equipment, etc.)
- ○ In-Plant (Captive) Screen Printing Departments (markings and decals on products)

SPAI estimates that there are at least 40,000 plants in the U.S. with screen presses, consisting of approximately 20,000 plants that focus on textile substrates (50 percent) and 20,000 graphics printers.[3] This number is derived from known addresses of screen printing shops. This estimate includes in-plant operations and the majority of industrial screen printing operations.[4]

Quantity of Sales and Percent of Market

According to Bruno's *Status of Printing 1989-90*, screen printing accounted for less than three percent of the total value of U.S. printing industry output in 1991. This figure excludes in-plant "captured" printing. It has been estimated that the screen printing industry posted gross sales of $13 billion in 1986.[5] A statistical weighted average calculation performed from 1990 SPAI

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[3] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 9.

[4] Correspondence between Kathryn Caballero, U.S. EPA, and Marcia Y. Kinter, Director of Government Affairs, SPAI, May 1994.

[5] Air and Waste Management Association, *Air Pollution Engineering Manual*, Buonicore, Anthony and Davis, Wayne T. (ed.), (New York:Van Nostrand Reinhold, 1992), p. 288.

Survey Information estimated U.S. annual sales volume estimate of $21.9 billion in 1990.[6] According to Bruno, the screen printing market is expected to show little or no growth between 1995 and 2025.[7]

Size of Screen Printers

The Screen Printing Industry is dominated by small businesses with the average screen print shop having approximately 15 employees.[8] From a 1992 Survey, *Screen Printing Magazine* estimates the following size categories for screen printing facilities:[9]

- ○ 1 to 20 employees (70.9 percent)
- ○ 21 to 50 employees (14.0 percent)
- ○ 51 to 100 employees (7.8 percent)
- ○ More than 100 employees (7.4 percent)

The SPAI 1990 survey of U.S. screen printing companies showed that respondents had slightly more than 20 employees and of the 20, approximately 14 were production workers, two were managers/supervisors, two were sales personnel, and two were classified as "other".

Definition and Overview of Screen Reclamation

Definition of Screen Reclamation

For the purposes of the Design for the Environment Printing Project, screen reclamation will be defined as the process that begins once excess ink has been carded off the screen and ends when the screen is ready for reuse. Ink removal performed at press side was not evaluated as part of this project.

Overview of Screen Reclamation

Purpose of Reclamation

Many screen printing facilities reclaim their screens for reuse because the screen material is valuable and costly to replace. Screen fabric can be one of the more expensive supplies that a screen printer uses and can have a large impact on cost of operations. For example, the most commonly used fabric, polyester, costs $10 to $40 per square yard.[10,11] A shop that wastes $100

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[6] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 10.

[7] *Bruno's Status of Printing 1989-90*, (1991), p. 17.

[8] Air and Waste Management Association, *Air Pollution Engineering Manual*, Buonicore, Anthony and Davis, Wayne T. (ed.), (New York:Van Nostrand Reinhold, 1992), p. 397.

[9] Duccilli, S., "The 1992 Industry Survey: Safety and Environmental Practices in the Screen-Printing Industry," *Screen Printing Magazine*, (April 1992), p. 50.

[10] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 15.

[11] Frecska, T., *Screen Printing Magazine*, (1992), p. 120.

to $200 per week, in fabric costs from ruining screens or failing to reclaim them, can increase its annual production costs by as much as $5000 to $10,000.[12] The average monthly expense for fabric is $360.[13] In addition, reclaiming screens has the advantage of saving labor time needed for stretching mesh across the frame and adjusting it to the correct tension. Some printers believe that using retensionable frames when stretching the mesh "work hardens" the fabric, improving the printability and longevity of the screen. Other printers note that reusing screens for other jobs, instead of storing them in an imaged screen inventory, saves both screen fabric costs and storage space often needed for presses.

Screen Reclamation Frequency

While 90.3 percent of screen printers reclaim screens daily,[14] not all screen printers attempt to reclaim every screen. Some orders of a specific stencil may be reordered systematically (for example, a stop sign or sale poster), in which case a screen printer may want to store the screen and stencil until the customer returns and requests another run of the print. In other cases, the screen may be very small (for example, a message printed on an plastic aspirin bottle). When screens are small, the time and effort needed to reclaim the screen can be higher than the cost of cutting out the fabric and replacing it.[15]

SPAI's 1990 Industry Profile Study reports that 68 percent of respondents reclaim between 1 and 10 screens per day and 17.3 percent reclaim between 11 and 20 screens per day.[16] Many operational factors determine the lifetime of a screen, including the roughness of substrate and ink, number of impressions, the daily handling of the screen, and the types of products used to reclaim the screen. The number of impressions printed affect the screen lifetime because repeated runs of the squeegee over the fabric can weaken and warp the fibers of the mesh. A printer may mark and date screens to keep track of the screen history, including number of impressions. Printers discard the screen when it has been reclaimed a certain number of times or shows signs of weakening.[17]

Screen Reclamation Process

> *Screen cleaning is the forgotten process in our industry. It generally takes place in a dungeon-like area in the most remote corner of the shop. As a result, the forgotten process has developed differently in every screen-printing business. Walk into ten shops and you could easily find just as many different solvents and disposal methods being used. -- Steven Duccilli, Editor.*[18]

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[12] Frecska, T., *Screen Printing Magazine*, (1992), p. 120.

[13] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 16.

[14] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 23.

[15] Personal communication between Beverly Boyd, U.S. EPA, and Dutch Drehle, Screen Printing Association International, May 1993.

[16] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 23.

[17] Personal communication between Beverly Boyd, U.S. EPA, and Dutch Drehle, Screen Printing Association International, May 1993.

[18] Duccilli, S., "In Search of Screen-Cleaning Standards," *Screen Printing Magazine*, (April 1993), p. 6.

While screen reclamation techniques may vary significantly from one screen printer to another, two basic functions must be performed in order to restore a used screen to a condition which it can be reused: removal of ink and removal of emulsion (stencil). A third step, removing any remaining "ghost image" or haze, may be required depending upon the type of ink used, effectiveness of ink removal and/or emulsion remover products, and the length of time that ink and stencil have been on the screen.

A variety of commercial products have been developed to perform each of these functions and a complementary series of products (i.e., a particular brand of ink remover product, emulsion remover product, and haze remover product) are often sold by manufacturers and distributors as a package. **For the purposes of this project, the trade-off issues associated with a particular *screen reclamation system*, consisting of an ink remover, emulsion remover and haze remover, are typically assessed**. Other products, such as screen degreaser and ink degradant, sometimes play a role in the reclamation of screens. These are not assessed. Different equipment, application techniques, and work practices play a role in the efficacy and quantity required of each product. All of these affect the trade-offs associated with product systems.

Ink Removal

Ink categories include: traditional solvent-based inks (which includes enamels), ultraviolet (UV)-curable inks, water-based inks and plastisols (for textile printing). Ink removal (also called screen washing or screen cleaning) precedes stencil removal so that excess ink does not interfere with removal of the stencil.

Ink is also removed at other times prior to screen reclamation (for example, when dust gets into the ink and clogs the screen mesh, or at lunch break, to avoid ink drying on the screen). This "process cleaning" usually occurs at press side. Screen cleaning performed as a part of screen reclamation may be performed at press side, in a separate ink removal area of the shop, or in an area where emulsion and haze are removed. This study will focus on ink removal performed as a part of the screen reclamation process and not on process or press-side cleaning.

Emulsion (Stencil) Removal

Several types of emulsions or stencils, such as indirect or direct photo stencils, are used in transferring an image to the screen.[19] Most direct stencils are water-soluble and thus incompatible with water-based inks. However, chemical curing of water-soluble stencils can improve their resistance to water. A water-resistant stencil must accompany a solvent-based ink, and a solvent-resistant stencil must accompany a water-based ink. Solvent and UV curable inks are typically coupled with water-resistant emulsions. Thus, a commercial facility using 90 percent solvent-based inks and 10 percent UV curable inks can use the same water resistant emulsion systems for both inks. If, however, the screen printing facility wants to replace some of its solvent-based inks with water-based inks, a new type of solvent resistant emulsion will have to be used to complement the water-based inks. Using solvent-resistent emulsion with water-based inks will cause the emulsion to erode quickly and pinholes will show up in the stencil.

Most emulsion removers are packaged in a water solution or as a powder to be dissolved in water; the water acts as a carrier for the actual reclaiming chemical. The predominant chemical in an emulsion remover is often sodium metaperiodate. Because periodate needs water as a carrier

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[19] Direct photostencils are exposed in direct contact with the screen, after adhesion to the mesh. Conversely, indirect photo stencils are exposed, developed and adhered to the mesh. Different chemicals are used for each type of stencil.

to reach certain chemical groups in the emulsion, it is more difficult to reclaim a water-resistant emulsion than one which is only solvent-resistant. Most commercially available emulsion remover products are able to remove either water resistant or solvent resistant emulsions. High pressure water spray can also facilitate emulsion removal and may lower the quantity of emulsion remover required. Special care must be taken to ensure that the emulsion remover does not dry on the screen, as the screen will become almost impossible to clean, even with repeated applications of the remover.

Haze (Ghost Image) Removal

A haze or ghost image is sometimes visible after the emulsion has been removed. This results from ink or stencil being caught in the knuckle (the area between the overlap of the screen threads) or dried/stained into the threads of the screen. Staining of the mesh frequently occurs when petroleum-based solvents are used in the ink removal process. The solvents dissolve the ink, leaving behind traces of the pigment and resin in the screen. The residual pigment and resin bonds to the screen after the solvent evaporates, leading to haze accumulation. Ghost images are especially common when dark inks (blue, black, purple and green) are used, or if an excessively long time period elapsed prior to ink removal from the screen. A ghost image is particularly likely when using solvent-based ink systems, as opposed to other ink systems. If the ghost image is dark or will interfere with later reimaging and printing, a haze remover product can be applied until the image disappears or fades. The level of cleanliness required at the end of the process varies depending on the kind of printing job that the screen will be used for after reclamation. Some printers can use screens with light ghost haze, others cannot.

Haze removal can potentially damage the screen mesh, particularly caustic haze removers that are traditionally used in the industry. The excessive use of these products, such as applying the chemical and leaving it on the screen too long, can weaken the mesh.

Printer Environmental Concerns about Screen Reclamation

Concern on the part of screen printers and SPAI about screen cleaning and reclamation stems from two sources; (1) the use of highly volatile organic solvents; (2) the common practice of screen printers of allowing water from screen washing and reclaiming to go directly down the drain without prior filtration. According to a 1992 survey by *Screen Printing* magazine, of the 250 companies that answered a question about the latter practice, 191 (76 percent) indicated they send unfiltered waste down the drain.[20] Depending on what is in the water (ink, ink remover chemicals, emulsion, emulsion remover chemicals, and/or haze remover) this practice could contribute to health and environmental problems since the water goes either directly to a wastewater treatment facility, a body of water (streams, etc.) or a printer's septic tank.

Publicly Owned Treatment Works (POTWs), particularly in the Western states, have increased awareness of the water discharge problem by tracing problem inputs into the sewer system back to screen printers and levying fines on offenders. Three major categories of concern have been raised by the POTWs:

○ Heavy metals, which can be found in the residue of ink, can enter the sewer system and contaminate sewage sludge

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[20] Duccilli, S., "The 1992 Industry Survey: Safety and Environmental Practices in the Screen-Printing Industry," *Screen Printing Magazine*, (April 1992), p. 53.

- ○ Heavy concentrations of certain chemicals can disrupt the pH balance at the treatment plant and disrupt the bacterial systems essential to the sewage treatment process

- ○ Combinations of mixtures with low flash points can cause flammability concerns in the sewage system

Concern has also been expressed about screen printing facilities that discharge waste water to septic tanks. In these cases, water containing ink cleaning solvents, ink residue, emulsion, emulsion remover, haze remover products or other wastes could disrupt the bacterial balance in septic tanks and/or contaminate local groundwater supplies.

Confusion has been exacerbated by "biodegradable", "drain safe", "solvent-free" claims on the labels of many ink removal and emulsion removal products. Unfortunately, some printing facilities that use so-called "biodegradable" products have mistaken these products for waste-disposal panaceas. Simply because the product itself is drain permissible, does not mean that the product combined with ink residue or emulsion residue from screen reclamation is also drain permissible. Also, something which is currently drain permissible may contribute environmental problems and may be subject to future regulation. Printers should always check with local, state and federal water regulations prior to discharging a product marked "drain-safe" to water. An effort to ascertain the environmental or health impact of the chemical may also be prudent.

While water concerns have inspired interest in this area, this Substitute Assessment document presents an analysis of cross media effects (air, waste disposal, etc.) and will outline the trade-off issues that are associated with different screen reclamation options, such as occupational exposure concerns, total cost differences, performance effectiveness and toxicity of waste water.

Identification of Screen Reclamation Functional Groups

Figure 1-1 is a graphical model of the integration of all screen reclamation methods. It separates the basic components of any screen reclamation process into five functional groups: ink removal, screen degreasing, ink degrading, emulsion (stencil) removal and haze removal. A general flow chart is depicted for the integration of these functional groups. However, this flow chart may not be representative of all types of screen reclamation *processes*. Several steps that may be included in the reclamation process are low-pressure and high-pressure water rinsing, which typically involve different equipment. Preparation of the screen or disposal of waste from screen reclamation are not included in this basic flow chart.

To concentrate on those functional groups most often associated with screen reclamation, this CTSA focuses on the three functional groups of ink removal, emulsion removal and haze removal. The parameters associated with the use of screen degreaser and ink degradant are *not* discussed.

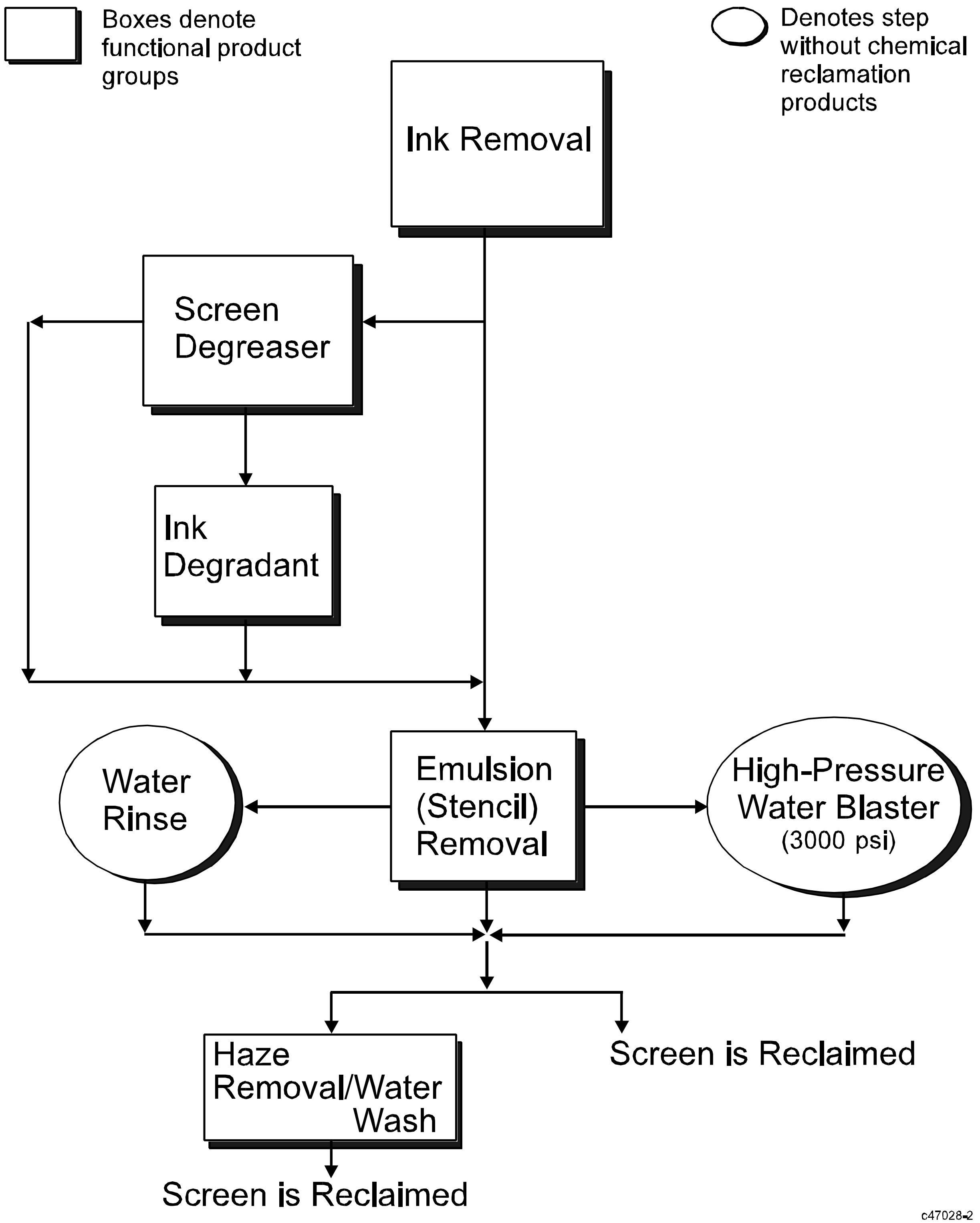
Identification of Screen Printing Substitute Trees for Screen Reclamation

Figure I-2 depicts the five main methods (including the automatic screen washer) that are used in screen reclamation. Because the actual process of screen reclamation can be performed using any of these methods, these methods "substitute" for each other in screen reclamation. In addition to the five methods, the substitute tree also suggests that the disposal of the screen mesh without screen reclamation would be an option. This disposal option is considered in Chapter VI, Overall Pollution Prevention Opportunities for Screen Reclamation.

Figure I - 1

Identification Of Screen Reclamation Functional Groups

This Exhibit is an Integration of Screen Reclamation Methods



Identification of Screen Reclamation Functional Groups

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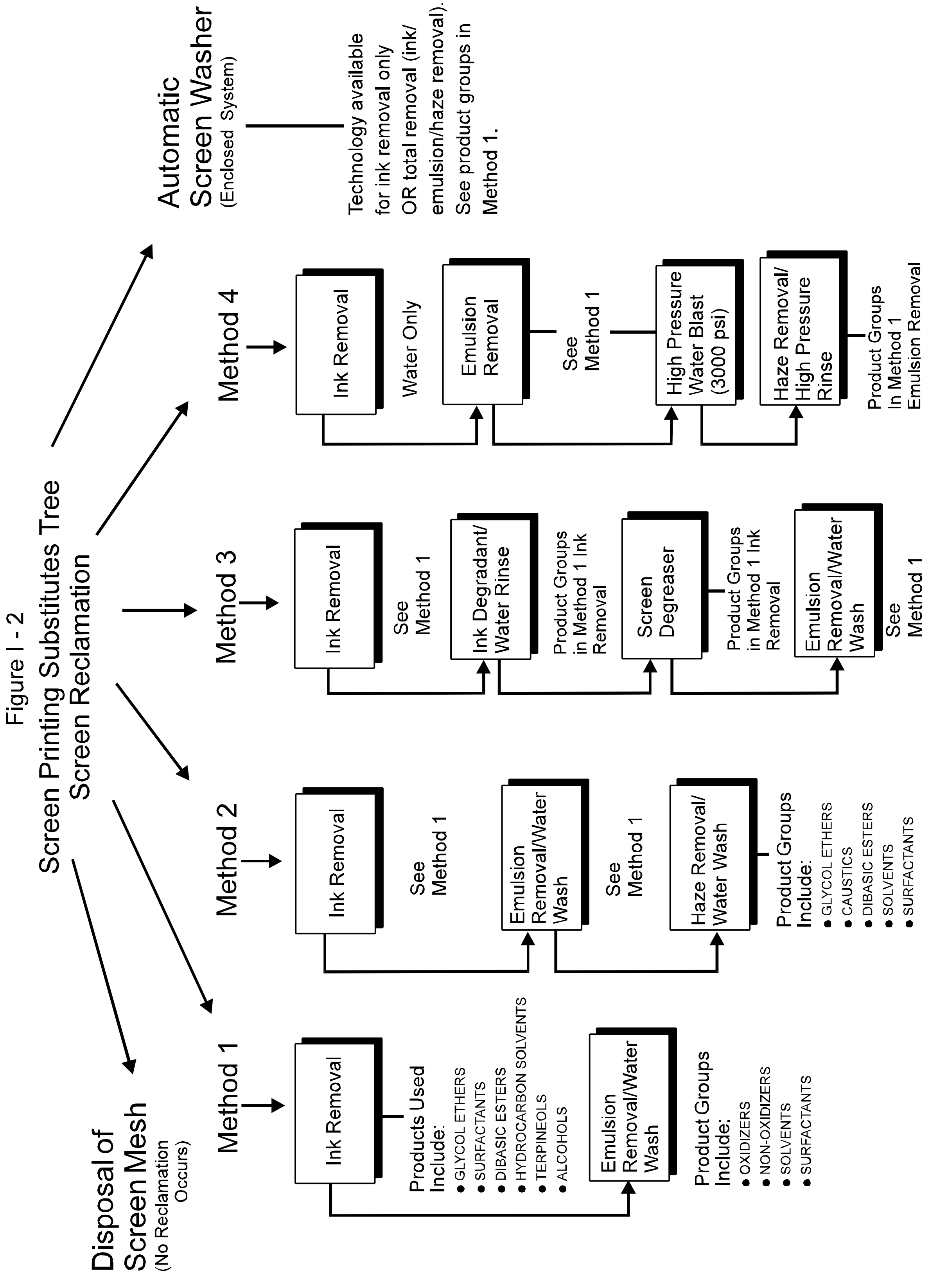

Figure I - 2
Screen Printing Substitutes Tree
Screen Reclamation

Identification of Screen Reclamation Functional Groups

Method 1 in Figure I-2 illustrates that screen reclamation is performed with products from the functional groups of ink removal and emulsion removal only. Under each functional group, some of the categories of chemicals that might be found in these products are listed. Currently, some screen printers only use products from these functional groups when reclaiming screens.

More common among screen printers is the additional use of a haze remover in the screen reclamation process, as depicted in Method 2.

Method 3 was developed by technical staff at SPAI and is currently taught at SPAI in workshop classes; it is referred to by the name "SPAI Workshop Process." It differs from Method 1 and Method 2 in that screen degreasers and ink degradants are used in the screen reclamation process. It also differs from Method 2 in that no haze remover is deemed necessary. Technical staff at SPAI developed this method to avoid the use of caustic haze removers, which can damage the screen mesh.

Method 4 employs both mechanical and chemical technologies to reclaim a screen. No ink remover is applied to the screen during Method 4; instead, removal of ink residue is accomplished by the action of a high-pressure water. A small quantity of diluted emulsion remover is applied to the screen prior to spraying with the high-pressure water blaster. Two different pressures are typically used to remove the emulsion, and subsequently, the remaining ink. If a ghost or haze image is apparent on the screen, a haze remover is sprayed on the screen and brushed from the surface. The pressure spray is repeated and for heavy ghost images, the screen is turned over and the action repeated on the reverse side.

Although the use of an automatic screen washer is not typically found at a screen printing facility, it is a technology that can be used to reclaim screens. Automatic screen washers can be used for ink removal only, or for ink removal, emulsion removal and haze removal. Some automatic processing systems also rinse and dry screens. The screen is immersed in an enclosed system, which then performs the desired screen reclamation function without the labor of the screen reclamation employee.

Potential Screen Reclamation Technologies

Introduction

The methods presented in Exhibit I-2 are traditional screen reclamation processes that use chemicals combined with water washes to clean and reclaim the screen, including a relatively new technology, the automated wash system. In order to fully examine alternatives in search of cleaner technologies, it is useful to identify other process technologies not traditionally used in the printing industry that may accomplish these same ink and the emulsion (stencil) removal functions. Exhibit I-3, Screen Printing Substitutes Tree, identifies technologies used in other industries to remove a material from a substrate that could potentially be modified to reclaim screens, but are not currently used for this purpose. Many of the suggested methods are established technologies in paint stripping and parts cleaning applications. They include blasting methods, stripping methods, and methods that involve pulse light energy. Water-soluble stencils/emulsions, also presented below, represent a product change that will affect other aspects of the printing and reclamation process (e.g., inks used). Except for the sodium bicarbonate blasting method, this CTSA does not evaluate the performance or cost of these technologies in screen reclamation. The intent of Figure I-3 is to bring further thought into how screen reclamation could be performed. The following are reviews of these technologies to evaluate potential feasibility and determine if further research is warranted.

Blasting Technologies

Blasting methods, commonly known as media blasting, use the abrasive and/or fractioning action of a propelled media to remove a coating. Dry media blasting uses air as the propellant for solids of plastic, wheat starch, ice, or carbon dioxide (dry ice); wet media blasting utilizes water as the propellant with sodium bicarbonate as the primary solid. To be effective the media must be hard enough to remove the coating, but soft enough not to damage the underlying substrate. Other factors affecting removal efficiency are application pressure, distance from surface, and angle of application.

There are many aspects that affect the use of blasting technologies for screen reclamation. The equipment required for a media blasting method is media dependent. Each method requires a pressurized air/water source and a specifically designed nozzle for media delivery (plastic and wheat starch units can be interchangeable). In addition, plastic media blasting will require media separation and recycling prior to waste disposal. Wheat starch media blasting may require dust control, but may not require media separation if the spent media and materials removed can be discharged to the sewer. Also, wheat starch is highly moisture sensitive, thus requiring moisture control within the process area. Carbon dioxide media blasting alleviates the potential disposal problems of plastic and wheat starch media blasting; CO_2 pellets, after impacting on the surface, sublime rapidly to the gaseous state, thus leaving only the removed coating behind for disposal. However, storage and pelletizing of CO_2 requires relatively complex, energy intensive equipment. Ice crystal blasting requires the maintenance of refrigeration, ice making, and ice handling equipment.

Media blasting technologies have been successfully applied to large, industrial operations such as building and bridge refinishing, and corrosion removal from process equipment.[21]

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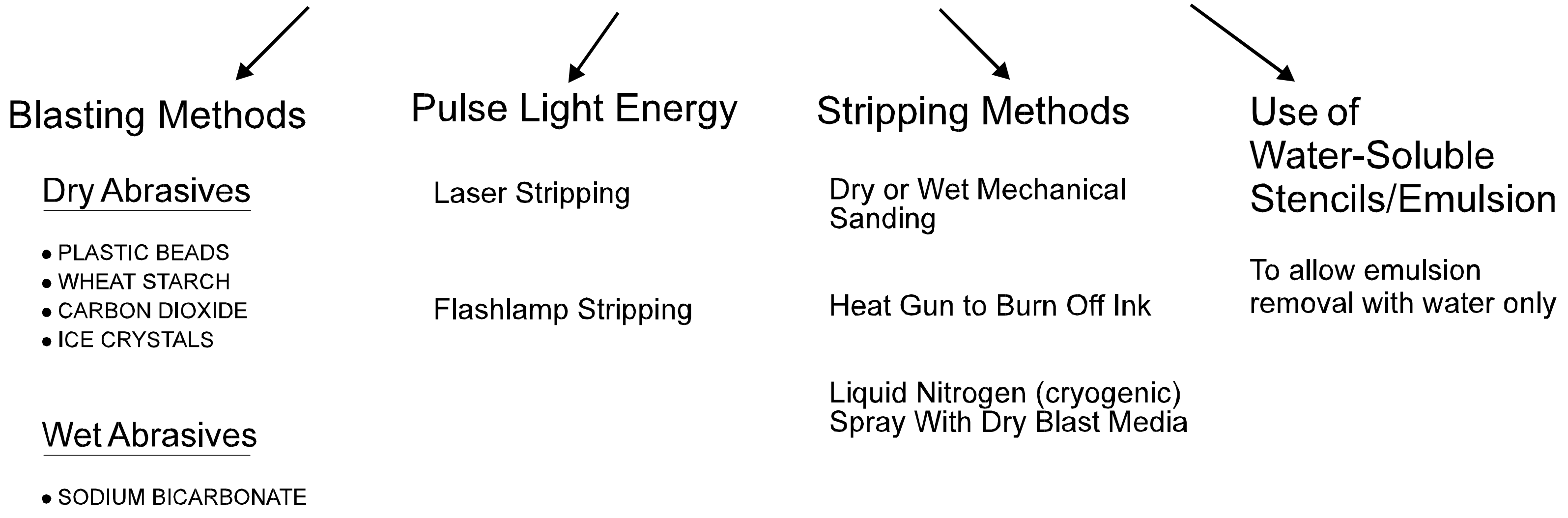
[21] Armex Blast Media, (1993).

Figure I - 3

Screen Printing Substitutes Tree

Undemonstrated Technologies In Screen Reclamation

(The cost and performance of these technologies in screen reclamation is undetermined)



c47028-1-2

Starch media blasting units include small hand cabinets, and sodium bicarbonate units can be either fixed or portable, both suggesting they can be used in small-scale applications.[22]

Other characteristics of the media blasting technologies may also lend themselves well to screen reclamation if further research is directed toward development. Small-scale screen reclamation applications may only require changes in operating pressure (reduced pressure), media hardness, and equipment down-sizing. For example, adjustment of application pressure and solids flow rate in the sodium bicarbonate system can control whether just oils and greases are removed from a painted surface, or the paint is removed along with the oils and greases.[23] Wheat starch has been used in industrial applications where surface etch must be avoided on substrates of aluminum and magnesium, and carbon dioxide pellet blasting has been applied to clean precise and delicate circuit boards.[24]

The small media size of wheat starch and sodium bicarbonate may adequately penetrate the weave of the screen, removing both ink and stencil to a degree which could eliminate or reduce the need for a haze removal step. Plastic media, as well as the other media blasting techniques, may cause excessive wear and stretching of the screen mesh. This may result in a shortened screen life and increased screen maintenance (e.g., adjustment of screen tension could be periodically required). It has been documented that crystalline carbon dioxide damages woven fibers, thus limiting its applications in the printing industry.[25] Sodium bicarbonate may have similar damaging effects on the materials of the screen mesh due to the chemical nature of the media which can revert to caustic soda ash in the presence of water and heat.[26] These limitations, however, should not prevent further evaluation of many blasting technologies as a potential clean technology for the screen reclamation process.

Pulse Light Energy Technologies

Pulse light energy technologies use an energy source to vaporize and fracture coatings off of substrates. Laser and flashlamp methods are included in this technology. Laser stripping uses high energy photons generated by a CO_2 or neodymium (Nd) laser to vaporize the coating, leaving an ash behind for disposal. Laser frequency selection can maximize coating removal while minimizing substrate damage; layer-by-layer coating removal can be accomplished with proper control.[27] Initial tests and full-scale operations indicate heat damage of the substrate is a potential problem with laser removal methods.[28] Flashlamp methods use an intense pulse of light to

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[22] U.S. EPA Economics and Technology Division, Office of Toxic Substances, *Reducing Risk in Paint Stripping*, (Washington:GPO 12-13 February, 1991).

[23] Ibid.

[24] Ibid.

[25] Ibid.

[26] Ibid.

[27] "Light Stripping," *Manufacturing Engineering*, (September, 1992).

[28] Ibid.

vaporize the coating a microlayer at a time. Factors that contribute to the removal efficiency of the flashlamp method include flash repetition rate, intensity, spectral content and flash duration.[29]

The equipment required for the laser and flashlamp methods are unique to the pulse light energy technology. The energy (light) source may have a high capital cost, and energy requirements may be substantial. These units may also be automated. Dust control and waste disposal equipment may be combined in a single vacuum unit, with the volume of waste minimized due to vaporization of the coating. The vapors, however, generated by these methods may require personal protective equipment (respirators), as well as additional process area ventilation and emissions control. Portable, full-scale CO_2 laser units to remove paint from bridges (fitting on a flat bed truck) can cost between $750,000 and $1,000,000.[30]

As with media blasting technologies, pulse light energy technologies have had successful applications in large-scale operations such as bridge and airline fuselage refinishing. These technologies, however, have not been applied to small-scale operations.[31,32] Since many of the operating parameters of laser and flashlamp units can be controlled, it may be possible to optimize these methods to perform small-scale operations such as screen reclamation. The ability of these methods to remove a single or microlayer of material from a substrate may make them useful in a number of industries if they are cost effective. However, substrate heat sensitivity, vapor generation, and high capital and operating costs may limit these processes from entering other markets. A screen mesh, made of polymeric fibers, for example, may be permanently damaged in the reclamation process from the heat generated by the pulse light energy technologies. Also, the fumes generated from the vaporization of inks and stencils, when limited to a closed process area, may cause health and safety hazards. Finally, the current costs of these technologies are prohibitive to all but possibly the very largest screen printers. Pulse light energy technologies, however, may be suitable for screen reclamation and therefore further study may be warranted.

Stripping Technologies

Stripping methods in Exhibit I-3 include sanding, heat gun stripping, and cryogenic methods to remove a coating from a substrate. Sanding methods also use the abrasive properties of a media to remove the coating. The media, either on a sanding block (paper, cloth, etc.) or in a slurry, is applied to the substrate and mechanically worked to remove the coating. Heat guns are intended to either soften or burn the coating which is then scraped from the substrate. Cryogenic methods cool a coating to cause it to contract, weaken and loosen from the substrate. This thermal contraction is accomplished by the application of liquid nitrogen (-320°F at atmospheric pressure), and the weakened coating is removed by media blasting methods or another mechanical technique.[33]

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[29] U.S. EPA Economics and Technology Division, Office of Toxic Substances, *Reducing Risk in Paint Stripping*, (Washington:GPO 12-13 February, 1991).

[30] Correspondence between Dean Menke, UT Center for Clean Products, and Simon Engles, HDS Industries, July 1994.

[31] "Laser System Will Automate Paint Stripping," *Laser Focus World*, (June, 1991).

[32] "Nd:YAG Lasers Strip Paint Effectively," *Laser Focus World*, (October, 1992).

[33] U.S. EPA Economics and Technology Division, Office of Toxic Substances, *Reducing Risk in Paint Stripping*, (Washington:GPO 12-13 February, 1991).

Stripping methods utilize diverse, technology-specific equipment. Sanding methods have the potential to be automated, but are traditionally manual operations consisting solely of a sanding block or slurry applied to the surface to be refinished. Heat guns typically utilize an electrical power source to heat a metallic element held in contact with the coating. The heat softens or burns the coating thus simplifying removal. After heating, the coating is promptly removed by a scraping device or spatula. Cryogenics is the most energy intensive method of the stripping technologies. Equipment includes units to liquify nitrogen, a chamber for substrate-liquid nitrogen contact, and media blasting equipment.

Most stripping methods mentioned here appear to have a high potential to damage the screen. Manual sanding methods could damage the screen in areas where there is no stencil/emulsion and sanding media is in direct contact with the mesh. As with pulse light energy technologies, the polymeric materials used for screen mesh may be permanently damaged if subjected to temperature extremes; therefore, the heat gun method may not be feasible. Cryogenics, with its extreme operating temperatures (cold) may also damage screen mesh. However, the thermal resistance of most polymers to cold is greater than to heat, and the process may warrant further research. However, current cryogenic technologies are probably too costly for the average screen printer.

Stencils/Emulsions Chemistry

The substitute technologies presented above focussed on methods that could be used to remove a stencil/emulsion that would traditionally be removed with chemical products. The use of water-soluble stencils/emulsions, however, could eliminate the need for chemical removal products as well as any of the above mentioned alternatives. Certain products of the indirect stencil/emulsion process are water soluble and can be removed using only water to reclaim the screen; other indirect stencil/emulsion products may use an enzyme or gelatin film decoater.

The image printed on a substrate in the screen printing process is defined by the stencil -- the area of the screen on which there is no emulsion blocking the flow of ink through the mesh to the substrate. The stencil/emulsion is applied to the screen mesh using direct or indirect processes. In direct processes (either capillary direct or direct emulsion), the printed image is photographically developed after the emulsion is on the screen. This is accomplished by the following procedure:

1. apply a water dispersion of polymer and sensitizers over the screen,

2. allow this to dry (this dried dispersion is still completely water soluble until exposed to curing light),

3. block the desired image from the developing light,

4. expose the screen to light (usually UV), thus curing the dried dispersion (a reaction between the sensitizers and polymer creating a cross-linked emulsion film), and

5. wash the uncured dried dispersion away with water.

During screen reclamation, emulsion remover is required for these products to break the cross links and destroy the polymer network.

Indirect processes, on the other hand, photographically develop the image of the emulsion away from the screen and then apply the developed stencil/emulsion to the mesh. The procedure to accomplish this is as follows:

1. expose the thin film emulsion to the desired image,
2. develop the image using a developing solution in a shallow tray,
3. wash away the uncured emulsion (image) with a aerator water nozzle,
4. adhere thin film emulsion to screen mesh and allow to dry, and
5. remove the supporting plastic film from the dried emulsion.

This stencil/emulsion can be removed during screen reclamation using an enzyme or gelatin film decoater to soften the emulsion, which is then removed with a water spray. However, discussions with printers and vendors of indirect emulsions indicated that a warm water wash alone can be used to adequately remove the stencil/emulsion following ink removal. The water wash will take approximately five minutes to sufficiently soften the emulsion (longer than a process using chemicals), but this process time is chosen over chemical costs and disposal.[34] Limitations of this water-soluble stencil/emulsion lie in the inks used (no water-based inks, only oil- and rubber-based can be used) and possibly the operating conditions (low humidity required).

Conclusions

Many of the substitute technologies presented in Exhibit I-3 possess properties and characteristics that may be applicable to the screen reclamation process performed by screen printers. The technologies presented here are not exhaustive, and were solely intended to bring further thought into the area of potential alternative technologies. Currently, these technologies have high-tech applications, and therefore may not be economically feasible for the average printing establishment. However, that is not to say that further research into these technologies, and their continued development, could not result in more cost-effective, easy-to-use applications.

Issues that should be addressed when considering these alternative technologies in future research include the following: effectiveness of ink, emulsion and haze removal; cost, both capital and operating; potential of damaging screen; risk to human health and the environment from use of the methods; waste generation and disposal; and energy and natural resource use. A multi-media approach must be taken when researching the potential applications for these technologies. For example, wheat starch and bicarbonate media blasting may be cleaned by washing with water and disposing of the waste down the drain. This may simplify the cleaning process, but consideration must be given to the local disposal and permitting requirements of wastewater pretreatment and disposal; the inks and emulsion materials also washed down the drain could impart an additional load on the wastewater treatment facility, and have the potential to be hazardous. Also, as mentioned above, vapors generated from coating destruction by pulse light energy technologies may require personnel protection equipment, ventilation and control.

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[34] Correspondence between Dean Menke, UT Center for Clean Products, and Gary Coffey, Coffey Screen Printing, Knoxville, TN and John Uhlman, Ulano, Brooklyn, NY.

Alternative Sodium Bicarbonate Screen Reclamation Technology

General Summary of the Technology

The sodium bicarbonate screen reclamation technology consists of an enclosed spray cabinet where pressurized sodium bicarbonate (baking soda) and water are sprayed onto the parts inside the cabinet to clean them. Currently, this technology is used primarily for removing coatings, such as paint, grease, or teflon from metal parts. As part of the DfE Performance Demonstration, the sodium bicarbonate technology was tested to determine if it is potentially adaptable as an alternative screen reclamation technology. A risk assessment was not conducted for the use of this technology in screen reclamation. However, it is known that sodium bicarbonate (baking soda) is a fairly innocuous chemical that is not a skin irritant and has a low toxicity; it is a common ingredient in baked goods, toothpaste, detergents, air fresheners and deodorants.

Prior to this study, the sodium bicarbonate technology had never been tested for screen reclamation applications. The cleaning procedure used during the test was a method developed for cleaning metal parts, and adapted to screen reclamation. The screen was placed inside the enclosure and held under the pressurized baking soda spray to remove the ink, emulsion and haze from the screen simultaneously. The advantage of such a system for screen reclamation is that no hazardous chemicals are used, and the need for ink remover, emulsion remover, and haze remover is eliminated. In preliminary testing, the sodium bicarbonate technology showed potential for effectively removing solvent- or water-based inks. Results on a screen with UV ink, however, were poor. In all cases, further development and testing are needed before the technology could be used in a screen printing facility.

Application Method

At this time, the sodium bicarbonate-based technology has not been developed specifically for screen reclamation. It has been successful in replacing hazardous cleaning chemicals in other applications such as in metal parts degreasing and paint and adhesives removal. To determine if this technology could be adapted for screen reclamation, three screens were prepared for cleaning: one with solvent-based ink, one with UV-curable ink, and a third screen with water-based ink. All tests were conducted at the equipment manufacturer's facility. This particular manufacturer developed the enclosed spray cabinet, and is a distributor of sodium bicarbonate. Because this technology is still under development and is unproven for screen reclamation, no demonstrations were conducted at printing facilities. An observer from the DfE Printing Project was present to record information on the system's performance in cleaning the three test screens.

Tests were conducted in two different enclosures. Half of each screen was first cleaned in an enclosure which delivered dry, pressurized baking soda to the screen. The second half of each screen was cleaned in an enclosure which delivered both pressurized water and baking soda. The same cleaning procedure was used for the two systems. After excess ink was carded off, the screen was placed inside the enclosure with the flat side down. The door was locked and the operator placed his hands through the gloves built into the box. By stepping on a foot pedal, the operator started the flow of pressurized sodium bicarbonate from the fan nozzle mounted in the top of the enclosure. The fan nozzle, designed by the enclosure manufacturer, spreads out the impact of the sodium bicarbonate to reduce the stress on the screen. The nozzle used for testing dispersed the sodium bicarbonate over an area approximately one inch wide by three inches long. On the wet system, the same nozzle was used to deliver the sodium bicarbonate, and the water nozzle was mounted on the fan nozzle, so that the water and baking soda mixed together as they were discharged. Holding the screen under the fan nozzle, the operator moved the screen from side to side. The operator was able to see where the ink or emulsion remained on the screen by watching through the primary viewing area. This window was purged with air to enhance visibility by clearing the dust from the viewing area. When the first side was clean, the operator flipped the screen over and repeated the cleaning procedure on the other side until all ink, emulsion, and haze were removed.

During the test, the following parameters were used:

○	**Sodium Bicarbonate:**	75 micron particle size Delivered at 1 to 1.5 pounds/minute Sodium bicarbonate delivered at 5 to 30 psi Water delivered at 200 to 250 psi
○	**Screen:**	Polyester mesh mounted on wood frames Dual-cure emulsion 13" x 23" outside diameter
○	**Inks:**	<u>Solvent-based ink</u> = Naz-Dar 9700 Series All Purpose Ink 9724 Black <u>UV-cured ink</u> = Nor-Cote CD 1019 Opaque Black <u>Water-based ink</u> = TW Graphics WB-5018 Black
○	**Ink application:**	Each type of ink was applied to one screen, carded off, and the screen was allowed to dry for 18 hours before starting the cleaning test.

Alternative System Performance Results

Dry Cleaning Process

During the demonstration, several different application methods were tested to optimize the system performance. First, the screen with solvent-based ink was cleaned in a dry box; only pressurized baking soda was delivered, without any water. At a pressure of 5 psi, some of the ink and emulsion were removed, but very slowly. A heavy haze and some ink and emulsion residue remained. To accelerate the removal, the pressure was increased to 10 psi. This pressure proved to be too high and the screen developed pin holes and eventually ripped. The pressure was reduced to 5 psi. To reduce the stress on the mesh, a flat plate was placed behind the screen. Screen damage was reduced, but was not eliminated.

Similar results were obtained with the water-based ink screen. Significant ink and emulsion residue remained on the screen after cleaning a 4 inch by 4 inch area for 5 minutes. Again, screen wear and small holes were visible in some areas. After these disappointing results, dry testing was discontinued in favor of the wet delivery system. The water serves to soften the sodium bicarbonate, making it less abrasive than the dry delivery process. Because of the softening effect, a higher pressure could be used with the wet delivery system without damaging the screen.

After such poor performance was demonstrated using the dry cleaning process on the solvent- and water-based ink screens, the decision was made to skip the dry process for the UV ink screen, and start with the wet cleaning process. Additionally, the UV ink does not dry (unlike the solvent- and water-based inks), and the manufacturer felt that the application of the dry sodium bicarbonate would stick to the wet ink across the entire screen, instead of removing the ink. If the sodium bicarbonate was covering the screen, the wet cleaning process test would not be valid.

Wet Cleaning Process

All three screens were tested using the wet process. Water was sprayed onto the screen at 200 to 250 psi, while the sodium bicarbonate was sprayed out of a fan nozzle at varying pressures. On the screens where the dry process was used to clean half the screen, the wet process was used for the other half. Performance clearly improved using the wet technology.

On the screen with UV ink, the sodium bicarbonate-based technology was completely ineffective. After about 5 minutes of cleaning, there was almost no removal of the ink or the emulsion. The operator increased the pressure to 20 psi to improve the system performance. When there was no improvement at 20 psi, the pressure was increased to 30 psi. Even at the higher pressure, there was no significant removal of the ink or the emulsion from the screen. The operator put a glass plate behind the screen to concentrate the sodium bicarbonate and to support the screen, but this did not help to remove the ink or emulsion. After approximately 10 minutes of cleaning without any noticeable removal of ink, the test was stopped.

The solvent-based ink screen was cleaned first. At 5 psi, it took approximately 5 minutes to remove the ink and emulsion from a 4 inch by 4 inch area of the screen. At this point the screen was visually inspected. There was no visible damage to the screen, so the pressure was increased to 10 psi. Another 4 inch by 4 inch area was cleaned, and at 10 psi, it took approximately 3 minutes. Some areas of the emulsion came off in stringy pieces. After cleaning the rest of the screen, a light haze remained in the image area. Around the edges of the screen where the ink was fairly thick, a heavy residue remained, but there was no ink or emulsion residue in the image area. Total screen cleaning time for the half of the screen that was cleaned with the wet cleaning process (a 10 inch by 10 inch area), took approximately 16 minutes.

Performance on the screen with water-based ink was similar to the screen with solvent-based ink. On the water-based ink screen, all testing was conducted with the sodium bicarbonate pressure at 10 psi. Initially, the ink started to come off fairly well, but very slowly. After a few minutes, the ink began flaking off, instead of dissolving. The flaking made it significantly easier to remove the ink. Again, the emulsion came off in stringy rolls. Ink residue remained around the edges of the screen, but the image area was clean with a very slight haze. After closer inspection, some very small spots of ink residue were apparent. In an effort to remove these spots, the operator concentrated the spray on the small effected area. After one or two minutes, this concentrated pressure ripped the screen. Total cleaning time for the portion of the screen that was cleaned with wet cleaning (10 inches by 10 inches), was approximately 13 minutes.

Technology Potential

The cleaning procedures used during testing were the methods used for cleaning metal parts and were not specifically developed for screen reclamation. With further testing and research, this application method could be improved to clean the screens faster and with less possibility for screen damage. For example, during the test, a piece of rigid material (safety glass) was held behind the screen to reduce the pressure on the mesh. From the limited testing performed, this support seemed to concentrate the cleaning media on the desired area while reducing the stress on the screen. As another change that may improve performance, the operator suggested using hot water. When cleaning the screens with solvent- and water-based ink, the emulsion came off in stringy pieces that rolled off the screen. This reaction did not seem to increase or decrease the removal efficiency, however, hot water may help dissolve the emulsion, potentially accelerating the removal process. A third possible improvement in the application technique may be to add a small platform inside the enclosure which would help the operator hold the screen closer to the spray nozzle.

In addition to equipment modifications, several other variable changes that may be specific to each facility should also be investigated. These factors include increasing or decreasing the particle size of sodium bicarbonate, changing the pressure of the water or the sodium bicarbonate, and changing the rate of delivery of the medium. With further research into improvements in the sodium bicarbonate application, this technology could potentially reduce chemical use during screen reclamation for printers using solvent-based or water-based inks.

Cost

Because the equipment used during testing was not developed specifically for screen reclamation, it is difficult to estimate what the actual cost would be for a screen printing facility to implement this technology. However, some rough estimates of equipment and chemical use are available. The equipment used in the wet cleaning could range in cost from $32,000 to $52,000. This estimate is subject to a wide range of actual operating conditions, including the type of filtration and waste treatment that is necessary; the filtration and waste treatment needs will vary depending on the ink and emulsion components on the screen. The blast media can cost between $0.65 to $0.75 per pound, with the less expensive price available for large volume purchases. Further research into the use of the sodium bicarbonate-based technology in screen reclamation would give a better indication of the costs that could be expected for a typical screen printing facility.

Chapter II
Screen Reclamation Chemicals

Introduction

Chapter 2, in which the characteristics of individual chemicals are detailed, is intended for use as a reference section. The specific information concerning each chemical was developed to support the risk assessment of screen reclamation products. Such information includes physical/chemical properties, industrial synthesis, aquatic toxicity, environmental fate, and a hazard summary. Tables II-4 through II-6 detail aquatic toxicity and hazard summary data for the chemicals in the screen reclamation use cluster. The preface to these exhibits explains the technical language and abbreviations used throughout the exhibits.

The regulatory status of a chemical was also provided as a ready reference; Table II-3 lists those chemicals used in screen reclamation which trigger federal environmental regulations. In addition, market profile information was developed to assess the overall production of the chemical, and its use in screen reclamation. Originally, if it was determined that more than 5 percent of the U.S. production volume of a chemical was used in screen reclamation, an analysis of the bulk chemical production, including occupational and population exposure assessments, would be undertaken. However, due to the lack of information on the quantity of specific chemicals used in screen reclamation, the latter analysis was not developed for any one chemical. Instead, economists at EPA developed a methodology for estimating the quantity of specific chemicals used in screen reclamation; this methodology is outlined in Chapter 3.

The chemicals that are discussed in this chapter comprise the screen reclamation use cluster; Table II-1 lists all of the chemicals in the screen reclamation use cluster, as well as their particular function in screen reclamation. Table II-1 also provides the page number on which information about a specific chemical can be found. Table II-2 is a generic categorization of some of the screen reclamation chemicals that was developed to protect the proprietary nature of the alternative screen reclamation products submitted by manufacturers. In Chapters 4 and 5, specific chemicals in ink removers, emulsion removers and haze removers are occasionally not identified by name, but by a generic category. For example, the product category "propylene glycol series ethers" might refer to the presence of tripropylene glycol methyl ether, propylene glycol methyl ether and methoxypropanol acetate. Although this categorization was developed to protect proprietary formulations, the risk assessment conducted for each type of screen reclamation product details the hazard and risk associated with only those chemicals that occur in the actual product formulation.

Table II-1
Summary of Screen Reclamation Chemicals and Their Functions

Chemical	CAS Number	Ink Remover	Emulsion Remover	Haze Remover	Possible Substitutes	Page Number
Acetone	67-64-1	X	X	X		II-7
Alcohols, C_8-C_{10}, ethoxylated	71060-57-6	X				II-8
Alcohols, C_{12}-C_{14}, ethoxylated	68439-50-9	X				II-10
Benzyl alcohol	100-51-6	X				II-11
2-Butoxyethanol	111-76-2	X				II-13
Butyl Acetate	123-86-4	X	X			II-14
Butyrolactone	96-48-0	X	X			II-16
Cyclohexanol	108-93-0	X				II-17
Cyclohexanone	108-94-1	X	X	X		II-19
Diacetone alcohol	123-42-2	X	X			II-20
Dichloromethane	75-09-2	X				II-22
Diethyl adipate	141-28-6				X	II-23
Diethyl glutarate	818-38-2				X	II-25
Diethylene glycol	111-46-6	X				II-26
Diethylene glycol monobutyl ether	112-34-5	X	X	X		II-28
Diethylene glycol butyl ether acetate	124-17-4	X	X	X		II-29
Diisopropyl adipate	6938-94-9				X	II-31
Dimethyl adipate	627-93-0	X		X		II-32
Dimethyl glutarate	1119-40-0	X		X		II-34
Dimethyl succinate	106-65-0	X		X		II-35
Dipropylene glycol methyl ether	34590-94-8	X	X			II-36
Dodecyl benzene sulfonic acid, triethanol amine salt	27323-41-7			X		II-39

Table II-1
Summary of Screen Reclamation Chemicals and Their Functions

Chemical	CAS Number	Ink Remover	Emulsion Remover	Haze Remover	Possible Substitutes	Page Number
Ethyl acetate	141-78-6	X	X			II-41
Ethyl lactate	97-64-3				X	II-42
Ethyl oleate	111-62-6				X	II-44
Ethoxylated castor oil	61791-12-6	X		X		II-45
Ethoxylated nonylphenol (np 4-9.5)	9016-45-9	X	X	X		II-47
Ethoxypropanol	52125-53-8	X				II-48
Ethoxypropyl acetate	54839-24-6	X				II-50
Furfuryl alcohol	98-00-0			X		II-51
Isobutyl isobutyrate	97-85-8	X				II-53
Isobutyl oleate	10024-47-2				X	II-54
Isopropanol	67-63-0	X	X			II-55
d-Limonene	5989-27-5	X				II-57
Methanol	67-56-1	X				II-58
Methoxypropanol acetate	84540-57-8	X				II-60
Methyl ethyl ketone	78-93-3	X	X			II-61
Methyl lactate	547-64-8				X	II-62
Mineral spirits (straight run naphtha)	64741-41-9	X		X		II-64
Mineral spirits (light hydrotreated)	64742-47-8	X		X		II-66
N-methylpyrrolidone	872-50-4	X	X	X		II-68
2-Octadecanamine, N,N-dimethyl-, N-oxide	71662-60-7	X				II-69
Periodic acid	13444-71-8		X			II-70

Table II-1
Summary of Screen Reclamation Chemicals and Their Functions

Chemical	CAS Number	Ink Remover	Emulsion Remover	Haze Remover	Possible Substitutes	Page Number
Phosphoric acid, mixed ester w/ispropanol and ethoxylated tridecanol	68186-42-5			X		II-72
Potassium hydroxide	1310-58-3	X	X	X		II-73
Propylene carbonate	108-32-7				X	II-75
Propylene glycol	57-55-6	X		X		II-76
Propylene glycol methyl ether	107-98-2 1320-67-8	X	X			II-78
Propylene glycol methyl ether acetate	108-65-6	X	X			II-79
Silica	7631-86-9		X			II-81
Silica, fumed (amorphous, crystalline-free)	112945-52-5		X			II-82
Sodium bisulfate	10034-88-5		X			II-84
Sodium hexametaphosphate	10124-56-8		X	X		II-85
Sodium hydroxide	1310-73-2	X	X	X		II-87
Sodium hypochlorite	7681-52-9		X			II-88
Sodium lauryl sulfate	151-21-3			X		II-90
Sodium metasilicate	6834-92-0			X		II-91
Sodium periodate	7790-28-5		X			II-93
Sodium salt, dodecyl benzene sulfonic acid	25155-30-0			X		II-94
Solvent naphtha (petroleum), light aliphatic	64742-89-8	X				II-96
Solvent naphtha (petroleum), light aromatic	64742-95-6	X				II-98
Solvent naphtha (petroleum), heavy aromatic	64742-94-5	X				II-100
Tall oil, special	68937-42-5			X		II-101

Table II-1
Summary of Screen Reclamation Chemicals and Their Functions

Chemical	CAS Number	Ink Remover	Emulsion Remover	Haze Remover	Possible Substitutes	Page Number
Terpineols	8000-41-7	X	X			II-103
Tetrahydrofurfuryl alcohol	97-99-4			X		II-104
Toluene	108-88-3	X				II-106
1,1,1-Trichloroethane	71-55-6	X				II-107
1,2,4-trimethylbenzene	95-63-6	X				II-109
Tripropylene glycol methyl ether	25498-49-1	X		X		II-110
Trisodium phosphate	7601-54-9	X	X			II-112
Xylenes (dimethyl benzene)	1330-20-7	X		X		II-114

Categorization of Screen Reclamation Chemicals

In order to maintain confidentiality among the formulators and to simplify the evaluation of the different screen reclamation systems, some of the constituent chemicals were categorized. When a category is referred to (e.g., dibasic esters), that formulation includes one or more of the chemicals in that category (e.g., diethyl adipate, diethyl glutarate, diisopropyl adipate, etc.)

Table II-2.
Categorization of Screen Reclamation Chemicals for Use in Alternative System Formulations

Category	Chemicals from Screen Reclamation Use Cluster in Category
Alkali/caustic	Sodium hydroxide Potassium hydroxide
Alkyl benzyl sulfonates	Dodecyl benzene sulfonic acid, triethanol amine salt Sodium salt, dodecyl benzene sulfonic acid
Aromatic solvent naphtha	Solvent naphtha (petroleum), light aromatic Solvent naphtha (petroleum), heavy aromatic
Derivatized plant oil	Tall oil, special Ethoxylated castor oil
Dibasic esters	Diethyl adipate Diethyl glutarate Diisopropyl adipate Dimethyl adipate Dimethyl glutarate Dimethyl succinate
Diethylene glycol series ethers	Diethylene glycol butyl ether Diethylene glycol butyl ether acetate
Fatty alcohol ethers	Alcohols, C_8-C_{10}, ethoxylated Alcohols, C_{12}-C_{14}, ethoxylated
Phosphate salt	Sodium hexametaphosphate Trisodium phosphate
Propylene glycol series ethers	Dipropylene glycol methyl ether Propylene glycol methyl ether Tripropylene glycol methyl ether Propylene glycol methyl ether acetate Dipropylene glycol methyl ether acetate Ethoxypropanol Ethoxypropyl acetate Methoxypropanol acetate

Information on Individual Printing Chemicals

The following pages provide information on individual chemicals used in the screen printing industry for screen reclamation.

Acetone

Chemical Properties and Information	
Acetone [dimethyl ketone, 2-propanone]	C_3H_6O
CAS# 67-64-1	Structure: CH_3COCH_3
Molecular weight: 58.079	Boiling Point: 56.2°C (M)
Melting Point: -95.4 to -94°C (M)	Density: 0.7908_4^{20} g/ml (M)
Water Solubility: Miscible	Flash Point: -18°C (M)
Vapor Pressure: 185 mm Hg (20°C)	K_{oc}: 2 (E)
Log K_{ow}: -0.24 (M)	
Henry's Law Constant: 3.97×10^{-5} atm-m^3/mole (M)	
Chemistry of Use: Solvent	

Above data are either measured (M) or estimated (E)

Acetone is the simplest and most important of the ketones. It is a colorless, flammable liquid with a mildly pungent, somewhat aromatic odor. It shows typical reactions of aliphatic saturated ketones. It undergoes many condensation reactions; condensation with amines yields Schiff bases, and various esters condense readily with acetone in the presence of amine or ammonia. It is stable to many of the usual oxidants. Acetone is highly flammable and has a threshold limit value of 2400 mg/m^3.

The two common methods of manufacturing acetone are 1) cumene hydroperoxide cleavage and 2) the dehydrogenation of isopropyl alcohol. In the first process, benzene is alkylated to cumene, which is oxidized to cumene hydroperoxide, which, in turn, is cleaved to phenol and acetone. Acetone is a coproduct of this process, which is used to produce a large fraction of phenol produced in the U.S.. In the second process, which is endothermic, isopropanol is dehydrogenated catalytically, with a variety of possible catalysts, including copper, silver, platinum, and palladium metal; sulfides of transition metals, as well as zinc oxide-zirconium oxide, copper-chromium oxide, and copper-silicon dioxide combinations.

Market Profile

In 1992, total U.S. production was 230 million gallons. Imports were 9 million gallons and exports were 27 million gallons. Total U.S. quantity estimated for use in screen reclamation was 6.92 million gallons.

Regulatory Status

See Table II-3 and accompanying summary.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released on soil, acetone will volatilize into the air or leach into the ground where it will probably biodegrade. Photolysis will be important on terrestrial surfaces and in surface waters exposed to sunlight. If released to water, acetone may also be lost due to volatilization (estimated half-life 20 hr from a model river) and biodegradation. Bioconcentration in aquatic organisms and adsorption to sediment should not be important transport processes in water. In the atmosphere, acetone will be lost by photolysis and reaction with photochemically produced hydroxyl radicals. Half-life estimates from these combined processes average 22 days and are shorter in summer and longer in winter. In air, acetone may also be washed out by rain. Using a rapid and a moderate biodegradation rate for acetone in the STP fugacity model results in 97 and 84 percent, respectively, predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Alcohols, C_8-C_{10}, Ethoxylated

Chemical Properties and Information	
Alcohols, C_8-C_{10}, ethoxylated [ethoxylated fatty alcohols] CAS# 71060-57-6 Molecular weight: 150-220 Melting Point: <20°C (E) Water Solubility: Dispersable (n=3 to 10) (E) Vapor Pressure: <0.1 mm Hg (at 20°C) (E) Log K_{ow}: Not available Henry's Law Constant: Not available Chemistry of Use: Surfactant	Molecular formula varies Structure: R $(O\text{-}CH_2\text{-}CH_2)_nOH$, R = C_8 to C_{10} Boiling Point: Decomposes (E) Density: 1.02 g/cm^3 (E) Flash Point: >100°C (E) K_{oc}: Not available

Above data are either measured (M) or estimated (E)

These chemicals will exhibit surfactant-like properties for n=3 to 10. When n>10, they will behave as mild surfactants. Melting point, boiling point, and flash point will increase as n or R increases. They are soluble in alcohol and ether.

These chemicals are prepared by ethoxylation of alcohols with ethylene oxide.

Market Profile

Production volumes for C_8-C_{10} Ethoxylated Alcohols were not available. However, in 1992, total U.S. consumption of alcohol ethoxylates (including both C_8-C_{10} and C_{12}-C_{14}) was 386 million pounds. In 1988, 29 million pounds of this chemical was exported. Data for imported amounts was not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Alcohols, C_8-C_{10}, ethoxylated do not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, C_8-C_{10} ethoxylated alcohols are expected to rapidly biodegrade. Two factors influencing biodegradation are the number of ethylene oxide units in the hydrophilic moiety and the structure of the hydrophobic moiety. Studies have shown that the linearity of the hydrophobic moiety has a more pronounced effect on biodegradability than the hydrophobic chain length, point of attachment of the polyglycol chain (i.e., whether alcohol moiety is primary or secondary), or degree of ethoxylation. Biodegradation occurs by the β-oxidation of the alkyl chain, scission of the hydrophobic and hydrophic moieties and step-wise removal of ethoxylate groups, forming more hydrophobic metabolites. The C_8-C_{10} ethoxylated alcohols will be highly mobile in soil with the mobility increasing with increasing number of ethoxylate groups. Volatilization from soil to the atmosphere is not expected to occur. Studies have shown that C_8-C_{10} ethoxylated alcohols undergo rapid biodegradation in river water; degradation is essentially complete in about a week. Shorter chain ethoxylates may also partition to sediment and particulate matter in the water column. Volatilization of C_8-C_{10} ethoxylated alcohols to the atmosphere is not expected to occur. If released to the atmosphere, C_8-C_{10} ethoxylated alcohols will be associated with aerosols and will be removed by wet and dry deposition. Using a rapid biodegradation rate in the STP fugacity model results in 100 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Alcohols, C_{12}-C_{14}, ethoxylated

Chemical Properties and Information	
Alcohols, C_{12}-C_{14}, ethoxylated [ethoxylated fatty alcohols] CAS# 68439-50-9 Molecular weight: >200 Melting Point: <50°C (E) Water Solubility: Dispersable (n=3 to 10) (E)Vapor Pressure: <0.01 mm Hg (E) Log K_{ow}: Not available Henry's Law Constant: Not available Chemistry of Use: Surfactant	Molecular formula varies Structure: R $(O\text{-}CH_2\text{-}CH_2)_nOH$, R = C_{12} to C_{14} Boiling Point: Decomposes (E) Density: 0.95 g/cm^3 (E) Flash Point: >100°C (E) K_{oc}: Not available

Above data are either measured (M) or estimated (E)

These chemicals will exhibit surfactant-like properties for n=3 to 10. When n>10, they will behave as mild surfactants. Melting point, boiling point, and flash point will increase as n or R increases. They are miscible in organic solvents.

These chemicals are prepared by ethoxylation of alcohols with ethylene oxide.

Market Profile

Production volumes for C_{12}-C_{14} ethoxylated alcohols were not available. However, in 1992, total U.S. consumption of alcohol ethoxylates (including both C_8-C_{10} and C_{12}-C_{14}) was 386 million pounds. In 1988, 29 million pounds of this chemical was exported. Data for imported amounts was not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Alcohols, C_{12}-C_{14}, ethoxylated do not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, C_{12}-C_{14} ethoxylated alcohols are expected to rapidly biodegrade. Two factors influencing biodegradation are the number of ethylene oxide units in the hydrophilic moiety and the structure of the hydrophobic moiety. Studies have shown that the linearity of the hydrophobic moiety has a more pronounced effect on biodegradability than the hydrophobic chain length, point of attachment of the polyglycol chain (i.e., whether alcohol moiety is primary or secondary), or degree of ethoxylation. Biodegradation occurs by the β-oxidation of the alkyl chain, scission of the hydrophobic and hydrophic moieties and step-wise removal of ethoxylate groups, forming more hydrophobic metabolites. The C_{12}-C_{14} ethoxylated alcohols will be highly mobile in soil with the mobility increasing with increasing number of ethoxylate groups. Volatilization from soil to the atmosphere is not expected to occur. Studies have shown that C_{12}-C_{14} ethoxylated alcohols undergo rapid biodegradation in river water; degradation is essentially complete in about a week. Shorter chain ethoxylates may also partition to sediment and particulate matter in the water column. Volatilization of C_{12}-C_{14} ethoxylated alcohols to the atmosphere is not expected to occur. If released to the atmosphere, C_{12}-C_{14} ethoxylated alcohols will be associated with aerosols and will be removed by wet and dry deposition. Using a rapid biodegradation rate in the STP fugacity model results in 100 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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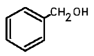
Benzyl Alcohol

Chemical Properties and Information	
Benzyl alcohol [Benzenemethanol, Benzene carbinol, α-Hydroxy toluene] CAS# 100-51-6 Molecular weight: 108.13 Melting Point: -15.19°C (M) Water Solubility: 40 g/L (M) Vapor Pressure: 0.048 mm Hg (at 20°C) (E) 1 mm Hg (at 58°C) (M) Log K_{ow}: 1.10 (M) Henry's Law Constant: $2.1X10^{-7}$ atm-m^3/mole (E) Chemistry of Use: Solvent	C_7H_8O Structure:  Boiling Point: 204.7°C (M) Density: 1.045 g/cm^3 (M) Flash Point: 101°C (closed cup) (M) 104°C (open cup) (M) K_{oc}: 5 - 16 (M)

Above data are either measured (M) or estimated (E)

This chemical has a faint aromatic odor and sharp burning taste. It is miscible with alcohol, ether, chloroform, acetone.

Benzyl alcohol is produced by reaction of sodium or potassium carbonate with benzyl chloride.

Market Profile

In 1988, total U.S. production was 4.8 million gallons; an additional 1.6 million gallons was imported. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Benzyl alcohol does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, benzyl alcohol is expected to display high mobility. Volatilization from moist soil to the atmosphere is not expected to be important, although it may slowly volatilize from dry soils. Microbial degradation in soil may be rapid, especially in acclimated soils. If released to water, benzyl alcohol is expected to undergo microbial degradation under aerobic conditions. Biodegradation may be rapid under acclimated conditions. It is also expected to slowly biodegrade under anaerobic conditions. Neither volatilization to the atmosphere, chemical hydrolysis, direct photolytic degradation, chemical oxidation, bioconcentration in fish and aquatic organisms, nor adsorption to sediment and suspended organic matter are expected to be significant processes in environmental waters. If released to the atmosphere, benzyl alcohol is expected to undergo a gas-phase reaction with photochemically produced hydroxyl radicals; the estimated half life for this process is 16 hours. Its water solubility indicates that benzyl alcohol may also undergo atmospheric removal by wet deposition processes; however, its short atmospheric residence time suggests that wet deposition may be of limited importance. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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2-Butoxyethanol

Chemical Properties and Information	
2-Butoxyethanol [Glycol ether EB; butyl Cellosolve; Dowanol EB; Poly-Solv EB; glycol butyl ether, ethylene glycol monobutyl ether] CAS# 111-76-2 Molecular weight: 118.18 Melting Point: -75°C (M) Water Solubility: Miscible (E) Vapor Pressure: 3 mm Hg (25°C)(E) Log K_{ow} = 0.57 (E) Henry's Law Constant: 2.1×10^{-8} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_6H_{14}O_2$ Structure: $CH_3CH_2CH_2CH_2OCH_2CH_2OH$ Boiling Point: 171.2°C (M) Density: 0.902 g/ml (M) Flash Point: Open cup: 74°C (M) Closed cup: 68°C (M) K_{oc}: 49 (E)

Above data are either measured (M) or estimated (E)

The physical state of 2-butoxyethanol is an oily, colorless liquid with mild rancid odor. Glycol ethers are both ethers and alcohols. Their hydroxyl groups can be etherified, esterified, chlorinated, or otherwise modified.

The reaction of ethylene oxide and alcohols gives a mixture of glycol monoethers and monoethers of the lower polyethylene glycols.

Market Profile

In 1991, total U.S. production was 350 million gallons. In 1991, imports were 2.8 million gallons and in 1988, exports were 73.1 million gallons. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary. The generic category of glycol ethers are also listed as Hazardous Air Pollutants in the Clean Air Act.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

2-butoxyethanol is not expected to undergo hydrolysis or direct photolysis in the environment. In water, volatilization, adsorption to sediments and suspended solids, and bioconcentration in aquatic organisms are not expected to be important transport processes for

2-butoxyethanol. Aqueous screening test data indicate that biodegradation is likely to be the most important removal mechanism of 2-butoxyethanol from aerobic soil and water. If released to soil, 2-butoxyethanol is expected to display very high mobility. Volatilization from dry soil surfaces will be important. In the atmosphere, 2-butoxyethanol is expected to exist almost entirely in the gas-phase and reactions with photochemically produced hydroxyl radicals should be fast (estimated half-life of 5.6 hrs). Using a rapid biodegradation rate for 2-butoxyethanol in the STP fugacity model results in 97 percent predicted removal from wastewater treatment plants; a moderate rate corresponds to 83 percent predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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Butyl Acetate

Chemical Properties and Information	
Butyl acetate [*n*-butyl acetate; butyl ethanoate]	$C_6H_{12}O_2$
CAS# 123-86-4	Structure: $CH_3COOCH_2CH_2CH_2CH_3$
Molecular weight: 116	Boiling Point: 125-6°C (M)
Melting Point: -77°C (M)	Density: 0.883 g/ml (M)
Water Solubility: 10 g/l (E)	Flash Point: 29°C (M)
Vapor Pressure: 12.8 mm Hg (25°C)(M)	K_{oc}: 23 (E)
Log K_{ow} = 1.82 (M)	Physical state: Liquid
Henry's Law Constant: 2.81 x 10^{-4} atm-m^3/mole (M)	
Chemistry of Use: Solvent	

Above data are either measured (M) or estimated (E)

Butyl acetate is a colorless, flammable liquid with a pleasant, fruity odor. It is miscible with most organic solvents. The threshold limit value for air is 150 ppm. The vapors are irritating to the eyes and respiratory tract. Synthetic esters are generally prepared by reaction of an alcohol with an organic acid in the presence of a catalyst such as sulfuric acid or *p*-toluene sulfonic acid. Butyl acetate thus may be prepared by the reaction of butanol and acetic acid.

Market Profile

In 1992, total U.S. production was 250 million gallons. In 1991, imports were less than 100,000 million gallons. In 1992, exports were 127.5 million gallons. Total U.S. production quantity for use in screen reclamation was estimated to be 1.92 million gallons.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, butyl acetate is expected to rapidly biodegrade. Chemical hydrolysis is not expected to occur in moist soils although it may occur in alkaline soils (pH greater than 8). Butyl acetate is expected to display high mobility. Volatilization of butyl acetate to the atmosphere from both dry and moist soil surfaces may be significant. If released to water, butyl acetate is expected to biodegrade under aerobic conditions as 5-day theoretical BODs of 23-58 percent using a sewage seed, 21 percent in river water, and 40 percent in salt water have been reported. Volatilization to the atmosphere is also expected to be important. The hydrolysis half-lives of butyl acetate at pHs 7.0, 8.0, and 9.0 are about 3.1 years, 114 days and 11.4 days, respectively, at 20 °C indicating that hydrolysis will be important only in very alkaline environmental waters. Adsorption to sediment and suspended organic matter and bioconcentration in fish and aquatic organisms are not expected to be significant processes. If released to air, butyl acetate will exist almost entirely in the gas-phase in the ambient atmosphere. It may undergo atmospheric removal by the gas-phase reaction with photochemically produced hydroxyl radicals with an estimated half-life of 2.5 days for this process. Butyl acetate may also undergo atmospheric removal by wet deposition processes; however, its short atmospheric residence time suggests that this process may be of limited importance. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Butyrolactone

Chemical Properties and Information

Butyrolactone [γ-Butyrolactone; dihydro-2(3H)-furanone; 1,2-butanolide; 1,4-butanolide; γ-hydroxybutyric acid lactone; 3-hydroxybutyric acid lactone; 4-hydroxybutanoic acid lactone]
CAS# 96-48-0
Molecular weight: 86
Melting Point: -44°C (M)
Water Solubility: miscible (M)
Vapor Pressure: 3.2 mm Hg (25° C)(M)
Log K_{ow} = -0.640 (M)
Henry's Law Constant: 1.81×10^{-5} atm-m^3/mole (E)
Chemistry of Use: Solvent

$C_4H_6O_2$
Structure:
Boiling Point: 204°C (M)
Density: 1.125 g/ml (M)
Flash Point: Open cup: 98°C (M)
K_{oc}: 53 (E)
Physical state: Liquid

Above data are either measured (M) or estimated (E)

Butyrolactone undergoes characteristic γ-lactone reactions including ring openings and reactions wherein oxygen is replaced by another ring heteroatom. There is also a marked reactivity of the alpha hydrogen atoms. Butyrolactone is soluble in methanol, ethanol, acetone, ether and benzene.

Two routes are used for commercial production: the dehydrogenation of butanediol, and hydrogenation of maleic anhydride to tetrahydrofuran and butyrolactone. In the former, the exothermic dehydrogenation is carried out in a fixed bed at atmospheric pressure with preheated butyrolactone over a copper-on-silica catalyst at 230 to 250°C. The yield of butyrolactone, purified by distillation, is approximately 90 percent.

Market Profile

In 1990, total U.S. production was 67 million gallons. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Butyrolactone does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary
See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

In aqueous solutions butyrolactone is in dynamic equilibrium with its free acid and under basic conditions the acid form may predominate. If released to soil, butyrolactone may volatilize from both dry and moist soil to the atmosphere. It is expected to display moderate to high mobility in soil. In basic soils, the free acid form may predominate which may alter both the rate at which butyrolactone volatilizes from soil and the degree to which it adsorbs. Biodegradation in acclimated aerobic soils is expected. If released to water, butyrolactone may volatilize from water to the atmosphere. The estimated half-life for volatilization from a model river is 1.5 days. Butyrolactone is not expected to bioconcentrate in fish and aquatic organisms, nor is it expected to adsorb to sediment and suspended organic matter. Biodegradation under aerobic conditions is expected. If released to the atmosphere, butyrolactone is expected to undergo a gas-phase reaction with photochemically produced hydroxyl radicals; the estimated half life for this process is 4.4 days. Butyrolactone may also undergo atmospheric removal by both wet and dry deposition processes. Using a rapid biodegradation rate for butyrolactone in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants. If a moderate biodegradation rate is used in this model, 83 percent predicted total removal may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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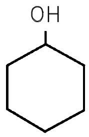
Cyclohexanol

Chemical Properties and Information	
Cyclohexanol [hexahydrophenol, hexalin] CAS# 108-93-0 Molecular weight: 100.16 Melting Point: 23 - 25°C (M) Water Solubility: 36 g/l (at 20°C) (M) Vapor Pressure: 0.8 torr (at 20°C) (M) Log K_{ow}: 1.23 (M) Henry's Law Constant: $1.02X10^{-4}$ atm-m^3/mole (M) Chemistry of Use: Solvent	$C_6H_{12}O$ Structure:  Boiling Point: 161°C (M) Density: 0.962 g/cm^3 (at 20°C) (M) Flash Point: 68°C (closed cup) (M) K_{oc}: 111 and 13 (E)

Above data are either measured (M) or estimated (E)

This chemical exists as hygroscopic crystals and has a camphor-like odor. Cyclohexanol is moderately flammable. It is miscible with ethanol, ethyl acetate, linseed oil, petroleum solvent, and aromatic hydrocarbons.

Cyclohexanol is formed either by oxidation of cyclohexane, or hydrogenation of phenol.

Market Profile

In 1992, total U.S. production for both cyclohexanol and cyclohexanone was 2.1 billion gallons. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Cyclohexanol does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, cyclohexanol will be expected to exhibit high to very high mobility in soil. It will not hydrolyze in moist soil, but it may be subject to volatilization from near surface soil. It may be subject to biodegradation in soil based upon results observed in laboratory aqueous screening tests. If released to water, it will not be expected to adsorb to sediment or suspended particulate matter or to bioconcentrate in aquatic organisms. It will not be expected to hydrolyze or directly photolyze in water. It may be subject to biodegradation in natural waters based upon results observed in laboratory biodegradation aqueous aerobic screening tests using sewage and activated sludge inocula. It will be subject to volatilization from surface waters with estimated half-lives of 23 hr for volatilization from a model river and 10.6 days for volatilization from a model pond, respectively. If released to the atmosphere, it can be expected to exist mainly in the vapor-phase in the ambient atmosphere based on its vapor pressure. The estimated half-life for vapor-phase reaction with photochemically produced hydroxyl radicals is 22 hr at an atmospheric concentration of $5X10^4$ hydroxyl radicals per cm^3. Cyclohexanol will not be expected to directly photolyze in the atmosphere. Using a rapid biodegradation rate for cyclohexanol in the STP fugacity model, 97 percent removal can be predicted from wastewater treatment plants. Using a moderate biodegradation rate for cyclohexanol in the STP fugacity model, 84 percent removal can be predicted from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Cyclohexanone

Chemical Properties and Information

Cyclohexanone [ketohexamethylene, pimelic ketone, cyclohexyl ketone, Hytrol O, Anone, Nadone]
CAS# 108-94-1
Molecular weight: 98
Melting Point: -47°C (M)
Water Solubility: 100 g/l (E)
Vapor Pressure: 3.975 mm Hg (M) (20°C)
Log K_{ow} = 0.81 (M)
Henry's Law Constant: 9×10^{-6} atm-m^3/mole (M)
Chemistry of Use: Solvent

$C_6H_{10}O$
Structure:
Boiling Point: 156.7°C (M)
Density: 0.9478 g/ml (M)
Flash Point: Closed cup: 42°C (M)
K_{oc}: 10 (E)

Above data are either measured (M) or estimated (E)

Cyclohexanone is a colorless liquid with an odor suggestive of peppermint and acetone. Cyclohexanone is miscible with methanol, ethanol, acetone, benzene, *n*-hexane, nitrobenzene, dimethyl ether, naphtha, xylene, ethylene, glycol, isoamyl acetate, diethylamine, and most organic solvents.

Cyclohexanone may be produced by the catalytic hydrogenation of phenol, by the catalytic air oxidation of cyclohexanol, by the catalytic dehydrogenation of cyclohexanol, or by the oxidation of cyclohexanol. The hydrogenation of phenol, which is best carried out in the liquid phase, catalyzed by palladium on carbon, is the most efficient route.

Market Profile

In 1992, total U.S. production for both cyclohexanol and cyclohexanone was 2.1 billion gallons. Imports were 0.6 million gallons and exports were 48.5 million gallons. Total U.S. production quantity of cyclohexanone for use in screen reclamation was estimated to be 270,000 gallons.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to the atmosphere, cyclohexanone will degrade by reaction with sunlight produced hydroxyl radicals (half-life of about 1 day) and by direct photolysis (half-life of about 4.3 days). If released to water, cyclohexanone may degrade through biodegradation and photolysis. Volatilization from environmental waters will not be rapid except from rapidly moving, shallow streams. If released to soil, cyclohexanone will be susceptible to significant leaching. Volatilization and photodegradation will occur on soil surfaces. Using a rapid and a moderate biodegradation rate for cyclohexanone in the STP fugacity model results in about 97 and 83 percent, respectively, predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Diacetone Alcohol

Chemical Properties and Information	
Diacetone alcohol [4-hydroxy-4-methyl-2-pentanone, dimethylacetonylcarbinol, 2-methyl-2-pentanol-4-one; pyranton] CAS# 123-42-2 Molecular weight: 116 Melting Point: -44°C (M) Water Solubility: Miscible Vapor Pressure: 0.97 mm Hg (M) (20°C) Log K_{ow} = -0.34 (E) Henry's Law Constant: 1.4 x 10^{-9} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_6H_{12}O_2$ Structure: $(CH_3)_2C(OH)CH_2COCH_3$ Boiling Point: 164°C (M) Density: 0.9306 g/ml (M) Flash Point: Open Cup: -66°C (M) K_{oc}: 21 (E)

Above data are either measured (M) or estimated (E)

Technical grade diacetone alcohol contains up to 15 percent acetone. Diacetone alcohol is miscible with alcohol, ether, and other solvents. Its physical state is a colorless oily liquid with a faint pleasant odor.

Diacetone alcohol may be produced from acetone in the presence of a base such as barium hydroxide or calcium hydroxide. It can be isolated from the arctic bramble *Rubus articus*, from green algae and from the sleepy grass sp. *Stipa vaseyi*.

Market Profile

In 1990, total U.S. production volume was 18 million gallons. In 1992, imports were 0.5 million gallons and exports were 1.8 million gallons. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Diacetone alcohol does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, diacetone alcohol will be expected to exhibit very high mobility. Although no data were located regarding its biodegradation in soil, the compound may be subject to biodegradation in soil based upon results observed in laboratory biodegradation aqueous aerobic screening tests. It should not be subject to volatilization from moist near-surface soil. However, it may volatilize from dry near-surface soil and other dry surfaces. In water, it will not be expected to adsorb to sediment or suspended particulate matter or bioconcentrate in aquatic organisms. Diacetone alcohol has been demonstrated to biodegrade in aqueous aerobic screening tests. The compound may be subject to biodegradation in natural waters. It should not be subject to volatilization from surface waters. Hydrolysis should not be an important removal process. If released to the atmosphere, gas-phase diacetone alcohol will react with photochemically produced hydroxyl radicals; the estimated half-life is 8 days (12-hr daylight day). Diacetone alcohol may be susceptible to direct photolysis in the atmosphere based upon its possible absorption of light at wavelengths greater than 290 nm. The compound may be susceptible to removal from the atmosphere by washout because of its high water solubility. Using a moderate biodegradation rate for diacetone alcohol in the STP fugacity model, 83 percent total removal can be predicted from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Dichloromethane

Chemical Properties and Information	
Dichloromethane [methylene chloride; methylene dichloride; Freon 30; DCM] CAS# 75-09-2 Molecular weight: 84.93 Melting Point: -97°C (M) Water Solubility: 17 g/l (M) Vapor Pressure: 340 mm Hg (20°C) (M) Log K_{ow} = 1.25 (M) Henry's Law Constant: 3.25 x 10^{-3} atm-m^3/mole (M) Chemistry of Use: Solvent	CH_2Cl_2 Structure: CH_2Cl_2 Boiling Point: 40-41°C (M) Density: 1.33_4^{15} g/ml (M) Flash Point: -96.8°C (M) K_{oc}: 67 (M) Physical state: Clear, colorless volatile liquid

Above data are either measured (M) or estimated (E)

Methylene chloride is nonflammable, and stable under normal laboratory storage conditions. It is soluble in ether. Methylene chloride may form explosive mixtures with certain materials.

Methylene chloride is produced industrially by (1) first reacting hydrogen chloride and methanol in the vapor phase with the aid of a catalyst to give methyl chloride, and then chlorinating, (the predominant method) or (2) directly reacting excess methane with chlorine at high temperature (≅ 485-510°C), which produces multiple coproducts.

Market Profile

In 1991, total U.S. production was 240 million gallons. Imports were 5.6 million gallonsss and exports were 79.0 million gallons. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, dichloromethane is expected to display high mobility. It may rapidly volatilize from both moist and dry soil to the atmosphere. Aerobic biodegradation may be important for dichloromethane in acclimated soils. If released to water, volatilization to the atmosphere is expected to be a rapid process. Neither bioconcentration in fish and aquatic organisms nor adsorption to sediment and suspended organic matter are expected to be significant. Dichloromethane has been found to slowly biodegrade under aerobic conditions. It is also expected to slowly biodegrade under anaerobic conditions in sediment and groundwater. If released to the atmosphere, dichloromethane is expected to persist for long periods of time. The estimated half-life for the gas-phase reaction of dichloromethane with hydroxyl radicals is approximately 88 days. Direct photolytic degradation is not expected to occur. Dichloromethane may undergo atmospheric removal by wet deposition processes although any removed by this processes is expected to rapidly re-volatilize to the atmosphere. Using a slow biodegradation rate for dichloromethane in the STP fugacity model, 64 percent total removal can be predicted from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Diethyl Adipate

Chemical Properties and Information	
Diethyl adipate [Diethyl ester adipic acid] CAS# 141-28-6 Molecular weight: 202.25 Melting Point: -19.8°C (M) Water Solubility: 0.1 g/L (E) Vapor Pressure: 0.8 mm Hg (25°C)(E) Log K_{ow} = 2.37 (E) Henry's Law Constant: 2.3×10^{-7} atm-m^3/mole (E) Chemistry of Use: Lubricant, Plasticizer	$C_{10}H_{18}O_4$ Structure: $(C_2H_5O)CO(CH_2)_4OC(OC_2H_5)$ Boiling Point: 245°C (M) Density: 1.002 g/ml (M) Flash Point: 110°C (M) K_{oc}: 44 (E) Physical state: Colorless liquid

Above data are either measured (M) or estimated (E)

Diethyl adipate is soluble in alcohol and ether. When heated to decomposition, it emits acrid smoke and fumes. The production of adipic acid esters is second only to the production of adipic acid polyamides. These esters are marketed as plasticizers.

Diethyl adipate is the esterification product of adipic acid and ethanol. Adipic acid is produced by the oxidation with air and nitric acid, separately, of cyclohexane. Diethyl adipate, along with other esters, is produced in the mother liquor during adipic acid manufacturing. Diethyl adipate is produced along with other esters, and is subsequently separated and refined by distillation.

Market Profile

In 1991, total U.S. production of adipate plasticizers was 35 million pounds. Data specific to diethyl adipate was not available; nor were data for imported and exported amounts. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Diethyl adipate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, diethyl adipate is expected to display high mobility. Biodegradation in aerobic soils may be rapid. Volatilization of diethyl adipate from both moist and dry soil to the atmosphere is expected to be very slow. Chemical hydrolysis of the ester group is not expected to be significant except for highly basic soils (pH greater than8). If released to water, aerobic biodegradation may be rapid. Diethyl adipate is not expected to bioconcentrate in fish and aquatic organisms or adsorb to sediment and suspended organic matter. Volatilization of diethyl adipate from water to the atmosphere will be very slow. Chemical hydrolysis may occur in highly basic waters. If released to the atmosphere, diethyl adipate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 1.9 days. It may also undergo atmospheric removal by both wet and dry deposition processes; however, its short atmospheric residence time suggests that wet deposition is of limited importance. Using a rapid biodegradation rate for diethyl adipate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants. If a moderate biodegradation rate is used in this model, 85 percent predicted total removal may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Diethyl Glutarate

Chemical Properties and Information	
Diethyl glutarate [Diethyl ester glutaric acid; diethyl pentanedioic acid] CAS# 818-38-2 Molecular weight: 188.2 Melting Point: -24.1°C (M) Water Solubility: 8.8 g/L (at 20° C) (M) Vapor Pressure: 0.1 mm Hg (25°C)(E) Log K_{ow} = 1.88 (E) Henry's Law Constant: 1.65×10^{-7} atm-m^3/mole (E) Chemistry of Use: Plasticizer	$C_9H_{16}O_4$ Structure: $(C_2H_5O)CO(CH_2)_3CO(OC_2H_5)$ Boiling Point: 237°C (M) Density: 1.022 g/ml (M) Flash Point: 96°C (M) K_{oc}: 20 (E) Physical state: Colorless liquid

Above data are either measured (M) or estimated (E)

Diethyl glutarate is incompatible with acids, bases, oxidizing agents, and reducing agents. It is soluble in alcohol and ether. Diethyl glutarate can be isolated from the water extracts of crude wool.

Diethyl glutarate is produced by the oxidation of cyclopentanol or cyclopentanone. The resulting glutaric acid is then reacted with ethanol to give the product diethyl glutarate. Esterification of glutaric acid followed by distillation gives adequate results.

Market Profile

In 1991, total U.S. production for glutarate plasticizers was 3 million pounds. This category includes both diethyl glutarate and dimethyl glutarate, among others. Data specific to Diethyl Glutarate were not available; nor were data for imported and exported amounts. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Diethyl glutarate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, diethyl glutarate is expected to display very high mobility. Biodegradation in acclimated aerobic soils may be rapid. Volatilization of diethyl glutarate from moist soil to the atmosphere is expected to be very slow although volatilization from dry soil may be significant. Chemical hydrolysis of the ester group is not expected to be significant except for highly basic soils (pH greater than8). If released to water, aerobic biodegradation may be rapid especially in acclimated waters. Diethyl glutarate is not expected to appreciably bioconcentrate in fish and aquatic organisms or adsorb to sediment and suspended organic matter. Volatilization of diethyl glutarate from water to the atmosphere will likely be very slow. Hydrolysis may occur in highly basic waters. If released to the atmosphere, diethyl glutarate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 2.5 days. It may also undergo atmospheric removal by both wet and dry deposition processes. Using a rapid biodegradation rate for diethyl glutarate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants. If a moderate biodegradation rate is used in this model, 84 percent predicted total removal may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Diethylene Glycol

Chemical Properties and Information	
Diethylene glycol [2,2'-oxybisethanol, 2,2'-oxydiethanol, diglycol, ß,ß'-dihydroxydiethyl ether, dihydroxyethyl ether, ethylene diglycol, 3-oxa-1,5-pentanediol, DEG, Dicol, bis(2-hydroxyethyl) ether, diglycol] CAS# 111-46-6 Molecular weight: 106.12 Melting Point: -6.5°C (M) Water Solubility: Miscible Vapor Pressure: <0.0013 mm Hg at 25°C (M) Log K_{ow}: -1.47 (E) Henry's Law Constant: 2.03X10^{-9} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_4H_{10}O_3$ Structure: $HOCH_2CH_2OCH_2CH_2OH$ Boiling Point: 245.8°C (M) Density: 1.11 (M) Flash Point: 138°C (M) K_{oc}: 4 (E)

Above data are either measured (M) or estimated (E)

Diethylene glycol is readily esterified with mono- and dicarboxylic acids to yield plasticizers and resins. Diethylene glycol is similar in many respects to ethylene glycol but contains an ether group. 1,4-Dioxane is prepared directly from diethylene glycol. It is miscible with water and other polar solvents.

Diethylene glycol is a co-product when ethylene glycol is produced by ethylene oxide hydrolysis. The acid-catalyzed hydrolysis reaction is conducted in a large excess of water at moderate temperatures. This reaction yields approximately 9 to 10 percent diethylene glycol as the primary by-product.

Market Profile

In 1991, total U.S. production was 369.2 million gallons. Imports in 1992 were about 99 million gallons; exports were about 25 million gallons. Total U.S. production quantity for use in screen reclamation was estimated to be 122,000 gallons.

Regulatory Status

Diethylene glycol does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, diethylene glycol is expected to biodegrade under aerobic conditions and it may be rapid if acclimated organisms are present. It is expected to display high mobility, although rapid biodegradation will decrease its potential to leach through soil. Volatilization of diethylene glycol from both moist and dry soil to the atmosphere is not expected to be important. If released to water, diethylene glycol is expected to biodegrade under aerobic conditions and it may be rapid if acclimated organisms are present. Diethylene glycol is also expected to slowly degrade under anaerobic conditions. Neither bioconcentration in fish and aquatic organisms, adsorption to sediment and suspended organic matter, nor volatilization to the atmosphere are expected to be important. If released to the atmosphere, diethylene glycol is degraded rapidly by reaction with photochemically produced hydroxyl radicals (typical half-life of 6.2 hours). Physical removal by wet deposition processes may also occur because of its substantial water solubility; however, its short atmospheric residence time suggests that wet deposition may be of limited importance. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants; a moderate rate corresponds to 84 percent predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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Diethylene Glycol Monobutyl Ether

Chemical Properties and Information

Diethylene glycol monobutyl ether [2-(2-butoxyethoxy) ethanol; butyl ethyl Cellosolve; diethylene glycol butyl ether; butyl Carbitol; Dowanol DB; Poly-Solv DB; butoxydiglycol, butyl digol, butyl diicinol]
CAS# 112-34-5
Molecular weight: 162.2
Melting Point: -68°C (M)
Water Solubility: Miscible (E)
Vapor Pressure: 0.02 mm Hg (E) (20° C)
Log K_{ow} = 0.29 (E)
Henry's Law Constant: 1.5×10^{-9} atm-m^3/mole (E)
Chemistry of Use: Solvent

$C_8H_{18}O_3$
Structure: $C_4H_9OCH_2CH_2OCH_2CH_2OH$
Boiling Point: 231° C (M)
Density: 0.954 g/ml (M)
Flash Point: Open cup: 110°C (M)
Closed cup: 78°C (M)
K_{oc}: 34 (E)

Above data are either measured (M) or estimated (E)

Glycol ethers are both ethers and alcohols. Their hydroxyl groups can be etherified, esterified, chlorinated, or otherwise modified. Diethylene glycol monobutyl ether is miscible in many organic solvents. It is a colorless liquid with a mild pleasant odor.

The reaction of ethylene oxide and alcohols gives a mixture of glycol monoethers and monoethers of the lower polyethylene glycols.

Market Profile

In 1991, total U.S. production was 100 million gallons. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation was estimated to be 420,000 gallons.

Regulatory Status

Diethylene glycol monobutyl ether does not trigger any federal environmental regulations. However, the generic category of glycol ethers is listed as Hazardous Air Pollutants in the Clean Air Act.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Diethylene glycol monobutyl ether is not expected to undergo hydrolysis or direct photolysis in the environment. Volatilization, adsorption and bioconcentration are not important transport processes of diethylene glycol monobutyl ether in water. Aqueous screening test data indicate that biodegradation may be an important removal mechanism of diethylene glycol monobutyl ether from aerobic soil and water. If released to soil, diethylene glycol monobutyl ether is expected to display very high mobility. Volatilization from dry soil surfaces will be important. In the atmosphere, diethylene glycol monobutyl ether is expected to exist almost entirely in the gas-phase and reactions with photochemically produced hydroxyl radicals should be fast (estimated half-life of 3.5 hours). Physical removal of diethylene glycol monobutyl ether from air by wet deposition may occur due to its high water solubility; however, its short atmospheric residence time suggests that wet deposition is of limited importance. Using a rapid biodegradation rate for diethylene glycol monobutyl ether in the STP fugacity model results in 97 percent predicted removal from wastewater treatment plants; a moderate rate corresponds to 83 percent predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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Diethylene Glycol Butyl Ether Acetate

Chemical Properties and Information	
Diethylene glycol butyl ether acetate [2-(2-butoxyethoxy) ethanol acetate; butyl diethylene glycol acetate; diglycol monobutyl ether acetate] CAS# 124-17-4 Molecular weight: 204.26 Melting Point: -32.2°C (M) Water Solubility: 65 g/l (M) Vapor Pressure: <0.01 mm Hg (M) (20° C) Log K_{ow} = 1.3 (E) Henry's Law Constant: 9.9×10^{-8} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_{10}H_{20}O_4$ Structure: $C_4H_9(OC_2H_4)_2OOCCH_3$ Boiling Point: 246.7°C (M) Density: 0.9810 g/ml (M) Flash Point: Open cup: 115.6°C (M) K_{oc}: 15 (E)

Above data are either measured (M) or estimated (E)

Diethylene glycol monobutyl ether acetate is soluble in ethanol, ether, acetone, and other organic solvents. It is a liquid with a mild, not unpleasant odor. Its fire potential is moderate; when exposed to heat or flame it emits degradation products, it can react with oxidizing materials.

Diethylene glycol butyl ether acetate is manufactured by the esterification of diethylene glycol monobutyl ether with acetic acid or acetic anhydride.

Market Profile

In 1991, total U.S. production of "other" E-series glycol ethers was 500,000 pounds. This category includes diethylene glycol butyl ether acetate, as well as other minor E-series glycol ethers. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Diethylene glycol butyl ether acetate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Diethylene glycol butyl ether acetate is not expected to undergo hydrolysis or direct photolysis in the environment. In water, volatilization, adsorption to sediments and suspended solids, and bioconcentration in aquatic organisms are not expected to be important transport processes for diethylene glycol butyl ether acetate. Biodegradation is likely to be the most important removal mechanism of diethylene glycol butyl ether acetate from aerobic soil and water based on a 4-week BOD of 100 percent of theoretical. If released to soil, diethylene glycol butyl ether acetate is expected to display very high mobility. Volatilization from dry soil surfaces will be important. In the atmosphere, diethylene glycol butyl ether acetate is expected to exist almost entirely in the gas-phase and reactions with photochemically produced hydroxyl radicals should be fast (estimated half-life of 3.8 hrs). Physical removal of diethylene glycol butyl ether acetate from air by wet deposition may occur due to its high water solubility; however, its short atmospheric residence time suggests that wet deposition is of limited importance. Using a rapid biodegradation rate for diethylene glycol butyl ether acetate in the STP fugacity model results in 97 percent predicted removal from wastewater treatment plants; a moderate rate corresponds to 83 percent predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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Diisopropyl Adipate

Chemical Properties and Information	
Diisopropyl adipate [Disopropyl adipate; 2,3-dimethylbutyl adipate; adipic acid diisopropyl ester] CAS# 6938-94-9 Molecular weight: 230.34 Melting Point: -1.1°C (M) Water Solubility: 1 g/L (E) Vapor Pressure: 0.02 mm Hg (25°C)(E) Log K_{ow} = 3.2 (E) Henry's Law Constant: 1.3 x 10^{-6} atm-m^3/mole (E) Chemistry of Use: Lubricant, Plasticizer	$C_{12}H_{22}O_4$ Structure: -i-$C_3H_7O_2C(CH_2)_4CO_2$-i-C_3H_7 Boiling Point: 257°C (at 760 mm Hg) (E) Density: 0.9569 g/ml (M) Flash Point: 116°C (M) K_{oc}: 1311 (E) Physical state: Colorless, odorless liquid

Above data are either measured (M) or estimated (E)

Diisopropyl adipate is soluble in alcohol, ether, acetone and acetic acid. When heated to decomposition, it emits acrid smoke and fumes. The largest consumption of adipic acid after polyamides is the production of esters. These esters are marketed as plasticizers.

Diisopropyl adipate is the result of the esterification of adipic acid. Acid catalysts are normally used, but the reaction will proceed at elevated temperatures if water is removed during the reaction. Diisopropyl adipate, along with other esters, is produced in the mother liquor during adipic acid manufacturing. Diisopropyl adipate is subsequently separated and refined by distillation.

Market Profile

In 1991, total U.S. production of adipate plasticizers was 35 million pounds. This category includes diisopropyl adipate, diethyl adipate, dimethyl adipate, and possibly others. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Diisopropyl adipate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, diisopropyl adipate is expected to display low mobility. Biodegradation in acclimated aerobic soils may be rapid. Volatilization of diisopropyl adipate from moist soil to the atmosphere is expected to be very slow although volatilization from dry soil may occur. Chemical hydrolysis of the ester group is not expected to be important except for highly basic soils (pH greater than 8). If released to water, aerobic biodegradation may be rapid especially in acclimated waters. Diisopropyl adipate is not expected to appreciably bioconcentrate in fish and aquatic organisms although it may adsorb to sediment and suspended organic matter. Volatilization of diisopropyl adipate from water to the atmosphere will likely be very slow. Chemical hydrolysis may occur in highly basic waters. If released to the atmosphere, diisopropyl adipate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 1 day. Using a rapid biodegradation rate for diisopropyl adipate in the STP fugacity model results in 98 percent predicted total removal from wastewater treatment plants. If a moderate biodegradation rate is used in this model, 88 percent predicted total removal may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Dimethyl Adipate

Chemical Properties and Information	
Dimethyl adipate [Dimethyl hexanedioate; methyl adipate; dimethyl ester adipic acid] CAS# 627-93-0 Molecular weight: 174.25 Melting Point: 8°C (M) Water Solubility: 0.1 g/L (E) Vapor Pressure: 0.06 mm Hg (25°C)(E) Log K_{ow} = 1.39 (E) Henry's Law Constant: 1.3 x 10^{-7} atm-m^3/mole (E) Chemistry of Use: Lubricant, Plasticizer	$C_8H_{14}O_4$ Structure: $(CH_3O)CO(CH_2)_4CO(OCH_3)$ Boiling Point: 193.7°C (at 760 mm Hg)(E) Density:1.063 g/ml (M) Flash Point: 107°C (M) K_{oc}: 136 (E) Physical state: Colorless, odorless liquid

Above data are either measured (M) or estimated (E)

Dimethyl adipate is soluble in alcohol, ether and acetic acid. It is incompatible with acids, bases, oxidizing agents and reducing agents. When heated to decomposition, it emits acrid smoke and irritating fumes.

Dimethyl adipate is the result of the esterification of adipic acid. Adipic acid is produced by the oxidation of cyclohexane first with air, then with nitric acid. The adipic acid is then methylated to produce the dimethyl adipate.

Market Profile

In 1991, total U.S. production of adipate plasticizers was 35 million pounds. This category includes diisopropyl adipate, diethyl adipate, dimethyl adipate, and possibly others. Data for imported and exported amounts were not available. Total U.S. production quantity of dimethyl adipate for use in screen reclamation was estimated to be 304,000 gallons.

Regulatory Status

Dimethyl adipate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, dimethyl adipate is expected to display moderate to high mobility. Biodegradation in acclimated aerobic soils may be rapid. Volatilization of dimethyl adipate from moist soil to the atmosphere is expected to be very slow although volatilization from dry soil may be significant. Chemical hydrolysis of the ester group is not expected to be important except in highly basic soils (pH greater than8). If released to water, aerobic biodegradation may be rapid especially in acclimated waters. Dimethyl adipate is not expected to appreciably bioconcentrate in fish and aquatic organisms or adsorb to sediment and suspended organic matter. Volatilization of dimethyl adipate from water to the atmosphere will be very slow. Chemical hydrolysis may occur in highly basic waters. If released to the atmosphere, dimethyl adipate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 3.3 days. It may also undergo atmospheric removal by wet deposition processes because of its moderate water solubility. Using a rapid biodegradation rate for dimethyl adipate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants. If a moderate biodegradation rate is used in this model, 85 percent predicted total removal may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Dimethyl Glutarate

Chemical Properties and Information

Dimethyl glutarate [glutaric acid, dimethyl ester; pentanedioic acid, dimethyl ester]
CAS# 1119-40-0
Molecular weight: 160.17
Melting Point: -42.5°C (M)
Water Solubility: 1 g/L (E)
Vapor Pressure: 0.1 mm Hg (E)
Log K_{ow}: 0.90 (E)
Henry's Law Constant: $9.1\text{X}10^{-8}$ atm-m^3/mole (E)
Chemistry of Use: Solvent

$C_7H_{12}O_4$
Structure: $CH_3O_2C(CH_2)_3CO_2CH_3$
Boiling Point: 214°C (M)
Density: 1.088 g/cm^3 (M)
Flash Point: 100°C (E)
K_{oc}: 6 (E)

Above data are either measured (M) or estimated (E)

This chemical has a faint, agreeable odor. It is soluble in alcohols and ether.

This chemical is synthesized by the reaction of methanol with glutaric acid.

Market Profile

In 1991, total U.S. production of glutarate plasticizers was 3.4 million pounds. This category includes both dimethyl glutarate and diethyl glutarate, among others. Total U.S. production quantity of dimethyl glutarate for use in screen reclamation was estimated to be 609,000 gallons.

Regulatory Status

Dimethyl glutarate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, dimethyl glutarate is expected to readily biodegrade especially if acclimated organisms are present. In moist, highly alkaline soils, chemical hydrolysis may also occur. It has a very low estimated adsorptivity to soil and therefore should be highly mobile in soil. Volatilization from soil should not be important. If released to water, dimethyl glutarate is expected to biodegrade. Since its estimated alkaline hydrolysis half-life is 60 days at pH 8, chemical hydrolysis may contribute to its loss in alkaline waters (pH greater than8). Volatilization, bioconcentration in aquatic organisms, and adsorption to sediment and suspended organic matter are not expected to be important. If released to the atmosphere, dimethyl glutarate will degrade by reaction with photochemically-produced hydroxyl radicals (estimated half-life of 9 days). Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Dimethyl Succinate

Chemical Properties and Information	
Dimethyl succinate [succinic acid, dimethyl ester; butanedioic acid, dimethyl ester; methyl succinate] CAS# 106-65-0 Molecular weight: 146.14 Melting Point: 19°C (M) Water Solubility: 8.3 g/L (M) Vapor Pressure: 0.1 mm Hg (E) Log K_{ow}: 0.19 (M) Henry's Law Constant: $5.8X10^{-6}$ atm-m^3/mole (E) Chemistry of Use: Solvent	$C_6H_{10}O_4$ Structure: $CH_3O_2C(CH_2)_2CO_2CH_3$ Boiling Point: 196.4°C (M) Density: 1.12 g/cm^3 (M) Flash Point: 100°C (E) K_{oc}: 3 (E)

Above data are either measured (M) or estimated (E)

This is a colorless liquid. It is soluble in alcohols, acetone and ether. This chemical is synthesized by the reaction of methanol with succinic acid.

Market Profile

Data for total U.S. production of this chemical is unknown. Total U.S. production quantity for use in screen reclamation was estimated to be 304,000 gallons.

Regulatory Status

Dimethyl succinate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, dimethyl succinate is expected to biodegrade and this process may be rapid if acclimated organisms are present. In moist, highly alkaline soils, chemical hydrolysis may also occur. It is expected to be highly mobile in soil. Volatilization of dimethyl succinate from both moist and dry surface soil to the atmosphere may contribute to its loss. If released to water, dimethyl succinate it is expected to biodegrade. Neither bioconcentration in fish and aquatic organisms nor adsorption to sediment and suspended organic matter are expected to be important. Volatilization from water may contibute to its loss from bodies of water with a strong current or wind; the estimated half-life in a model river is 8 days. The estimated alkaline hydrolysis half-life at pH 8 is 85 days and therefore chemical hydrolysis may occur in alkaline environmental media (pH greater than 8). If released to the atmosphere, dimethyl succinate will degrade by reaction with photochemically-produced hydroxyl radicals (estimated half-life of 37 days). Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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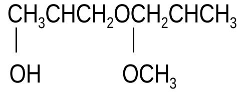
Dipropylene Glycol Methyl Ether

Chemical Properties and Information	
Dipropylene glycol methyl ether [Glycol ether DPM; Dowanol DPM] CAS# 34590-94-8 Molecular weight: 148.2 Melting Point: -80°C (M) Water Solubility: Miscible (E) Vapor Pressure: 0.4 mm Hg (M) (25° C) Log K_{ow} = -0.35 (E) Henry's Law Constant: 1.15 x 10^{-9} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_7H_{16}O_3$ Structure: $CH_3CHOHCH_2OCH_2CH(OCH_3)CH_3$ or  $CH_3\underset{OH}{CH}CH_2OCH_2\underset{OCH_3}{CH}CH_3$ Boiling Point: 188.3°C (M) Density: 0.951 g/ml (M) Flash Point: 75°C (M) K_{oc}: 15 (E) Physical state: liquid

Above data are either measured (M) or estimated (E)

Glycol ethers are both ethers and alcohols. Their hydroxyl group can be etherified, esterified, chlorinated, or otherwise modified. Dipropylene glycol methyl ether is miscible in many organic solvents. It is a liquid with a mild, not unpleasant odor.

Glycol ethers are prepared by reacting propylene oxide with methanol.

Market Profile

In 1991, total U.S. production was 22 million pounds. Imports were less than 100,000 million gallons and exports were 0.6 million gallons. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Dipropylene glycol methyl ether does not trigger any federal environmental regulations. However, the generic category of glycol ethers is listed as Hazardous Air Pollutants in the Clean Air Act.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

In water, dipropylene glycol methyl ether would not be expected to sorb to sediments or to bioconcentrate in fish and aquatic organisms. The main degradation mechanism in water is expected to be biodegradation. Unpublished data support this, with 34 percent and 72.9 percent of theoretical being observed in two screening tests (Strum test and OECD Screenin g Test, respectively) and 93.7 percent of theoretical in a Zahn-Wellens test. Photolysis and hydrolysis are probably not important removal processes for dipropylene glycol methyl ether in water. Volatilization from water will not be important. In the atmosphere, dipropylene glycol methyl ether will react with photochemically produced hydroxyl radicals (half-life of approximately 3.4 hours). In soil, dipropylene glycol methyl ether will be highly mobile and may leach to groundwater. In soil biodegradation will probably be the primary removal mechanism; however, this process may require an acclimation period. Dipropylene glycol methyl ether may volatilize from dry soil surfaces. Using a rapid biodegradation rate for dipropylene glycol methyl ether in the STP fugacity model, 97 percent removal can be predicted from wastewater treatment plants. Using a moderate biodegradation rate for dipropylene glycol methyl ether in the STP fugacity model, 83 percent removal can be predicted from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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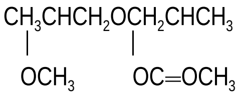
Dipropylene Glycol Methyl Ether Acetate

Chemical Properties and Information	
Dipropylene glycol methyl ether acetate [Dowanol DPMA; Acrosolv DPMA] CAS# 88917-22-0 Molecular weight: 190 Melting Point: -90°C (M) Water Solubility: Miscible (E) Vapor Pressure: 0.02 mm Hg (E) (25° C) Log K_{ow} = 0.66 (E) Henry's Law Constant: 7.5 x 10^{-8} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_9H_{18}O_4$ Structure:  $CH_3\underset{OCH_3}{\underset{\vert}{CH}}CH_2OCH_2\underset{OC{=}OCH_3}{\underset{\vert}{CH}}CH_3$ Boiling Point: 200°C (E) Density: 0.90 g/ml (E) Flash Point: 60°C (M) K_{oc}: 5 (E) Physical state: liquid

Above data are either measured (M) or estimated (E)

Dipropylene glycol methyl ether acetate is a glycol derivative that is both an ether and an ester. Dipropylene glycol methyl ether acetate is soluble in organic solvents.

Dipropylene glycol methyl ether acetate is produced by the esterification of dipropylene glycol methyl ether.

Market Profile

In 1991, total U.S. production of "other" P-series glycol ethers was 1 million pounds. This category includes dipropylene glycol methyl ether acetate, ethoxypropanol, ethoxypropyl acetate, and propylene glycol methyl ether acetate, among possibly others. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Dipropylene glycol methyl ether acetate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Dipropylene glycol methyl ether acetate is not expected to undergo hydrolysis or direct photolysis in the environment. In water, volatilization, adsorption to sediments and suspended solids, and bioconcentration in aquatic organisms are not expected to be important transport processes for dipropylene glycol methyl ether acetate. Biodegradation is likely to be an important removal mechanism of dipropylene glycol methyl ether acetate from aerobic soil and water based on screening studies from structurally similar glycol ether compounds. If released to soil, dipropylene glycol methyl ether acetate is expected to display very high mobility. Volatilization from dry soil surfaces will be important. In the atmosphere, dipropylene glycol methyl ether acetate is expected to exist almost entirely in the gas-phase and reactions with photochemically produced hydroxyl radicals should be fast (estimated half-life of 3.4 hrs). Using a rapid biodegradation rate for dipropylene glycol methyl ether acetate in the STP fugacity model results in 97 percent predicted removal from wastewater treatment plants; a moderate rate corresponds to 83 percent predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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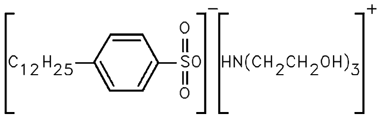
Dodecyl Benzene Sulfonic Acid, Triethanol Amine Salt

Chemical Properties and Information	
Dodecyl benzene sulfonic acid, triethanol amine salt [benzenesulfonic acid, dodecyl-, compd. with 2,2',2''-nitrilotris[ethanol](1:1)] CAS# 27323-41-7 Molecular weight: 475.5 Melting Point: Not available Water Solubility: Low Solubility (E) Vapor Pressure: $<10^{-5}$ mm Hg (E) Log K_{ow}: -1.49 (E) Henry's Law Constant: Not applicable Chemistry of Use: Surfactant	$C_{24}H_{45}NO_6S$ Structure:  Boiling Point: Not available Density: 1.09 g/cm^3 (M) Flash Point: Not available K_{oc}: 10,000 (E)

Above data are either measured (M) or estimated (E)

This chemical exists in a pale yellow, slightly viscous paste, and has a bland odor.

This chemical is synthesized by reacting dodecyl benzene sulfonic acid with triethanolamine.

Market Profile

In 1990, total U.S. production was 8.2 million pounds. Imports and exports of this chemcial are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, dodecyl benzene sulfonic acid, triethanol amine salt, is expected to biodegrade under aerobic conditions, especially when acclimated organisms are present. Although dodecyl benzene sulfonic acid, triethanol amine salt is an ionic compound, studies have shown that dodecyl benzene sulfonic acid salts strongly adsorb to soil and that the force dominating this process is the hydrophobic nature of the non-polar tail of the molecule. Volatilization of dodecyl benzene sulfonic acid, triethanol amine salt from surface soil will not be significant. If released to water, dodecyl benzene sulfonic acid, triethanol amine salt is expected to biodegrade. It will also adsorb to sediment and particulate matter in the water column. Volatilization of dodecyl benzene sulfonic acid, triethanol amine salt from water should be insignificant. Experimental data indicate that similar dodecyl benzene sulfonic acids do not bioconcentrate in fish and aquatic organisms. If released to the atmosphere, triethanol amine salt, dodecyl benzene sulfonic acid will be associated with aerosols and be removed by gravitational settling. Using a rapid biodegradation rate for the parent acid in the STP fugacity model results in 97 percent predicted total removal for dodecyl benzene sulfonic acid, triethanol amine salt from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Ethyl Acetate

Chemical Properties and Information	
Ethyl acetate [Acetic ester] CAS# 141-78-6 Molecular weight: 88 Melting Point: -83.6°C (M) Water Solubility: 77 g/l (E) Vapor Pressure: 90 mm Hg (M) (25°C) Log K_{ow} = 0.730 (M) Henry's Law Constant: 1.34×10^{-4} atm-m^3/mole (M) Chemistry of Use: Solvent	$C_4H_8O_2$ Structure: $CH_3COOCH_2CH_3$ Boiling Point: 77.1°C (M) Density: 0.884 g/ml (M) Flash Point: -4.4°C (M) K_{oc}: 9 (E) Physical state: volatile liquid

Above data is either measured (M) or estimated (E)

Ethyl acetate is a volatile, flammable liquid with a characteristic fruity odor. It is found in cereal crops, radishes, fruit juices, beer, and wine. The threshold limit value for air is 440 ppm. Ethyl acetate is miscible with most organic solvents.

Ethyl acetate occurs naturally, and recovery can be accomplished by steam distillation, extraction or pressing, or a combination of these. Synthetic esters are generally prepared by reaction of an alcohol and an organic acid in the presence of a catalyst such as sulfuric acid or *p*-toluene sulfonic acid. Ethyl acetate thus may be prepared synthetically by the catalyzed reaction of ethanol and acetic acid.

Market Profile

In 1991, total U.S. production was 245 million gallons. Imports were 12.3 million gallons and exports were 96.2 million gallons. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, ethyl acetate is expected to display high mobility. Biodegradation in both aerobic and anaerobic soils is expected to be rapid. Volatilization of ethyl acetate from both moist and dry soil to the atmosphere is expected to occur. If released to water, ethyl acetate is expected to rapidly degrade under both aerobic and anaerobic conditions. Five-day theoretical BODs of 50 percent and 53 percent using an activated sludge seed and in seawater, respectively, have been observed. Under anaerobic conditions using a water/sediment aquifer slurry obtained from under a municipal landfill, 94 percent conversion to methane was observed. Ethyl acetate is not expected to appreciably bioconcentrate in fish and aquatic organisms or adsorb to sediment and suspended organic matter. Volatilization of ethyl acetate from water to the atmosphere may also occur. If released to the atmosphere, ethyl acetate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 8 days. It may also undergo atmospheric removal by wet deposition processes because of its high water solubility. A pilot plant activated sludge system removed 100 percent of the 167 mg/L of influent ethyl acetate with 93 percent lost through biodegradation and 7 percent lost though stripping.

Health Hazard

See Table II-6 and accompanying summary

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Ethyl Lactate

Chemical Properties and Information	
Ethyl lactate [(*S*)-Ethyl lactate; ethyl-2-hydroxypropanate; Acytol] CAS# 97-64-3 Molecular weight: 118.13 Melting Point: -26°C (M) Water Solubility: Miscible Vapor Pressure: 5 mm Hg (E) (25°C) Log K_{ow} = -0.180 (E) Henry's Law Constant: 5.8 x 10^{-6} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_5H_{10}O_3$ Structure: $CH_3CH(OH)COOCH_2CH_3$ Boiling Point: 154°C (M) Density: 1.042 g/ml (M) Flash Point: 48°C (M) K_{oc}: 8 (E) Physical state: Colorless, odorless liquid

Above data are either measured (M) or estimated (E)

Ethyl lactate is incompatible with oxidizing agents, bases and acids. It is miscible with alcohols, ketones, esters, hydrocarbons and oils. Ethyl lactate is combustible. Ethyl lactate has a fruity, buttery taste when used as a flavoring.

Ethyl lactate is primarily derived from lactonitrile by the esterification of lactic acid with ethanol. It is also produced by combining acetaldehyde with hydrogen cyanide to form acetaldehyde cyanohydrin, which is converted to ethyl lactate by treatment with ethanol and an inorganic acid.

Market Profile

Market information for this chemical is not available.

Regulatory Status

Ethyl lactate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, ethyl lactate is expected to display very high mobility. Biodegradation in acclimated aerobic soils may be rapid. Volatilization of ethyl lactate from the upper layers of dry soil to the atmosphere may be significant although volatilization from moist soil may be relatively slow. In basic soil with a pH greater than8, chemical hydrolysis of ethyl lactate may occur. If released to water, aerobic biodegradation may be rapid especially in acclimated waters. Ethyl lactate is not expected to bioconcentrate in fish and aquatic organisms nor adsorb to sediment and suspended organic matter. Volatilization of ethyl lactate from water to the atmosphere may occur at a moderate rate. In basic waters, ethyl lactate may undergo chemical hydrolysis with an estimated half-life of approximately 7 days at pH 8. If released to the atmosphere, ethyl lactate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 6.4 days. It may also undergo atmospheric removal by wet deposition processes. Using a rapid biodegradation rate for ethyl lactate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Ethyl Oleate

Chemical Properties and Information	
Ethyl oleate [9-octadecenoic acid; ethyl ester oleic acid] CAS# 111-62-6 Molecular weight: 310.53 Melting Point: -32°C (M) Water Solubility: 0.01g/l (E) Vapor Pressure: 0.01 mm Hg (E) (25°C) Log K_{ow} = 8.51 (E) Henry's Law Constant: 1.0×10^{-2} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_{20}H_{38}O_2$ Structure: $CH_3(CH_2)_7CH{=}CH(CH_2)_6CH_2COOCH_2CH_3$ Boiling Point: 205-208°C (M) Density: 0.870 g/ml (M) Flash Point: 175°C (M) K_{oc}: >10,000 (E) Physical state: Colorless, oily liquid

Above data are either measured (M) or estimated (E)

Ethyl oleate is soluble in alcohol and ether. Ethyl oleate is combustible. It is incompatible with strong oxidizing agents and is light-sensitive and air-sensitive.

Ethyl oleate is produced from the esterification of oleic acid. Oleic acid is derived from fruits or plant seeds. Once refined, the fats are heated in the presence of a strong base, and esterification occurs at the glycerol hydroxides. The reaction occurs with the appropriate alcohol to provide the desired product.

Market Profile

In 1992, total U.S. production of salt and esters of oleic, linoleic, or linoleric acids was 36 million pounds. Greater specificity is not available due to the low number of companies producing these products. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Ethyl oleate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment.

Environmental Fate

If released to soil, ethyl oleate is expected to be essentially immobile. Biodegradation in acclimated aerobic soils may be rapid. Chemical hydrolysis of the ester group is not expected to be significant except in highly basic soils (pH greater than8). Volatilization of ethyl oleate from moist soil to the atmosphere may be a significant process although it is likely to be relatively slow from dry soil. If released to water, aerobic biodegradation may be rapid especially in acclimated waters. Bioconcentration in fish and aquatic organisms and adsorption to sediment and suspended organic matter may also occur. Volatilization from water to the atmosphere may be rapid although its expected strong adsorption to sediment and suspended organic matter may significantly attenuate the rate of this process. Chemical hydrolysis may occur in highly basic waters. If released to the atmosphere, ethyl oleate may undergo rapid oxidation by the both the gas-phase reaction with hydroxyl radicals and ozone with estimated half-lives of approximately 1.5 and 1.4 hours for the trans isomer, respectively, with similar rates for the cis isomer. Using a either a rapid or moderate biodegradation rate for ethyl oleate in the STP fugacity model results in greater than99 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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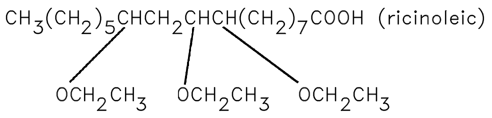
Ethoxylated Castor Oil

Chemical Properties and Information	
Ethoxylated castor oil [cosmetol, ricinus oil, neoloid CAS# 61791-12-6 Molecular weight: 298.47 (ricinoleic) + 135 (ethoxy) Melting Point: 5.5°C (M) Water Solubility: 0.003 g/L (E) Vapor Pressure: <0.1 mm Hg at 20°C (M) Log K_{ow}: Not available Henry's Law Constant: Not available Chemistry of Use: Drying/coating agent	$C_{18}H_{34}O_3$ (ricinoleic) + $(C_2H_5O)_3$ (ethoxy) Structure:  $CH_3(CH_2)_5CHCH_2CHCH(CH_2)_7COOH$ (ricinoleic) OCH_2CH_3 OCH_2CH_3 OCH_2CH_3 Boiling Point: 313°C (M) Density: 0.961 (M) Flash Point: 299°C (M) K_{oc}: Not available

Above data are either measured (M) or estimated (E)

Ethoxylated castor oil is derived from the bean of the castor plant. The composition of ethoxylated castor oil is ricinoleic acid, palmitic acid, stearic acids, oleic acids, and several ethoxy groups. Ricinoleic acid comprises nearly 90 percent of castor oil. Ethoxylated castor oil is a drying agent. It is soluble in ethyl alcohol and polar organic solvents.

Castor oil is recovered by use of hydraulic presses followed by solvent extraction. Oil taken from mechanical presses requires refining steps to remove toxic proteins, improve the color, and reduce the fatty acid content. Fatty acid content is reduced by treatment with caustic soda solution. In the polyethoxylation reaction the hydroxyl groups undergo alkylation to produce the polyethoxyl triglyceride fatty acid. Common catalysts for the dehydration procedure are sulfuric acid and its acid salts.

Market Profile

In 1992, total U.S. production was 22.3 million gallons. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Ethoxylated castor oil does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, ethoxylated castor oil is expected to rapidly biodegrade as do linear primarily alcohol ethoxylates. Biodegradation occurs by the β-oxidation of the alkyl chain, scission of the hydrophobic and hydrophic moeties and step-wise removal of ethoxylate groups to more hydrophobic metabolites. The mobility of ethoxylated castor oil will increase with increasing number of ethoxylate groups although the expected rapid biodegradation of the ethoxylate groups will reduce the importance of leaching. Volatilization from soil to the atmosphere is not expected to occur. If released to water, ethoxylated castor oil is expected to undergo rapid biodegradation. Experimental studies on other ethoxylated natural oils possessing 3-20 ethoxylate groups have resulted in five-day theoretical BODs of up to 100 percent and those containing 50 or more ethoxylate groups are also amenable to biodegradation. Shorter chain ethoxylates may also partition to sediment and particulate matter in the water column. Volatilization of ethoxylated castor oil to the atmosphere is not expected to occur. If released to the atmosphere by mechanical means, ethoxylated castor oil is expected to undergo removal by both wet and dry processes due to its appreciable water solubility and low expected vapor pressure, respectively. Using a rapid biodegradation rate in the STP fugacity model results in 100 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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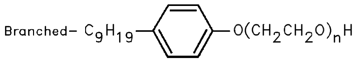
Ethoxylated Nonylphenol

Chemical Properties and Information	
Ethoxylated nonylphenol [poly(oxy-1,2-ethanediyl), α-(nonylphenyl)-Ω-hydroxy-; Antarox; polyethylene glycol mono (nonylphenyl) ether] CAS# 9016-45-9 Molecular weight: 630 (for n=9.5) (typical range 500 - 800) Melting Point: -20 to +10°C (E) Water Solubility: Soluble (M) Vapor Pressure: $<10^{-6}$ mm Hg (E) Log K_{ow}: 3.93 (E) (np = 7) Henry's Law Constant: $1.81X10^{-22}$ atm-m^3/mole (E) (np = 7) Chemistry of Use: Nonionic surfactant	$C_{34}H_{62}O_{10}$ (for n=9.5) Structure:  n = 9.5 (for screen printing formulation product) Boiling Point: >300°C (E) (decomposes) Density: 0.8 g/cm^3 (E) Flash Point: 200 - 260°C (E) K_{oc}: 0.64 (E) (np = 7)

Above data are either measured (M) or estimated (E)

This chemical is colorless with a mild odor. It is stable under normal conditions. Its properties vary with degree of ethoxylation. It is soluble in oil, alcohols, and aromatic solvents.

This chemical is synthesized by reacting branched nonylphenol with ethylene oxide.

Market Profile

In 1992, total U.S. production was 394.7 million gallons. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Ethoxylated nonylphenol does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Ethoxylated nonylphenol has a high primary biodegradation rate which has been demonstrated in wastewater treatment, river water, soil, and sediment. The rate of ultimate degradation of ethoxylated nonylphenol, however, is low. Biodegradation proceeds by the step-wise removal of ethoxylate groups, leading to the accumulation of more hydrophobic metabolites, namely mono- and diethoxylates, nonylphenol, and mono- and dicarboxylates. The mobility of ethoxylated nonylphenols varies with the number of ethoxy groups. Estimates based on molecular structure indicates that K_{oc} is 110 for four ethoxylate groups. Longer chain ethoxylates ($n \geq 4$) should therefore be fairly mobile in soil. The mobility of the mono- and diethoxylate should be low. If released to soil, ethoxylated nonylphenol is expected to leach into the soil and biodegrade. Volatilization from soil will be negligible. If released in water ethoxylated nonylphenol should undergo rapid primary biodegradation. Shorter chain ethoxylates may adsorb to sediment and particulate matter in the water column. Volatilization will not be significant. If released to the atmosphere, vapor-phase ethoxylated nonylphenol should degrade rapidly by reaction with photochemically-produced hydroxyl radicals (estimated half-life of approximately 3.7 hours). However, it is anticipated that ethoxylated nonylphenols will have very low vapor pressures and therefore would be associated with aerosols rather than in the vapor. Using a rapid primary biodegradation rate in the STP fugacity model results in 100 percent predicted removal in wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Ethoxypropanol

Chemical Properties and Information	
Ethoxypropanol [propylene glycol monoethyl ether] CAS# 52125-53-8 Molecular weight: 104.1 Melting Point: -100°C (M) Water Solubility: Completely miscible with water (M) Vapor Pressure: 7.2 mm Hg (at 25°C) (M) Log K_{ow}: 0.002 (E) Henry's Law Constant: 2.45×10^{-8} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_5H_{12}O_2$ Structure: $CH_3CH_2OCH_2CHOHCH_3$ Boiling Point: 132°C (M) Density: 0.895 g/cm^3 (at 25°C) (M) Flash Point: 43°C (open cup) (M) K_{oc}: 24 (E)

Above data are either measured (M) or estimated (E)

Glycol ethers are both ethers and alcohols. Their hydroxyl groups can be etherified, esterified, chlorinated, or otherwise modified. Miscible with acetone, benzene, carbon tetrachloride, ethyl ether, petroleum ether.

This chemical is synthesized by reaction of ethanol with propylene oxide.

Market Profile

In 1991, total U.S. production of "other" P-series glycol ethers was 1 million gallons. This category includes dipropylene glycol methyl ether acetate, ethoxypropanol, ethoxypropyl acetate, and propylene glycol methyl ether acetate, among possibly others. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Ethoxypropanol does not trigger any federal environmental regulations. However, the generic category of glycol ethers is listed as Hazardous Air Pollutants in the Clean Air Act.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, ethoxypropanol is expected to biodegrade under aerobic conditions and it may be rapid if acclimated organisms are present. It is expected to display high mobility; however, rapid biodegradation will decrease its potential of leaching through soil. Volatilization of ethoxypropanol from both moist and dry soil to the atmosphere is not expected to be important. If released to water, ethoxypropanol is expected to biodegrade under aerobic conditions and it may be rapid if acclimated organisms are present. Neither bioconcentration in fish and aquatic organisms, adsorption to sediment and suspended organic matter, nor volatilization to the atmosphere are expected to be important. If released to the atmosphere, ethoxypropanol is degraded rapidly by reaction with photochemically produced hydroxyl radicals (typical half-life of 6.2 hours). Physical removal by wet deposition processes may also occur because of its substantial water solubility; however, its short atmospheric residence time suggests that wet deposition may be of limited importance. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants; a moderate rate corresponds to 84 percent predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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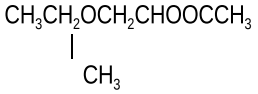
Ethoxypropyl Acetate

Chemical Properties and Information	
Ethoxypropyl acetate [propylene glycol, monoethyl ether acetate, 2-propanol, 1-ethoxy-, acetate] CAS# 54839-24-6 Molecular weight: 146.1 Melting Point: -100°C (E) Water Solubility: Miscible Vapor Pressure: 3.5 mm Hg (at 20°C) (E) Log K_{ow}: -0.46 (E) Henry's Law Constant: 9.09X10^{-12} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_7H_{14}O_3$ Structure:  $CH_3CH_2OCH_2\underset{\overset{|}{CH_3}}{CH}OOCCH_3$ Boiling Point: 153.2°C (E) Density: 1.0 g/cm^3 (E) Flash Point: 40°C (E) K_{oc}: 13 (E)

Above data are either measured (M) or estimated (E)

Ethoxypropyl acetate is a glycol derivative that is both an ether and an ester. It is soluble in organic solvents.

Ethoxypropyl acetate is prepared by hydrolysis of propylene oxide. Etherification is by reaction with ethanol. Esterification is accomplished by reaction with acetic acid.

Market Profile

In 1991, total U.S. production of "other" P-series glycol ethers was 1 million gallons. This category includes dipropylene glycol methyl ether acetate, ethoxypropanol, ethoxypropyl acetate, and propylene glycol methyl ether acetate, among possibly others. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Ethoxypropyl acetate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, ethoxypropyl acetate is expected to biodegrade under aerobic conditions and it may be rapid if acclimated organisms are present. It is expected to display high mobility; however, rapid biodegradation will decrease its potential of leaching through soil. Volatilization of ethoxypropyl acetate from moist soil to the atmosphere is not expected to be important although it may slowly volatilize from dry soil. If released to water, ethoxypropyl acetate is expected to biodegrade under aerobic conditions and it may be rapid if acclimated organisms are present. Chemical hydrolysis will be important only in very alkaline environmental media (pH greater than 8.5). Neither bioconcentration in fish and aquatic organisms, adsorption to sediment and suspended organic matter, nor volatilization to the atmosphere are expected to be important. If released to the atmosphere, ethoxypropyl acetate is degraded rapidly by reaction with photochemically produced hydroxyl radicals (typical half-life of 6.2 hours). Physical removal by wet deposition processes may also occur because of its substantial water solubility; however, its short atmospheric residence time suggests that wet deposition may be of limited importance. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants; a moderate rate corresponds to 84 percent predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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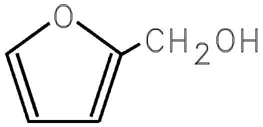
Furfuryl Alcohol

Chemical Properties and Information	
Furfuryl alcohol [2-Furanmethanol; 2-Furylcarbinol; 2-Hydroxymethylfuran] CAS# 98-00-0 Molecular weight: 98.1 Melting Point: Not available Water Solubility: Miscible (unstable) (M) Vapor Pressure: 0.45 mm Hg (at 20°C) (M) Log K_{ow}: 0.28 (M) Henry's Law Constant: $7.86X10^{-8}$ atm-m^3/mole (E) Chemistry of Use: Solvent	$C_5H_6O_2$ Structure:  Boiling Point: 170°C (M) Density: 1.13 g/cm^3 (M) Flash Point: 75°C (M) K_{oc}: 8.5 (E)

Above data are either measured (M) or estimated (E)

Furfuryl alcohol has a faint burning odor and bitter taste. It is very soluble in alcohol and ether.

Furfuryl alcohol is prepared from furfural by the Cannizzaro reaction. It is prepared industrially by the catalytic reduction of furfural using nickel and Cu-CrO catalysts.

Market Profile

In 1992, total U.S. production was 39.2 million gallons. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in sreen reclamation is unknown.

Regulatory Status

Furfuryl alcohol does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, furfuryl alcohol will be expected to exhibit very high mobility, based upon its estimated soil adsorption coefficient. It may be subject to biodegradation in soil based upon results observed in a laboratory aqueous biodegradation aerobic screening test using an activated sludge inoculum. No information was found regarding its rate of biodegradation in soil. Volatilization of furfuryl alcohol from moist soil should not be important. However, some volatilization would occur from dry surface soil and other dry surfaces. If furfuryl alcohol is released to water, it would be expected biodegrade according to results of laboratory screening studies. It should not adsorb to sediment or suspended particulate matter in the water column or to bioconcentrate in aquatic organisms. Furfuryl alcohol absorbs radiation greater than290 nm and therefore it may directly photolyze in surface waters. According to its estimated Henry's Law constant, volatilization from water will not be important. In the atmosphere, furfuryl alcohol will exist mainly in the vapor phase. It will be rapidly degraded by reaction with photochemically-produced hydroxyl radicals (typical half-life 3.7 hours). It may also undergo atmospheric degradation by direct photolysis. Physical removal by rain would occur because of its miscibility in water. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Isobutyl Isobutyrate

Chemical Properties and Information	
Isobutyl isobutyrate [propanoic acid, 2-methyl-, 2-methylpropyl ester, isobutyric acid, isobutyl ester] CAS# 97-85-8 Molecular weight: 144.21 Melting Point: -81°C (M) Water Solubility: <1 g/L (M) Vapor Pressure: 3.2 mm Hg (at 20°C) (M) Log K_{ow}: 2.68 (E)Henry's Law Constant: 8.22 x 10^{-4}atm-m^3/mole (M) Chemistry of Use: Solvent	$C_8H_{16}O_2$ Structure: $(CH_3)_2CHCOOCH_2CH(CH_3)_2$ Boiling Point: 147°C (M) Density: 0.855 g/cm^3 (at 20°C) (M) Flash Point: 38°C (closed cup) (M) 44°C (open cup) (M) K_{oc}: 98 (E)

Above data are either measured (M) or estimated (E)

This is a slow evaporating solvent, and is blush resistant. It is miscible with alcohol and ether.

This chemical is prepared from the reaction of isobutyric acid and isobutyl alcohol.

Market Profile

Total U.S. production is unavailable. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation was estimated to be 2.63 million gallons.

Regulatory Status

Isobutyl isobutyrate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, isobutyl isobutyrate is expected to biodegrade under aerobic conditions and it may be rapid in acclimated soils. It is expected to display high mobility in the absence of significant biodegradation. Volatilization of isobutyl isobutyrate from both moist and dry soil to the atmosphere may be important. If released to water, it is expected to biodegrade under aerobic conditions and it may be rapid if acclimated organisms are present. Neither bioconcentration in fish and aquatic organisms nor adsorption to sediment and suspended organic matter are expected to be important. Volatilization of isobutyl isobutyrate from water to the atmosphere may be relatively rapid. Chemical hydrolysis will be important only in very alkaline environmental media (pH greater than 8.5). If released to the atmosphere, isobutyl isobutyrate will degrade by reaction with photochemically produced hydroxyl radicals (estimated half-life of 2.3 days). Using a rapid biodegradation rate in the STP fugacity model results in 98 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Isobutyl Oleate

Chemical Properties and Information

Isobutyl oleate [Isobutyl ester oleic acid]
CAS# 10024-47-2
Molecular weight: 395
Melting Point: -26°C (M)
Water Solubility: 0.001g/l (E)
Vapor Pressure: 0.01 mm Hg (E) (25°C)
Log K_{ow} = 9.42 (E)
Henry's Law Constant: 2.5×10^{-2} atm-m^3/mole (E)
Chemistry of Use: Numerous

$C_{22}H_{42}O_2$
Structure: $CH_3(CH_2)_7CH{=}CH(CH_2)_6CH_2COO\text{-}i\text{-}C_4H_{11}$
Boiling Point: 226°C (M)
Density: 0.86 g/ml (M)
Flash Point: 180°C (M)
K_{oc}: >10,000 (E)
Physical state: Oily liquid

Above data are either measured (M) or estimated (E)

Isobutyl oleate may be harmful if absorbed through the skin. Vapor and mist are irritating to the respiratory tract and eyes. Isobutyl oleate is soluble in ethanol.

Isobutyl oleate is produced from the esterification of oleic acid. Oleic acid is derived by mechanic means from the seeds of specific fruits and plants. Once refined, the oleate is heated in the presence of a strong base and an alcohol. Esterification occurs at the glycerol hydroxides of the oleic acid.

Market Profile

In 1992, total U.S. production of salt and esters of oleic, linoleic, or linoleric acids was 36 million pounds. Greater specificity is not available due to the low number of companies producing these products. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Isobutyl oleate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, isobutyl oleate is expected to be essentially immobile. Biodegradation in acclimated aerobic soils may be rapid. Chemical hydrolysis of the ester group is not expected to be significant except for highly basic soils (pH greater than8) . Volatilization of isobutyl oleate from moist soil to the atmosphere may be a significant process although it is likely to be relatively slow from dry soil. If released to water, aerobic biodegradation may be rapid, especially in acclimated waters. Bioconcentration in fish and aquatic organisms and adsorption to sediment and suspended organic matter may also occur. Volatilization from water to the atmosphere may be rapid although its expected strong adsorption to sediment and suspended organic matter may attenuate the rate of this process. Chemical hydrolysis may occur in highly basic waters. If released to the atmosphere, isobutyl oleate may undergo rapid oxidation by the both the gas-phase reaction with hydroxyl radicals and ozone with estimated half-lives of approximately 1.5 and 1.3 hours for the trans isomer, respectively, with similar rates for the cis isomer. Using either a rapid or moderate biodegradation rate for isobutyl oleate in the STP fugacity model results in greater than99 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Isopropanol

Chemical Properties and Information	
Isopropanol [Isopropyl alcohol; 2-propanol, dimethyl carbinol, *sec*-propyl alcohol] CAS# 67-63-0 Molecular weight: 60.1 Melting Point: -88.5°C (M) Water Solubility: Miscible Vapor Pressure: 33 mm Hg (M) (20°C) Log K_{ow} = 0.05 (M) Henry's Law Constant: 8.1 x 10^{-6} atm-m^3/mole (M) Chemistry of Use: Solvent	C_3H_8O Structure: $(CH_3)_2CHOH$ Boiling Point: 164°C (M) Density: 0.7849 g/ml (M) Flash Point: Tag Open Cup: 17.2°C (M) Closed Cup: 11.7° C (M) K_{oc}: 25 (E) Physical State: Colorless, volatile, flammable liquid

Above data are either measured (M) or estimated (E)

Isopropanol is a colorless, volatile, flammable liquid. Its odor is slight, resembling a mixture of ethyl alcohol and acetone. Isopropanol boils only 4°C higher than ethyl alcohol and possesses similar solubility properties, and thus the two products compete for many solvent applications. Because of its tendency to associate in solution, isopropanol forms azeotropes with compounds from a variety of chemical groups. As an alcohol, it can be dehydrogenated, oxidized, esterified, etherified, aminated, halogenated, or otherwise modified.

Indirect hydration is the common process for commercial manufacture of isopropanol in the United States. This two-step method involves: (1) formation of mono- and diisopropyl sulfates by reacting propylene with sulfuric acid, and (2) hydrolysis of the sulfates to isopropyl alcohol. The catalytic hydration process, increasingly used in Europe and Japan, uses superheated steam and high pressures to directly convert propylene to isopropanol:

$$CH_3CH = CH_2 + H_2O \leftrightarrow (CH_3)_2CHOH$$

catalyst

Market Profile

In 1991, total U.S. production was 1.4 billion gallons. In 1992, imports were 91.5 million gallons and exports were 416.9 million gallons. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, biodegradation is expected to be an important removal process for isopropanol. Adsorption to soil will not be important. In water, biodegradation is expected to be fast, even under anaerobic conditions. Bioconcentration in fish, adsorption to sediment, photolysis, and hydrolysis will not be important for isopropanol. Volatilization from water is slow. In the atmosphere, isopropanol will photodegrade primarily by reaction with photochemically produced hydroxyl radicals with a half-life of 1-2 days. Using a rapid and a moderate biodegradation rate for isopropanol in the STP fugacity model results in about 97 and 83 percent, respectively, predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

d-Limonene

Chemical Properties and Information	
d-Limonene [1-methyl-4-(1-methylethenyl) cyclohexene; (+)-carvene; citrene; 1,8-*p*-menthadiene; 4-isopropenyl-1-methylcyclohexene cinene; cajeputene; kautschin] CAS# 5989-27-5 Molecular weight: 136 Melting Point: -74°C (M) Water Solubility: 0.014 g/L (M) Vapor Pressure: 5 mm Hg (E) (25°C) Log K_{ow} = 4.83 (E) Henry's Law Constant: 0.38 atm-m^3/mole (E) Chemistry of Use: Wetting and Dispersing Agent	$C_{10}H_{16}$ Structure: Boiling Point: 176°C (M) Density: 0.84 g/ml (M) Flash Point: 48°C (M) K_{oc}: 1,000 - 4,800 (E)

Above data are either measured (M) or estimated (E)

d-Limonene is a terpenoid in a group of closely related compounds called *p*-menthadienes. The *p*-menthadienes can all be hydrogenated to produce *p*-menthane, the hydroperoxide of which is useful in the rubber industry. Limonene isomerizes rather slowly to terpinolene, while the irreversible isomerization of terpinolene to α-terpinene is very rapid. The physical state of limonene is a liquid with a fresh, citrus odor and taste.

d-Limonene is naturally occurring and is obtained from lemon and orange peel, dill, cumin, neroli, bergamot, and caraway. The lemon oil that is obtained in 0.35 percent yield from lemon peel is approximately 80 percent limonene (*d* and *dl*). Nonetheless, the characteristic odor and flavor of lemon comes not from limonene, but from citral and other compounds.

Market Profile

In 1988, total U.S. production was 28 million pounds. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation was estimated to be 150,000 gallons.

Regulatory Status

d-Limonene does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, *d*-limonene is expected to exhibit low to slight mobility. It is expected to rapidly volatilize from both dry and moist soil surfaces and biodegrade at a moderate rate in soil. However, strong adsorption to soil may attenuate the rate of this process. If released to water, *d*-limonene may bioconcentrate in fish and aquatic organisms and it may adsorb to sediment and suspended organic matter. It is expected to rapidly volatilize from water to the atmosphere. The estimated half-life for volatilization of *d*-limonene from a model river is 3.4 hrs, although adsorption to sediment and suspended organic matter may attenuate the rate of this process. If released to the atmosphere, *d*-limonene is expected to rapidly undergo gas-phase oxidation reactions with photochemically produced hydroxyl radicals and ozone, and to react at night with nitrate radicals. Calculated half-lives for these processes are 2.3-2.6 hrs, 25-26 min and 3.1 min, respectively. Using a moderate biodegradation rate for d-limonene in the STP fugacity model results in greater than99 percent predicted total removal from wastewater treatment plants. Assuming no biodegradation in the STP fugacity model also results in greater than99 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Methanol

Chemical Properties and Information	
Methanol [methyl alcohol, carbinol, wood spirit, wood alcohol] CAS# 67-56-1 Molecular weight: 32.04 Melting Point: -97.8°C (M) Water Solubility: Miscible (M) Vapor Pressure: 93.7 mm Hg (at 20°C) (M) Log K_{ow}: -0.770 (M) Henry's Law Constant: $4.55X10^{-6}$ atm-m^3/mole (M) Chemistry of Use: Solvent	CH_4O Structure: CH_3OH Boiling Point: 64.7°C (M) Density: 0.792 g/cm^3 (M) Flash Point: 12°C (closed cup) (M) K_{oc}: not available

Above data are either measured (M) or estimated (E)

Pure methanol has a slight alcoholic odor, but more crude forms of methanol may have repulsive odors. Methanol is generally a better solvent than ethanol. Methanol is flammable and mobile. Methanol has an ignition temperature of 470°C. It is miscible with ethanol, ether, benzene, ketones, and most other organic compounds.

Methanol is usually manufactured from hydrogen and carbon monoxide at high pressure and temperature.

Market Profile

In 1992, total U.S. production of methanol was 1.4 billion gallons. About 521 million gallons were imported and 55 million gallons were exported. Total U.S. production quantity for use in screen reclamation was estimated to be 610,000 gallons.

Regulatory Status

See Table II-3 and accompanying summary.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, methanol is expected to rapidly biodegrade under aerobic conditions. Methanol is also expected to slowly biodegrade under anaerobic conditions in soil. It is expected to display very high mobility although its rapid rate of biodegradation limits its potential to leach through soil. Volatilization of methanol from moist soil to the atmosphere is not expected to occur although it may be important from dry soils. If released to water, methanol is expected to rapidly biodegrade under aerobic conditions. Slow biodegradation in anoxic sediments is also expected to occur. Neither volatilization to the atmosphere, bioconcentration in fish and aquatic organisms, adsorption to sediment and suspended organic matter, chemical hydrolysis, oxidation, nor photolysis are expected to occur. If released to the atmosphere, methanol is expected to undergo a gas-phase reaction with photochemically produced hydroxyl radicals; the estimated half life for this process is 11 days. Its substantial water solubility indicates that wet deposition may also be an important atmospheric removal process. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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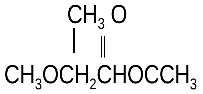
Methoxypropanol Acetate

Chemical Properties and Information	
Methoxypropanol acetate [propylene glycol methyl ether acetate] CAS# 84540-57-8 (also 108-65-6) Molecular weight: 132 Melting Point: -100°C (E) Water Solubility: 200 g/L (M) Vapor Pressure: 3.7 mm Hg (M) Log K_{ow}: 0.43 (M) Henry's Law Constant: $4.2X10^{-6}$ atm-m^3/mole (M) Chemistry of Use: Solvent	$C_6H_{12}O_3$ Structure:  $CH_3OCH_2\overset{\overset{CH_3}{\mid}}{C}HO\overset{\overset{O}{\|}}{C}CH_3$ Boiling Point: 140°C (M) Density: 0.97 g/cm^3 (M) Flash Point: 45°C (setaflash) (M) K_{oc}: 0.36 (M)

Above data are either measured (M) or estimated (E)

Methoxypropanol acetate is a glycol derivative that is both an ether and an ester. It is combustible and has an ester like odor. It is soluble in organic solvents.

Propylene glycol methyl ether acetate is prepared by reacting propylene oxide with methyl alcohol and esterifying with acetic acid or acetic anhydride.

Market Profile

In 1991, total U.S. production was 67.1 million gallons. About 6.9 million gallons were exported. Total U.S. production quantity for use in screen reclamation was estimated to be 420,000 gallons.

Regulatory Status

Methoxypropanol acetate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, methoxypropanol acetate is expected to readily biodegrade. Methoxypropanol acetate has a very low soil adsorption coefficient and is expected to be highly mobile in soil. Volatilization of methoxypropanol acetate from dry surface soil and other surfaces may be important, but volatilization from moist surface soil will be minimal. If released to water, methoxypropanol acetate is expected to biodegrade. The estimated half-life resulting from base-catalyzed chemical hydrolysis at pH 8 is 88 days and therefore chemical hydrolysis would only be significant in highly alkaline water. The volatilization half-life of methoxypropanol acetate from a model river is 10 days and therefore volatilization may occur under some circumstances. Neither bioconcentration in aquatic organisms nor adsorption to sediment and suspended organic matter should be significant. If released to the atmosphere, methoxypropanol acetate is degraded by reaction with photochemically-produced hydroxyl radicals (estimated half-life 34 hours). Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Methyl Ethyl Ketone

Chemical Properties and Information

Methyl ethyl ketone [2-Butanone; Ethyl methyl ketone; Methyl acetone; MEK]
CAS# 78-93-3
Molecular weight: 72.11
Melting Point: -87°C (M)
Water Solubility: 24 g/L (M)
Flash Point: -7°C
Log $K_{ow} = 0.29$ (M)
Henry's Law Constant: 5.69×10^{-5} atm-m^3/mole (M)
Chemistry of Use: Solvent

C_4H_8O
Structure: $H_3CCH_2COCH_3$
Boiling Point: 79.6°C (M)
Density: 0.8049_4^{20} g/ml (M)
Vapor Pressure: 77.5 mm Hg (M) (20°C) (M)
K_{oc}: 5 (E)
Physical State: Clear colorless liquid

Above data are either measured (M) or estimated (E)

Methyl ethyl ketone is stable under normal laboratory conditions and is miscible in ethanol, benzene, and diethyl ether. It is highly flammable. Forms a constant-boiling mixture with water, b.p. 73.40° containing 11.3 percent water. Strong oxidizing agents can cause spontaneous ignition and violent reaction; ignition on reaction with potassium t-butoxide; can attack many plastics, resins, and rubber; incompatible with chlorosulfonic acid, chloroform, hydrogen peroxide, and nitric acid.

Methyl ethyl ketone is mainly produced from sec-butanol and butylene.

Market Profile

In 1992, total U.S. production was 510 million gallons. Imports were 56.6 million gallons and exports were 132.2 million gallons. Total U.S. production quantity for use in screen reclamation was estimated to be 3.72 million gallons.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil surfaces, methyl ethyl ketone will either volatilize into the atmosphere, directly photolyze, or leach into the ground where it will biodegrade. If methyl ethyl ketone leaches to groundwater, biodegradability studies in anaerobic systems suggest slow biodegradation after a long acclimation period. In surface waters, methyl ethyl ketone will volatilize, photolyze, or biodegrade. Chemical hydrolysis, adsorption to sediment, bioconcentration in aquatic organisms, and indirect photooxidation will not be important fate processes for methyl ethyl ketone in water. If released to the atmosphere, gas-phase methyl ethyl ketone will react with photochemically-produced hydroxyl radicals (estimated half-lives of less than 10 days). Methyl ethyl ketone may be removed from air via wet deposition. Using a rapid and a moderate biodegradation rate for methyl ethyl ketone in the STP fugacity model results in 97 and 84 percent, respectively, predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Methyl Lactate

Chemical Properties and Information	
Methyl lactate [2-Hydroxypropanoicacid methyl ester; lactic acid; methyl ester] CAS# 547-64-8 Molecular weight: 104 Melting Point: -66°C (M) Water Solubility: Miscible Vapor Pressure: 7.7 mm Hg (E) (25°C) Log K_{ow} = -0.67 (E) Henry's Law Constant: 8.5×10^{-9} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_4H_8O_3$ Structure: $CH_3CH(OH)COOCH_3$ Boiling Point: 145°C (M) Density: 1.0939 g/ml (M) Flash Point: 49°C (M) K_{oc}: 8 (E) Physical State: Colorless liquid

Above data are either measured (M) or estimated (E)

Methyl lactate is acetylated with acetic anhydride to produce the acetyl derivative. Methyl lactate is soluble in alcohol and ether. It is a dye solvent. A dye solvent has a high boiling point, it is practically nonvolatile and maintains the dye in the solution long enough to stain the wood. Methyl lactate decomposes in water.

Methyl lactate is a byproduct in the formation of lactic acid. Methyl lactate results from the esterification of lactic acid with methyl alcohol. The methyl lactate is distilled and hydrolyzed with a strong acid catalyst to produce semi-refined lactic acid. It is also produced by hydrolyzing lactonitrile with sulfuric acid and purifying with methanol to form methyl lactate.

Market Profile

Market information on this chemical is unavailable.

Regulatory Status

Methyl lactate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, methyl lactate is expected to display very high mobility. Biodegradation in acclimated aerobic soils may be rapid. Volatilization of methyl lactate from the upper layers of dry soil to the atmosphere may be significant although volatilization from moist soil will be very slow. In basic soil with a pH greater than8, chemical hydrolysis of methyl lactate may occur. If released to water, aerobic biodegradation may be rapid, especially in acclimated waters. Methyl lactate is not expected to bioconcentrate in fish and aquatic organisms nor is it expected to adsorb to sediment and suspended organic matter. Volatilization of methyl lactate from water to the atmosphere is expected to be very slow. In basic waters methyl lactate may undergo chemical hydrolysis with an estimated half-life of approximately 7 days at pH 8. If released to the atmosphere, methyl lactate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 6 days. It may also undergo atmospheric removal by wet deposition processes. Using a rapid biodegradation rate for methyl lactate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

Mineral Spirits (Naphtha, Heavy Straight-run)

Chemical Properties and Information	
Mineral spirits [Many trade names by companies including Amsco, Apco, Epesol, Exxon, Phillips, Shell, etc., most of which include "mineral spirits" in the name] CAS# 64741-41-9 Molecular weight: 86 for n-hexane; 112 for ethycyclohexane, for example Melting Point: -60°C (E) Water Solubility: 0.001 g/L (E) Vapor Pressure: 1 mm Hg (E) (25°C) Log K_{ow} = 3.4 - >6 (E) Henry's Law Constant: 1.5×10^{-3} - 13 atm-m^3/mole (E) Chemistry of Use: Solvent	Molecular formula: C_nH_{2n+2} (paraffin) and C_nH_{2n} (cycloparaffin) Structure: Typical structures include normal paraffins, $CH_3(CH_2)_nCH_3$, branched paraffins, and cycloparaffins Boiling Point: 160-200°C (M) Density: 0.78 g/ml (M) Flash Point: 43°C (M) K_{oc}: 500 - >5000 (E) Physical State: Liquid

Above data are either measured (M) or estimated (E)

The term mineral spirits refers to a range of petroleum solvents consisting largely of saturated hydrocarbons, including both straight-chain and branched paraffins, and cycloparaffins, which may have alkyl side chains. Up to one-fourth of some mineral spirits consists of aromatic hydrocarbons. A typical boiling range for mineral spirits is 160-200°C. Mineral spirits are miscible with petroleum solvents.

Mineral spirits may be prepared by fractionation of straight-run, cracked, and reforming petroleum distillates or fractionation of crude petroleum. The naphtha streams are generally divided into heavy and light, and may then be further fractionated. The naphthas are usually treated (chemically, with lye or other compounds, or hydrotreated) to remove sulfur compounds and aromatic hydrocarbons, leaving the solvent consisting mostly of aliphatic hydrocarbons.

Market Profile

No information is available on the production volumes of the numerous specific naphtha fractions, excluding special naphthas. The production volume for all naphthas was 2.1 billion pounds in 1991. The vast majority of naphthas are used in the production of gasoline and other petroleum products and not directly as solvents. Data for imported and exported amounts is not available. Total U.S. production for both mineral spirits (naphtha, heavy-straight-run and distillates, hydrotreated light) use in screen reclamation was estimated to be 6.9 million gallons.

Regulatory Status

Mineral spirits does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Naphtha, heavy straight-run is a mixture of components chiefly C_6-C_{12} cyclic and alicyclic hydrocarbons. If released to soil, naphtha, heavy straight-run is expected to biodegrade at a moderate rate under aerobic conditions, although some of the cycloalkanes may be resistant to biodegradation. Some components of naphtha, heavy straight-run are expected to adsorb very strongly to soil. Naphtha, heavy straight-run may rapidly volatilize from both moist and dry soils to the atmosphere, although strong adsorption may significantly attenuate the rate of this process. If released to water, naphtha, heavy straight-run is expected to biodegrade at a moderate rate under aerobic conditions with the exception of some cycloalkanes. Some components are expected to significantly bioconcentrate in fish and aquatic organisms and strongly adsorb to sediment and suspended organic matter. The estimated half-life for volatilization of naphtha, heavy straight-run components from a model river is approximately 1 hour while that from a model lake is greater than100 days; the former model does not account for the attenuating affect of strong adsorption. If released to the atmosphere, the dominant atmospheric removal process for naphtha, heavy straight-run is expected to be oxidation by hydroxyl radicals with an estimated half-life of 1-2 days. Using representative components that either biodegrade rapidly and display moderate sludge adsorption and those that are moderately biodegradable and display strong adsorption to sludge, the STP fugacity model indicates that greater than 94 percent total removal from wastewater treatment plants may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Mineral Spirits (Distillates, Hydrotreated Light)

Chemical Properties and Information

Mineral spirits [Many trade names by companies including Amsco, Apco, Epesol, Exxon, Phillips, Shell, etc., most of which include "mineral spirits" in the name]
CAS# 64741-47-8
Molecular weight: 86 for n-hexane; 112 for ethycyclohexane, for example
Melting Point: -60°C (E)
Water Solubility: 0.001 g/L (E)
Vapor Pressure: 0.5-1 mm Hg (E) (25°C)
Log K_{ow} = 4.76 - 8.25 (E)
Henry's Law Constant: 0.2 - 3.4 atm-m^3/mole (E)
Chemistry of Use: Solvent

Molecular formula: C_nH_{2n+2} (paraffin) and C_nH_{2n} (cycloparaffin)
Structure: Typical structures include normal paraffins, $CH_3(CH_2)_nCH_3$, branched paraffins, and cycloparaffins
Boiling Point: 140-180°C (M)
Density: 0.78 g/ml (M)
Flash Point: <43°C (M)
K_{oc}: 220 - >5000 (E)
Physical State: Liquid

Above data are either measured (M) or estimated (E)

The term mineral spirits refers to a range of petroleum solvents consisting largely of saturated hydrocarbons, including both straight-chain and branched paraffins, and cycloparaffins, which may have alkyl side chains. Up to one-fourth of some mineral spirits consists of aromatic hydrocarbons. A typical boiling range for mineral spirits is 160-200°C. Mineral spirits are miscible with petroleum solvents.

Mineral spirits may be prepared by fractionation of straight-run, cracked, and reforming petroleum distillates or fractionation of crude petroleum. The naphtha streams are generally divided into heavy and light, and may then be further fractionated. The naphthas are usually treated (chemically, with lye or other compounds, or hydrotreated) to remove sulfur compounds and aromatic hydrocarbons, leaving the solvent consisting mostly of aliphatic hydrocarbons.

Market Profile

No information is available on the production volumes of the numerous specific naphtha fractions, excluding special naphthas. The production volume for all naphthas was 2.1 billion pounds in 1991. The vast majority of naphthas are used in the production of gasoline and other petroleum products and not directly as solvents. Data for imported and exported amounts were not available. Total U.S. production quantity for both mineral spirits (naphtha, heavy-straight-run and distillates, hydrotreated light) use in screen reclamation was estimated to be 6.9 million gallons.

Regulatory Status

Mineral spirits does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Distillates, hydrotreated light is a mixture of components, chiefly C_9-C_{16} cyclic and alicyclic alkanes. If released to soil, distillates, hydrotreated light is expected to biodegrade at a moderate rate under aerobic conditions although some cyclic paraffins may be resistant to biodegradation. Some components of distillates, hydrotreated light may adsorb very strongly to soil and some may rapidly volatilize from both moist and dry soils to the atmosphere although strong adsorption may significantly attenuate the rate of this process. If released to water, distillates, hydrotreated light is expected to biodegrade at a moderate rate under aerobic conditions although some components may be resistant. Some components may significantly bioconcentrate in fish and aquatic organisms and strongly adsorb to sediment and suspended organic matter. The estimated half-life for volatilization of distillates, hydrotreated light components from a model river is approximately 1.5 hours while that from a model lake is greater than100 days; the former model does not account for the attenuating affect of strong adsorption. If released to the atmosphere, the dominant atmospheric removal process for distillates, hydrotreated light is expected to be oxidation by hydroxyl radicals with an estimated half-life of less than 1 day. Using representative components that either biodegrade rapidly and display moderate sludge adsorption and those that are moderately biodegradable and display strong adsorption to sludge, the STP fugacity model indicates that greater than 99 percent total removal from wastewater treatment plants may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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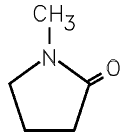
N-Methylpyrrolidone

Chemical Properties and Information	
N-methylpyrrolidone [1-methyl-2-pyrrolidone; 1-methylazacyclopentan-2-one; N-methyl-γ-butyrolactam] CAS# 872-50-4 Molecular weight: 99.13 Melting Point: -17 to -23°C (M) Water Solubility: Miscible (M) Vapor Pressure: 0.334 mm Hg (E) (25°C) Log K_{ow} = -0.73 (E) Henry's Law Constant: 1.56×10^{-8} atm-m^3/mole (E) Chemistry of Use: Solvent	C_5H_9NO Structure:  Boiling Point: 202°C (M) Density: 1.03 g/ml (M) Flash Point: 96°C (M) K_{oc}: 10 (E) Physical State: Colorless liquid with mild amine odor

Above data are either measured (M) or estimated (E)

N-Methylpyrrolidone is a dipolar aprotic solvent. It is steam volatile and forms hydrates. It dissolves many organic and inorganic compounds. N-methylpyrrolidone is soluble in ether and acetone, miscible in castor oil, miscible with lower alcohols and ketones, ethyl acetate, chloroform and benzene, and moderately soluble in aliphatic hydrocarbons.

N-Methylpyrrolidone is an N-substituted heterocycle. In addition to its chemical synthesis, it may be a naturally occurring compound as it has been identified as a volatile component of roasted nuts.

Market Profile

Total U.S. production in 1991 was 55 million gallons. In 1992, exports were 14.8 million gallons. Data for imported amounts was not available. Total U.S. production quantity for use in screen reclamation was estimated to be 38,000 gallons.

Regulatory Status

N-Methylpyrrolidone does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, N-methylpyrrolidone has the potential to biodegrade under aerobic conditions. It is expected to display very high mobility in soil. N-Methylpyrrolidone may slowly volatilize from dry soil to the atmosphere, but it is not expected to volatilize from moist soil. If released to water, screening studies indicate that N-methylpyrrolidone will biodegrade under aerobic conditions after a short lag period. N-Methylpyrrolidone is not expected to bioconcentrate in fish and aquatic organisms nor is it expected to adsorb to sediment or suspended organic matter. N-Methylpyrrolidone is not expected to volatilize from water to the atmosphere. The estimated half-life for volatilization of N-methylpyrrolidone from a model river is greater than2,000 days. If released to the atmosphere, N-methylpyrrolidone is expected to undergo a gas-phase reaction with photochemically produced hydroxyl radicals with an estimated half-life of 5.2 hrs. It may undergo atmospheric removal by wet deposition processes; however, its short atmospheric residence time suggests that wet deposition is of limited importance. Using a fast biodegradation rate for N-methylpyrrolidone in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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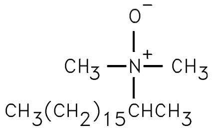
2-Octadecanamine, N,N-dimethyl-, N-oxide

Chemical Properties and Information	
2-Octadecanamine, N,N-dimethyl-, N-oxide [2-Octadecyldimethylamine oxide] CAS# 71662-60-7 Molecular weight: 313.22 Melting Point: >200°C (decomposes) (E) Water Solubility: Soluble (<10 g/L) / Dispersable (E) Vapor Pressure: $<10^{-6}$ mm Hg (E) Log K_{ow}: 9.2 (E) Henry's Law Constant: 3.62×10^{-4} atm-m^3/mole (E) Chemistry of Use: Surfactant	$C_{20}H_{43}NO$ Structure:  Boiling Point: Not applicable Density: Not available Flash Point: Not available K_{oc}: 890,000 (E)

Above data are either measured (M) or estimated (E)

This chemical is a surfactant. It is soluble in polar solvents.

This chemical is synthesized via oxidation of alkyl dimethyl amine.

Market Profile

No market information was available for this chemical.

Regulatory Status

2-Octadecanamine, N,N-dimethyl-, N-oxide does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Long chain dimethyl amine oxides degrade completely and rapidly in screening studies and therefore, if released to soil, 2-octadecanamine, N,N-dimethyl-, N-oxide would be expected to rapidly biodegrade. It would adsorb strongly to soil because of its long hydrophobic alkyl chain. If released in water, 2-octadecanamine, N,N-dimethyl-, N-oxide would be expected to rapidly biodegrade based on results of screening tests on analogous long chain dimethyl amine oxides. Initially it would be expected to strongly adsorb to sediment and particulate matter in the water column. Volatilization of 2-octadecanamine, N,N-dimethyl-, N-oxide to the atmosphere should be important (estimated half-life from a model river 4.7 hours). If released to the atmosphere, 2-octadecanamine, N,N-dimethyl-, N-oxide will be associated with aerosols and will be removed by gravitational settling. Using a rapid biodegradation rate in the STP fugacity model results in 100 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Periodic Acid

Chemical Properties and Information	
Periodic Acid [Metaperiodic acid] CAS# 13444-71-8 Molecular weight: 191.9 Melting Point: 130° C (M) decomposes Water Solubility: 3,700 g/l (M) Vapor Pressure: Negligible (E) Chemistry of Use: Oxidizing agent	HIO_4 Structure: HIO_4 Boiling Point: Not applicable Density: 3.0 g/ml (E) Flash Point: Not applicable Physical State: White crystals

Above data are either measured (M) or estimated (E)

Periodic acid is a powerful oxidant especially in acid solution. It undergoes a potentially explosive reaction with DMSO. It is soluble in alcohol and slightly soluble in ether.

Periodic acid is prepared by electrolytic oxidation of iodic acid in a diaphragm cell. Alternatively, an alkaline solution of sodium iodate is oxidized with chlorine and the resulting sodium periodate is converted to the acid via the barium salt.

Market Profile

The total U.S. production is unknown. Imports and exports for this chemical are unknown. Total U.S. quantity for use in screen reclamation is estimated to be 1.02 million pounds.

Regulatory Status

Periodic acid does not trigger any any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, the powerful oxidant periodic acid is expected to readily oxidize organic matter and will be short-lived. If released to water, oxidation of organic matter is expected to be sufficiently rapid to dominate all other potential fate pathways. If released to the atmosphere, periodic acid is expected to undergo removal by both wet and dry deposition processes. Depending on the composition of other components that may be present in the water droplets, periodic acid may be transformed by oxidizing either organic, inorganic, or metallic species present before deposition occurs. In wastewater treatment plants, periodic acid is expected to undergo complete removal through the oxidation of numerous organic, inorganic, or metallic species present in the wastewater.

Health Hazard

See Table II-6 and accompanying summary

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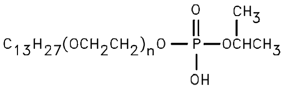
Phosphoric Acid, Mixed Ester with Isopropanol and Ethoxylated Tridecanol

Chemical Properties and Information	
Phosphoric acid, mixed ester with isopropanol and ethoxylated tridecanol [poly (oxy-1,2-ethanediyl) α-tridecyl-ω-hydroxy-, 1-methylethyl phosphate] CAS# 68186-42-5 Molecular weight: >540 Melting Point: Not available Water Solubility: Soluble/Dispersable Vapor Pressure: <10^{-6} mm Hg (E) Log K_{ow}: Not available Henry's Law Constant: Not available Chemistry of Use: Surfactant	Varies Structure:  $C_{13}H_{27}(OCH_2CH_2)_nO-\underset{\underset{OH}{\vert}}{\overset{\overset{O}{\Vert}}{P}}-O\overset{\overset{CH_3}{\vert}}{C}HCH_3$ n = 5 to 20 Boiling Point: High Boiling (E) Density: Not available Flash Point: Not available K_{oc}: Not available

Above data are either measured (M) or estimated (E)

This chemical is a phosphate surfactant. It is soluble in polar solvents and alcohols

This chemical is synthesized via phosphorolation of ethoxylated alcohol.

Market Profile

Total U.S. production is unknown. The majority of this chemical was imported/exported. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Phosphoric acid, mixed ester with isopropanol and ethoxylated tridecanol, does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, phosphoric acid, mixed ester w/isopropanol and ethoxylated tridecanol would be expected to biodegrade. Studies on a series of phosphate esters and ethoxylate phosphates confirm that they are suseptible to primary biodegradation. Phosphoric acid, mixed ester w/isopropanol and ethoxylated tridecanol is expected to be immobile in soil because of the long hydrophobic alkyl group and because of complex formation with metal cations, especially calcium and iron. Volatilization to the atmosphere is not expected to occur. If released to water, phosphoric acid, mixed ester w/isopropanol and ethoxylated tridecanol would be expected to biodegrade. Initially, it would be expected to adsorb to sediment and particulate matter in the water column. It may bioconcentrate in aquatic organisms because of its low water solubility, but this may be attenuated due to rapid biodegradation. Volatilization from water would not be expected. If released to the atmosphere, phosphoric acid, mixed ester w/isopropanol and ethoxylated will be associated with aerosols and will be removed by gravitational settling. Using a rapid biodegradation rate in the STP fugacity model results in 100 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Potassium Hydroxide

Chemical Properties and Information	
Potassium hydroxide [caustic potash]	KOH
CAS# 1310-58-3	Structure: KOH
Molecular weight: 56	Boiling Point: 1320-1324°C (M)
Melting Point: 380°C (M)	Density: 2.0 g/ml (E)
Water Solubility: 1500 g/L (E)	Flash Point: Not applicable
Vapor Pressure: Not applicable	Physical State: Solid, white or slightly yellow lumps, rods, pellets
Chemistry of Use: Caustic	

Above data are either measured (M) or estimated (E)

Potassium hydroxide is strongly basic and highly caustic to tissue; a 0.1 M aqueous solution has a pH of 13.5. It is extremely corrosive and toxic via ingestion. Potassium hydroxide is soluble in 3 parts alcohol or 2.5 parts glycerol.

Potassium hyroxide is prepared industrially by electrolysis of potassium chloride. In diaphragm cells, the product liquor contains potassium hydroxide (10-15 weight percent) and potassium chloride. Most of the potassium chloride crystallizes during concentration by evaporation and subsequent cooling, which results in purification of the potassium hydroxide solution. The anode is constructed of titanium; the cathode is a flowing layer of metallic mercury. Feed to the cells consists of brine, which is saturated with potassium chloride at a moderate temperature. Water is added to the potassium-mercury amalgam that results, to form potassium hydroxide and hydrogen.

Market Profile

In 1990, total U.S. production was 3.6 billion pounds. Imports were 8,740.6 million pounds and exports were 1,140 million pounds. Total U.S. production quantity for use in screen reclamation was estimated to be 1.06 million pounds.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

The environmental fate of potassium hydroxide is that of its aqueous solution; the dominant fate of solid potassium hydroxide release will be its dissolution in water. In aqueous solution, potassium hydroxide will dissociate into potassium cations (K^+) and the hydroxide anion (OH^-). Potassium ions are naturally present in surface water, groundwater, and rainwater as are hydroxide ions due to the ionization of water. Given that the components of potassium hydroxide are naturally present and participate in the reactions of natural systems, their fate will be determined by both the amount released and the composition of the receiving medium. Depending on the size of the release and the buffering capacity of the receiving medium, which is in a large part determined by the amount of naturally occurring acids such as hydrogen sulfide, humic acids, and those produced from carbon dioxide (the carbonate system), silica, and inorganic phosphates, the resulting pH may either increase or remain constant. In those systems with limited buffering capacity, the increase in basicity with the increase in the hydroxide ion concentration may lead to the formation and precipitation of insoluble transition metal complexes such as iron, aluminum, and manganese hydroxides. In soils with limited buffering capacity or a low organic content, potassium hydroxide may display high mobility. Potassium hydroxide will not volatilize to the atmosphere but it or its aqueous solutions may be released to the atmosphere by mechanical means during its production, use, or transport. If released to the atmosphere, potassium hydroxide will undergo removal by either wet or dry deposition processes. In wastewater treatment plants, potassium hydroxide will undergo reactions similar to those described above with the net result being an increase in the potassium ion concentration of the effluent.

Health Hazard

See Table II-6 and accompanying summary

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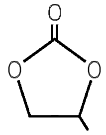
Propylene Carbonate

Chemical Properties and Information	
Propylene carbonate [1,2-Propylene carbonate; 4-methyl-1,3-dioxolane-2-one] CAS# 108-32-7 Molecular weight: 118 Melting Point: -55°C (M) Water Solubility: 100 g/L (E) Vapor Pressure: 0.44 mm Hg (E) (25°C) Log K_{ow} = 0.54 (E) Henry's Law Constant: 3.6×10^{-4} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_4H_6O_3$ Structure:  Boiling Point: 241.7°C (M) Density: 1.20 g/ml Flash Point: 132.2°C (M) K_{oc}: 6 (E) Physical State: Colorless, odorless liquid

Above data are either measured (M) or estimated (E)

Propylene carbonate is combustible. It has a high solubility for CO_2. This solubility makes propylene carbonate widely used for drying natural gas. Propylene carbonate is miscible with acetone, benzene, chloroform, ether and ethyl acetate.

Propylene oxide is reacted with carbon dioxide to yield propylene carbonate. Propylene carbonate can be further hydrolyzed to propylene glycol. The reaction is catalyzed by potassium iodide, calcium bromide or magnesium bromide.

Market Profile

In 1989, total U.S. production was 8.3 million gallons. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Propylene carbonate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, propylene carbonate is expected to display very high mobility. Biodegradation in acclimated aerobic soils may be rapid. Volatilization of propylene carbonate from both moist and dry soil to the atmosphere is expected to occur at a moderate rate. If released to water, aerobic biodegradation may occur and it may be rapid in acclimated waters. Propylene carbonate is not expected to bioconcentrate in fish and aquatic organisms or to adsorb to sediment and suspended organic matter. Volatilization of propylene carbonate from water to the atmosphere is expected to be relatively rapid. If released to the atmosphere, propylene carbonate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 2.5 days. It may also undergo atmospheric removal by wet deposition processes. Using a rapid biodegradation rate for propylene carbonate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants. If a moderate biodegradation rate is used in this model, 84 percent predicted total removal may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Propylene Glycol

Chemical Properties and Information	
Propylene glycol [1,2-propanediol, methyl glycol, 1,2-dihydroxypropane, methylethylene glycol, trimethyl glycol] CAS# 57-55-6 Molecular weight: 76.10 Melting Point: -60°C (M) Water Solubility: Miscible Vapor Pressure: 0.2 mm Hg at 20°C (M) Log K_{ow}: -.920 (M) Henry's Law Constant: 1.3×10^{-8} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_3H_8O_2$ Structure: $HOCH(CH_3)CH_2OH$ Boiling Point: 187.3°C (M) Density: 1.038 (M) Flash Point: 101°C (M) K_{oc}: 7 (E)

Above data are either measured (M) or estimated (E)

Propylene glycol is practically odorless with a slight taste. More volatile than ethylene glycol, it is three times as viscous at room temperature. Although propylene glycol has a secondary hydroxyl group, its chemistry parallels that of ethylene glycol. It is miscible with water and other polar solvents.

Propylene glycol is produced by the hydrolysis of propylene oxide. The hydrolysis is carried out under pressure at high temperature without catalysts. The proportion of products is controlled by the ratio of water to propylene oxide.

Market Profile

In 1989, total U.S. production was 651 million gallons. In 1989, imports were 0.3 million gallons. In 1988, exports were 144.5 million gallons. Total U.S. production quantity for use in screen reclamation was estimated to be 203,000 gallons.

Regulatory Status

Propylene glycol does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, propylene glycol may rapidly degrade under aerobic conditions. It is expected to display very high mobility; however, its expected rapid biodegradation will decrease its potential of leaching through soil. Volatilization of propylene glycol from moist soil to the atmosphere will not be important although it may occur slowly from dry soils. If released to water, propylene glycol may biodegrade rapidly under aerobic conditions. It may also slowly degrade under anaerobic conditions. Neither volatilization to the atmosphere, bioconcentration in fish and aquatic organisms, adsorption to sediment and suspended organic matter, chemical hydrolysis, nor oxidation are expected to occur. If released to the atmosphere, propylene glycol is degraded rapidly by reaction with photochemically produced hydroxyl radicals (typical half-life of 11 hours). Physical removal by wet deposition processes may also occur because of its substantial water solubility; however, its short atmospheric residence time suggests that wet deposition may be of limited importance. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Propylene Glycol Methyl Ether

Chemical Properties and Information	
Propylene glycol methyl ether [Glycol ether PM] CAS# 107-98-2 Molecular weight: 90.12 Melting Point: -95°C (M) Water Solubility: Miscible Vapor Pressure: 8.03 mm Hg (M) (20°C) Log K_{ow} = -0.49 (E) Henry's Law Constant: 1.8×10^{-8} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_4H_{10}O_2$ Structure: $CH_3OCH_2CH(CH_3)OH$ Boiling Point: 121°C (M) Density: 0.9234 g/ml (M) Flash Point: Open cup: 36°C (M) Closed Cup: 33°C (M) K_{oc}: 13 (E) Physical State: Liquid

Above data are either measured (M) or estimated (E)

Glycol ethers are both ethers and alcohols. Their hydroxyl groups can be etherified, esterified, chlorinated, or otherwise modified. Propylene glycol methyl ether is miscible with acetone, benzene, carbon tetrachloride, ethyl ether and petroleum ether. Glycol monoethers are prepared by conventional etherification procedures, including the reaction of an alkali metal glycolate with an alkyl halide, and reaction of propylene oxide with methanol.

Market Profile

In 1991, total U.S. production was 125 million gallons. Imports were less than 100,000 million gallons and exports were 28.7 million gallons. Total U.S. production quantity for use in screen reclamation was estimated to be 418,000 gallons.

Regulatory Status

Propylene glycol methyl ether does not trigger any federal environmental regulations. However, the generic category of glycol ethers is listed as Hazardous Air Pollutants in the Clean Air Act.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Propylene glycol methyl ether is not expected to undergo hydrolysis or direct photolysis in the environment. In water, volatilization, adsorption to sediments and suspended solids, and bioconcentration in aquatic organisms are not expected to be important transport processes for propylene glycol methyl ether. Biodegradation is likely to be the most important removal mechanism of propylene glycol methyl ether from aerobic soil and water based on a 4-week

BOD of 88-92 percent of theoretical. If released to soil, propylene glycol methyl ether is expected to display very high mobility. Volatilization from dry soil surfaces will be important. In the atmosphere, propylene glycol methyl ether is expected to exist almost entirely in the gas-phase and reactions with photochemically produced hydroxyl radicals should be fast (estimated half-life of 8.2 hrs). Physical removal of propylene glycol methyl ether from air by wet deposition may occur; however, its short atmospheric residence time suggests that wet deposition is of limited importance. Using a rapid biodegradation rate for propylene glycol methyl ether in the STP fugacity model results in 97 percent predicted removal from wastewater treatment plants; a moderate rate corresponds to 83 percent predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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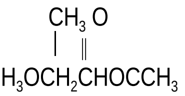
Propylene Glycol Methyl Ether Acetate

Chemical Properties and Information	
Propylene glycol methyl ether acetate[1-Methoxy-2-acetoxypropane; 1-Methoxy-2-propyl acetate; 2-Acetoxy-1-methoxypropane] CAS# 108-65-6 Molecular weight: 132 Melting Point: -100°C (E) Water Solubility: Miscible Vapor Pressure: 2 mm Hg (E) (25°C) Log K_{ow} = 0.56 (M) Henry's Law Constant: 4.26×10^{-6} atm-m^3/mole (M) Chemistry of Use: Solvent	$C_6H_{12}O_3$ Structure:  $CH_3OCH_2\overset{\overset{CH_3}{\vert}}{CH}O\overset{\overset{O}{\Vert}}{C}CH_3$ Boiling Point: 140°C (E) Density: 0.90 g/ml (E) Flash Point: 40°C (E) K_{oc}: 2 (M) Physical State: Liquid

Above data are either measured (M) or estimated (E)

Propylene glycol methyl ether acetate is a glycol derivative that is both an ether and an ester. Propylene glycol methyl ether acetate is soluble in organic solvents.

Propylene glycol methyl ether acetate is made by reacting propylene oxide with methanol followed by acetylation.

Market Profile

In 1991, total U.S. production of "other" P-series glycol ethers was 1 million pounds. This category includes dipropylene glycol methyl ether acetate, ethoxypropanol, ethoxypropyl acetate, and propylene glycol methyl ether acetate, among possibly others. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation was estimated to be 217,000 gallons.

Regulatory Status

Propylene glycol methyl ether acetate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, propylene glycol methyl ether acetate is expected to display very high mobility. Biodegradation in acclimated aerobic soils may be rapid. Hydrolysis of the ester group is not expected to be significant except for highly basic soils (pH greater than8). Volatilization of propylene glycol methyl ether acetate from dry soil to the atmosphere may be significant although it is likely to be a slow process from wet soil. If released to water, aerobic biodegradation is likely to be the dominant removal process with 20-day BODs of 61 percent of theoretical reported. Neither bioconcentration in fish and aquatic organisms, adsorption to sediment and suspended organic matter, hydrolysis, nor volatilization to the atmosphere are expected to be significant fate processes in surface water. If released to the atmosphere, propylene glycol methyl ether acetate may undergo oxidation by the gas-phase reaction with hydroxyl radicals with an estimated half-life of approximately 11 hours. It may also undergo atmospheric removal by wet deposition processes; however, its short atmospheric residence time suggests that wet deposition is of limited importance. Propylene glycol methyl ether acetate is listed as degradable in the Japanese MITI test which uses an acclimated sludge seed and it is expected to undergo significant removal in a wastewater treatment plant. Using a rapid biodegradation rate for propylene glycol methyl ether acetate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Silica

Chemical Properties and Information	
Silica [silicon dioxide] CAS# 7631-86-9 Molecular weight: 60 Melting Point: 1550°C (M) Water Solubility: Practically insoluble; vitreous form more soluble than quartz Vapor Pressure: (E) Log K_{ow}: Not applicable Henry's Law Constant: Not applicable Chemistry of Use: Anticaking/defoaming agent	SiO_2 Structure: Occurs as a variety of minerals including quartz; crystals are hexagonal Boiling Point: Density: 2.65 (quartz) (M); 2.2 (amorphous) Flash Point: (E) K_{oc}: Not applicable

Above data are either measured (M) or estimated (E)

Silica combines with many elements and oxides in the general realm of ceramic chemistry. It occurs in nature as agate, amethyst, chalcedony, cristobalite, flint, quartz, sand, tridymite, carnelian, onyx, and jasper; hydrated amorphous forms include opal, infusorial earth, and diatomaceous earth. A common vitreous form is obsidian. It is practically insoluble in acids, except aqueous HF, in which it readily dissolves, forming SiF_4 and H_2SiF_6.

It is naturally occurring.

Market Profile

In 1992, total U.S. production was 1.8 billion pounds. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Silica does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, silica is expected to be essentially immobile. Although silica slowly dissolves in water to a limited extent, adsorption to soil is expected through strong silica-soil interactions. Experimental data to assess the degree of adsorption of silica to soil are not available. Silica is not expected to biodegrade in soil nor volatilize to the atmosphere. Silica's ultimate fate in soil is expected to be chemical hydrolysis to silicic acid and participation in the natural silicon cycle although this process occurs on a geological time scale. If released to water, silica may slowly dissolve and may also undergo very slow chemical hydrolysis to silicic acid. Its dominant aquatic fate process is expected to be adsorption to sediment although ultimately it will enter the natural silicon cycle. Volatilization to the atmosphere, biodegradation, and bioconcentration in fish and aquatic organisms are not expected to occur. If released to the atmosphere as particulates, it is expected return to the earth via dry deposition and rain-out. Removal of silica from wastewater treatment plants is expected to be essentially complete due to its high degree of adsorption to sludge and complexation with metals.

Health Hazard

See Table II-6 and accompanying summary

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Silica, Fumed
(amorphous, crystalline-free)

Chemical Properties and Information	
Silica, fumed [pyrogenic silica, aerosil, amorphous silica] CAS# 112945-52-5 Molecular weight: 60 Melting Point: 1550°C (E) Water Solubility: 0.1 g/L (E) Vapor Pressure: Not applicable Log K_{ow}: Not applicable Henry's Law Constant: Not applicable Chemistry of Use: Thickener/reinforcer	SiO_2 Structure: Lack of crystalline structure Boiling Point: 2950°C (E) Density: 2.16 g/cm^3 (M) Flash Point: Not available K_{oc}: Not applicable

Above data are either measured (M) or estimated (E)

Fumed silica is an extremely pure form of silica. It is insoluble in all acids except HF (M).

Fumed silica is made by burning $SiCl_4$ with H_2 and O_2 at 1000°C.

Market Profile

In 1992, total U.S. production was 48.6 million pounds. In 1992, about 2.6 million pounds were imported and 2.0 million pounds were exported. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Silica, fumed, does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, fumed silica is expected to be essentially immobile. Although fumed silica slowly dissolves in water to a limited extent, adsorption to soil is expected through strong silica-soil interactions. Experimental data to assess the degree of adsorption of fumed silica to soil are not available. Fused silica is not expected to biodegrade in soil nor volatilize to the atmosphere. Fumed silica's ultimate fate in soil is expected to be chemical hydrolysis to silicic acid and participation in the natural silicon cycle although this process will occur on a geological time scale. If released to water, fumed silica may slowly dissolve and may also undergo very slow chemical hydrolysis to silicic acid. Its dominant aquatic fate process is expected to be adsorption to sediment although ultimately it will enter the natural silicon cycle. Volatilization to the atmosphere, biodegradation, and bioconcentration in fish and aquatic organisms are not expected to occur. If released to the atmosphere as particulates, it is expected return to the earth via dry deposition and rain-out. Removal of fumed silica from wastewater treatment plants is expected to be essentially complete due to its high degree of expected adsorption to sludge and complexation with metals.

Health Hazard

See Table II-6 and accompanying summary

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Sodium Bisulfate

Chemical Properties and Information	
Sodium bisulfate [sulfuric acid, monosodium salt, monohydrate] CAS# 10034-88-5 Molecular weight: 138 Melting Point: Decomposes (M) Water Solubility: 1250 g/L (M) Vapor Pressure: Not applicable Log K_{ow}: Not applicable Henry's Law Constant: Not applicable Chemistry of Use: Salt	H_3NaO_5S Structure: $HOSO_3Na{\cdot}H_2O$ Boiling Point: Not Applicable Density: >2 g/cm^3 (E) Flash Point: Not applicable K_{oc}: Not applicable

Above data are either measured (M) or estimated (E)

This chemical changes to pyrosulfate when strongly heated. This chemical exists as colorless, odorless crystals. This chemical is corrosive and its aqueous solution is strongly acidic. It decomposes in alcohol.

This chemical is made by crystallization from an aqueous solution containing $NaHSO_4$.

Market Profile

No information on production volumes of sodium bisulfate was available. In 1990, total U.S. production of sodium sulfate was 812 million pounds. In 1991, about 34.6 million pounds of sodium sulfate were imported and about 250 million pounds of sodium sulfate were exported. Total U.S. production of sodium bisulfate for use in screen reclamation was estimated to be 2.35 million pounds.

Regulatory Status

Sodium bisulfate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

The environmental fate of sodium bisulfate is that of its aqueous solution; the dominant fate of solid sodium bisulfate release will be its dissolution in water. In aqueous solution, sodium bisulfate will ionize to sodium cations (Na^+) and the bisulfate anion (HSO_4^-). In water, the bisulfate ion will rapidly dissociate to the sulfate ion (SO_4^{-2}) and a hydronium ion (H_3O^+). Sodium ions are naturally present in surface water, groundwater, and rainwater as are sulfate ions. Sulfate ions are also important components of the sulfur cycle. Depending on the size of the sodium bisulfate release and the buffering capacity of the receiving medium, the resulting pH may either decrease or remain constant. In soil and water systems with limited buffering capacity, the increase in acidity with the increase in hydronium ion concentration may lead to the solubilization of metal complexes of phosphate, magnesium, calcium, iron, and aluminum. Sodium bisulfate will not volatilize to the atmosphere but it may be released to the atmosphere by mechanical means during its production, use, or transport. If released to the atmosphere, sodium bisulfate will undergo removal by either wet deposition due to its appreciable water solubility or dry deposition due to settling. In wastewater treatment plants, sodium bisulfate will undergo rapid ionization and subsequent dissociation and will pass through the treatment plant as the ions.

Health Hazard

See Table II-6 and accompanying summary

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Sodium Hexametaphosphate

Chemical Properties and Information	
Sodium hexametaphosphate [Metaphosphoric acid, hexasodium salt; sodium polymetaphosphate; Graham's salt; glassy sodium metaphosphate] CAS# 10124-56-8 Molecular weight: 611.17 Melting Point: 628°C (M) Water Solubility: Very Soluble Vapor Pressure: Not applicable Log K_{ow}: Not applicable Henry's Law Constant: Not available Chemistry of Use: Corrosion inhibitor/dispersant	$(NaPO_3)_6$ Structure: 12 member ring with alternating P and O atoms $Na^{+1}{}_6(P_6O_{18})^{-6}$ Boiling Point: Not available Density: 2.4 g/cm^3 (E) Flash Point: Not available K_{oc}: Not applicable

Above data are either measured (M) or estimated (E)

This chemical appears as a clear, hygroscopic glass. Sodium hexametaphosphate is a mixture of polymeric metaphosphates, and is not a hexamer. It depolymerizes in aqueous solution to form sodium trimetaphosphate and sodium ortho phosphates.

Sodium hexametaphosphate is prepared by rapidly chilling molten sodium metaphosphate.

Market Profile

In 1989, total U.S. production was 88 million pounds. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, sodium hexametaphosphate is expected to be essentially immobile due to the formation of insoluble complexes with metal salts, particularly calcium and iron. Sodium hexametaphosphate is expected to be unstable in soils and will eventually degrade to orthophosphate. Degradation rates increase in clay containing soils resulting from metal catalyzed processes. Volatilization to the atmosphere is not expected to occur. If released to water, sodium hexametaphosphate will undergo slow chemical hydrolysis to orthophosphate with a half-life of approximately 1 month at 40 °C at neutral pH. If organisms containing phosphatase enzymes are present, sodium hexametaphosphate will undergo rapid hydrolysis in environmental waters. In the absence of rapid hydrolysis, adsorption to sediment and suspended organic matter may occur initially, followed by chemical degradation. Neither volatilization to the atmosphere or bioconcentration in fish and aquatic organisms are expected. If released to a wastewater treatment plants, complete removal of sodium hexametaphosphate is expected from hydrolysis due to the relatively high local phosphatase concentration. Available data indicate that metaphosphates in raw sewage are predominately hydrolyzed to orthophosphate before they even reach the treatment plant

Health Hazard

See Table II-6 and accompanying summary

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Sodium Hydroxide

Chemical Properties and Information	
Sodium hydroxide [caustic soda; lye; sodium hydrate; soda lye] CAS# 1310-73-2 Molecular weight: 39.9 Melting Point: 323°C (M) Water Solubility: 1,180 g/L (E) Vapor Pressure: Negligible (E) 1 mm Hg (M) (739°C) Chemistry of Use: Caustic	NaOH Structure: NaOH Boiling Point: 1390°C (M) Density: 2.13 g/ml (M) Flash Point: Not applicable Physical State: Deliquescent orthorhombic white powder

Above data are either measured (M) or estimated (E)

Sodium hydroxide is an important industrial alkali. It readily reacts with atmospheric CO_2 to form Na_2CO_3. It reacts with all the mineral acids to form the corresponding salts. Sodium hydroxide is very soluble in ethanol and soluble in glycerol. It is insoluble in diethyl ether and acetone.

Sodium hydroxide is manufactured either by electrolysis of brine (Castner-Kellner process) or by treatment of Na_2CO_3 or $NaHCO_3$ with CaO or $Ca(OH)_2$. It can also be prepared from sodium metal and water vapor at low temperature.

Market Profile

In 1991, total U.S. production was 25 billion pounds. In 1992, imports were 1,138 million pounds and in exports were 2,536 million pounds. Total U.S. production quantity for use in screen reclamation was estimated to be 1.45 million pounds.

Regulatory Status

See Table II-3 and accompanying summary.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

The environmental fate of sodium hydroxide is that of its aqueous solution; the dominant fate of solid sodium hydroxide release will be its dissolution in water. In aqueous solution, sodium hydroxide will dissociate into sodium cations (Na^+) and the hydroxide anion (OH^-). Sodium ions are naturally present in surface water, groundwater, and rainwater as are hydroxide ions due to the ionization of water. Given that the components of sodium hydroxide are naturally present and participate in the reactions of natural systems, their fate will be determined by both the amount released and the composition of the receiving medium. Depending on the size of the release and the buffering capacity of the receiving medium, which is in a large part determined by the amount of naturally occurring acids such as hydrogen sulfide, humic acids, and those produced from carbon dioxide (the carbonate system), silica, and inorganic phosphates, the resulting pH may either increase or remain constant. In those systems with limited buffering capacity, the increase in basicity with the increase in the hydroxide ion concentration may lead to the formation and precipitation of insoluble transition metal complexes such as iron, aluminum, and manganese hydroxides. In soils with limited buffering capacity or a low organic content, sodium hydroxide may display high mobility. Sodium hydroxide will not volatilize to the atmosphere but it or its aqueous solutions may be released to the atmosphere by mechanical means during its production, use, or transport. If released to the atmosphere, sodium hydroxide will undergo removal by either wet or dry deposition processes. In wastewater treatment plants, sodium hydroxide will undergo reactions similar to those described above with the net result being an increase in the sodium ion concentration of the effluent.

Health Hazard

See Table II-6 and accompanying summary

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Sodium Hypochlorite

Chemical Properties and Information	
Sodium hypochlorite [chloric(I) acid, sodium salt; hypochlorous acid, sodium salt; Clorox, Dazzle, Eau de Labarraque] CAS# 7681-52-9 Molecular weight: 74.4 Melting Point: 18° C (M) crystals decompose Water Solubility: 260 g/l (M) Vapor Pressure: Not applicable Chemistry of Use: Oxidizing agent	NaOCl Structure: NaOCl Boiling Point: Not applicable Density: 1.21 g/ml (M) Flash Point: Not applicable

Above data are either measured (M) or estimated (E)

Sodium hypochlorite is a strong oxidizing agent usually stored and used in solution. There is a fire risk in contact with organic materials. It is highly reactive. The physical state of sodium hypochlorite is a greenish yellow liquid (in solution) with a disagreeable sweetish odor.

Sodium hypochlorite is synthesized by bubbling Cl_2 through aqueous NaOH in the presence of CO_2. It is manufactured by the electrolysis of brine.

Market Profile

In 1990, total U.S. production was 380 million gallons. In 1991, imports and exports were believed to be negligible. Total U.S. production quantity for use in screen reclamation was estimated to be 69,000 gallons.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

The environmental fate of sodium hypochlorite is essentially that of its aqueous solutions; the dominant fate of solid sodium hypochlorite release will be its dissolution in water. If released to soil, sodium hypochlorite is expected to readily oxidize organic matter and is likely to be short-lived. If released to water, sodium hypochlorite is expected to be short-lived although its aquatic fate is partially dependent on the pH of receiving water. Sodium hypochlorite is expected to dissociate to hypochlorous acid which may, in the presence of additional chloride ions under acidic conditions, form chlorine. At pH 7.5, the hypochlorite ion and hyperchlorous acid are at approximately equal concentrations; at pH 8.5, only 10 percent of the added sodium hypochlorite would exist as hypochlorous acid. Hypochlorous acid and, if formed, chlorine may undergo significant volatilization to the atmosphere. Sodium hypochlorite itself is not expected to volatilize from water. Chlorine, hypochlorous acid, as well as sodium hypochlorite are expected to readily oxidize organic compounds. Hypochlorous acid, which is always in equilibrium with the hypochlorite ion, may also oxidize sulfur compounds, nitrate ions, and certain metals such as Fe(II) an Mn(II). Hypochlorous acid may also decompose under the influence of UV light. Reduction is ultimately expected to be the dominant removal process for sodium hypochlorite in water. Sodium hypochlorite will not volatilize to the atmosphere but it or its aqueous solutions may be released to the atmosphere by mechanical means during its production, use, or transport. If released to the atmosphere, sodium hypochlorite is expected to removed by both wet and dry deposition processes. Depending on the composition of other components that may be present in the water droplets, sodium hypochlorite may be transformed by oxidizing organics, certain metals, and some inorganic species (such as nitrate ions) before deposition occurs. In activated sludge wastewater treatment plants, sodium hypochlorite is expected to undergo rapid and complete removal via the reductive pathways discussed above.

Health Hazard

See Table II-6 and accompanying summary

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Sodium Lauryl Sulfate

Chemical Properties and Information	
Sodium lauryl sulfate [sulfuric acid monododecyl ester sodium salt; sodium dodecyl sulfate; SDS; irium] CAS# 151-21-3 Molecular weight: 288.38 Melting Point: Decomposes Water Solubility: 100 g/L (M) Vapor Pressure: Not applicable Log K_{ow}: L7 (E) Henry's Law Constant: Not available Chemistry of Use: Detergent	$C_{12}H_{25}NaO_4S$ Structure: $CH_3(CH_2)_{11}OSO_3^-Na^+$ Boiling Point: Decomposes Density: 1 g/cm^3 (E) Flash Point: Not applicable K_{oc}: 80,000 (E)

Above data are either measured (M) or estimated (E)

Sodium lauryl sulfate has a mild fatty odor. It is an anionic detergent and lowers the surface tension of aqueous solutions. It is soluble in alcohols and ethers.

Sodium lauryl sulfate is synthesized by sulfation of lauryl alcohol, followed by neutralization with sodium carbonate.

Market Profile

No market information was available for this chemical.

Regulatory Status

Sodium lauryl sulfate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, sodium lauryl sulfate is expected to readily biodegrade under aerobic conditions. The first step in the biodegradation pathway is believed to be hydrolysis to the alcohol and inorganic sulfate. Sodium lauryl sulfate is chemically stable in neutral and alkaline solutions, but readily hydrolyses in the presence of acids. Since the sodium bisulfate produced in the hydrolysis is strongly acidic, once hydrolysis starts it is autocatalytic. Although sodium lauryl sulfate is ionic, studies have shown that long chain alkyl sulfates strongly adsorb to soil and that the force dominating this process is the hydrophobic nature of the non-polar tail of the molecule. Volatilization of sodium lauryl sulfate from surface soil will not be significant. If released to water, sodium lauryl sulfate is expected to rapidly biodegrade. It should also adsorb to sediment and particulate matter in the water column. Volatilization of sodium lauryl sulfate from water should be insignificant. Experimental data on similar long-chain alkyl sulfates indicate that bioconcentration in fish and aquatic organisms is not an important process. If released to the atmosphere, sodium lauryl sulfate will be associated with aerosols and be removed by gravitational settling. Using a rapid biodegradation rate in the STP fugacity model results in 100 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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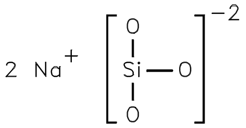
Sodium Metasilicate

Chemical Properties and Information	
Sodium metasilicate [waterglass] CAS# 6834-92-0 Molecular weight: 122.08 Melting Point: 1089°C (decomposes) (M) Water Solubility: Completely soluble in cold water (M) Vapor Pressure: $<10^{-8}$ torr (E) Log K_{ow}: Not applicable Henry's Law Constant: Not applicable Chemistry of Use: Corrosion inhibitor	Na_2O_3Si Structure: $2\ Na^{+}\left[\begin{array}{c}O\\ \vert\\ Si-O\\ \vert\\ O\end{array}\right]^{-2}$ Boiling Point: Not applicable Density: 2.614 g/cm^3 (M) Flash Point: Not available K_{oc}: Not applicable

Above data are either measured (M) or estimated (E)

This chemical is usually obtained as a glass, and sometimes as orthorhombic crystals. It is hydrolyzed in hot water. It is insoluble in organics and alcohols. Sodium metasilicate is prepared from sand (SiO_2) and soda ash (Na_2CO_3) by fusion.

Market Profile

In 1992, total U.S. production was 106 million pounds. In 1992, for all metasilicates, about 3,062 million pounds were imported and 23,058 million pounds were exported. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Sodium metasilicate does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, sodium metasilicate's mobility is likely dependent on both the silicate species present and the type of soil. Highly polymerized forms of sodium metasilicate are not expected to be mobile due to surface complexation with either active sites in soil via ion exchange reactions or adsorption onto insoluble metal oxides. Mono and oligomeric silicates are expected to display increased mobility yet may adsorb strongly onto clay soils due to silicate-metal interactions. Experimental data to assess the degree of adsorption to soil are not available. Sodium metasilicate is not expected to biodegrade nor volatilize to the atmosphere. Alkaline earth silicates are one part of the natural buffer system of environmental waters and if released to water, sodium metasilicate is expected to undergo typical acid/base reactions of silicate buffers which, depending upon the pH of the receiving water, may include proton exchange, polymerization, or depolymerization reactions. Volatilization to the atmosphere, biodegradation, and bioconcentration in fish and aquatic organisms are not expected to occur. The degree in which sodium metasilicate adsorbs to sediment is dependent on the same factors influencing its adsorption to soil. The degree to which sodium metasilicate is removed from wastewater treatment plants is also dependent on the nature of the silicates and the water being treated. Highly polymerized soluble silicates are used in water treatment to precipitate metal oxides and metal ions and these silicates are expected to be efficiently removed from wastewater treatment plants via complexation with metals and adsorption to sludge. Mono and oligomeric sodium metasilicates may not undergo significant removal in wastewater treatment plants. Removal by biodegradation and volatilization of sodium metasilicate from wastewater treatment plants is expected to be negligible.

Health Hazard

See Table II-6 and accompanying summary

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Sodium Periodate

Chemical Properties and Information	
Sodium periodate [sodium metaperiodate; sodium iodate(VII); Iodic(VII) acid, sodium salt; periodic acid, sodium salt] CAS# 7790-28-5 Molecular weight: 213.8 Melting Point: 300° C (M) decomposes Water Solubility: 140 g/l (M) Vapor Pressure: Negligible (E) Chemistry of Use: Oxidizing agent	$NaIO_4$ Structure: $Na^+ IO_4^-$ Boiling Point: Not applicable Density: 3.865 g/ml (M) Flash Point: Not applicable Physical State: Colorless tetragonal crystals

Above data are either measured (M) or estimated (E)

Sodium metaperiodate is a strong oxidizer; contact with combustible or flammable materials can cause fire or explosion. It is soluble in acetic acid. Sodium metaperiodate is synthesized by direct oxidation of $NaIO_3$ using O_2 in the presence of an alkali at 300°C and 34 atm. It is also a product of the thermal decomposition of $NaH_4IO_6 \bullet H_2O$.

Market Profile

The total U.S. production is unknown. Total U.S. quantity for use in screen reclamation was estimated to be 11.7 million pounds.

Regulatory Status

Sodium periodate does not trigger any federal environmental regulations

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

The environmental fate of sodium periodate is that of its aqueous solution; the dominant fate of solid sodium periodate release will be its dissolution in water. If released to soil, sodium periodate is expected to readily oxidize organic matter and will be short-lived. If released to water, oxidation of organic matter is expected to be sufficiently rapid to dominate all other potential fate pathways. If released to the atmosphere, sodium periodate is expected to undergo removal by both wet and dry deposition processes. Depending on the composition of other components that may be present in the water droplets, sodium periodate may be transformed by oxidizing either organic, inorganic, or metallic species present before deposition occurs. In wastewater treatment plants, sodium periodate is expected to undergo complete removal through the oxidation of numerous organic, inorganic, or metallic species present in the wastewater.

Health Hazard

See Table II-6 and accompanying summary

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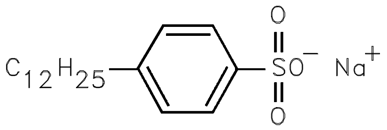
Sodium Salt, Dodecyl Benzene Sulfonic Acid

Chemical Properties and Information	
Sodium salt, dodecyl benzene sulfonic acid [Sodium dodecylbenzenesulfonate; Conoco C-50; Santomerse #1] CAS# 25155-30-0 Molecular weight: 348.49 Melting Point: Not available Water Solubility: Low Solubility (E); dispersible (E) Vapor Pressure: $<10^{-5}$ mm Hg (E) Log K_{ow}: 1.96 (M) Henry's Law Constant: Not available Chemistry of Use: Surfactant	$C_{18}H_{29}NaO_3S$ Structure:  Boiling Point: Not available Density: 0.5 g/cm^3 (E) Flash Point: Not available K_{oc}: 100,000 (M)

Above data are either measured (M) or estimated (E)

This chemical is synthesized by reacting dodecyl benzene sulfonic acid with sodium carbonate.

Market Profile

In 1990, total U.S. production was 224.6 million pounds. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, sodium salt, dodecyl benzene sulfonic acid is expected to biodegrade under aerobic conditions, especially when acclimated organisms are present. Although sodium salt, dodecyl benzene sulfonic acid is ionic, studies have shown that dodecyl benzene sulfonic acid salts strongly adsorb to soil and that the force dominating this process is the hydrophobic nature of the non-polar tail of the molecule. Volatilization of sodium salt, dodecyl benzene sulfonic acid from surface soil will not be significant. If released to water, sodium salt, dodecyl benzene sulfonic acid is expected to biodegrade. It will also adsorb to sediment and particulate matter in the water column. Volatilization of sodium salt, dodecyl benzene sulfonic acid from water should be insignificant. Experimental data indicate that bioconcentration in fish and aquatic organisms is not an important processes. If released to the atmosphere, sodium salt, dodecyl benzene sulfonic acid will be associated with aerosols and be removed by gravitational settling. Using a rapid biodegradation rate for the parent acid in the STP fugacity model results in 97 percent predicted total removal of sodium salt, dodecyl benzene sulfonic acid from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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Solvent Naphtha, Petroleum, Light Aliphatic (VM&P Naptha)

Chemical Properties and Information	
Solvent naphtha, petroleum, light aliphatic [VM&P #66; lacolene; rubber solvent; petroleum ether; naphtha; varnish makers' and painters' solvent; VM&P Naphtha] CAS# 64742-89-8 Molecular weight: 86 for n-hexane; 112 for ethycyclohexane, for example Melting Point: <-80°C (M) Water Solubility: 0.001 g/L (E) Vapor Pressure: 20 mm Hg (E) (25°C) Log K_{ow} = 3.27 - > 6 (E) Henry's Law Constant: 8.0×10^{-3} - 5 atm-m^3/mole (E) Chemistry of Use: Solvent	Molecular Formula: C_nH_{2n+2} (paraffin) and C_nH_{2n} (cycloparaffin) Structure: Typical structures include normal paraffins, $CH_3(CH_2)_nCH_3$, branched paraffins, and cycloparaffins Boiling Point: 35-160°C (M) Density: 0.7 g/ml (E) Flash Point: 0°C (E) K_{oc}: 200 - >5,000 (E) Physical State: Liquid

Above data are either measured (M) or estimated (E)

These commercial products are all light aliphatic solvent naphthas with similar compositions and properties. Most consist of 80 to 90 percent paraffins most of which are straight- or branched-chain alkanes in the range of C_5 through C_{10}. Up to 10 percent is typically aromatics, with only a fraction of this being C_8 and above. They are miscible with petroleum solvents.

Solvent naphthas are prepared by fractionation of straight-run, cracked, and reforming distillates, or by fractionation of crude petroleum or natural gasoline. The naphtha streams are divided into heavy and light, and may be further fractionated. The naphthas are usually treated to remove sulfur, either chemically, with lye or other compounds, or by hydrotreating processes. Aromatic hydrocarbons are also removed by solvent extraction or by destructive hydrogenation.

Market Profile

Based on boiling range and other evidence, it has been assumed that this naphtha fraction corresponds to "special naphthas." The 1990 production volume for this naphtha was 4.2 billion pounds. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation was estimated to be 12.6 million pounds.

Regulatory Status

Solvent naphtha (petroleum), light aliphatic, does not trigger any federal environmental regulations

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Solvent naphtha, light aliphatic is a mixture of components, chiefly C5-C10 alkanes typically with up to 10 percent aromatics. If released to soil, solvent naphtha, light aliphatic is expected to biodegrade at a fast to moderate rate under aerobic conditions. Some components of solvent naphtha, light aliphatic may adsorb very strongly to soil. Solvent naphtha, light aliphatic may rapidly volatilize from both moist and dry soils to the atmosphere although strong adsorption may significantly attenuate the rate of this process. If released to water, solvent naphtha, light aliphatic is expected to biodegrade at a fast to moderate rate under aerobic conditions. Some components may significantly bioconcentrate in fish and aquatic organisms and strongly adsorb to sediment and suspended organic matter. The estimated half-life for volatilization of solvent naphtha, light aliphatic components from a model river is approximately 1 hour while that from a model lake is greater than100 days; the former model does not account for the attenuating affect of strong adsorption. If released to the atmosphere, the dominant atmospheric removal process for solvent naphtha, light aliphatic is expected to be oxidation by hydroxyl radicals with an estimated half-life of 1-3 days. Using representative components that either biodegrade rapidly and display moderate sludge adsorption or are moderately biodegradable and display strong adsorption to sludge, the STP fugacity model indicates that greater than 94 percent total removal from wastewater treatment plants may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Solvent Naphtha, Petroleum, Light Aromatic

Chemical Properties and Information	
Solvent naphtha, petroleum, light aromatic [Comsolv 100] CAS# 64742-95-6 Molecular weight: 128 for naphthalene Melting Point: -80°C (E) Water Solubility: 0.03 g/L (M) for naphthalene Vapor Pressure: 0.5 mm Hg (E) (25°C) Log K_{ow} = 3.0 - 3.5 (E) Henry's Law Constant: 4.8×10^{-4} - 8×10^{-3} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_{10}H_8$ for naphthalene Structure: Consist chiefly of aromatic hydrocarbons, including small fused-ring compounds such as naphthalene Boiling Point: 135-210°C (E) Density: 0.87 g/ml (E) Flash Point: 38°C (E) K_{oc}: 500 - 2,000 (E) Physical State: Liquid

Above data are either measured (M) or estimated (E)

The light aromatic solvent naphtha products are a complex combination of hydrocarbons that consists chiefly of C_8 through C_{10} aromatics, but they also may contain up to 30 percent paraffins and cycloparaffins

Solvent naphthas are prepared by fractional distillation of petroleum. Sulfur compounds are most commonly removed or converted to a harmless form by chemical treatment with lye or other agent, or by hydrorefining processes.

Market Profile

No information is available on the production volumes of the numerous specific naphtha fractions, excluding special naphthas. The production volume for all naphthas was 2,100 million pounds in 1991. The vast majority of naphthas are used in the production of gasoline and other petroleum products and not directly as solvents. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Solvent naphtha (petroleum), light aromatic, does not trigger any federal environmental regulations

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Solvent naphtha, light aromatic is a mixture of components, chiefly C8-C10 aromatics. If released to soil, solvent naphtha, light aromatic is expected to biodegrade at a moderate rate under aerobic conditions. Some components of solvent naphtha, light aromatic may adsorb strongly to soil. Solvent naphtha, light aromatic may rapidly volatilize from both moist and dry soils to the atmosphere although adsorption may significantly attenuate the rate of this process. If released to water, solvent naphtha, light aromatic is expected to biodegrade at a moderate rate under aerobic conditions. Some components may significantly bioconcentrate in fish and aquatic organisms and adsorb to sediment and suspended organic matter. The estimated half-life for volatilization of solvent naphtha, light aromatic components from a model river is approximately 2 hours while that from a model lake is greater than100 days; the former model does not account for the attenuating affect of adsorption. If released to the atmosphere, the dominant atmospheric removal process for solvent naphtha, light aromatic is expected to be oxidation by hydroxyl radicals with an estimated half-life of 0.5-2 days. Using representative components that biodegrade either at a rapid or moderate rate and display moderate sludge adsorption, the STP fugacity model indicates that greater than 92 percent total removal from wastewater treatment plants may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Solvent Naphtha, Petroleum, Heavy Aromatic (Aromatic 150)

Chemical Properties and Information	
Solvent naphtha, petroleum, heavy aromatic [Aromatic 150; Comsolv 150] CAS# 64742-94-5 Molecular weight: 128 for naphthalene Melting Point: -80°C (E) Water Solubility: 0.03 g/L (M) for naphthalene Vapor Pressure: 0.5 mm Hg (E) (25°C) Log K_{ow} = 3.5 - >5 (E) Henry's Law Constant: 8 x 10^{-4} - 8 x 10^{-3} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_{10}H_8$ for naphthalene Structure: Consist chiefly of aromatic hydrocarbons, including small fused-ring compounds such as naphthalene Boiling Point: 150-290°C (E) Density: 0.87 g/ml (E) Flash Point: 38°C (E) K_{oc}: 700 - >5,000 (E) Physical State: Liquid

Above data are either measured (M) or estimated (E)

The heavy aromatic solvent naphtha products consist chiefly of C_8 through C_{16} aromatics, but they also may contain up to 30 percent paraffins and cycloparaffins. It is soluble in petroleum solvents and other organics.

Solvent naphthas are prepared by fractional distillation of petroleum. Sulfur compounds are most commonly removed or converted to a harmless form by chemical treatment with lye or other agent, or by hydrorefining processes.

Market Profile

No information is available on the production volumes of the numerous specific naphtha fractions, excluding special naphthas. The production volume for all naphthas was 2.1 billion pounds in 1991. The vast majority of naphthas are used in the production of gasoline and other petroleum products and not directly as solvents. Data for imported and exported amounts were not available. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Solvent naphtha (petroleum), heavy aromatic does not trigger any federal environmental regulations

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Solvent naphtha, heavy aromatic is a mixture of components, chiefly C9-C16 aromatic hydrocarbons. If released to soil, solvent naphtha, heavy aromatic is expected to biodegrade at a moderate rate under aerobic conditions. Most components of solvent naphtha, heavy aromatic are expected to adsorb strongly to soil. Solvent naphtha, heavy aromatic may volatilize from both moist and dry soils to the atmosphere although its expected strong adsorption may significantly attenuate the rate of this process. If released to water, solvent naphtha, heavy aromatic is expected to biodegrade at a moderate rate under aerobic conditions. Most components are expected to bioconcentrate in fish and aquatic organisms and strongly adsorb to sediment and suspended organic matter. The estimated half-life for volatilization of solvent naphtha, heavy aromatic components from a model river is approximately 2 hours while that from a model lake is greater than100 days; the former model does not account for the attenuating affect of strong adsorption. If released to the atmosphere, the dominant atmospheric removal process for solvent naphtha, heavy aromatic is expected to be oxidation by hydroxyl radicals with an estimated half-life of 1-2.5 days. Using representative components that biodegrade at a moderate to slow rate and display strong adsorption to sludge, the STP fugacity model indicates that greater than 96 percent total removal from wastewater treatment plants may be achieved.

Health Hazard

See Table II-6 and accompanying summary

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Tall Oil, Special

Chemical Properties and Information	
Tall oil, special [fatty acids, C_{18} and C_{18}-unsatd., me esters, methyl stearate, methyl oleate] CAS# 68937-81-5 Molecular weight: 296-298 Melting Point: 36-39°C (E) Water Solubility: Insoluble (M) (<0.1 g/L) (E) Vapor Pressure: $<10^{-3}$ mm Hg (E) Log K_{ow}: Not available Henry's Law Constant: Not available Chemistry of Use: Solvent	$C_{19}H_{36}O_2$ and $C_{19}H_{38}O_2$ Structure: $CH_3(CH_2)_{16}COOCH_3$ and $CH_3(CH_2)_7CH=CH(CH_2)_7COOCH_3$ Boiling Point: 325°C (E) Density: 0.88 g/cm^3 (E) Flash Point: 200°C (E) K_{oc}: Not available

Above data are either measured (M) or estimated (E)

This chemical exists as white crystals. It is soluble in alcohol and ether. The methyl oleate portion of this mixture is made by refluxing oleic acid with p-toluene sulfonic acid in methanol.

Market Profile

In 1987, total U.S. production of all tall oil was 1.892 million pounds. Information specific to special tall oil was not available. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Tall oil (special) does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

The long chain unsaturated acids and rosin acids that are the principal components of special tall oil will adsorb strongly to soil because of their long hydrophobic alkyl chain. They readily biodegrade by β-oxidation. Henry's Law constants estimated for the principal components of special tall oil range from 2×10^{-5} to 7×10^{-6} atm-m^3/mole. If released to soil, special tall oil would initially be expected to adsorb strongly to soil and readily biodegrade. If released in water, special tall oil would be expected to rapidly biodegrade based on results of screening tests on its principal components and tall oil soaps. Initially it would be expected to strongly adsorb to sediment and particulate matter in the water column. Volatilization of special tall oil to the atmosphere may be significant (estimated half-lives of principal components from a model river range from 3 to 12 days). If released to the atmosphere, special tall oil will be associated with aerosols and be removed by gravitational settling. Using a rapid biodegradation rate in the STP fugacity model results in 100 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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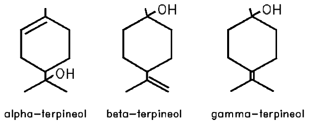
Terpineols

Chemical Properties and Information	
Terpineols [r-Butyrolactone; dihydro-2(3H)-furanone, terpineol 318] CAS# 8000-41-7 Molecular weight: 154 Melting Point: NA Water Solubility: 2 g/L (M) Vapor Pressure: 0.023 mm Hg (M) (20°C) Log K_{ow} = 3.33 - 3.46 (E) Henry's Law Constant: 3 x 10^{-6} atm-m^3/mole (E) Chemistry of Use: Cleaner/Disinfectant	$C_{10}H_{18}O$ Structure: α-terpineol β-terpineol γ-terpineol (98-55-5) (1380-87-4) (586-81-2)  Boiling Point: 218°C (M) Density: 0.9412 g/ml (M) Flash Point: 75°C (E) K_{oc}: 60 - 1,800 (E) Physical State: Pure α-isomer is white, crystalline powder

Above data are either measured (M) or estimated (E)

The terpineols are 10-carbon alcohols of the structures shown above that are included in a class of oxygenated isoprene derivatives called terpenes or terpenoids. Many of these compounds, including terpineols, occur naturally in essential oils. All pine oils contain α-terpineol as the main oxygenated component. Terpineols are soluble in propylene glycol and are soluble in 1:8 proportion or more in 50 percent alcohol.

Terpineols are the major constituents in pine oils, which may be obtained in three ways: (1) by steam distillation of the extract from aged pine stumps in the southeastern U.S.; (2) by fractionation of crude sulfate turpentine; or (3) synthetically, by the acid-catalyzed hydration of pinene, followed by distillation. High-grade perfumery α-terpineol is made by partial dehydration of terpin hydrate under weakly acidic conditions. It may also be prepared from isoprene and methyl vinyl ketone, using methyl magnesium iodide.

Market Profile

In 1991, total U.S. production for α-terpineols was 2.4 million pounds. In 1989, imports were 0.8 million pounds. Data for exported amounts were not available. Terpineols are important constituents of a number of chemical products, such as pine oils and lime oils; 1991 U.S. synthetic pine oil production, of which terpineol is a chief constituent, totaled 71 million pounds. Thus, although unknown, the total volume of terpineols produced may be significantly higher than the cited volume.

Total U.S. production quantity for use in screen reclamation was estimated to be 1.1 million pounds.

Regulatory Status

Terpineols do not trigger any federal environmental regulations

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to the atmosphere, gas-phase terpineol is expected to degrade by reaction with photochemically produced hydroxyl radicals (estimated half-life of 4 hours). Reaction with ozone molecules may also be an important fate process for terpineol in air. If released to soil, terpineol is expected to exhibit low adsorption potential. One biological treatment study suggests that biodegradation may be fast in soil and water; however, data are limited. In water, hydrolysis, adsorption to sediment, and bioconcentration in aquatic organisms are not expected to be important for terpineol. Volatilization half-lives for α-terpineol of 15 and 110 days have been estimated for a model river (one meter deep) and a model environmental lake, respectively. Using a fast biodegradation rate for terpineol in the STP fugacity model results in 99 percent predicted total removal from wastewater treatment plants; a moderate biodegradation rate results in 92 percent total removal.

Health Hazard

See Table II-6 and accompanying summary

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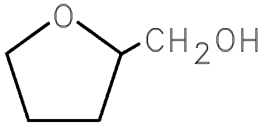
Tetrahydrofurfuryl Alcohol

Chemical Properties and Information	
Tetrahydrofurfuryl alcohol [2-furanmethanol, tetrahydro, aliphatic ether alcohol] CAS# 97-99-4 Molecular weight: 102.13 Melting Point: <-80°C (M) Water Solubility: Miscible with water (M) Vapor Pressure: 0.64 mm Hg (20°C) (E) Log K_{ow}: -0.11 (E) Henry's Law Constant: $4.09 \mathrm{X} 10^{-9}$ atm-m^3/mole (E) Chemistry of Use: Solvent	$C_5H_{10}O_2$ Structure:  Boiling Point: 178°C (M) Density: 1.0543 g/cm^3 (M) Flash Point: 84°C (open cup) (M) K_{oc}: 0.5 (E)

Above data are either measured (M) or estimated (E)

This chemical is a hygroscopic and is colorless. It is flammable in air. It is miscible with alcohol, ether, acetone, chloroform, benzene. Tetrahydrofurfuryl alcohol is manufactured by catalytic hydrogenation of furfural or furfuryl alcohol.

Market Profile

In 1992, total U.S. production was 14.2 million gallons. In 1992, about 0.1 million gallons were imported and 4.4 million gallons were exported. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

Tetrahydrofurfuryl alcohol does not trigger any federal environmental regulations.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, tetrahydrofurfuryl alcohol will be expected to exhibit very high mobility, based upon its estimated soil adsorption coefficient. Two biodegradation screening studies have found tetrahydrofurfuryl alcohol to be readily biodegradable and biodegradation should be the dominant degradative process in soil. Volatilization of tetrahydrofurfuryl alcohol from moist soil should not be important, however, some volatilization would occur from dry surface soil and other dry surfaces. Biodegradation is expected to be the dominant environmental fate process for tetrahydrofurfuryl alcohol in water. Chemical hydrolysis, volatilization, adsorption to sediment, and bioconcentration are not expected to be environmentally important. In the atmosphere, tetrahydrofurfuryl alcohol is expected to exist almost entirely in the vapor phase. It will degrade in the ambient atmosphere by reaction with photochemically-produced hydroxyl radicals (estimated half-life of 13 hours). Physical removal from air via wet deposition is probable since tetrahydrofurfuryl alcohol is miscible in water. Using a rapid biodegradation rate in the STP fugacity model results in 97 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

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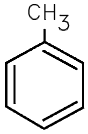
Toluene

Chemical Properties and Information	
Toluene [Methylbenzene, Phenylmethane, Toluol] CAS# 108-88-3 Molecular weight: 92.14 Melting Point: -95.0 to -93°C (M) Water Solubility: 0.5 g/L (M) Vapor Pressure: 55 mm Hg (M) (25°C) Log K_{ow} = 2.73 (M) Henry's Law Constant: 6.64×10^{-3} atm-m^3/mole (M) Chemistry of Use: Solvent	C_7H_8 Structure:  Boiling Point: 110.6°C (M) Density: 0.8660_4^{20} g/ml (M) Flash Point: 4°C (M) K_{oc}: 38 - 300 (M) Physical State: Clear, colorless liquid

Above data are either measured (M) or estimated (E)

Chemical derivatives of toluene are formed by substitution of the hydrogen atoms of the methyl group, by substitution of the hydrogen atoms of the ring, and by addition to the double bonds of the ring. Toluene can also undergo a disproportionation reaction in which two molecules react to yeld one molecule of benzene and one of xylene. Toluene has a TLV of 375. It is highly flammable, and reacts violently with oxidants. It is stable under normal laboratory storage conditions. Toluene is miscible in ethanol, chloroform, diethyl ether, acetone, and acetic acid.

Toluene is generally produced along with benzene, xylenes and C_9 aromatics by the catalytic reforming of straight-run naphthas. The resulting crude reformate is extracted, most frequently with sulfolane, to yield a mixture of benzene, toluene, xylenes and C_9 aromatics, which are then separated by fractionation. The catalyst may be Pt-Al_2O_3-based, or bimetallic, containing both platinum and rhenium. Toluene was formerly produced from coke ovens and coal-tar products.

Market Profile

In 1990, total U.S. production was 6 billion gallons. In 1991, imports were 520.8 million gallons and exports were 438.8 million gallons. Total U.S. production quantity for use in screen reclamation was estimated to be 2.67 million gallons.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If toluene is released to soil, it will be lost by evaporation from near-surface soil and is expected to be very mobile. Biodegradation occurs at a moderate to rapid rate in soil and may occur in acclimated groundwater, but at high concentrations, toluene may be toxic to microorganisms. The presence of acclimated microbial populations may allow rapid biodegradation in aerobic soil and water. It will not hydrolyze in soil or water under normal environmental conditions. If toluene is released into water, its concentration will decrease due to evaporation and biodegradation. This removal can be rapid or take several weeks, depending on temperature, mixing conditions, and acclimation of microorganisms. It may adsorb to sediment, but should not bioconcentrate in aquatic organisms. If toluene is released to the atmosphere, it will degrade by reaction with photochemically produced hydroxyl radicals (half-life 3 hr to slightly over 1 day) or be washed out in rain. It will not be subject to direct photolysis. Using a fast biodegradation rate for toluene in the STP fugacity model results in 98 percent predicted total removal from wastewater treatment plants; a moderate biodegradation rate corresponds to 92 percent predicted total removal.

Health Hazard

See Table II-6 and accompanying summary

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1,1,1-Trichloroethane

Basic Chemical Properties	
1,1,1-Trichloroethane [methyl chloroform; solvent 111; TCA; chlorothene] CAS# 71-55-6 Molecular weight: 133.42 Melting Point: -30.4°C (M) Water Solubility: 4.4 g/L (M) Vapor Pressure: 127 mm Hg (M) (25°C) Log K_{ow} = 2.49 (M) Henry's Law Constant: 1.72×10^{-2} atm-m^3/mole (M) Chemistry of Use: Solvent	$C_2H_3Cl_3$ Structure: CCl_3CH_3 Boiling Point: 74.2°C (M) Density: 1.33 g/ml (M) Flash point: Not applicable K_{oc}: 107 (M) Physical State: Liquid with sweetish, chloroform-like odor

Above data are either measured (M) or estimated (E)

Releases of 1,1,1-trichloroethane in water and soil volatilize or leach out. Releases to air can travel long distances. Common routes of exposure are air and drinking water. Soluble in acetone, benzene, methanol and carbon tetrachloride.

1,1,1-Trichloroethane is prepared by action of chlorine on 1,1-dichloroethane, or by catalytic addition of hydrogen chloride to 1,1-dichloroethylene. It can be produced by chlorination of vinyl chloride derived from 1,2-dichloroethane; hydrochlorination of vinylidene chloride derived from 1,2-dichloroethane; or thermal chlorination of ethane.

Market Profile

In 1990, total U.S. production was 500 million gallons. In 1991, imports were 2.41 million gallons and exports were 101.8 million gallons. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

If released to soil, 1,1,1-trichloroethane is expected to rapidly volatilize from both moist and dry soil to the atmosphere. Biodegradation may occur slowly in both aerobic and anaerobic soils. It has a high potential to leach into soil. If released to water, volatilization to the atmosphere is expected to be the dominant fate process. Neither bioconcentration in fish and aquatic organisms nor adsorption to sediment and suspended organic matter are expected to be significant. The biodegradation of 1,1,1-trichloroethane in water has been well studied and removal under aerobic conditions has not occurred to any significant extent. Experimental half-lives for the anaerobic degradation of 1,1,1-trichloroethane in water or water/sediment systems range from 1 day to 16 weeks; high concentrations (greater than 1 mg/L) were found to be toxic to microorganisms. 1,1-Dichloroethane has been identified as the primary anaerobic degradation product of 1,1,1-trichloroethane. If released to the atmosphere, 1,1,1-trichloroethane is expected to persist for long periods of time. Half-lives for the gas-phase reaction of 1,1,1-trichloroethane with hydroxyl radicals ranging from 2 to 6 years have been reported. Direct photolytic degradation of 1,1,1-trichloroethane in the troposphere does not occur to any significant extent. It may undergo atmospheric removal by wet deposition processes, although any 1,1,1-trichloroethane removed by this processes is expected to rapidly re-volatilize to the atmosphere. In experimental studies using a model wastewater treatment system, 1,1,1-trichloroethane underwent 99 percent removal due entirely to volatilization and not biodegradation.

Health Hazard

See Table II-6 and accompanying summary

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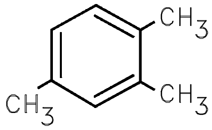
1,2,4-Trimethyl Benzene

Chemical Properties and Information	
1,2,4-Trimethyl benzene [pseudocumene, trimethyl benzene, asymmetrical trimethyl benzene] CAS# 95-63-6 Molecular weight: 120.19 Melting Point: -43.78°C (M) Water Solubility: 0.02 g/l (E) Vapor Pressure: 10.34 torr (at 54.4°C) (M) Log K_{ow}: 3.78 (M) Henry's Law Constant: 6.16×10^{-3} atm-m^3/mole (M) Chemistry of Use: Solvent	C_9H_{12} Structure:  Boiling Point: 169 -171°C (M) Density: 0.876 g/cm^3 (M) Flash Point: 54.4°C (M) K_{oc}: 440-2,700 (E)

Above data are either measured (M) or estimated (E)

This chemical occurs naturally in coal tar and in many petroleums. It is soluble in alcohols, benzene, and ether.

1,2,4-Trimethyl benzene is synthesized by extraction from C_9 hydrocarbon reformate by superfractionation.

Market Profile

In 1992, total U.S. production of alkylbenzenes was 1.2 billion pounds. Information specific to 1,2,4-trimethyl benzene was not available. Imports and exports of this chemical are unknown. Total U.S. production quantity for use in screen reclamation is unknown.

Regulatory Status

See Table II-3 and accompanying summary.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

In the atmosphere, gas-phase 1,2,4-trimethyl benzene will degrade by reaction with photochemically produced hydroxyl radicals (estimated half-life of 7 hours). Removal from air via wet deposition may also occur. If released to soil, 1,2,4-trimethyl benzene would have a high adsorption potential and exhibit slight to medium soil mobility. Biodegradation should be important in soil and water; however, this removal process may be hindered by high adsorption. On terrestrial surfaces, volatilization will be an important removal process. In surface waters, volatilization is expected to be the primary transport process with estimated half-lives of 1.2 and 105 hours from a model river (1 meter deep) and a model lake, respectively. Adsorption to sediment will also be important. Hydrolysis and photolysis are not expected to be important fate processes for 1,2,4-trimethylbenzene in water. Bioconcentration in fish may be important. Assuming a fast biodegradation rate for 1,2,4-trimethylbenzene in the STP fugacity model results in greater than99 percent predicted total removal from wastewater treatment plants; a moderate rate corresponds to 97 percent removal.

Health Hazard

See Table II-6 and accompanying summary

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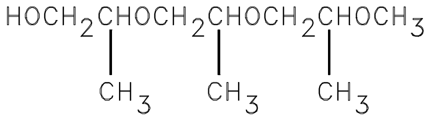
Tripropylene Glycol Methyl Ether

Chemical Properties and Information	
Tripropylene glycol methyl ether [propanol, [2-(2-methoxy-methylethoxy) methylethoxy]-, 2, 2, 2, Methoxypropoxy propoxy propanol] CAS# 25498-49-1 Molecular weight: 206.3 Melting Point: Not available Water Solubility: Completely miscible in water (E) Vapor Pressure: 0.022 torr (at 75°C) (E) 0.002 torr (at 20°C) (E) Log K_{ow}: 0.56 (E) Henry's Law Constant: 2.02×10^{-9} atm-m^3/mole (E) Chemistry of Use: Solvent	$C_{10}H_{22}O_4$ Structure:  $HOCH_2\underset{\substack{\vert \\ CH_3}}{CH}OCH_2\underset{\substack{\vert \\ CH_3}}{CH}OCH_2\underset{\substack{\vert \\ CH_3}}{CH}OCH_3$ Boiling Point: 242.4°C (at 1 atm) (E) Density: 0.96 g/cm^3 (E) Flash Point: 260°C (open cup) (E) K_{oc}: 48 (E

Above data are either measured (M) or estimated (E)

The chemical properties were estimated by comparing this chemical to tripropylene glycol monoethyl ether (2-Propanol, 1-[2-(2-methoxy-1-methyl ethoxy)-1-methyl ethoxy]-), which has CAS number 20324-33-8. It is miscible with organics.

This chemical is synthesized by the addition of three moles of propylene oxide to methanol.

Market Profile

In 1991, total U.S. production was about 4.3 million gallons. Of this quantity, 1.6 million gallons were exported. Total U.S. production quantity for use in screen reclamation was estimated to be 623,000 gallons.

Regulatory Status

Tripropylene glycol methyl ether does not trigger any federal environmental regulations. However, the generic category of glycol ethers is listed as Hazardous Air Pollutants in the Clean Air Act.

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Dipropylene glycol isopropyl ether is not expected to undergo hydrolysis or direct photolysis in the environment. In water, volatilization, adsorption to sediments and suspended solids, and bioconcentration in aquatic organisms are not expected to be important transport processes for dipropylene glycol isopropyl ether. Biodegradation is likely to be the most important removal mechanism of dipropylene glycol isopropyl ether from aerobic soil and water based on screening studies of other glycol ether compounds. If released to soil, dipropylene glycol isopropyl ether is expected to display very high mobility. Volatilization from dry soil surfaces will be important. In the atmosphere, dipropylene glycol isopropyl ether is expected to exist almost entirely in the gas-phase and reactions with photochemically produced hydroxyl radicals should be fast (estimated half-life of 2.5 hrs). Using a rapid biodegradation rate for dipropylene glycol isopropyl ether in the STP fugacity model results in 97% predicted removal from wastewater treatment plants; a moderate rate corresponds to 83% predicted removal.

Health Hazard

See Table II-6 and accompanying summary

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Trisodium Phosphate

Basic Chemical Properties	
Trisodium phosphate [phosphoric acid, trisodium salt; sodium phosphate; tribasic sodium phosphate; trisodium orthophosphate; TSP; Oakite] CAS# 7601-54-9 Molecular weight: 163.9 Melting Point: 75°C (M) Water Solubility: 145 g/L (M) Vapor Pressure: Negligible (E) Chemistry of Use: Caustic	$Na_3(PO_4)$ Structure: $Na_3(PO_4)$ Boiling Point: 1583°C (M) Density: 2.5 g/ml (M) Flash point: Not applicable Physical State: Colorless crystals

Above data are either measured (M) or estimated (E)

Trisodium phosphate behaves as a moderately strong alkali; many of its applications are based on this property. Trisodium phosphate commercially contains excess sodium hydroxide. It readily forms a variety of double salts with other sodium compounds. Trisodium phosphate is insoluble in alcohol and carbon disulfide.

Trisodium phosphate is synthesized from solid state reactions such as $Na_4P_2O_7 + Na_2CO_3$ at 800° or $Na_2HPO_4 + Na_2CO_3$ at 600°, which provide the high-temperature form initially. It is also manufactured by mixing soda ash and phosphoric acid in proper proportions to form disodium phosphate and then adding caustic soda.

Market Profile

In 1991, total U.S. production was 46 million pounds. In 1989, imports were 2.8 million pounds and in 1991, exports were 3.6 million pounds. Total U.S. production quantity for use in screen reclamation was unknown.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

Phosphorous is an essential nutrient for all organisms and trisodium phosphate is expected to participate in the biological assimilation and mobilization inherent in the natural phosphorous cycle. If released to soil, trisodium phosphate is expected to be quickly sorbed and converted to less soluble metal salts which will become essentially immobile. The use of phosphate as a soil fertilizer has shown that this fixation processes is appreciable in all but very coarse-textured soils and that only one fourth of the applied phosphate is usable by plants with the rest being lost to the occluded soil fraction. Trisodium phosphate may also be removed from soil during its assimilation as a nutrient in the metabolism of other organic compounds. Trisodium phosphate loss by volatilization to the atmosphere is expected to be negligible. If released to water, trisodium phosphate will dissociate into $H_2PO_4^-$, HPO_4^{-2}, and PO_4^{-3} ions depending on the pH of the receiving medium. In seawater (pH = 8), 87 percent of inorganic phosphate exists as HPO_4^{-2}, 12 percent as PO_4^{-3}, and 1 percent as $H_2PO_4^-$ and these species can complex with metals other than sodium. There are significant bodies of data indicating that inorganic phosphates are responsible for algal blooms; however, uptake by aquatic plants may not remove phosphate from the aquatic system as it is available to microorganisms in decaying alga. Dependent on the medium, insoluble salts of iron, calcium, and aluminum may form resulting in the phosphate being deposited on sediment. If released to the atmosphere, particulate trisodium phosphate is likely to undergo removal by both wet and dry deposition processes. If released to a wastewater treatment plants, essentially complete removal of trisodium phosphate by precipitation is expected when aluminum and iron salts are added.

Health Hazard

See Table II-6 and accompanying summary

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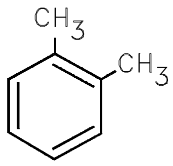
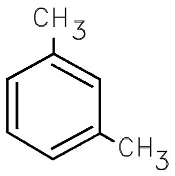
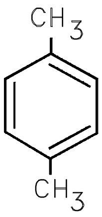
Xylene

Basic Chemical Properties	
Xylene [Dimethylbenzene; methyltoluene; xylol] CAS# 1330-20-7 Molecular weight: 106.2 Vapor Pressure: 10 mm Hg (E) (25°C) Water Solubility: 0.1 g/L (E) Melting Point: o: -25°C (M) m: -48°C (M) p: 13°C (M) Log K_{ow} = 3.12 - 3.20 (M) Henry's Law Constant: 5.18×10^{-3} - 7.53×10^{-3} atm-m^3/mole (M) Chemistry of Use: Solvent	C_8H_{10} Structure: o-xylene m-xylene p-xylene  o–xylene  m–xylene  p–xylene Boiling Point: 137-140°C (M) Density: 0.864 g/ml (M) Flash Point: o: 17°C (M) m: 29°C (M) p: 27°C (M) K_{oc}: 25 - 166 (M) Physical State: Colorless liquid

Above data are either measured (M) or estimated (E)

The commercial product "mixed xylenes" is a technical product generally containing approximately 40 percent m-xylene and 20 percent each of o-xylene, p-xylene, and ethylbenzene, as well as small quantities of toluene. Xylene is produced in large quantities and is an agent of major chemical and occupational significance. Xylene is miscible with absolute alcohol, ether, and many other organic liquids.

Xylene is recovered from petroleum-derived catalytic reformate or pyrrolyis of gasoline. It is recovered from crude light oil, a by product of coke manufacture. It is also synthesized by the disproportionation of toluene.

Market Profile

In 1992, total U.S. production was 5.5 billion gallons. Imports were 305 million gallons and exports were 318.8 million gallons. Total U.S. production quantity for use in screen reclamation was estimated to be 6.88 million gallons.

Regulatory Status

See Table II-3 and accompanying summary

Hazard Summary

Aquatic Toxicity

See Table II-4, Table II-5 and accompanying summary

See Appendix M for the comprehensive methodology for this assessment

Environmental Fate

In the atmosphere, xylenes will degrade by reaction with photochemically produced hydroxyl radicals. Half-lives for this reaction in air are typically 1-16 hours. Photolysis and reaction with ozone will not be important. If released to water or soil surfaces, volatilization to the ambient atmosphere will be the dominant removal process. Hydrolysis and bioconcentration in aquatic organisms will not be important fate processes for xylenes in water. Xylenes may partition from the water column to sediment. In soil, xylenes exhibit moderate adsorption potential. Biodegradation will be important in soil and water where volatilization does not occur. Xylenes are readily degradable in standard aerobic biodegradability tests using a variety of inocula including sewage, activated sludge, and seawater. Under anaerobic conditions, an acclimation period may be required for significant biodegradation. Using a moderate biodegradation rate for xylenes in the STP fugacity model results in 94 percent predicted total removal from wastewater treatment plants.

Health Hazard

See Table II-6 and accompanying summary

Federal Environmental Regulations that Affect Screen Reclamation Chemicals

This section describes the federal environmental regulations that affect the use of screen reclamation chemicals. Discharges of screen reclamation chemicals may be restricted by air, water and solid waste regulations; in addition, facilities may be required to report releases of some reclamation products subject to the federal toxic release inventory program. Table II-3 identifies federal regulations that govern releases of specific screen reclamation chemicals; in addition, emissions or disposal of some chemicals may be regulated under general provisions.

Table II-3
Screen Reclamation Use Cluster Chemicals Which Trigger Federal Environmental Regulations[a]

Chemical	CAS#	CWA Reportable Quantity (lbs)	CWA Priority Pollutant	CAA Hazardous Air Pollutant[b]	CERCLA Reportable Quantity (lbs)	SARA 313 (TRI)	RCRA Hazardous Waste Code
Acetone	67-64-1				5,000	X	U002
Butylacetate	123-86-4	5,000			5,000		
Cyclohexanone	108-94-1				5,000		U057
Dichloromethane	75-09-2		X	X	1,000	X	U080
Ethyl acetate	141-78-6				5,000		U112
Isopropanol	67-63-0					X	
Methanol	67-56-1			X	5,000	X	U154
Methyl ethyl ketone	78-93-3			X	5,000	X	U159 D035[c]
Potassium hydroxide	1310-58-3	1,000			1,000		
Sodium hexametaphosphate	10124-56-8	5,000			5,000		
Sodium hydroxide	1310-73-2	1,000			1,000		
Sodium hypochlorite	7681-52-9	100			100		
Sodium salt, dodecyl benzene sulfonic acid	25155-30-0	1,000			1,000		
1,1,1-Trichloroethane	71-55-6		X	X	1,000	X	U208
Triethanol amine salt, dodecyl benzene sulfonic acid	27323-41-7	1,000			1,000		
1,2,4-Trimethylbenzene	95-63-6					X	
Trisodium phosphate	7601-54-9	5,000			5,000		
Toluene	108-88-3	1,000	X	X	1,000	X	U220
Xylene	1330-20-7	1,000		X	1,000	X	U239

[a] See following pages for a description of each acronym and regulation.

[b] The generic category of glycol ethers are also listed as Hazardous Air Pollutants in the Clean Air Act Amendments.

[c] In addition to being listed as a U waste, methyl ethyl ketone also exhibits a characteristic of toxicity which causes it to be considered hazardous waste.

CWA

The Clean Water Act (CWA) is the basic Federal law governing water pollution control in the United States today.

Part 116 of the Federal Water Pollution Control Act (FWPCA) designates hazardous substances under Section 311(b)(2)(a) of the Clean Water Act, and Part 117 of the FWPCA establishes the *Reportable Quantity* (RQ) for each substance listed in Part 116. When an amount equal to or in excess of the RQ is discharged, the facility must provide notice to the Federal government of the discharge, following Department of Transportation requirements set forth in 33 Code of Federal Regulations (CFR) 153.203. This requirement does not apply to facilities that discharge the substance under an National Permit Discharge Elimination System (NPDES) Permit or a Part 404 Wetlands (dredge and fill) Permit, or to a Publicly Owned Treatment Works (POTW), as long as any applicable effluent limitations or pretreatment standards have been met.

The National Permit Discharge Elimination System permit program contains regulations governing the discharge of pollutants to waters of the United States. The NPDES program requires permits for the discharge of "pollutants" from any "point source" into "navigable waters". The Clean Water Act defines all of these terms broadly, and a source will be required to obtain an NPDES permit if it discharges almost anything directly to surface waters. A source that sends its wastewater to a publicly owned treatment works (POTW) will not be required to obtain an NPDES permit, but may be required to obtain an industrial user permit from the POTW to cover its discharge.

In addition to other permit application requirements, facilities in the industrial category of Printing and Publishing, and/or in Photographic Equipment and Supplies, will need to test for all 126 *priority pollutants* listed in 40 CFR 122 Appendix D. Each applicant also must indicate whether it knows or has reason to believe it discharges any of the other hazardous substances, or non-conventional pollutants located at 40 CFR 122 Appendix D. Quantitative testing is not required for the other hazardous pollutants; however, the applicant must describe why it expects the pollutant to be discharged and provide the results of any quantitative data about its discharge for that pollutant. Quantitative testing is required for the non-conventional pollutants if the applicant expects them to be present in its discharge.

For the purpose of reporting on effluent characteristics in permit applications, there exists a small business exemption (40 CFR 122.21 (g)(8)) for all applicants for NPDES permits with gross total annual sales averaging less than $100,000 per year (in second quarter 1980 dollars). This exempts the small business from submitting quantitative data on certain organic toxic pollutants (see 40 CFR 122.21 Table II, Appendix D). However, the small business must still provide quantitative data for other toxic pollutants (metals and cyanides) and total phenols, as listed in 40 CFR 122.21 Table III, Appendix D. The same regulations apply to the small business concerning the other hazardous pollutants and non-conventional pollutants as for the larger facilities (see previous paragraph).

CAA

The Clean Air Act (CAA), with its 1990 amendments, sets the framework for air pollution control. Part 112 of the Clean Air Act establishes requirements that directly restrict the emission of 189 hazardous air pollutants. The EPA is authorized to establish Maximum

Achievable Control Technology (MACT) standards for source categories that emit at least one of the pollutants on the list. Currently, there is no MACT standard scheduled for proposal in the commercial screen printing industry.

CERCLA

Comprehensive Environmental Response, Compensation and Liability Act (also known as CERCLA, or more commonly as Superfund). CERCLA is the Act that created the Superfund and set up a variety of mechanisms to address risks to public health, welfare, and the environment caused by hazardous substance releases.

Substances deemed hazardous by CERCLA are listed in 40 Code of Federal Regulations (CFR) 302.4. Based on criteria that relate to the possibility of harm associated with the release of each substance, CERCLA assigns a substance-specific reportable quantity (RQ); RQs are either 1, 10, 100, 1000, or 5000 pounds (except for radionuclides). Any person in charge of a facility (or a vessel) must immediately notify the National Response Center as soon as a person has knowledge of a release (within a 24-hour period) of an amount of a hazardous substance that is equal to or greater than its RQ.[1] There are some exceptions to this requirement, including exceptions for certain continuous releases and for Federally permitted releases.

SARA 313

CERCLA was enacted in 1980 and, among other amendments, was amended in 1986 by Title I of the Superfund Amendments and Reauthorization Act (SARA). Under SARA 313, a facility that has more than 10 employees and that manufactures, processes or otherwise uses more than 10,000 or 25,000 pounds per year of any toxic chemical listed in 40 Code of Federal Regulations (CFR) 372.65 must file a toxic chemical release inventory (TRI) reporting form (EPA Form R) covering releases of these toxic chemicals (including those releases specifically allowed by EPA or State permits) with the EPA and a State agency. The threshold for reporting releases is 10,000 or 25,000 pounds, depending on how the chemical is used (40 CFR 372.25). Form R is filed annually, covers all toxic releases for the calendar year, and must be filed on or before the first of July of the following year. Table II-3 lists chemicals used by facilities in screen reclamation that are listed in the Toxic Release Inventory (TRI). Individual facilities may use other chemicals which are listed in the TRI, but are not in Table II-3.

RCRA

One purpose of the Resource Conservation and Recovery Act (RCRA) of 1976 (as amended in 1984) is to set up a cradle-to-grave system for tracking and regulating hazardous waste. The EPA has issued regulations, found in 40 CFR Parts 260-299, which implement the Federal statute. These regulations are Federal requirements. As of March 1994, 46 States have been authorized to implement the RCRA program and may include more stringent requirements in their authorized RCRA programs. In addition, non-RCRA-authorized States (Alaska, Hawaii, Iowa and Wyoming) may have State laws that set out hazardous waste

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[1] The national toll-free number for the National Response Center is (800)-424-8802; in Washington, D.C., call (202)-426-2675.

management requirements. A facility should always check with the State when analyzing which requirements apply to their activities.

Assuming the material is a solid waste, the first evaluation to be made is whether it is also considered a hazardous waste. Part 261 of 40 Code of Federal Regulations (CFR) addresses the identification and listing of hazardous waste. The waste generator has the responsibility for determining whether a waste is hazardous, and what classification, if any, may apply to the waste. The generator must examine the regulations and undertake any tests necessary to determine if the wastes generated are hazardous. Waste generators may also use their own knowledge and familiarity with the waste to determine whether it is hazardous. Generators may be subject to enforcement penalties for improperly determining that a waste is not hazardous.

Wastes can be classified as hazardous either because they are listed by EPA through regulation and appear in the 40 CFR Part 261 or because they exhibit certain characteristics. Listed wastes are specifically named, e.g., discarded commercial toluene, spent non-halogenated solvents. Characteristic wastes are defined as hazardous if they "fail" a characteristic test, such as the RCRA test for ignitability.

There are four separate lists of hazardous wastes in 40 CFR 261. If any of the wastes from a printing facility is on any of these lists, the facility is subject to regulation under RCRA. The listing is often defined by industrial processes, but all wastes are listed because they contain particular chemical constituents (these constituents are listed in Appendix VII to Part 261). Section 261.31 lists wastes from non-specific sources and includes wastes generated by industrial processes that may occur in several different industries; the codes for such wastes always begin with the letter "F." The second category of listed wastes (40 CFR 261.32) includes hazardous wastes from specific sources; these wastes have codes that begin with the letter "K." The remaining lists (40 CFR 261.33) cover commercial chemical products that have been or are intended to be discarded; these have two letter designations, "P" and "U." Waste codes beginning with "P" are considered acutely hazardous, while those beginning with "U" are simply considered hazardous. Listed wastes from chemicals that are commonly used in the screen reclamation are shown in Table II-3. While these exhibits are intended to be as comprehensive as possible, individual facilities may use other chemicals and generate other listed hazardous wastes that are not included in Table II-3. Facilities may wish to consult the lists at 40 CFR 261.31-261.33.[2]

Generator status defines how to dispose of a listed or characteristic waste. The hazardous waste generator is defined as any person, by site, who creates a hazardous waste or makes a waste subject to RCRA Subtitle C. Generators are divided into three categories:

- ○ Large Quantity Generators -These facilities generate at least 1000 kg (approximately 2200 lbs.) of hazardous waste per month, or greater than 1 kg (2.2 lbs) of acutely hazardous waste[3] per month.

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[2] Lists of the "F, P, K and U" hazardous wastes can also be obtained by calling the EPA RCRA/Superfund/EPCRA Hotline at (800) 424-9346.

[3] The provisions regarding acutely hazardous waste are not likely to affect printers. Acutely hazardous waste includes certain "F" listed wastes that do not apply to printers, and "P" listed wastes, none of which were identified as in use in the commercial screen printing industry. (See 40 CFR 261.31-33 for more information).

- ○ Small Quantity Generators (SQG) — These facilities generate greater than 100 kg (approx. 220 lbs.) but less than 1000 kg of hazardous waste per month, and up to 1 kg (2.2 lbs) per month of acutely hazardous waste.

- ○ Conditionally exempt small quantity generators (CESQG) — These facilities generate no more than 100 kg (approx. 220 lbs) per month of hazardous waste and up to 1 kg (2.2 lbs) per month of acutely hazardous waste.

Large and small quantity generators must meet many similar requirements. 40 CFR 262 provides that SQGs may accumulate up to 6000 kg of hazardous waste on-site at any one time for up to 180 days without being regulated as a treatment, storage, or disposal (TSD) facility and thereby having to apply for a TSD permit. The provisions of 40 CFR 262.34 (f) allow SQGs to store waste on-site for 270 days without having to apply for TSD status provided the waste must be transported over 200 miles. Large quantity generators have only a 90-day window to ship wastes off-site without needing a RCRA TSD permit. Keep in mind that most provisions of 40 CFR 264 and 265 (for hazardous waste treatment, storage and disposal facilities) do not apply to generators who send their wastes off-site within the 90- or 180-day window, whichever is applicable.

Hazardous waste generators that do not meet the conditions for conditionally exempt small quantity generators must (among other requirements such as record keeping and reporting):

- ○ Obtain a generator identification number;

- ○ Store and ship hazardous waste in suitable containers or tanks (for storage only);

- ○ Manifest the waste properly;

- ○ Maintain copies of the manifest, a shipment log covering all hazardous waste shipments, and test records;

- ○ Comply with applicable land disposal restriction requirements; and

- ○ Report releases or threats of releases of hazardous waste.

Summary of the Environmental Hazard Assessment for the Screen Reclamation Chemicals

The chemicals in screen reclamation are divided into three groups: (1) discrete organic chemicals, (2) petroleum products, and (3) inorganic chemicals. While the assessment process is the same for all three groups, the methodology used to provide estimates of the aquatic toxicity of the chemicals varies.

Methodology

The Environmental Effects Branch uses a standard assessment process (see Appendix M) for assessing the hazards of chemicals to the aquatic environment. The process has been described and published in several publications, both inside and outside the Agency. A summary of the hazard assessment process and references are in Appendix M. The methodology involves the development of a standard hazard profile for each chemical consisting of three acute toxicity values and three chronic values for aquatic species. The standard hazard profile consists of the following toxicity values:

- ○ Fish acute value (Usually a Fish 96-hour LC_{50} value)
- ○ Aquatic invertebrate acute value (Usually a Daphnid 48-hour LC_{50} value)
- ○ Green Algal Toxicity value (Usually an Algal 96-hour EC_{50} value)
- ○ Fish Chronic value (Usually a Fish 28-day early life stage no effect concentration (NEC).
- ○ Aquatic Invertebrate Chronic value (Usually a Daphnid 21-day NEC.
- ○ Algal Chronic value (Usually a Algal 96 hour NEC value for biomass)

The toxicity values may be obtained from the results of standard toxicity tests reported to the Agency, published in the literature, or estimated using predictive techniques. For this study, discrete organic chemicals were assessed using predictive equations called Structure Activity Relationships (SARs) to estimate the inherent toxicity of these chemicals to aquatic organisms.

The petroleum products such as mineral spirits and solvent naphtha are mixtures and do not lend themselves readily to the standard hazard assessment process using SARs. The chemical constituents and the percentage of each in the mixture varies. The constituents in these products include linear and branched paraffins, cyclic paraffins with the total number of carbons varying between 5 and 16. The toxicity of the petroleum products were determined by estimating the toxicity of each individual constituent and then evaluating the potential hazard of the product.

The estimates of toxicity for the inorganic chemicals was either based on information extracted from a report by the U.S. Atomic Energy Commission (1973) or assessed using actual data and nearest analog information taken from open literature.

Environmental Hazard Ranking

For the purpose of an overall assessment, the listed chemicals can be ranked according to the estimated chronic value. This ranking is based on scoring the chemicals as High, Moderate or Low concern for chronic effects according to the following criteria:

$\leq$ 0.1 mg/L	High
$\geq$ 0.1 to $\leq$ 10 mg/L	Moderate
> 10 mg/L	Low

See Appendix M for the basis and citations supporting these criteria.

The results of this ranking are summarized in Table II-5. The chemicals are ranked from the highest hazard potential to the lowest based on lowest of the three estimated chronic values for each chemical. The petroleum products are rated as high hazard to aquatic organisms and the concern is for chronic effects. Also included in the high hazard category are periodic acid and sodium periodate, both which are strong oxiding agents and highly reactive. The concern for trisodium phosphate is for phosphorus enrichment of receiving waters leading to algal blooms.

This relative ranking of toxicity, provides guidance to the selection and use of chemicals that are less hazardous to aquatic organisms.

A search for toxicity data in the AQUIRE database (AQUatic toxicity Information REtrieval database) has been completed. The search indicates that some data were available for 22 of the chemicals being assessed in the data set. These data were evaluated and the measured toxicity values compared favorably with the predicted values.

Results

The toxicity values for acute and chronic effects to aquatic organisms were estimated using predictive equations based on SARs, except for the inorganic chemicals. The values for inorganic chemicals were obtained from published reports. The results are summarized in Table II-4. The chemicals are listed alphabetically. For each chemical, the estimated toxicity values in mg/L (ppm) for acute and chronic effects of fish, daphnid and algae are given. The last column shows the concern concentration set for the chemical in the water. This value is derived by dividing the lowest of the three chronic values by a factor of 10. If the discharge of a chemical to the aquatic environment results in a concentration equal to or greater than the concern concentration set, then the chemical would be hazardous to aquatic organisms.

To assess the potential hazard of the petroleum products, toxicity values were estimated for the individual components, i.e., C_5 to C_{16} linear and branched paraffins and cyclic paraffins. To estimate the toxicity of a product, the assumption is made that each component is present as an equal percentage in the product and the geometric mean of the range of estimates provides the best estimate of the toxicity. For example, for a C_9 to C_{12} linear paraffin, the estimated chronic values for the Daphnid Chronic are 0.019, 0.008, 0.004 and 0.002 mg/L and the geometric mean is 0.006 mg/L. Based on these procedures the hazard potential of the various products are discussed in the following paragraphs.

Mineral Spirits

Mineral spirits consist of linear and branched paraffins and cyclo paraffins. Based on the information provided, the assessment was based on the estimated toxicity for n-hexane and ethylcyclohexane. The linear form of n-hexane is approximately two times more toxic than cyclic hexane. The lowest chronic value for n-hexane is 0.004 mg/L for fish and the lowest chronic value for ethylcylohexane is 0.09 mg/L for fish.

Naphtha Solvents

The monomers associated with the various naphtha mixtures include linear and branched paraffins, cyclic paraffins and aromatics such as naphthalene. The carbon chain lengths vary from product to product and spans range from 5 to 16.

Inorganics

The toxicity values for the hydroxides of sodium and potassium are based on the inherent toxicity of the compounds at pH 7.0. Sodium hypochlorite is a bleaching agent and the best estimate of toxicity indicates acute toxicity values to fish and daphnids at or below 2 mg/L. Periodic acid and sodium periodate are highly reactive and strong oxidizing agents and as such are expected to be highly toxic at 1 mg/L or less. All estimates on the remaining inorganic chemicals (sodium bisulfate, sodium hexametaphosphate, silica, silica (fumed), and trisodium phosphate) were based on pH 7.0 test conditions. Fumed silica and silica were considered the same and showed no effects at their aqueous water solubility limits.

Table II-4
Estimated Aquatic Toxicity Values
(Values in mg/L)

Chemical	Fish Acute	Daphnid Acute	Algal Acute	Fish Chronic	Daphnid Chronic	Algal Chronic	Concern Conc.[a]
Acetone	>1000	>1000	>1000	490	100	76	7.6
Alcohols, C_8-C_{10}, Ethoxylated	24	24	24	2.4	2.4	2.4	0.24
Alcohols, C_{12}-C_{14}, Ethoxylated	2.2	2.2	2.2	0.22	0.22	0.22	0.020
Benzyl alcohol	56.6	13.5	33.0	8.2	6.07	2.0	0.20
2-Butoxyethanol	>1000	>1000	620	120	33	32	0.32
Butyl Acetate	25	160	1.9	2.5	16	1.4	0.14
Butyrolactone	140	>1000	>1000	14	>100	7.5	0.75
Cyclohexanol†							1.4
Cyclohexanone	950	950	550	100	29	28	2.8
d-Limonene	0.86	1.1	0.76	0.16	0.14	0.27	0.014
Diacetone alcohol	>1000	>1000	>1000	745	154	124	12.4
Dichloromethane	320	320	190	36	12	13	1.2
Diethyl adipate	44	295	3.4	4.4	29.5	2.6	0.26
Diethyl glutarate	78	830	6.0	7.8	83	4.6	0.46
Diethylene glycol	>1000	>1000	>1000	>1000	>1000	656	70.0
Diethylene glycol monobutyl ether	>1000	>1000	760	140	41	40	4.0
Diethylene gylcol butyl ether acetate	41	263	3.2	4.1	26.3	3.1	0.31
Diisopropyl adipate	24	94	1.9	2.4	9.4	1.5	0.15
Dimethyl adipate	140	>1000	11	14	>100	8.4	0.84

[a] Concern concentration is derived by dividing the lowest chronic value (in mg/L) by 10.

† Data will be inserted in the final version.

Table II-4 (cont.)
Estimated Aquatic Toxicity Values
(Values in mg/L)

Chemical	Fish Acute	Daphnid Acute	Algal Acute	Fish Chronic	Daphnid Chronic	Algal Chronic	Concern Conc.[a]
Dimethyl glutarate	246	>1000	18.3	25.0	650	13.6	1.0
Dimethyl succinate	165	>1000	12.4	17.0	530	9.2	1.0
Dipropylene glycol methyl ether	>1000	>1000	>1000	184	149	877	14.9
Dipropylene glycol methyl ether acetate	674	>1000	49	67.4	>100	36	3.6
Dodecyl benzene sulfonic acid	2.6	2.6	0.5	0.4	0.4	0.13	0.01
Ethyl acetate	64	>1000	4.8	6.4	>100	3.6	0.36
Ethyl lactate	143	>1000	11	14.3	>100	8	0.8
Ethyl oleate	N.E.S.	N.E.S.[b]	N.E.S.	N.E.S.	N.E.S.	N.E.S.	N.E.S.
Ethoxylated castor oil	0.07	0.10	0.08	0.02	0.03	0.07	0.002
Ethoxylated nonylphenol (np 4-9.5)	2.0	2.0	2.0	0.2	0.2	0.5	0.02
Ethoxypropanol	>1000	>1000	>1000	>1000	311	227	20.0
Ethoxypropyl acetate	80.0	>1000	6.1	8.0	102	4.5	0.5
Furfuryl alcohol	>1000	>1000	>100	147	31.6	25.9	3.0
Isobutyl isobutyrate	12.7	45.6	1.03	1.3	4.6	0.8	0.08
Isobutyl oleate	N.E.S.	N.E.S.[b]	N.E.S.	N.E.S.	N.E.S.	N.E.S.	N.E.S.

[a] Concern concentration is derived by dividing the lowest chronic value (in mg/L) by 10.

[b] N.E.S. - No Adverse Effects expected in a saturated solution during the specified exposure period.

[c] Estimated toxicity at pH 7.0.

[d] Toxicity of Power Plant Chemicals to Aquatic Life. WASH-1249, United States Atomic Energy Commission, June 1973. (Environmental Effects Files)

† Data will be inserted in the final version.

Table II-4 (cont.)
Estimated Aquatic Toxicity Values
(Values in mg/L)

Chemical	Fish Acute	Daphnid Acute	Algal Acute	Fish Chronic	Daphnid Chronic	Algal Chronic	Concern Conc.[a]
Isopropanol	>1000	.1000	>1000	285	62	51	5.1
Methanol	>1000	>1000	>1000	777	128	90.0	9.0
Methoxypropanol acetate	305	>1000	22.4	30.5	>1000	16.6	2.0
1-Methyl-4-(1-methyl-ethenyl) cyclohexane (limonene)	0.86	1.1	0.76	0.16	0.14	0.27	0.014
Methyl ethyl ketone	>1000	>1000	>1000	224	53	45	4.5
Methyl lactate	243	>1000	18	24.3	>100	13	1.3
Mineral spirits (straight run naptha) C_{10} Linear	N.E.S.	N.E.S.	0.02	0.004	0.008	0.021	0.001
Mineral spirits (light hydrotreated) C_{10} Linear	N.E.S.	N.E.S.	0.02	0.004	0.008	0.008	0.001
N-methylpyrrolidone	>1000	>1000	>1000	>1000	373	265	26.5
2-Octadecanamine, N,N-dimethyl N-oxide†							0.002
Periodic Acid	≤1	≤1	≤1	<0.1	≤0.1	≤0.1	≤0.01
Phosphoric Acid, mixed ester, with isopropanol and ethoxylated tridecanol†							0.018
Potassium hydroxide[c,d]	>1000	>1000	>1000	>100	>100	>100	>10

[a] Concern concentration is derived by dividing the lowest chronic value (in mg/L) by 10.

[b] Estimated toxicity at pH 7.0.

[c] Toxicity of Power Plant Chemicals to Aquatic Life. WASH-1249, United States Atomic Energy Commission, June 1973. (Environmental Effects Files)

† Data will be inserted in the final version.

Table II-4 (cont.)
Estimated Aquatic Toxicity Values
(Values in mg/L)

Chemical	Fish Acute	Daphnid Acute	Algal Acute	Fish Chronic	Daphnid Chronic	Algal Chronic	Concern Conc.[a]
Propylene carbonate	177	>1000	13	17.7	>100	10	1.0
Propylene glycol	>1000	>1000	>1000	>1000	495	329	30.0
Propylene glycol methyl ether	>1000	>1000	>1000	>1000	210	158	15.8
Propylene glycol methyl ether acetate	304	>1000	22	30.4	>100	17	1.7
Silica	NES	NES	NES	NES	NES	NES	NES
Silica, fumed	NES	NES	NES	NES	NES	NES	NES
Sodium bisulfate	>100	>100	>100	10.0	10.0	10.0	1.0
Sodium hexameta-phosphate	>100	>100	<1.0	0.1	>10.0	0.06	0.006
Sodium hydroxide[b,c]	>1000	>1000	>1000	>100	>100	>100	>10
Sodium hypochlorite[b,c]	<1.7	<2.0	<2.0	<0.17	<0.2	<0.2	<0.02
Sodium lauryl sulfate	2.6	2.6	0.5	0.4	0.4	0.13	0.01
Sodium metasilicate†							[d]
Sodium periodate	≤1	≤1	≤1	≤0.1	≤0.1	≤0.1	≤0.01
Sodium salt, dodecyl benzene sulfonic acid	2.6	2.6	0.5	0.4	0.4	0.13	0.01
Solvent Naphtha light aliphatic C_5 - C_{10}	0.64	0.86	0.23	0.05	0.05	0.11	0.005

[a] Concern concentration is derived by dividing the lowest chronic value (in mg/L) by 10.

[b] Estimated toxicity at pH 7.0.

[c] Toxicity of Power Plant Chemicals to Aquatic Life. WASH-1249, United States Atomic Energy Commission, June 1973. (Environmental Effects Files)

[d] No adverse effects expected in a saturated solution during prescribed test duration.

† Data will be inserted in the final version.

Table II-4 (cont.)
Estimated Aquatic Toxicity Values
(Values in mg/L)

Chemical	Fish Acute	Daphnid Acute	Algal Acute	Fish Chronic	Daphnid Chronic	Algal Chronic	Concern Conc.[a]
Solvent Naphtha light aromatic C_8 - C_{10}	5.6	6.7	4.5	0.9	0.6	1.0	
Solvent Naphtha heavy aromatic C_8 - C_{16}	5.6	6.7	4.5	0.9	0.6	1.0	0.06
Tall oil, special†							[d]
Terpineols (Mixed Isomers)	28	31	20	4.0	2.1	3.0	0.21
Tetrahydrofurfuryl alcohol	>1000	>1000	>1000	268	64.6	56.7	6.0
Toluene	14	16	10	2.0	1.1	1.6	0.11
1,1,1-Trichloroethane	34	38	24	4.8	2.4	3.2	0.24
1,2,4-trimethylbenzene†							0.015
Trisodium phosphate[b]	>100	>100	<1	.10	>10	0.06	0.006
Xylenes, (mixed isomers)	3.5	4.1	2.8	0.57	0.40	0.64	0.04

[a] Concern concentration is derived by dividing the lowest chronic value (in mg/L) by 10.

[b] Estimated toxicity at pH 7.0.

[c] Toxicity of Power Plant Chemicals to Aquatic Life. WASH-1249, United States Atomic Energy Commission, June 1973. (Environmental Effects Files)

† Data will be inserted in the final version.

Table II-5
Ecological Hazard Ranking of Screen Reclamation Chemicals Based on the Estimated Chronic Values

Chemical	Lowest Value (mg/L)	Chronic Eco Hazard Rank
Solvent naphtha (light aliphatic)	0.004	H
Mineral spirits (light hydrotreated)	0.004	H
Mineral spirits (straight run)	0.004	H
Trisodium phosphate	0.06	H
2-Octadecanamine, N,N-dimethly N-oxide	0.02	H
Alcohols, ethoxylated C_{12}-C_{14}	0.1	H
Periodic acid	0.10	H
Sodium periodate	0.10	H
Phosphoric Acid, mixed ester, with isopropanol and ethoxylated tridecanol	0.18	H
1-methyl-4-(1-methylethenyl) cyclohexane (limonene)	0.14	M
1,2,4-trimethylbenzene	0.15	M
Sodium hypochlorite	0.17	M
Xylenes	0.40	M
Solvent naphtha (light aromatic)	0.60	M
Solvent naphtha (heavy aromatic)	0.60	M
Toluene	1.1	M
Butyl acetate	1.4	M
Diisopropyl adipate	1.5	M
Terpineols	2.1	M
1,1,1-trichloroethane	2.4	M
Alcohols, ethoxylated, C_8-C_{10}	2.5	M
Diethyl adipate	2.6	M
Diethylene glycol butyl ether acetate	3.1	M
Ethyl acetate	3.6	M
Diethyl glutarate	4.6	M
Butyrolactone	7.5	M
Ethyl lactate	8.0	M
Dimethyl adipate	8.4	M
Propylene carbonate	10	M
Dichloromethane	12	L

Table II-5
Ecological Hazard Ranking of Screen Reclamation Chemicals Based on the Estimated Chronic Values

Chemical	Lowest Value (mg/L)	Chronic Eco Hazard Rank
Methyl lactate	13	L
Cyclohexanone	28	
Cyclohexanol	14	L
Propylene glycol methyl ether acetate	17	L
2-Butoxyethanol	32	L
Dipropylene glycol methyl ether acetate	36	L
Diethylene glycol monobutyl ether	40	L
Methyl ethyl ketone	45	L
Isopropanol	51	L
Acetone	76	L
Sodium hydroxide	100	L
Potassium hydroxide	100	L
Tripropylene glycol methyl ether	120	L
Diacetone alcohol	124	L
Dipropylene glycol methyl ether	149	L
Propylene glycol methyl ether acetate	158	L
N-methylpyrrolidone	265	L
Isobutyl oleate	[a]	L
Ethyl oleate	[a]	L
Sodium metasilicate	[a]	L
Tall oil, special	[a]	L

[a] No adverse effects expected in a saturated solution during prescribed test duration.

Summary of Human Hazard Information for Screen Reclamation Chemicals

Table II-6 summarizes toxicity information obtained, to date, on the chemicals used in screen reclamation. Initial literature searches were limited to secondary sources such as EPA's Integrated Risk Information System (IRIS) and the National Library of Medicine's Hazardous Substances Data Bank.

Explanation of Table II-6

The "TOX ENDPOINT" column lists adverse toxicological effects that have been reported in the literature. This is simply a qualitative listing of reported effects and does not imply anything about the severity of the effects nor the doses at which the effects occur. Furthermore, an entry in this column does not necessarily imply that EPA has reviewed the reported studies or that EPA concurs with the authors' conclusions. Toxicological effects are abbreviated as follows:

- car = carcinogenicity
- dev = developmental toxicity, i.e. adverse effects on the developing embryo, fetus, or newborn
- repro = reproductive toxicity, i.e. adverse effects on the ability of either males or females to reproduce
- gene = genetic toxicity, such as point mutations or chromosomal aberrations
- neur = adverse neurological effects; includes a wide range of effects from serious neuropathology to transient CNS depression commonly seen with high exposures to solvents
- chron = chronic effects not otherwise listed; commonly includes target organ toxicity such as liver and kidney effects.

"RfD/RfC" is the EPA Reference Dose or Reference Concentration. The RfD is an estimate of a daily exposure to the human population that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime. The RfD is usually expressed as an oral dose in mg/kg/day. The RfC is an analogous value for continuous inhalation exposure, usually expressed in mg/m^3.

"NOAEL/LOAEL" is the no-observed-adverse-effect level or the lowest-observed-adverse-effect level, respectively. The NOAEL is an exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects in the exposed population. The LOAEL is the lowest exposure level at which adverse effects have been shown to occur.

"SLOPE/UNIT RISK" is a measure of cancer potency derived from the dose-response curve from a carcinogenicity study (usually an animal study). The slope factor is expressed as risk per mg/kg-daily dose. Unit risk is a similar measure for air or water exposure levels and is expressed as risk per ug/m^3 in air or as risk per ug/l in water.

"WOE" refers to the EPA weight-of-evidence classification for carcinogens. The WOE categories are as follows:

- Group A -- human carcinogen
- Group B -- probable human carcinogen. B1 indicates limited human evidence; B2 indicates sufficient evidence in animals and inadequate or no evidence in humans.
- Group C -- possible human carcinogen

- ○ Group D -- not classifiable as to human carcinogenicity
- ○ Group E -- evidence of noncarcinogenicity for humans

Table II-6
Human Health Hazard Effects

Chemical Name	Cas No.	Tox Endpoint	RfD/RfC	NOAEL/ LOAEL	Slope/ Unit Risk	WOE	Comment
Acetone	67-64-1	neur, chron	~0.1 mg/kg/day (kidney)			D	
Alcohols, ethoxylated C8-C10	71060-57-6						no data found
Alcohols, ethoxylated C12-C14	68439-50-9						
Benzyl alcohol	100-51-6	dev, neur, chron	0.3 mg/kg/day (forestom. hyperplasia)				not carc in NTP study;not mutag. in several tests
2-Butoxyethanol	111-76-2	dev, chron	RfC in review				NTP carcinogenicity study in review
Butyl acetate	123-86-4	dev, neur, chron					
Butyrolactone	96-48-0	dev*, repro, neur, chron					
Cyclohexanol	108-93-0	dev, repro, neur, chron					
Cyclohexanone	108-94-1	gene,dev,repro,neur,chron	5 mg/kg/day (decreased wt gain)	1000 ppm-N,650 ppm-N			1000 ppm NOAEL for repro tox, 650 ppm NOAEL for dev tox
Diacetone alcohol	123-42-2	neur, chron					

Table II-6 (cont.)
Human Health Hazard Effects

Chemical Name	Cas No.	Tox Endpoint	RfD/RfC	NOAEL/ LOAEL	Slope/ Unit Risk	WOE	Comment
Dichloromethane	75-09-2	car, gene, dev, neur, chron	0.06 mg/kg/day (liver)		4.7E-7/ug/ m3	B2	RfC in review
Diethyl adipate	141-28-6	gene, dev					
Diethyl glutarate	818-38-2						
Diethylene glycol	111-46-6	dev, neur, chron					negative in Salmonella mutagenicity test
Diethylene glycol monobutyl ether	112-34-5	dev, chron		51 mg/kg/day-L, 2000 mg/kg/day-N			LOAEL for chronic, dermal NOAEL for dev tox
Diethylene glycol butyl ether acetate	124-17-4	dev, chron					RfC in review, sec. 4 data
Diisopropyl adipate	6938-94-9						
Dimethyl adipate	627-93-0	dev, chron					chron, repro(- result) studies on mixture of dibasic esters
Dimethyl glutarate	1119-40-0	chron					chron, dev(- result), repro(-) studies on mixture of dibasic esters

Table II-6 (cont.)
Human Health Hazard Effects

Chemical Name	Cas No.	Tox Endpoint	RfD/RfC	NOAEL/ LOAEL	Slope/ Unit Risk	WOE	Comment
Dimethyl succinate	106-65-0	chron					chron, dev(- result), repro(-) studies on mixture of dibasic esters
Dipropylene glycol methyl ether	34590-94-8	neur, chron					health effects at high concentrations
Dipropylene glycol methyl ether acetate	88917-22-0						
Dodecyl benzene sulfonic acid, TEA salt	27323-41-7						only acute toxicity data found
Ethoxylated castor oil	61791-12-6						very little data
Ethoxylated nonylphenol	9016-45-9						
Ethoxypropanol	52125-53-8	dev, chron	0.7 mg/kg/day				dev tox at high doses
Ethoxypropyl acetate	54839-24-6						
Ethyl acetate	141-78-6	neur, chron					health effects at high dose
Ethyl lactate	97-64-3	neur*					
Ethyl oleate	111-62-6						
Ethylene glycol propyl ether	2807-30-9	dev, chron					
Furfuryl alcohol	98-00-0	neur					NIOSH 40 mg/m3 TWA; 60 mg/m3 STEL (skin); NTP carc in progress

Table II-6 (cont.)
Human Health Hazard Effects

Chemical Name	Cas No.	Tox Endpoint	RfD/RfC	NOAEL/ LOAEL	Slope/ Unit Risk	WOE	Comment
Isobutyl isobutyrate	97-85-8						no effects in subchronic rat study up to 1000 mg/kg/day
Isobutyl oleate	10024-47-2						
Isopropanol	67-63-0	dev, neur, chron					limited chronic data
d-Limonene	5989-27-5	dev, chron		150 mg/kg/day LOAEL			LOAEL on kidney effect
Methanol	67-56-1	gene, dev, neur, chron	0.5 mg/kg/day (liver)				in review at NTP
Methyl ethyl ketone	78-93-3	dev, neur, chron	0.6 mg/kg/day, 1.0mg/m3			D	RfD/RfC on developmental toxicity
Methyl lactate	547-64-8						
Mineral spirits (straight run naphtha)	64741-41-9						
Mineral spirits (light hydrotreated)	64742-47-8						
N-methylpyrrolidone	872-50-4	dev, repro, chron		175 mg/kg/day NOAEL			NOAEL on developmental toxicity
2-Octadecanamine, N,N-dimethyl, N-oxide	71662-60-7						

Table II-6 (cont.)
Human Health Hazard Effects

Chemical Name	Cas No.	Tox Endpoint	RfD/RfC	NOAEL/ LOAEL	Slope/ Unit Risk	WOE	Comment
Periodic acid	13444-71-8						oxidizer
Phosphoric acid, mixed ester w/isopropanol and ethoxilated tridecanol	68186-42-5						
Potassium hydroxide	1310-58-3	corrosive					
Propylene carbonate	108-32-7						CTFA assess; tech grade may contain propylene oxide, a carcinogen
Propylene glycol	57-55-6	chron	20 mg/kg/day				negative Genetox for SCE and cell transformation
Propylene glycol methyl ether	107-98-2	dev, neur	RfD 0.7 mg/kg/day, RfC 2.0 mg/m3	3000 ppm-L			LOAEL on dev, RfC on neur, RfD on liver, kidney
Propylene glycol methyl ether acetate	108-65-6						
Silica	7631-86-9	carc, chron					crystalline silica is IARC 2A carcinogen
Silica, fumed	112945-52-5						
Sodium bisulfate	10034-88-5	corrosive					

Table II-6 (cont.)
Human Health Hazard Effects

Chemical Name	Cas No.	Tox Endpoint	RfD/RfC	NOAEL/ LOAEL	Slope/ Unit Risk	WOE	Comment
Sodium hexametaphosphate	10124-56-8	chron					not mutagenic in Salmonella or S. cerevisiae; chron effects at high doses
Sodium hydroxide	1310-73-2	corrosive					
Sodium hypochlorite	7681-52-9	gene, dev, chron					oxidizer
Sodium lauryl sulfate	151-21-3	dev, chron		300 mg/kg/day, 400 mg/kg/day-N			NOAELS are 300 mg/kg/day dev't tox and 400 mg/kg/day chronic tox
Sodium metasilicate	6834-92-0	dev, corrosive					
Sodium periodate	7790-28-5						oxidizer
Naphtha, light aliphatic	64742-89-8						
Naphtha, light aromatic	64742-95-6	dev					developmental toxicity data on C9 fraction
Sodium salt, dodecyl benzenesulfonic acid	25155-30-0						
Solvent naphtha, heavy aromatic	64742-94-5						
Tall oil, special	68937-81-5						

Chapter III
Background Information on Methodologies Used In Screen Reclamation Risk, Performance and Cost Evaluation

This chapter is intended to serve as a reference section for the CTSA document and contains details of data collection and methodologies used in the CTSA risk assessment, performance demonstration and cost evaluation. The methodologies and assumptions underlying the evaluations in Chapter 5 are outlined in this chapter, including:

- Screen Printing Workplace Practices Questionnaire
- Occupational Exposures (inhalation and dermal)
- Environmental Releases
- Population Exposure Assessments
- Risk Assessments
- Performance Evaluations
- Cost Estimates

Overview of Data from the Screen Printing Industry Used in Risk Assessment

In August and September 1993, screen printers were surveyed on the workplace practices associated with the screen cleaning/reclamation process. The survey tool was the "Workplace Practices Questionnaire for Screen Printers" (Appendix B), developed by the Screen Printing Association International (SPAI), the University of Tennessee Center for Clean Products and Clean Technologies and staff of the EPA Design for the Environment Program. The survey was developed to characterize typical screen printing facilities and workplace practices associated with the screen cleaning/reclamation process. This information was needed to estimate the amounts and types of environmental releases from the screen cleaning/reclamation process and to estimate exposure from the process. The results were also used to help identify pollution prevention opportunities for screen printers.

SPAI distributed the workplace practices questionnaire to approximately 300 printers, focusing on printers with 20 or fewer employees. Respondents mailed completed questionnaires to SPAI, which sent them to the University of Tennessee Center for Clean Products and Clean Technologies, where they were entered into a data base using FOXPRO software. The University of Tennessee, under a research grant from the EPA Office of Pollution Prevention and Toxics, developed a summary of responses to the questionnaire. Respondents to the survey were guaranteed anonymity and their identities withheld from the computerized database provided to EPA and from the summary of results.

All facilities that received the questionnaire were asked to respond to pages one, two and 11 of the questionnaire, which included a business profile, major products produced, general facility information, equipment and materials use, and pollution prevention opportunities for screen printers. Only screen printers who used solvent or UV-based inks printed on plastic/vinyl substrates were asked to respond to the remainder of the questionnaire.

Appendix C presents the summary of responses to the questionnaire. A total of 115 screen printers responded to the questionnaire, which represents an approximate 38 percent response rate. Representatives from SPAI and the screen printers who participated in the survey should be congratulated for this exceptionally high response rate to a direct mail questionnaire. Of the total, 107 respondents were screen printers who primarily use solvent or UV-based inks printed on plastic/vinyl substrates.

Environmental Releases and Occupational Exposure Assessment

Specific quantities for environmental releases and occupational exposure to chemicals can be determined for a particular system used in screen reclamation. This summary provides an overview of the releases and exposure and methodology used in determining the releases and exposure for the traditional ink remover, emulsion remover, and haze remover products.

While the greatest environmental releases and occupational exposure occur during the actual process of screen reclamation, releases and exposure also occur from volatilization from open containers, transfer operations, sampling operations, and waste rags. Air releases and the inhalation exposures occur as a result of volatilization during these operations. Releases to air occur by volatilization of chemicals from open containers, from the surface of the screen as it is being cleaned, and from rags used in the cleaning process. Estimation of releases to land and water is based on a mass balance relationship. Dermal exposures can also be estimated based on operations, formulation concentrations, and established dermal exposure models.[1]

It is assumed that workers perform the following activities during each step of the screen reclamation process. Some of these steps are not necessary or are altered for certain methods assessed here. See Figure I-2 for an outline of the steps involved in each method.

Step 1. Ink removal

- Open 55-gallon drum of ink remover
- Pour ink remover into 5-gallon pail
- Dip rag or brush into pail
- Remove ink from screen
- Toss rag into laundry pile
- Drum waste ink for disposal

Step 2. Emulsion removal

- Open container of emulsion remover
- Dip brush into container
- Remove emulsion from screen
- Rinse screen

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[1] U.S. EPA. *Dermal Exposure Assessment: Principles and Applications*. Office of Health and Environmental Assessment, Jan. 1992, Document no. EPA/600/8-9/011F.

Step 3. Haze removal

○ Open container of haze remover
○ Dip brush into container
○ Remove haze from screen
○ Rinse screen

To support the assessments, numerous sources of information were used in gathering data. Preliminary information was collected from the 11-page Screen Printing Workplace Practices Questionnaire. Meetings with printers to discuss the basic data assumptions used in the assessment were held at Screen Print '93 in New Orleans in October 1993 and at the SPAI Environmental Committee Meeting in January 1994. Information was also verified though facilities participating in the Screen Printing Performance Demonstration from February to May 1994. These operation assumptions and data are presented in Table III-1.

Table III-1
Assumptions and Data from Industry and Trade Groups

Type of Data	Average value	
	Number	Units
Number of employees involved in ink removal	3	employees
Hours per employee per day in ink removal	1	hours
Number of employees in screen reclamation	2	employees
Hours per employee per day in screen reclamation	1.5	hours
Average number of screens cleaned per day	6	screens
Average screen size	2,127	in^2
Size of combined screen reclamation/ink removal area	80	ft^2
Amount of ink remover per screen	8 (traditional) 4 (alternative)	oz
Amount of emulsion remover per screen	3.5	oz
Amount of haze remover per screen	3	oz

[a] Normalized from Workplace Practices Questionnaire to remove printing establishments larger than 20 employees.

Estimation Methodology

In general, in evaluating traditional and alternative screen reclamation systems, it is assumed that all releases to air, land, or water occur via the four scenarios described below. Using this assumption cleaning fluid usage has been partitioned to air, land, and water with concentrations of mass. Volatilization is estimated using a number of established models as documented below. Water and land releases are estimated to be all cleaning fluids not volatilized. The exposure/release scenarios are defined as follows:

○ Scenario I. Actual screen cleaning operations. Air releases are due to volatilization of chemicals from the screen surface. Unvolatilized material is assumed to be disposed to land or water. Ink, emulsion, and haze removal for 6 screens a day; each screen is approximately 2100m^2.

○ Scenario II. Releases to the atmosphere from pouring of 1 oz of material for sampling. This is assumed to take place over 15 minutes each day.

○ Scenario III. Releases to the atmosphere from pouring of cleaning mixtures from a 55-gallon drum into a 5 gallon pail.

○ Scenario IV. Releases from rags stored in a two-thirds empty drum. The water releases in this case occur in a commercial laundry. The drum is opened to add more rags once per day and to transfer the rags from the storage drum to a laundry. Rags are used only for the ink removal step.

Releases shown in the above scenarios will occur during the use of Reclamation Methods 1,2, and 4 of Exhibit 1-2. In addition to these releases, in Method 3 (SPAI Workshop Process), an ink degradant is applied after the ink remover, followed by a water rinse; a screen degreaser is then applied prior to use of the emulsion remover. For the purposes of this assessment, Method 3 is evaluated only in conjunction with system Omicron.

Assumptions for Environmental Releases

The environmental releases model prepared for this report assumes that releases to air equal the total airborne concentration of chemicals from:

○ volatilization of solvents from screens
○ emissions from transfer operations
○ emissions from sampling operations
○ volatilization from waste dirty rags

The following assumptions and sources of information were used in the model:

○ typical airborne concentrations

○ typical ventilation rates

○ emission factors from EPA (AP-42) (an EPA compendium of emission factors from the Office of Air)

○ formulation data and physical properties

○ average amounts of ink, haze, and emulsion remover used per site-day of 36 ounces, 21 ounces, and 18 ounces

The model addresses releases to three media: air, water, and land. Releases to air result from volatilization from the screens during cleaning, and fluid sampling and transfers. Releases for all systems studied were associated with ink removal, emulsion removal, and haze removal.

Water releases result primarily from the emulsion removal phase which is typically a rinse step using a water and sodium hypochlorite or sodium periodate solution for the traditional systems, and a water and sodium periodate solution for the alternative systems. The emulsion removal phase may also generate a contaminated rinsewater. In either phase, waste water results from screen rinsing and the spray or rag application of haze and emulsion removers.

Off-site releases to land result from the cleaning of non-disposable rags and the landfilling of disposable rags. It is assumed that rags are used only to remove the ink. The model assumes that non-disposable rags sent to a laundry contain 0.75 grams of ink remover per 18 rags. This assumption is based on:

○ limited data on how much material stays on a damp shop rag with mineral spirits
○ the average number of rags used to remove ink per screen (3 per screen)
○ the average number of screens cleaned per day (6 screens)

The model assumes weekly laundering of non-disposable shop rags and 250 days of use per year. Similarly, rags sent to a landfill are assumed to contain 0.75 grams of ink remover per 18 rags.

For Systems Omicron and Beta, which have ink remover products that are water-miscible, it was assumed that nonlaunderable rags were used and the discharge to water occurred at the screen printing facility. This assumption was made given that a water rinse is used with these products in removing ink.

For aqueous solutions, the density of all components is assumed equal to 1 g/cm^3. For nonaqueous solutions, ideal solution behavior is assumed and the density of each component is used to find the amount of the component in 4 ounces of ink remover. (See Appendix D for a further explanation).

Assumptions for Occupational Exposure

In order to estimate occupational exposure to chemicals during the screen cleaning process, an inhalation model and a dermal exposure model was developed. The assumptions underlying each model are described below.

Inhalation Model

The inhalation model used in the CTSA is a mass balance model. It assumes that the amount of a chemical in a room equals the amount leaving the room minus any generated in the room. The model is valid for estimating the displacement of vapors from containers, and the volatilization of liquids from open surfaces. Assumptions include:

○ incoming room air is contaminant-free

- ○ generation and ventilation rates are constant over time
- ○ room air and ventilation air mix ideally
- ○ Raoult's law is valid (i.e., the volatilization and interaction of vapors)
- ○ ideal gas law applies (i.e., the interaction of vapors)
- ○ inhaled doses of each chemical were based on "typical case" ventilation parameters, since these seem to give the best fit to the highest observed values (see below). Actual ventilation conditions are unknown.
- ○ median values were used for the composition; worst case evaluation for air releases would include the most volatile compound at its maximum concentration.

We used the following assumptions for the frequency and duration of inhalation exposure for ink, emulsion, and haze removal:

- ○ 6 screens cleaned per day
- ○ 1 to 3 workers per site
- ○ 3 hours per day exposure total
- ○ 250 days per year

The four scenarios described on page III-4 were modelled for assessing inhalation exposure. Inhalation exposures occur as a result of volatilization during these scenarios. The model assumes that shop workers do not wear respirators in any of the four scenarios.

Dermal Model

Dermal exposure is caused by contact with the material. Contact with the material includes touching damp rags, dipping hand(s) into a pail of ink remover, and manually applying the brush or rag to the screen to loosen the ink. Two scenarios, routine contact with two hands and routine immersion with two hands, were modelled for assessing dermal exposure. Routine contact occurs from touching rags and manually applying the brush or rag to the screen. Routine immersion occurs from dipping hand(s) into a pail or ink, haze, or emulsion remover.

Dermal contact models from the CEB handbook (CEB, 1991) were used by adjusting the concentration of the chemical in the mixture. Dermal exposure assumes no gloves or barrier creams will be used. Although exposure was estimated for the emulsion removers or haze removers containing sodium hypochlorite or sodium hydroxide, it is usually expected that use of these chemicals would result in negligible exposure given that use of these solutions without gloves causes irritation and corrosivity effects.

Overview of Methodology

CEB (Chemical Engineering Branch) models the evaporation of chemicals from open surfaces, such as the surface of a screen, using the following model:

$$G = \frac{0.02MP}{RT}\sqrt{\frac{D_{ab}v}{\pi z}} \tag{1}$$

where

G = Volatilization rate, g.m^{-2}.s^{-1}
M = Molecular weight, g.mol^{-1}
P = Vapor pressure, mm Hg
R = Gas constant, 0.0624 mmHg.m^{3}.mol^{-1}.K^{-1}
T = Temperature, K
D_{ab} = Diffusivity, cm^{2}.s^{-1}
v_z = Air velocity, m.s^{-1}
z = Distance along pool surface, m

The air velocity is assumed to be v_z = 100 ft.min^{-1}. Since D_{ab} is not available for many of the chemicals of interest to CEB, the following estimation equation is used:

$$D_{ab} = \frac{4.09\times10^{-5}T^{1.9}(1/29+1/M)^{0.5}M^{-0.33}}{P_t} \tag{2}$$

where

D_{ab} = Diffusion coefficient in air, cm^{2}.sec^{-1}
T = Temperature, K
M = Molecular weight, g.mol^{-1}
P_t = Total pressure, atm

This equation is based on kinetic theory and generally gives values of D_{ab} that agree closely with experimental data. The value of G computed from eqs (1) and (2) above is used in the following mass balance expression to compute the airborne concentration in the breathing zone:

$$C_v = \frac{1.7\times10^{5}TGA}{MQk} \tag{3}$$

where

C_v = Airborne concentration, ppm
T = Ambient temperature, K
G = Vapor generation rate, g.m^{-2}.sec^{-1}
M = Molecular weight, g.mol^{-1}
A = Area of surface, m^{2}
Q = Ventilation rate, ft^{3}.min^{-1}
k = Mixing factor, dimensionless

The mixing factor accounts for slow and incomplete mixing of ventilation air with room air. CEB sets this factor to 0.5 for the typical case and 0.1 for the worst case. CEB commonly uses values of the ventilation rate Q from 500 ft^{3}.min^{-1} to 3,500 ft^{3}.min^{-1}. An effective ventilation rate of 250 ft^{3}/min was used, which was equal to the mixing factor of 0.5 multiplied by the lowest ventilation rate (500 ft^{3}/min). The value of C_v from equation (3) is converted to mass/volume units as follows:

$$C_m = C_v \frac{M}{V_m} \tag{4}$$

where

C_m = Airborne concentration, mg.m^{-3}
C_v = Airborne concentration, ppm
M = Molecular weight, g.mol^{-1}
V_m = Molar volume of an ideal gas, l.mol^{-1}

At 25 °C, V_m has the value 24.45 l.mol^{-1}. Since a worker can be assumed to breathe about 1.25 m^3 of air per hour, it is a straightforward matter to compute inhalation exposure once C_m has been determined. Equations (3) and (4) can be combined to yield the following, given the "typical case" choice of ventilation parameters:

$$I = 0.48GAt \tag{5}$$

where

I = Total amount inhaled, mg.day^{-1}
G = Vapor generation rate, g.m^{-2}.s^{-1}
A = Area of surface, m^2
t = Duration of exposure, s

The advantage of equation (5) is that the quantity GAt is often known beforehand, since it is equal to the total amount of the chemical released to the atmosphere. It is also useful when computing the total dose due to a sudden release of material, such as occurs when a container is opened. In this case, it is difficult to ascertain the duration of exposure, but it is a simple matter to estimate the amount of vapor in the container's headspace.

Example 1. *Estimate the vapor generation rate and worker exposure during removal of ink from a printing screen using 100 percent toluene. The worker cleans screens for 1 hour each day in a room with a ventilation rate of 3,000 ft^3.min^{-1}. The screen area is 2,217 in^2. Assume a mixing factor of $k = 0.5$.*

Toluene has the following physical properties:

Molecular weight:	92.14 g.mol^{-1}
Vapor pressure:	28 mmHg at 25 °C
Diffusion coefficient:	0.076 cm^2.sec^{-1}

Using these values in equation (1) gives:

Generation rate G:	0.28 g.s^{-1}.m^{-2}
Airborne concentration:	141 ppm (C_v)
	534 mg.m^{-3} (C_m)
Exposure over 1 hour:	667 mg

If the CEB worst-case parameters are used in equation (2), i.e., a mixing factor of $k = 0.1$ and a ventilation rate of 500 ft^3.min^{-1}, then the estimated airborne concentration is $C_v = 4{,}216$ ppm. Exposures and volatilization rates are calculated by multiplying the pure-component values from Exhibit 4 by the mole fraction of that component in the liquid phase. A typical screen has an area of 2127 in^2 = 1.37 m^2. Each worker cleans screens for 1 hour per day. Amounts released should be checked against amount used to ensure mass balance.

Example 2. *If a worker cleans 6 screens using 8 oz/screen of mineral spirits, the amount of spirits used will be:*

6 x 8 x 29.57 fluid oz/cc x 0.78 g/cc = 1107 g

The amount volatilized will be:

$0.01087\ g.m^{-2}.s^{-1} \times 3600\ s \times 1.37\ m^2 = 53\ g$

Thus, the amount volatilized is not limited by the amount used. For the case of the traditional haze remover, however, volatilization is limited by the amount used. If 3 oz of haze remover containing 30 wt percent (32 volume percent or 21 mole percent) acetone is used per screen, the total amount available is:

6 x 3 x 0.32 x 29.57 fluid oz/cc x 0.79 = 133 g

The amount that would volatilize over 1 hour is:

1.49 x 1.37 x 3600 s = 7,350 g

Uncertainties

Occupational Exposure: Uncertainties

Determining occupational exposure levels associated with screen cleaning requires making assumptions about the cleaning process, the workplace environment, health and safety practices, and waste management practices. This section describes the uncertainties involved in assessing occupational exposure for screen cleaning. It also explains the assumptions underlying the exposure assessment model developed for the CTSA.

EPA has published Guidelines for Exposure Assessment in the Federal Register. These are guidelines for the basic terminology and principles by which the Agency is to conduct exposure assessments. There are several important issues relevant to this assessment. If the methodology is one which allows the assessor to in some way quantify the spectrum of exposure, then the assessor should assess typical exposures, as well as high end exposures or bounding exposures. Typical exposures refer to exactly that, how much the typical person is exposed to the particular substance in question. High end refers to a person exposed to amounts higher than 90 percent of the people (or ecological species of interest) exposed to the substance. Bounding estimates are judgements assuming that no one will be exposed to amounts higher than that calculated amount. However, in many cases, all we can do is give a picture of what the exposure would be under a given set of circumstances, without characterizing the probability of these circumstances actually occurring. These are called "What if" scenarios. They do not try to judge where on the exposure scale the estimate actually falls. All of the exposure assessments fall into the "What if" category for this assessment.

Although the screen cleaning process is relatively straightforward, occupational exposure levels will differ in actual shop environments because of many variables such as variations in:

- toxicity of the chemicals used
- amount of chemicals applied
- how the chemicals are applied
- compliance with health and safety and waste management procedures
- equipment operating time
- ventilation conditions and shop lay-out
- temperature conditions (ambient and solvent)

All of these variables will influence the impacts of chemicals used in the screen cleaning process on shop workers. Based on studies of screen printing operations conducted by the National Institute for Occupational Safety and Health (NIOSH), it appears that many of the small to medium sized operations do not follow health and safety precautions.[2] Specifically, workers were observed performing screen reclamation without protective gloves or proper breathing apparatus. Nor did shop workers wear protective aprons to reduce dermal exposure. According to one study, some workers used solvent to wash their arms and hands after completing the screen cleaning process. In another study, rags and paper towels contaminated with solvent were placed in an open trash can. Both of these practices will also increase exposure levels significantly.

There are also differences in how screen printers wash the screens; this affects occupational exposure. Some shops use automated screen washers which blast the screens with solvent or hot water in an enclosed system. Others use a hose in a sink to flush the screens by hand or the cleaner is spread on the screen by hand, and the worker uses a rag or paper towel to wipe down the screen. Exposure levels will differ if individual workers use more (or less) cleaner than specified, and if they allow it to remain on the screen longer than specified.

During research to support this assessment a NIOSH Health Hazard Evaluation (HHE) document on screen washing was located and used to validate exposure estimates. CEB initially estimated occupational exposures by applying the relatively conservative models that are normally used for review of new chemicals. The resulting exposure estimates were high in comparison to actual monitoring data. These data indicated that, after necessary corrections were made, the exposures predicted by the CEB model were within the range of the NIOSH observations, as long as the "typical case" ventilation parameters were chosen. Use of the "worst case" ventilation parameters in the CEB model leads to results that exceed the range of the experimental data by about an order of magnitude. The theoretical basis of the CEB model was investigated and a standard engineering formula for mass transfer in laminar boundary layers was found to provide a closer approximation to the upper end of NIOSH data when used with the same "worst case" ventilation parameters.

Both the CEB model (when used with the "typical case" ventilation parameters) and the boundary-layer approach can provide estimates of inhalation exposures which agree with the experimental data within one order of magnitude or better. It is difficult to obtain better agreement than this without knowing a great deal more about each exposure scenario, such as

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[2] Sources: Health Hazard Evaluation Report No. HETA 84-299-1543, (Chicago, IL:Impressions Handprinters). Health Hazard Evaluation Report No. HETA 81-383-1151, (Chicago, IL:Main Post Office).

the details of the screen cleaning process at each site, the solvent temperature, the air temperature, and the ventilation pattern in the screen cleaning area. These items are not routinely recorded by NIOSH investigative teams. A report documenting an alternative volatilization and exposure model based on laminar boundary layers is provided in Appendix E.

Dermal Exposure Model

The dermal exposure model is based on the concentration of material contacting the skin and the surface area contacted. Dermal exposure levels will differ in actual shop environments because of many variables such as variations in:

- type of worker activity
- likelihood or type of contact (i.e., routine or immersion)
- frequency of contact (i.e., routine or incidental)
- potential surface area contacted
- likelihood and effectiveness of protective equipment being used
- amount of chemical remaining on the skin
- evaporation rate of the chemical

In estimating dermal exposure, it was assumed that gloves were not worn. However, assuming that gloves are worn, dermal exposure is assumed to be negligible to none depending on the chemical in question. In situations where the chemical is corrosive (e.g., sodium hypochlorite), dermal exposure to shop workers using gloves is zero. The model assumes that one hand (surface area 650 cm^2) is routinely exposed during the screen cleaning process (1 to 3 mg/cm^2 typically remaining on the skin)[3]

Environmental Releases: Uncertainties

Determining environmental releases associated with screen cleaning requires making assumptions about the cleaning process, the workplace environment, and waste management practices. This section describes the uncertainties involved in assessing environmental releases associated with screen cleaning. It also explains the assumptions underlying the environmental release assessment model developed for the CTSA.

Uncertainties

Uncertainties related to environmental releases overlap with the uncertainties associated with occupational exposure. They include variations in:

- toxicity of the chemicals used
- amount of chemicals applied
- how the chemicals are applied
- compliance with waste management procedures
- equipment operating time
- ventilation conditions and shop lay-out
- temperature conditions (ambient and solvent)

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[3] Source: U.S. Environmental Protection Agency, *Chemical Engineering Branch Manual for the Preparation of Engineering Assessments*, (February 28, 1991), p. 4-36.

Release Amounts vs. Occupational Exposures

Air releases were computed in two different ways, depending on the particular scenario under consideration. For Scenario I (evaporation from a screen) and Scenario II (evaporation during sampling), the equations used for computing the total mass of material volatilized can be condensed into the following expression:

$$GAt = \frac{8.24\times10^{-8} M^{0.835} P\left(\frac{1}{29}+\frac{1}{M}\right)^{0.25} v_z^{0.5} At}{T^{0.05} z^{0.5} P_t^{0.5}} \tag{6}$$

where:

GAt = Mass released (= flux x area x time)
M = Molecular weight (g.mol^{-1})
P = Vapor pressure (mmHg)
v_z = Air velocity (ft.min^{-1})
A = Area of surface (cm^2)
t = Duration of release (s)
T = Air temperature (K)
z = Length of surface (cm)
P_t = Total pressure (atm)

For all cases of interest here, the temperature T, total pressure P_t, and air velocity v_z are assigned fixed values. These are 298 K, 1 atmosphere, and 100 ft.min^{-1}, respectively. In addition, the surface is taken to be square, so that $z = A^{0.5}$. Thus, the mass of material released has the following dependencies:

$$GAt \propto M^{0.835}\left(\frac{1}{29}+\frac{1}{M}\right)^{0.25} \tag{7}$$

$$GAt \propto P \tag{8}$$

$$QAt \propto A^{0.75} \tag{9}$$

For Scenario III (releases from pouring) and Scenario IV (releases from drum of rags), the vapor space of the container was assumed to be saturated. The model used can be represented as:

$$QAt = \frac{MPV}{(24.45)(760)} \tag{10}$$

where:

M = Molecular weight (g.mol^{-1})

P = Vapor pressure (mmHg)
V = Volume of container (l)

For each scenario, the container volume is fixed, so that:

$$QAt \propto M \tag{11}$$

$$QAt \propto P \tag{12}$$

Releases to water and/or land disposal are computed by a mass balance approach; any chemical not volatilized is assumed to be disposed to one of these two media.

The amount of each chemical inhaled by workers is given by the following expression:

$$I = \frac{719}{Qk} GAt \tag{13}$$

where
I = Inhaled dose (mg.day^{-1})
Q = Ventilation rate (ft^3.min^{-1})
k = Mixing factor (dimensionless)

In this report, Q is fixed at 3,000 ft^3.min^{-1} and $k = 0.5$. Thus,

$$I = 0.48 GAt \tag{14}$$

Thus, the inhaled dose has the same dependencies as the amount released, no additional variables being introduced.

Based on the above expressions, the amount released to the atmosphere in Scenarios I and II is approximately proportional to $M^{0.835}P$. For Scenario III and IV, the dependence is approximately MP. The vapor pressure is generally lower for compounds with higher molecular weights. An idea of the sensitivity of vapor pressure to molecular weight can be obtained from a molecular model of the liquid state. According to Fowler and Guggenheim (*Statistical Thermodynamics*, Cambridge, 1956), for a liquid whose intermolecular potential energy can be represented by the Lennard-Jones function:

$$U(r) = 4\epsilon[(\frac{\sigma}{r})^6 - (\frac{\sigma}{r})^{12}] \tag{15}$$

the vapor pressure can be estimated to be:

$$p = 1158 \frac{\epsilon}{\sigma^3} e^{-8.136(\epsilon/kT)} \tag{16}$$

As noted in the development of an expression for D_{ab}, the diffusivity, in Appendix K of the CEB Manual, the quantities ϵ and σ can be roughly correlated with molecular weight. When these parameters are regressed against experimental data for C_1-C_9 and substituted into the expression for vapor pressure, a relationship of the following form is observed:

$$p \propto M^{0.23} e^{-M^{0.51}} \tag{17}$$

Somewhat different dependencies will be found with different sets of experimental data, but all of the resulting expressions will show that vapor pressure falls off rapidly with molecular weight within a homologous series of compounds. Thus, the amount of chemical volatilized and the resulting inhaled dose will be approximately proportional to

$$M^{0.69} e^{-M^{0.51}} \tag{18}$$

Population Exposure Assessment for Screen Reclamation Processes

The purpose of a general population exposure assessment is to account for amounts of chemicals with which people who are not directly involved in the screen printing process may be in contact. There are several ways that the general population may be exposed to substances used in the screen reclamation process. People may breathe the air containing vapors which have been carried away by air currents from a screen printing facility. The vapors would be environmental releases stemming from evaporation of products at the screen printing facility. People may drink water which contains residues from the reclamation products, which can originate with the facility discharging the products down the drain. People may also drink well water that contains contaminants which have migrated from a landfill where wastes are disposed. The amount which a person may come in contact with varies with how far away they are located from the facility, how many of the different routes of contact they actually have (such as drinking, breathing, touching), how long the chemical has been in the environment and how the chemical moves through the environment. The amounts also depend on such environmental conditions as the weather or the amount of water that is flowing in the receiving stream or river where the facility's discharges go.

EPA has published Guidelines for Exposure Assessment in the Federal Register. These are guidelines for the basic terminology and principles by which the Agency is to conduct exposure assessments. There are several important issues relevant to this assessment. If the methodology is one which allows the assessor to in some way quantify the spectrum of exposure, then the assessor should assess typical exposures, as well as high end exposures or bounding exposures. Typical exposures refer to exactly that, how much the typical person is exposed to the particular substance in question. High end refers to a person exposed to amounts higher than 90 percent of the people (or ecological species of interest) exposed to the substance. Bounding estimates are judgements assuming that no one will be exposed to amounts higher than that calculated amount. However, in many cases, all we can do is give a picture of what the exposure would be under a given set of circumstances, without characterizing the probability of these circumstances actually occurring. These are called "What if" scenarios. They do not try to judge where on the exposure scale the estimate actually falls. All of the exposure assessments fall into the "What if" category for this assessment.

The fate of the chemical in the environment is how we refer to the breakdown (transformation) and mobility of the chemical through air, water and land. There is a different chemical fate for release through a waste water treatment facility as opposed to an air release or a landfill release. There are also different processes by which degradation may occur. For example, in air, a chemical may be broken down by sunlight (by either direct photolysis or photooxidation) or by reaction with water in the atmosphere (hydrolysis). In water and soil, an important degradation process is biodegradation, where the substance may be decomposed by bacteria and other biota in the environment. Each of these processes will have its own rate (speed) at which it occurs, and this may vary with the concentration of the chemical in the system. Often the way we present the fate for a chemical is by giving a half-life value. This term simply means the amount of time it takes for one-half of the substance initially present to be lost by degradation. There are other ways to present fate. If we are interested in how much of a chemical is removed from water during its trip through a waste water treatment facility (such as a POTW - Publicly Owned Treatment Works), we will give a removal amount, usually in percent. There are summaries in Chapter 2 of the chemical fate of all of the chemicals identified as being used in screen reclamation products.

There are two perspectives to address when handling exposure concerns for any commercial process. The first is best described as a local point of view, i.e., a single facility in normal operation will have certain releases which affect a specific area and specific local population. Since we do not have information for each screen printing facility, we use a "model facility" approach to calculate typical releases and environmental concentrations. This will not allow us to specify the number of people around the facility, because the population varies considerably depending on the location of the screen printing facility. The other perspective is to view the overall impact, i.e., what is the impact of all of the printing facilities for the general population. While one facility may not be releasing very much of any given chemical, the cumulative effect of all of the printers in an area could be serious.

For this assessment, we have tried to present a view of the local concerns by presenting exposures for a standard set of conditions, by which we are trying to simulate a single facility for all of the methods and systems. The overall perspective is presented only for the traditional systems, which are the systems which are considered to already be in common use. It was felt that it would far too hypothetical to do an overall perspective for the alternative formulations since we do not have a basis for predicting how many screen printers might use any given formulation.

The effects of a chemical may be a short-term (acute) effect, such as the effect a poison would have on the body, or it could be long-term, such as a carcinogen. For long-term (chronic) effects, it is most helpful to have average, or typical, exposures, since the effect will vary with the cumulative exposure. For acute effects, a peak exposure estimate would be more helpful. This can then be compared to levels at which the chemical is known to give immediate health problems. In general for this assessment, average concentrations are calculated.

Overview by Media

Air

Releases to air are from evaporation of chemicals during the process. This may be from allowing screens to dry during reclamation, or from rags or open drums of chemicals located around the facility. These vapors are then carried and mixed with outside air. The air concentration will depend on weather conditions. Stagnant conditions will not move vapors away quickly, so local concentrations will be higher than the concentrations of the chemical farther from the plant. There is the potential that everyone outside the facility could be affected. The chemical concentrations will decrease with distance, but the number of people may increase with distance, depending on the location of the screen printing facility. Usually the exposure assessor will use a computer program to determine the number of people around a known facility by using census data. Since the locations of all the screen printing facilities across the country are not known to us, we use the model facility approach, and do not count population for the model facility.

For our model facility, we assume a building height of three meters, and a width of 10 meters. This is a building approximately the size of a garage. We then pick sample weather conditions, usually from San Bernardino, to determine what the air concentration of a chemical will be at a set distance from the printing facility. We use San Bernardino because the weather conditions there will give the highest average concentrations around the facility of any of the approximately 500 weather stations in the United States. However, none of the average concentrations across the country will be even ten times less than the average concentrations at San Bernardino. If the highest concentration were 10 ug/m^3, then anywhere in the country the concentration would be greater than 1 ug/m^3. We would say that there is less than an order of magnitude difference.

Methodology References

Air Modeling Parameters for ISCLT90

MODEL - Industrial Source Complex, Long Term; US EPA, Office of Air and Radiation, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, version 90, as implemented by the Office of Pollution Prevention and Toxics in the Graphical Exposure Modeling System, GEMS Atmospheric Modeling Subsection.

The following default parameters were used:

- ○ Regulatory default setting for ISCLT.
- ○ Facility location at 34° latitude, 117° longitude
- ○ The Star Station (meteorological) data from the station closest to the point of release, San Bernardino, CA.
- ○ Urban Mode (U3)

- ○ Standard Polar grid, with 3 calculations per segment.
- ○ Single point of release at the facility location.
- ○ Release height of 3 meters for fugitive releases from an area source of 10 meters by 10 meters (100 m^2).

Surface Water

Releases to surface water are those releases discharged through a drain at a screen printing facility that end up going to public sewers or Publicly Owned Treatment Works (POTWs). This discharge is treated before being released, and the effectiveness of the treatment determined, so that the amount actually getting through to the receiving water body can be calculated. The receiving water will dilute the discharge from the POTW, and a stream concentration can be calculated using stream flow information.

We use average stream concentrations to calculate average drinking water consumption. We assume that people actually drink the two liters a day that is recommended for good health. If the chemical is one that will accumulate in animals or plants, we calculate ingestion of the chemical from eating fish.

The other issue for surface water is the effect that a chemical may have on aquatic organisms, from algae to fish. If the food chain is broken in a stream, the consequences are dire. No algae, no fish. A healthy stream with numerous organisms will also have a better ability to handle chemical releases than one whose quality is already compromised. The organisms lower on the food chain, such as algae, tend to have shorter lives, making shorter exposure time periods more critical. Since concentrations will vary with the stream flow, there may be periods of lower flow conditions where the same amount released as on a regular flow situation will cause problems. We use historical stream data to try to predict how often this will happen.

Cumulative releases to the same POTW may be estimated by counting the number of screen printers in an area and distributing the releases across all the POTW's in the area. We have to assume that the releases are for the same products, or very similar products. As for air, this cumulative number is expected to be far more significant than the amount for any single screen printer.

Methodology Reference

Single Site

Concentration = Chemical Loading / Streamflow

In general, the concentration will be in ug/L, and the chemical loading is in grams or kilograms. The streamflow used is the harmonic mean streamflow in Million Liters per Day (MLD) for drinking water concerns, if the location is known. Otherwise, the streamflow will be assumed to be 1000 MLD.

US-Wide Water Releases

The methodology used is outlined in its entirety in a report from VERSAR, Inc for Task I-11, subtask 101, from Contract 68-D3-0013. Copies of this report are available from either VERSAR, Inc or from Sondra Hollister at EPA.

Septic Systems

There appears to be a significant minority of screen printers who do not release water to a waste water treatment plant. These printers are assumed to release to septic systems. The releases of this type are not modeled in this assessment. There are some general guidelines that may be used to determine if there will be exposure to any of the screen reclamation chemicals from septic system seepage. Each chemical will have an estimated potential migration to ground water, which is usually used for landfill assessments. This can be directly applied to septic systems, because the potential to migrate to ground water will be the same. Of course the individual characteristics of the system will determine the actual speed that each chemical travels into the ground water. If the septic system is relatively leaky, and the ground water table is relatively high, the time that a chemical takes to get into the ground water will be shorter than for a septic system which is sealed well and where the ground water table is low.

Landfill

Our usual techniques for estimating exposures from landfill releases are not applicable to printing. For a typical situation, we would assume one facility sending waste to a landfill. For the printing industry, the use of landfills cannot be so simplified. A lack of data limits the determination of exposures. We do not know how many printers are sending what types of wastes to any given landfill. There also is no way to account for a printer sending a portion of their wastes to a hazardous waste handler, and sending another portion to the county landfill, or how many printers will be sending to any given landfill. For these reasons, even though the exposures from landfill releases may be significant, we will not be able to calculate exposures from landfill seepage and migration into ground water. However, we can give the expected fate of the chemical in the landfill -- will the chemical migrate to ground water rapidly, moderately or negligibly.

Background on Risk Assessment for Screen Reclamation Processes

Human Health Risk

Assessment of the human health risks presented by chemical substances includes the following components of analysis:

- ○ **Hazard Identification** is the process of determining whether exposure to a chemical can cause an adverse health effect and whether the adverse health effect is likely to occur in humans.

- ○ **Dose-response Assessment** is the process of defining the relationship between the dose of a chemical received and the incidence of adverse health effects in the exposed population. From the quantitative dose-response relationship, toxicity values are derived that are used in the risk characterization step to estimate the likelihood of adverse effects occurring in humans at different exposure levels.

○ **Exposure Assessment** identifies populations exposed to a chemical, describes their composition and size, and presents the types, magnitudes, frequencies, and durations of exposure to the chemical.

○ **Risk Characterization** integrates hazard and exposure information into quantitative and qualitative expressions of risk. A risk characterization includes a description of the assumptions, scientific judgments, and uncertainties embodied in the assessment.

Quantitative Expressions of Hazard and Risk

The manner in which estimates of hazard and risk are expressed depends on the nature of the hazard and the types of data upon which the assessment is based. For example, cancer risks are most often expressed as the probability of an individual developing cancer over a lifetime of exposure to the chemical in question. Risk estimates for adverse effects other than cancer are usually expressed as the ratio of a toxicologic potency value to an estimated dose or exposure level. A key distinction between cancer and other toxicologic effects is that most carcinogens are assumed to have no dose threshold; that is, no dose or exposure level can be presumed to be without some risk. Other toxicologic effects are generally assumed to have a dose threshold; that is, a dose or exposure level below which a significant adverse effect is not expected.

Cancer Hazard and Risk

EPA employs a "weight-of-evidence" approach to determine the likelihood that a chemical is a human carcinogen. Each chemical evaluated is placed into one of the five weight-of-evidence categories listed below.

○ Group A - human carcinogen

○ Group B - probable human carcinogen. B1 indicates limited human evidence; B2 indicates sufficient evidence in animals and inadequate or no evidence in humans.

○ Group C - possible human carcinogen

○ Group D - not classifiable as to human carcinogenicity

○ Group E - evidence of noncarcinogenicity for humans

When the available data are sufficient for quantitation, EPA develops an estimate of the chemical's carcinogenic potency. EPA "slope factors" express carcinogenic potency in terms of the estimated upper-bound incremental lifetime risk per mg/kg average daily dose. "Unit risk" is a similar measure of potency for air or drinking water concentrations and is expressed as risk per ug/m^3 in air or as risk per ug/l in water for continuous lifetime exposures.

Cancer risk is calculated by multiplying the estimated dose or exposure level by the appropriate measure of carcinogenic potency. For example an individual with a lifetime average daily dose of 0.3 mg/kg of a carcinogen with a potency of 0.02/mg/kg/day would experience a lifetime cancer risk of 0.006 from exposure to that chemical. In general, risks from exposures to more than one carcinogen are assumed to be additive, unless other information points toward a different interpretation.

Chronic Health Risks

Because adverse effects other than cancer and gene mutations are generally assumed to have a dose or exposure threshold, a different approach is needed to evaluate toxicologic potency and risk for these "systemic effects." "Systemic toxicity" means an adverse effect on any organ system following absorption and distribution of a toxicant to a site in the body distant from the toxicant's entry point. EPA uses the "Reference Dose" approach to evaluate chronic (long-term) exposures to systemic toxicants. The Reference Dose (RfD) is defined as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime" and is expressed as a mg/kg/day dose. The RfD is usually based on the most sensitive known effect; that is, the effect that occurs at the lowest dose. EPA calculates a comparable measure of potency for continuous inhalation exposures called a Reference Concentration or RfC, expressed as a mg/m^3 air concentration. Although some RfDs and RfCs are based on actual human data, they are most often calculated from results obtained in chronic or subchronic animal studies. The basic approach for deriving an RfD or RfC involves determining a "no-observed-adverse-effect level (NOAEL)" or "lowest-observed-adverse-effect level(LOAEL)" from an appropriate toxicologic or epidemiologic study and then applying various uncertainty factors and modifying factors to arrive at the RfD/RfC.

RfDs and RfCs can be used to evaluate risks from chronic exposures to systemic toxicants. EPA defines an expression of risk called a "Hazard Quotient" which is the ratio of the estimated chronic dose/exposure level to the RfD/RfC. Hazard Quotient values below unity imply that adverse effects are very unlikely to occur. The greater the Hazard Quotient exceeds unity, the greater is the level of concern. However, it is important to remember that the Hazard Quotient is not a probabilistic statement of risk. A quotient of 0.001 does not mean that there is a one-in-a-thousand chance of the effect occurring. Furthermore, it is important to remember that the level of concern does not necessarily increase linearly as the quotient approaches or exceeds unity because the RfD/RfC does not provide any information about the shape of the dose-response curve.

An expression of risk that can be used when an RfD/RfC is not available is the "Margin-of-Exposure (MOE)." The MOE is the ratio of a NOAEL or LOAEL (preferably from a chronic study) to an estimated dose or exposure level. Very high MOE values such as values greater than 100 for a NOAEL-based MOE or 1000 for a LOAEL-based MOE imply a very low level of concern. As the MOE decreases, the level of concern increases. As with the Hazard Quotient, it is important to remember that the MOE is not a probabilistic statement of risk.

Developmental Toxicity Risks

Because of the many unique elements associated with both the hazard and exposure components of developmental toxicity risk assessment, these risks are treated separately from other systemic toxicity risks.

EPA defines developmental toxicity as adverse effects on the developing organism that may result from exposure prior to conception, during prenatal development, or postnatally to the time of sexual maturation. Adverse developmental effects may be detected at any point in the life span of the organism. The major manifestations of developmental toxicity include: (1) death of the developing organism, (2) structural abnormality, (3) altered growth, and (4) functional deficiency.

There is a possibility that a single exposure may be sufficient to produce adverse developmental effects. Therefore, it is assumed that, in most cases, a single exposure at any of several developmental stages may be sufficient to produce an adverse developmental effect. In the case of intermittent exposures, examination of the peak exposure(s) as well as the average exposure over the time period of exposure is important.

EPA has derived Reference Doses and Reference Concentrations for developmental toxicants in a similar manner to the RfDs and RfCs for other systemic toxicants. The RfD_{DT} or RfC_{DT} is an estimate of a daily exposure to the human population that is assumed to be without appreciable risk of deleterious developmental effects. The use of the subscript DT is intended to distinguish these terms from the more common RfDs and RfCs that refer to chronic exposure situations for other systemic effects.

Developmental toxicity risk can be expressed as a Hazard Quotient (dose or exposure level divided by the RfD_{DT} or RfC_{DT}) or Margin-of-Exposure (NOAEL or LOAEL divided by the dose or exposure level), with careful attention paid to the exposure term, as described above.

NOTE: The closely related area of reproductive toxicity is also an important aspect of systemic toxicity. For purposes of this report, toxicity information on adult male and female reproductive systems will be assessed as part of the chronic toxicity risk.

Assumptions and Uncertainties

Estimated doses assume 100 percent absorption. The actual absorption rate may be significantly lower, especially for dermal exposures to relatively polar compounds. The assessment used the most relevant toxicological potency factor available for the exposure under consideration. In some cases the only potency factor available was derived from a study employing a different route of exposure than the exposure being evaluated. For example, oral RfD values were sometimes used to calculate Hazard Quotients for inhalation and dermal exposures. For the occupational risk assessment, RfC values were converted to units of dose assuming a breathing rate of 20 m^3/day and a body weight of 70 kg. This conversion was done because occupational inhalation exposures were calculated as a daily dose rather than as an average daily concentration. The general population risk estimates compare RfC values directly to average daily concentrations because continuous exposure is assumed for the general population. Most of the Margin-of-Exposure calculations presented in the assessment are based on toxicity data that have not been formally evaluated by the Agency. Simple esters of glycol ethers were assumed to present the same hazards at approximately the same potencies as the corresponding alcohol. The same potency data were used in risk estimates for each alcohol and its corresponding ester unless specific data for each compound were available.

All risk estimates are based on release and exposure values estimated from information on product usage and work practices obtained from industry surveys. No actual measures of chemical release or exposure levels were available.

Certain formulation components are described in the CTSA by their category name, such as propylene glycol series ethers. However, all risk calculations in the CTSA are based on chemical-specific hazard and exposure data. Thus, risk values may appear for some category members but not others because of limitations in available data.

Ecological Risk

The basic elements of ecological risk assessment are similar to those employed in human health risk assessment. This report will address only ecological risks to aquatic species. Quantitative evaluation of aquatic risks involves deriving an "ecotoxicity concern concentration (ECO CC)" for chronic exposures to aquatic species. The ECO CC may be based either on actual toxicologic test data on the subject chemical or on quantitative structure-activity relation analysis of test data on similar chemicals. The ECO CC is typically expressed as a mg/l water concentration. Concentrations below the ECO CC are assumed to present low risk to aquatic species. A notation of "N.E.S." rather than a numeric estimate of the ECO CC indicates that no adverse effects are expected in a saturated solution during the specified exposure period.

For further background on the determination of ecological hazard, see Appendix M.

Background and Methodology for Performance Demonstrations

Background

One purpose of the DfE Printing Project was to collect and disseminate to printers information concerning the performance of several screen reclamation alternatives. This section of the CTSA summarizes performance information collected during laboratory and production run performance demonstrations with alternative screen reclamation products carried out between January and April 1994. Performance data collected includes time spent on ink removal, volume used, and appearance of the screen following each step. Information from the performance demonstrations, taken in conjunction with risk, cost and other information in the CTSA, provides a more complete assessment of product systems than has otherwise been available from one source. DfE participants believe that this information will allow printers to make a number of comparisons that were not previously possible. For example, printers can compare cost, risk and performance between screen reclamation systems currently used and alternative systems as well as across the alternative systems evaluated during the performance demonstrations.

In a joint and collaborative effort, EPA and the Screen Printing Association International (SPAI) organized and conducted the performance demonstrations of 11 screen reclamation product systems and one alternative technology.[4] The DfE project staff contacted all known product manufacturers to request submission of product systems. The industry participants and the internal EPA workgroup decided to request that alternative product systems contain no stratospheric ozone depleting substances and no chlorinated compounds. This is due, in part,

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[4] Product systems are whatever combination of specific ink removers, emulsion removers, and haze removers the participating manufacturer submitted or recommended.

to the expectation that impending regulations may effect market availability and use of these substances. The DfE Project Staff did not solicit those products containing chlorinated compounds due to the scheduled phase-out of many of these chemicals under the 1990 Clean Air Act Amendments.

Performance data were collected for each product system in a laboratory setting at the Screen Printing Technical Foundation (SPTF) and also in production runs at 23 volunteer facilities. The performance demonstration protocol was developed by consensus with the involvement of EPA, product manufacturers, and screen printers. The protocol was designed to allow the evaluation of the maximum number of product systems given the resources available to the project. The intent of the SPTF evaluations was to assure that the product systems sent to printers would provide an acceptable level of performance. This screening level evaluation also provided another set of observations to compare with in-facility demonstration results. In-facility testing was undertaken at the request of printers participating in the DfE project so that product systems would be evaluated during production runs at printing facilities. It should be noted that the performance demonstrations are not rigorous scientific investigations. Instead, the performance information in Chapter 5 documents the printers' experiences with and opinions of these products as they were used in production runs at their facilities.

Methodology

Performance evaluations were conducted in two distinct phases of the project. SPTF evaluated products under very controlled and consistent conditions. Volunteer printing facilities nationwide collected much of the same information, but did so under more variable conditions during production. The methodologies for data collection at SPTF and at the printing facilities are outlined below.

SPTF Evaluations

At SPTF, each product system was tested on three imaged screens; one with solvent-based ink, one with UV-cured ink and one with water-based ink. One of the most important aspects of the SPTF methodology is that all evaluations were conducted under consistent screen conditions (e.g., tension, mesh type, emulsion type, thread count, image) for all screens. In addition, the same technician conducted the evaluations for all product systems at SPTF. The technician at SPTF recorded the following information: amount of product used, time spent on each reclamation step, level of effort required, and a qualitative assessment of product effectiveness and screen condition. (See Appendix L for SPTF methodology.)

Printing Facility Demonstrations

SPAI recruited volunteer screen printers who print on plastic and vinyl substrates from across the country. EPA and SPAI staff matched the submitted product systems to volunteer printing facilities based on existing equipment, ink type, and current practices. Most products were scheduled to be evaluated in two or three facilities to provide performance data from different operating and ambient conditions. Prior to shipping product systems to printers, SPTF repackaged products or removed identifying marks and brand names so that those printers (and the DfE observers) evaluating the products did not know the manufacturer or product name. Masked MSDSs were also developed and shipped along with the product systems to be evaluated.

The appropriate staff at each volunteer facility were asked to:

○ provide background information on the facility, its screen printing operations, and its current screen reclamation process and products;

○ participate in a one-day site visit in which a DfE observer would observe and document current practices, introduce facility staff to data recording and reporting needs of the project and allow the observation of screen reclamation using the alternative system;

○ record information on product performance over a four-week period; and

○ participate in a weekly telephone call with the DfE observer.

In designing the protocol and record-keeping, every effort was made to keep volunteer printers' burden low and to minimize production disruptions.

The printers recorded the same performance information as described in the SPTF methodology. Following the receipt of a facility background questionnaire sent by SPAI, the DfE observer called each facility to review the details of their operation and to schedule a site visit. (See Appendix G.) Alternative product systems, MSDSs, application instructions, and spray bottles were shipped to each facility prior to the DfE observer's site visit.

DfE observers were not EPA employees, but were drawn from staff from Abt Associates, Inc., and its subcontractor, Radian Corporation. They conducted the initial site visits to all facilities. During these visits, the observer documented current screen reclamation procedures and the performance of current product systems, as well as three screen reclamations with the alternative system. Printers were asked to comment on the effectiveness of each product (ink remover, emulsion remover and haze remover) and to determine if screen cleanliness was sufficient for future re-imaging and printing. (See Appendix H for an example of the site visit evaluation sheet.) After the observer's visit, the facility continued to use the alternative systems for one month. During this time, facility staff recorded performance information (including subsequent print image quality) on the alternative systems for approximately 12 screen reclamations per week, using the standardized observation forms. (See Appendices I and J for examples of the evaluation sheets for ink removal and for haze and emulsion removal.) Where possible, facilities tracked the screens used in the demonstration to collect information on the long-term performance and effects of these products. Each week, the DfE observer called the facility staff for an update on the product system's performance, as well as to identify any changes in the way the products were used. These calls were documented in telephone logs. (See Appendix K for an example.)

A more detailed explanation of the methodology and product review protocols is provided in Appendix L.

Data Collection

The information summarized in chapters 4 and 5 comes from five sources.

○ Each product system was evaluated at SPTF using ink types compatible with the product system (up to three types: solvent-based, UV-cured, and water-based).

- ○ Each facility completed a background questionnaire profiling printing and reclamation operations. The questionnaire was typically either completed or reviewed with the DfE observer during the initial site visit.

- ○ DfE observers visited each facility. During the visits they observed a reclamation with the current product system and up to three reclamations using the alternative system.

- ○ The facility staff completed as many as 12 observation forms per week for four weeks.

- ○ Weekly follow-up calls made by the DfE observers.

Data Summary and Analysis

Summaries and analyses were prepared for each product system keeping each facilities' experiences with that product system separate. A number of statistics correlations were attempted for each facility but the results are typically not statistically significant due to small sample size. Correlations included:

- ○ the effectiveness of ink removal compared with variables, such as, effort/time spent on ink removal, ink color, number of impressions

- ○ the condition of screen after emulsion removal step compared with variables, such as, effort/time spent on emulsion removal, prior ink coverage

- ○ the condition of screen after all reclamation steps are complete (is screen reusable for all types of print jobs) compared with effort/time spent on haze removal, effectiveness of previous steps

Where appropriate, these results are included within the text summaries in Chapter 5 of each product system. Some summary statistics, such as average amount of product used, are presented in accompanying tables.

Limitations

As noted previously, the inclusion of widely variable conditions across and within facilities and the short duration of the performance demonstrations does not allow the results to be interpreted as definitive performance assessments of the product systems. In addition, some facilities did not provide the full complement of observation forms for several reasons including, unacceptable performance of the product system, personnel problems, insufficient volume of products supplied, and lost records of the performance demonstrations.

As mentioned above, the performance demonstrations are not scientifically rigorous but are subjective assessments which reflect the conditions and experience of two to three individual facilities. There are a number of reasons why the results of performance demonstrations for one particular product system may differ from one facility to another and/or from the SPTF results. Among these reasons are:

- Variability of screen conditions. Because performance demonstrations were carried out during production runs, many factors which affect the performance of reclamation products were not controlled during the performance demonstrations including age of screen, ink color, ink coverage, image size, ink type and drying time prior to reclamation.

- Variability of ambient conditions. Conditions, such as temperature and humidity, were recorded but not controlled during performance demonstrations. Many screen printers reported that ambient conditions affect performance of products they use (e.g., temperature effect on drying of ink on screens).

- Chemical interactions with products used previously on screen. Printers and manufacturers have reported that the use of several different types of chemicals previously applied to clean a screen can affect the performance of products currently used to clean the screen. Product systems are often designed for chemical compatibility during the screen reclamation process; if another product is added to the product system that is chemically incompatible, cleaning performance of the system may be affected. This may occur when a particular chemical, such as lacquer thinner, is used to remove ink at press-side during a print run (such as removing ink while the printer stops for lunch); if a printer is using a water-based screen reclamation product system, chemical incompatibilities can affect product system performance. If a printer has been using a variety of hydrocarbon solvents, such as acetone and xylene, to clean a screen, prior to demonstrating the effectiveness of an alternative system, the performance of the alternative system may be affected by a residue of hydrocarbons on the surface of the screen. In the second case, the testing would be more effective if a new screen was used; however, this was typically not the case in the performance demonstration. In either case, the performance demonstration may have been affected by (1) residue chemicals on the surface of the screen or (2) the chemical "conditioning" of the screen.

- Variability of staff involved in performance demonstrations. At SPTF, the same technician conducted and recorded all testing. At the volunteer facilities, more than one individual often conducted the reclamations during which data were collected. Reclaimers' past experience also differs and can affect their perception of performance. For example, a screen reclaimer who has only used highly effective ink removers may differ in their opinion of "moderate scrubbing effort" from a reclaimer whose current ink remover instructions call for one to two minutes of scrubbing with a brush.

Product System Summaries

A performance summary of each product system is detailed in Chapter 5. In each is a general summary of product performance, a description of the product application method, results from the evaluation at SPTF, details of product performance reported separately for each volunteer printing facility, and facility background information. For each product system, a table is also included which provides certain summary statistics from the performance demonstrations at the volunteer printing facilities and at SPTF (for three ink types). For a quick summary of the results, the table providing summary statistics is very helpful.

Chemical Volume Estimates

Volumes for chemicals used within screen reclamation were estimated. Volumes of the chemicals produced within the nation, export volumes, and import volumes were estimated from information obtained from the following sources: Chemical Economics Handbook[5], US ITC[6], Mansville[7], US EPA reports[8], Kirk-Othmer[9], and industry sources. In some cases, volumes reported represent broader categories than the individual chemical. Volumes for the portion of the chemicals used within screen reclamation was not readily available.

The Workplace Practices Questionnaire,[10] SPAI's 1990 Survey,[11] and expert opinion estimates were used to develop an estimate of the chemical volumes. The following methodology summarizes the assumptions and calculations used to estimate the annual national totals of chemicals used in screen reclamation.

The information needed to develop the estimates included the average screen size, the per screen volume of each type of reclamation product, market shares, the number of screens cleaned yearly, and the number of screen printing operations. This information, and its sources, is summarized in Table III-1.

The screen size, in conjunction with the amount of product used or purchased and the number of screens cleaned, was used to determine the per screen product usage. Typical formulations were then used to determine the chemical breakdown of the reclamation products. Combining this information resulted in estimates of the volumes of chemicals used for screen reclamation. Additional detail of the methodology is given below.

Average Screen Size

Estimated from the Workplace Practices survey, observations were weighted by the number of screens cleaned per day. This is a normalization technique which incorporates the frequency of screen cleaning as well as the size of the screens. The average screen size was

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[5] SRI. selected reports from 1985 to 1993. Chemical Economics Handbook. SRI International, Menlo Park, CA.

[6] USITC. 1993 and 1994 Synthetic Organic Chemicals: United States Production and Sales, 1991, U.S. International Trade Commission, Washington, DC.

[7] Manville. selected reports from 1990 - 1993. Manville Chemical Products Corporation, Asbury Park, NJ.

[8] US EPA reports, including the Toxic Substances Control Act Chemical Substance Inventory (1985), "Aqueous and Terpene Cleaning" (1990), "Economic Analysis of Final Test Rules for DGBE and DGBA" (1987), "Glycol Ethers: An Overview" (1985)

[9] Kirk-Othmer, 1981, "Oils,essential." Om: Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., vol 16. New York: Wiley.

[10] The Workplace Practices Questionnaire was developed by EPA, SPAI and the University of Tennessee in 1993. It contains information on 115 screen printing facilities' operating and work practice characteristics. See Appendix B for a reproduction of the blank questionnaire and Appendix C for a summary of responses.

[11] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991).

estimated to be 2,916 square inches. This value differs from the average in the appendix due to this normalization to incorporate incomplete responses.

Per Screen Product Usage

Usage levels for three types of reclamation products were calculated using information collected through the Workplace Practices Survey: ink remover, emulsion remover, and haze remover. Information used included average screens printed per day, volumes of products purchased each year, and the unit price of the products. Certain observations such as those from facilities carrying out in-plant recycling, were excluded from the calculations as these would distort the average volume used per screen of one-time ink removal operations. The average volume used per screen was calculated by dividing the annual amount of product purchased by the number of screens cleaned per year (assuming 252 working days and the midpoint of the range of screens cleaned per day).

Derivation of Market Share of Traditional and Alternative Screen Reclamation Products

Current use of screen reclamation products is divided between *traditional* products, generally high VOC solvents, and *alternative* products, usually low or no VOC content products. To calculate the market share represented by each type of product, data was collected from the Work Practices Survey (see Appendices B and C). In the calculation, market share is not based on volume used but rather on total screen area cleaned since traditional and alternative products may require very different quantities to clean the same screen area.

The formula used to calculate market share is as follows:

$$\text{Market Share}_{Alt} = A_{Alt}/A_{Alt+Tra} \qquad \text{Market Share}_{Tra} = A_{Tra}/A_{Alt+Tra}$$

Where:

$_{Alt}$ denotes Alternative Product
$_{Tra}$ denotes Traditional Product
A = total screen area cleaned daily = $\sum_{n}^{F}$ [# of screens cleaned daily x area of screens]
F = number of facilities cleaning screens

Ink Removers

A simplistic decision rule, based on expert opinion, was used to classify ink removers as alternative or traditional. If the price of an ink remover in the Work Practices Survey was below $5.60/gallon then it was considered traditional. If the unit price was above $18.90/gallon then the product was considered to be alternative. An additional seven ink removal products were assigned as traditional or alternative based on having a brand name in common with a product assigned using the price thresholds.[12] As the Work Practices Survey collected brand names, we did not know the composition of the product and had no other method to determine which category the products fit into. Once facilities were identified as using either traditional or alternative products, the screen area cleaned per day for each facility was estimated.[13] The screen area cleaned per day is then summed across facilities within product types. To estimate market share, the screen area cleaned using each type of product was then divided by the total screen area cleaned daily with both types of products. The results indicate that the percentage of total screen area cleaned using traditional products equals 65.6% and the percentage of total screen area cleaned using alternative products equals 34.4%.

Emulsion Removers

As there is little difference among emulsion removers used in the Work Practices survey no distinction was made between traditional and alternative emulsion removers.

Haze Removers

The market share of haze removers used by printing operations that is considered to be traditional and the market share that is considered to be alternative is not known. Consequently, in the cost analysis, it was assumed that all haze removers currently used are traditional products.

Number of Screens Cleaned

The number of screens cleaned per year was taken from SPAI's 1990 survey, where facilities reported which range they fit into. In order to use this information for our calculations, an average value was chosen to represent each range. For the top range of 41 screens or more, 50 screens per day was used. The remaining figures are reported in Table III-1.

Using an SPAI estimate of 20,000 screen printing facilities (excluding textile printers), the total number of screens cleaned per day can be estimated. For example, 57 percent of facilities clean one to ten screens, or an average of 5.5, a day, resulting in 62,700 screens a day for that particular range. Continuing the analysis results in an estimate of 272,710 screens cleaned per day.

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[12] A substantial portion (~ 70%) of screen area reported in the Work Practices survey could not be assigned to traditional or alternative products and were, therefore, not included in the above calculation.

[13] Data reported in the Work Practices Survey was limited to the total volume of alternative and traditional products purchased annually and the total number of screens cleaned per day at the facility. The number of screens cleaned per day with each type of product was not indicated. As a result, the average price of the ink remover was calculated and used to establish which type of product the facility was using.

Table III-2
Information for Screen Reclamation Chemical Volume Estimates

Description	Data		
Average screen size[a]	2916 sq in		
Per screen product usage[a]	Product	Oz/Screen (Gal/Screen)	
	Ink remover (traditional)	98 (0.7663)	
	Ink remover (alternative)	22 (0.1731)	
	Emulsion remover	8.8 (0.0685)	
	Haze remover	2 (0.0160)	
Ink remover market share[a,d]	Traditional - 65.6% Alternative - 34.4%		
Screens cleaned per day[b]	Range of # of Screens	Value used	% of facilities
	1 to 10	5.5	57.0
	11 to 20	15.5	23.2
	21 to 30	25.5	9.8
	31 to 40	35.5	4.1
	41 or more	50	5.9
Number of screen printing facilities[c]	20,000		
Number of screens cleaned per day[d]	272,710		

[a] Based on raw data from WPQ for screen printing adjusted for incomplete responses.
[b] SPAI's 1990 Industry Profile.
[c] SPAI estimate.
[d] Calculated value.

National Estimates of Screen Reclamation Products

Multiplying product usage per screen by market share by the total number of screens cleaned per year provides estimates of the amount of screen reclamation products used nationally. All facilities are assumed to use ink remover, emulsion remover, and haze remover; this may result in an overestimate of chemicals used as not all facilities use haze remover, at least not on all screens. Market share estimates, developed by EPA in consultation with industry experts, are provided in Table III-3.

Table III-3
Estimated Market Share for Screen Reclamation Products

Chemical	Market Share (%)
Ink Remover, Traditional Formulations	
Xylene	20
Mineral spirits	20
Acetone	20
Lacquer thinner[a]	40
Ink Remover, Alternative Formulations	
Propylene glycol methyl ether	10
Methoxypropanol acetate	10
Dibasic esters[b]	30
Diethylene glycol	3
Propylene glycol methyl ether acetate	5
Terpineols/d-limonene (50/50)	7
Propylene glycol	5
Tripropylene glycol methyl ether	15
Diethylene glycol butyl ether	10
Cyclohexanone	5
Emulsion Remover	
Bleach (sodium hypochlorite) (12% solution in water)	10
Sodium metaperiodate (4% solution in water)	80
Periodic acid (10% solution in water)	5
Sodium bisulfate (50% solution in water)	5
Haze Remover	
Sodium hydroxide (20% solution in water)	25
Potassium hydroxide (20% solution in water)	25
Sodium hypochlorite (12% solution in water)	10
Mixture of 65% Glycol ethers[c] and 35% N-methylpyrrolidone	10

Table III-3
Estimated Market Share for Screen Reclamation Products

Chemical	Market Share (%)
Mixture of 10% d-limonene, 20% Sodium hydroxide, and 70% water	10
Mixture of 10% Xylene, 30% Acetone, 30% Mineral spirits, and 30% Cyclohexanone	20

[a] The formulation for Lacquer thinner is as follows:

	CAS #	Percentage
(1) Methyl ethyl ketone	78933	30%
(2) n-butyl acetate	123-86-4	15%
(3) Methanol	67561	5%
(4) Solvent naphtha, light aliphatic	64742-89-8	20%
(5) Toluene	108883	20%
(6) Isobutyl isobutyrate	97858	10%

[b] This category includes dimethyl glutarate, dimethyl adipate, dimethyl succinate in a 2:1:1 ratio.

[c] This category includes propylene glycol methy ether, methoxypropanol acetate, propylene glycol methyl ether acetate, tripropylene glycol methyl ether, and diethylene glycol mono butyl ether in equal portions.

Estimates of Chemical Usage for Screen Reclamation

To estimate the amount of individual chemicals used, the product volumes estimated earlier were combined with the market share estimates to determine the amount of individual chemicals used. Chemicals that are solids at room temperature are reported in units of mass (pounds) and those that are liquids are reported in units of volume (gallons). The estimated amount of chemicals is reported in Table III-4. Many of the chemicals do not have estimates; the chemical's specific information provided for this analysis (reported in Table III-2) is an overview and, therefore, did not cover all of the chemicals used in screen reclamation. We were unable to collect volume information directly from reclamation product manufacturers.

Table III-4
Estimated Annual Amount of Chemicals Currently Used in Screen Reclamation
(Liquids are reported by volume, solids by weight)

Chemical	Volume (Gallons)	Weight (Pounds)
Acetone	6,920,000	
Alcohols, C8-C10, ethoxylated	NA[a]	NA
Alcohols, C12-C14, ethoxylated	NA	NA
Benzyl alcohol	NA	NA
2-Butoxyethanol	NA	NA
n-Butyl acetate	1,920,000	
Butyrolactone	NA	NA
Cyclohexanol	NA	NA
Cyclohexanone	270,000	
Diacetone alcohol	NA	NA
Dichloromethane	NA	NA
Diethyl adipate	NA	NA
Diethyl glutarate	NA	NA
Diethylene glycol	122,000	
Diethylene glycol monobutyl ether	420,000	NA
Diethylene glycol butyl ether acetate	NA	NA
Diisopropyl adipate	NA	NA
Dimethyl adipate		2,700,000
Dimethyl glutarate	609,000	5,500,000
Dimethyl succinate	304,000	
Dipropylene glycol methyl ether	NA	NA
Dipropylene glycol methyl ether acetate	NA	NA
Dodecyl benzene sulfonic acid, triethanol amine salt	NA	NA
Ethoxylated castor oil	NA	NA
Ethoxylated nonylphenol	NA	NA
Ethyl acetate	NA	NA
Ethyl lactate	NA	NA

Table III-4
Estimated Annual Amount of Chemicals Currently Used in Screen Reclamation
(Liquids are reported by volume, solids by weight)

Chemical	Volume (Gallons)	Weight (Pounds)
Ethyl oleate	NA	NA
Fumed silica	NA	NA
Furfuryl alcohol	NA	NA
Isobutyl isobutyrate	2,630,000	
Isobutyl oleate	NA	NA
Isopropanol	NA	NA
d-Limonene		1,100,000
Methoxypropanol acetate	420,000	
Methanol	610,000	
Methyl ethyl ketone	3,720,000	
Methyl lactate	NA	NA
Mineral Spirits	6,920,000	
N-Methyl pyrrolidone	38,000	
2-Octdecanamine, N,Ndimethyl, Noxide	NA	NA
Periodic acid		1,020,000
Phosphoric acid, mixed ester w/isopropanol and ethoxylated tridecanol	NA	NA
Potassium hydroxide		1,060,000
Propylene carbonate	NA	NA
Propylene glycol	203,000	
Propylene glycol methyl ether	418,000	
Propylene gycol methyl ether acetate	217,000	
Silica	NA	NA
Silica, fumed (amorphous, crystalline-free)	NA	NA
Sodium bisulfate		2,350,000
Sodium hexametaphosphate	NA	NA
Sodium hydroxide		1,450,000
Sodium hypochlorite	69,000	

Table III-4
Estimated Annual Amount of Chemicals Currently Used in Screen Reclamation
(Liquids are reported by volume, solids by weight)

Chemical	Volume (Gallons)	Weight (Pounds)
Sodium lauryl sulfate	NA	NA
Sodium metasilicate	NA	NA
Sodium periodate		11,700,000
Sodium salt, dodecylbenzene sulfonic acid	NA	NA
Solvent naphtha, heavy aromatic	NA	NA
Solvent naphtha, light aliphatic	2,160,000	
Solvent naphtha, light aromatic	NA	NA
Special tall oil	NA	NA
Terpineols		1,100,000
Tetrahydrofurfuryl alcohol	NA	NA
Toluene	2,670,000	
1,1,1-Trichloroethane	NA	NA
1,2,4-Trimethylbenzene	NA	NA
Triethanolamine salt, dodecyl benzene sulfonic acid	NA	NA
Tripropylene glycol methyl ether	623,000	
Trisodium phosphate	NA	NA
Xylene	6,880,000	

[a]Not available. Some chemical amounts were not estimated; sufficient information on the use of those chemicals in the screen printing industry was not available.

Cost Analysis Methodology

The following methodology was used to estimate the costs of baseline screen reclamation as well as the cost of six alternative chemical, technological and work practice substitutes. The cost estimation methodology is intended to reflect standard industry practices and representative data for the given screen reclamation substitutes. The performance demonstrations conducted during production runs at 23 volunteer facilities in early 1994 were the predominant source of information for the cost estimates. Information from the performance demonstrations was supplemented by several other sources, including (1) product evaluations undertaken by the Screen Printing Technical Foundation (SPTF), (2) equipment specifications from manufacturers and distributors, (3) industry statistics collected by trade groups, (4) EPA's risk assessment work undertaken as part of the CTSA, and (5) industry experts and suppliers.

For each substitute method, annual facility costs and per screen costs were estimated for individual facilities (those involved in the performance demonstrations) whose operations were characteristic of the given substitute method. For the hypothetical baseline facility, the total annual cost and per screen cost were estimated for reclaiming six screens (2,127 in^2) per day. In addition, each facility's costs were normalized to allow cross-facility comparisons, particularly with the baseline scenario. Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario.

A general description of the cost estimation methodology and data sources used is presented below. The second section presents additional details for the baseline scenario and each of the six substitute screen reclamation methods.

General Description of Costing Methodology

The baseline screen reclamation scenario and substitutes are defined as follows:

○ Baseline. Traditional chemical formulations for ink removal, emulsion removal and haze removal.

○ Method 1. Chemical substitutes for ink removal and emulsion removal. No haze removal required.

○ Method 2. Chemical substitutes for ink removal, emulsion removal and haze removal.

○ Method 3. SPAI Workshop Process -- Chemical substitutes for ink removal, ink degradant, degreasing and emulsion removal. No haze removal required.

○ Method 4. Technology substitute of high pressure wash for ink removal; technology substitute and reclamation products used for emulsion and haze removal.

○ Technology substitute. Use of automatic screen washer for ink removal.

○ Work practice substitute. Screen disposal in lieu of reclamation.

In general, the cost estimate for each reclamation method was composed of the sum of six distinct cost elements: labor, reclamation products, materials, resource use, equipment, and waste disposal.

○ Labor. The printer's staff time spent on each reclamation step (e.g., ink removal, emulsion removal, haze removal and degreasing) was collected or estimated from various sources. The total time estimate does not include collecting screens from printing areas, waiting for product reactions as might be specified in the manufacturers's application instructions, maintenance of reclamation area, or handling of segregated waste materials. The labor cost was calculated as the total time spent multiplied by (1) the average wage rate for screen reclaimers of $6.53/hour (as reported in SPAI's *1993 Wage Survey Report for the Screen Printing Industry*) and (2) an industry multiplier of 2.01 (calculated from SPAI's *1992 Operating Ratios Study*) to account for fringe and overhead costs.

○ Reclamation products. The average usage per screen was calculated for each product (i.e., ink remover, emulsion remover, haze remover, and degreaser) used by a particular facility. Because of wide variations, no attempt was made to average across facilities or product systems within the same substitute method. For comparative purposes, "normalized" average quantities were calculated by multiplying actual usage with the ratio of the baseline screen size of 2,127 in^2 to the recorded screen size. Multiplying usage with the unit cost of each product (provided by each participating manufacturer and summarized in Table III-5) yielded the reclamation product costs. Costs associated with special storage requirements for products were not considered in the cost analysis.

Table III-5
Alternative Screen Printing Systems: Manufacturer Pricing

System	Ink Remover	Emulsion Remover	Haze Remover
Alpha	$18.18/gallon (5 gallons/$91) (55 gallons/$850)	$4.00/gallon	$9.39/gallon (5 kg/$50)
Beta	$15.10/gallon	Ink remover only	Ink remover only
Chi	$31.20/gallon (5 gallons/$156) (55 gallons/$1,315)	$32.00/gallon (5 gallons/$160) (15 gallons/$438) (55 gallons/$1,238)	$31.20/gallon (5 gallons/$156) (55 gallons/$1,315)
Delta	$20.00/gallon (5 gallons/$100) (55 gallons/$900)	$32.00/gallon (5 gallons/$160) (15 gallons/$438) (55 gallons/$1,238)	$20.00/gallon (5 gallons/$100) (55 gallons/$900)
Epsilon	$7.80/gallon (5 gallons/$39)	$13.54/gallon (5 kg/$149)	$1.09/gallon (15 kg/$36)
Gamma	$10.90/gallon (25 liters/$72) (5 gallons/$55)	$1.60/lb (15 kg/$53)	$9.39/gallon (25 liters/$62) (5 gallons/$52)
Mu	($7.76/gallon) (20 liters/$41) (5 gallons/$39)	$10.34/gallon (3 five liter units/$41) (5 gallons/$52)	$7.57/gallon (5 five liter units/$50) (5 gallons/$189)
Phi	$24.95/gallon	$24.95/gallon	$39.95/gallon
Omicron	$13.40/gallon (5 gallons/$67) (55 gallons/$540)	$11.00/gallon (5 gallons/$55) (55 gallons/$530)	$18.00/gallon (5 gallons/$90)
Theta	No ink remover costs Other costs: $5,170	$21.95/gallon	$43.00/gallon

Table III-5
Alternative Screen Printing Systems: Manufacturer Pricing

System	Ink Remover	Emulsion Remover	Haze Remover
Zeta	$23.00/gallon	$23.00/gallon	$30.00/gallon

Note: Volume conversions were made using 3.785 liters/gallon.
The price of the greatest volume in the table (e.g., 55 gallons) was used when estimating cost for a particular system.

- Materials (e.g., rags, screens). This element is most important for the work practice substitute of screen disposal. A supplier quote was used for the unit cost of screen mesh (40" wide, 260 threads per square inch). Wastage was assumed to be 10 percent of the screen size. For all methods, rag use was estimated or recorded for the baseline and all substitute methods. It was assumed that rags were leased and laundered at a cost of $0.15/rag. Changes in the number of application brushes between the baseline and substitute methods is considered inconsequential.

- Resource Use. The cost of electricity and water was addressed quantitatively only for Method 4 (high pressure wash). The equipment was assumed to be in operation only for the recorded time spent on ink removal. Equipment specifications for flow rate and electrical rating provided by the manufacturer allow the calculation of water and electricity use. The cost of water, electricity and sewer were estimated using utility rates in the Northeast, a generally conservative assumption. For all other methods, changes in resource use are considered inconsequential.

- Equipment. Equipment costs were considered for Method 4 (high pressure wash) and the automatic screen washer only. Equipment costs common to all the methods and the baseline were excluded from the analysis. The capital costs were amortized over a ten-year period, the estimated engineering life of the equipment. An interest rate of 7 percent for small business loans was used (which represents the marginal rate of return on capital). The annualized cost of equipment was adjusted (using a marginal tax rate of 34 percent) to reflect the nontaxable nature of interest and (10-year) depreciation for such equipment.

- Waste disposal. Hazardous waste disposal costs were assumed only if the reclamation products contain RCRA-listed chemicals or if the products are defined as characteristic wastes due to their ignitable nature (See Table III-6). For each product system, hazardous waste generation rates (in g/day for 6 screens), were estimated by chemical engineers on EPA's staff. This methodology does not consider the possible effect residual inks may have on the waste's hazard classification. It also assumes that other wastestreams at the facility are hazardous; thus, the labor cost of training and managing hazardous wastes is not associated with screen reclamation only. Given that filtration systems used to remove residual inks and reclamation products from spent wash water (spent filters must be disposed of) may be required for both baseline and alternative systems, filtration system and filter disposal costs were not included in the cost analysis. The analysis focuses on quantifying cost differences among reclamation methods.

Table III-6
Alternative Screen Printing Systems: Determination of RCRA Hazardous Waste Listing

System	Ink remover	Emulsion remover	Haze remover
Alpha	RCRA Characteristic waste (ignitable) Flashpoint = 101°F/38°C	None	None
Beta	None	Ink remover only	Ink remover only
Chi	None	None	None
Delta	None	None	None
Epsilon	RCRA Listed waste (cyclohexanone - all other components qualify as listed under mixture rule). Also Characteristic waste (ignitable) Flashpoint = 46°C/115°F	None	1:1 dilution with ink remover. All components quality as hazardous waste under mixture rule.
Gamma	None	None	None
Mu	RCRA Characteristic waste (ignitable) Flashpoint = 131°F/55°C	None	None
Phi	None	None	None
Omicron (AE & AF)	None	None	None
Theta	No ink remover	None	RCRA Listed waste (cyclohexanone - all other components qualify as listed under mixture rule)
Zeta	RCRA Characteristic waste (ignitable) Flashpoint = 101°F/38°C	None	None

All information on flashpoint was gathered from masked MSDSs submitted by supplier. None of the above information should be used for compliance purposes. None of the chemicals in these formulations is listed as toxic characteristic contaminants and were not treated as such in the cost analysis; however, printers should use the Toxicity Characteristic Leaching Procedure (TCLP) to determine the applicability of the toxicity characteristic to their particular waste stream.

Details Related to Data Sources and Methodological Approach

In addition to the methodological approach outlined above, there a number of important assumptions and differences specific to the cost estimations of each screen reclamation method. Details related to data sources and the methodological approach used to estimate the cost of each reclamation method are presented below.

Baseline Screen Reclamation

Four traditional systems are defined in Chapter 5, the primary distinction among them being the chemical constituents of the ink remover, emulsion remover and haze remover. Traditional System #4 was used to estimate baseline costs, as it was expected to be more representative of systems currently in use. The baseline products used are described as follows:

Ink remover = lacquer thinner
Emulsion remover = 1.25% sodium periodate in water
Haze remover = 10% xylene (by weight)
30% acetone

30% mineral spirits
30% cyclohexanone

For ink remover, time and volume information was taken from SPTF testing. An average price for lacquer thinner was calculated from prices reported in the Workplace Practices Questionnaire conducted by SPAI and the University of Tennessee. Time, volume, and price information for baseline emulsion removal was taken from the Zeta system used in performance demonstrations. Time and volume information for the four-chemical baseline haze remover was not available from the performance demonstrations and had to be estimated based on the SPTF evaluation of a similar haze remover, resulting in a time of 11.5 minutes. A volume of 3 ounces for haze removal was taken from the application instructions developed for SPTF. A price for purchasing this formulation in a 55-gallon drum quantity was quoted by Ashland Chemical.

A second baseline scenario was developed which excluded the haze removal step. The second baseline reflects the fact that between 27 and 80 percent of facilities regularly use a haze remover. The second baseline also allowed comparisons of Method 1 (no haze removal) with a similar baseline.

Substitute Method 1: Chemical Substitutes for Ink Removal and Emulsion Removal. No Haze Removal Required.

Two assumptions affect the cost analysis of Substitute Method 1. Eliminating haze removal avoids both the material and labor costs of haze removal. The estimated cost difference between Substitute Method 1 and the baseline may also be affected by the assumption that the baseline facility uses haze remover during all screen reclamations; however, industry figures indicate that haze removal is undertaken on between 27 and 80 percent of reclamations. Therefore, the baseline used in the analysis of this alternative method excludes haze removal. The amount of ink remover and emulsion remover used and time spent on reclamation were taken from performance demonstrations. Product prices were provided by participating suppliers. Performance demonstration results from product systems Chi (excluding the haze removal step) and Beta (including an emulsion removal step from System Zeta) were used to estimate the cost of Substitute Method 1.

Substitute Method 2: Chemical substitutes for ink removal, emulsion removal and haze removal.

The amount of each reclamation product used and time spent on reclamation were available from the performance demonstrations. Product prices were provided by participating suppliers. Performance demonstration results for product systems Alpha, Chi, Delta, Epsilon, Gamma, Mu, Phi, Omicron-AE, Omicron-AF, and Zeta were used to estimate the cost of Substitute Method 2.

Substitute Method 3: SPAI Workshop Process -- Chemical substitutes for ink removal, ink degradant, degreasing and emulsion removal. No haze removal required.

The amounts of ink and emulsion removers used were available from performance demonstrations of product system Omicron. Based on information about the SPAI Workshop Process, which indicated that the overall time spent reclaiming screens would not change appreciably from a typical reclamation process, the average time spent (including 5 minutes for treatment with ink degradant and degreasing) from the evaluation of product system Omicron by four facilities was used to estimate labor costs. Documentation of the SPAI Workshop Process was used to estimate the amount of ink degradant (3 ounces) and degreaser (3 ounces) used. Product prices were available from participating suppliers.

Substitute Method 4: Technology substitute of high pressure wash for ink removal; technology substitute and reclamation products used for emulsion and haze removal.

Data collected by SPTF staff during a facility visit and equipment specifications provided by the manufacturer were used to develop the cost for this method. The capital cost of this equipment was annualized by the method described above and added to the recurring operating and maintenance costs and divided by the number of screens reclaimed per year to arrive at the per screen equipment costs. Water, wastewater and electrical usage costs were included in the cost estimate for this method only. As in all other cost estimations, the cost of a filtration system was not included as the analysis was focused on quantifying cost differences between reclamation systems, without accounting for filtration costs that could be expected to occur in all cases.

Technology Substitute of Automatic Screen Washer for Ink Removal

Although several suppliers of automatic screen washers were asked to participate in performance demonstrations, none accepted. As information on automatic screen washers was, therefore, not collected as part of the performance demonstrations, it was gathered from other sources, including an equipment supplier and a printer. Two cost estimates were developed which reflect the baseline facility's operations and size and the range of equipment available. Typically, automatic screen washers substitute for the ink removal step; emulsion removal and haze removal may still be required.

Automatic Screen Washer #1 was a large capacity (in terms of the maximum size of screen) enclosed washer with a fully automated feed system to move the screens through separate wash and rinse areas. It was assumed that mineral spirits were in both reservoirs. As mineral spirits were used in the ink removal step, the cost analysis of automatic screen washer #1 assumes the same emulsion and haze removal costs as in the baseline. Its purchase price was assumed to be $95,000, the original manufacturer's list price, although the printer purchased the equipment at auction. The only operating costs were related to solvent make-up (daily) and replacement of the reservoirs' contents 70 gallons (every eight to nine months). Information on other operating costs was not available; it was assumed that these costs would be minimal as compared to the equipment costs. Time spent loading and unloading the washers was taken from manufacturer's documentation of the equipment. As the equipment's electrical rating was not available from information provided by the distributor, electrical costs were not included. The price of mineral spirits ($4.00/gallon) was taken from the Work Practice Survey. Emulsion removal and haze removal costs were assumed to be similar to those of the baseline system.

Automatic Screen Washer #2 is a smaller unit. Screens must be loaded and unloaded by hand. Because it uses a solvent with lower volatile fraction than #1, more solvent remains on the screen and must be washed off following ink removal. Time spent loading and unloading the washers was taken from manufacturer's documentation of the equipment. Two pumps operate using compressed air which is reportedly available from other sources at the facility; the cost of a generator was not included in the cost analysis. The price of the ink remover was provided by the equipment supplier. Emulsion removal costs were assumed to be similar to those of the baseline system. The manufacturer indicated that a haze remover was not required given the formulation of the ink remover.

Work Practice Substitute of Screen Disposal

The cost estimate of screen disposal was developed for comparison to other reclamation methods. Information on screen disposal was not collected as part of the performance demonstrations. Consequently, one cost estimate was developed which reflects the baseline facility's operations and size. It should be noted that screen disposal is most cost effective under two circumstances not assumed for the model facility's operations: where production runs approach the useful life of a screen and where the size of the screen is relatively small. A number of assumptions were used to estimate the cost of this substitute method, including:

○ No other changes in operations or equipment were required.

○ Waste screens do not need to be handled as hazardous waste under RCRA which would greatly increase the estimated cost.

- The replacement of screens (after reaching the end of the useful life of the mesh) was not considered in the baseline nor in any of the other reclamation methods; it is estimated to be approximately $0.60/screen reclaimed. Consequently, this value was deducted from the total cost of this method.

- The average wage rate of screen stretchers ($6.87), which is slightly higher than for screen reclaimers, was used to calculate labor costs for this method.

Chapter IV
Screen Reclamation Products: Functional Groups

The intent of this chapter is to define the characteristics associated with each ink remover, emulsion remover and haze remover. Because of the specific functions these three types of products perform, they have been designated as functional groups in a screen reclamation system. Information on the characteristics associated with each of these functional groups is presented in a format that will allow comparison of several types of products within each functional group. For example, given a hazard summary, purchase cost, exposure analysis and risk characterization for several different types of ink removers, decisions regarding which one of these products would work best in an individual facility could be made. However, to gain a better understanding of all the issues associated with the ink removers, performance information in Chapter V should be referenced. In this chapter information about the different ink removers is combined with emulsion and haze removers, forming a product system by which they are typically sold. In this way the variables of performance and total cost can be fully evaluated.

In the sections below, characteristics of many of the different formulations associated with ink, emulsion and haze removers are described. However, these formulations are not all-inclusive; other formulations may be available commercially. These particular formulations were selected by a workgroup consisting of screen printing manufacturers who participated in the performance demonstration, SPAI and DfE staff. For the purposes of this document, an ink remover has been defined as any chemical, set of chemicals, process or technology that removes ink from the screen surface. Ink removers can also be referred to as ink degradants. Because the final screen reclamation process is being considered, not press-side in-process activities, some of the ink removers may also remove emulsions. An emulsion or stencil remover has been defined as any chemical, set of chemicals, process or technology that removes an emulsion from the screen surface. Lastly, a haze remover has been defined as any chemical, set of chemicals, process or technology that can remove the residual pigment and resin in screen mesh so as to eliminate ghost images.

Each functional group is evaluated as follows:

○ Hazard Summary and Cost
○ Occupational Exposure
○ Occupational Risk Conclusions and Observations
○ Environmental Releases in Screen Cleaning Operations
○ Ecological Risks from Water Releases
○ General Population Exposure Conclusions and Observations

At the end of this chapter is a brief discussion of the process of manufacturing screen reclamation chemical products and a general source release assessment on product formulation. Energy and natural resources use in product formulation is also discussed. Information on these areas could not be discussed for each formulation or technology due to limited data availability.

Information about pollution prevention opportunities through workpractice changes and equipment modifications is discussed in Chapter VI.

Ink Removal Function

Substitute Comparative Assessment

Table IV-1 below lists some of the chemical ink removers that are available to screen printers. In addition to chemical ink removers, specific technologies, such as high-pressure water wash systems, are commercially available. Reference Method 4 in Chapter V for a discussion of this option. In Table IV-1, a brief hazard summary and a list of purchase prices is included for each ink remover. For information on the chemical properties and industrial synthesis of the bulk chemicals, refer to Chapter II and for performance information on these products in a given system see Chapter V. Market information on the volume of specific ink remover products sold is not available.

Table IV-1
Hazard Summaries and Costs: Ink Removers

Formulation	% VOC Flash Pt. V.P.[a]	Hazard Summary		Purchase Cost
		Health Effects Description	Aquatic Hazard Rankings[b]	
Traditional Systems				
System 1 100% Mineral spirits	100 % 109 F 1 mm Hg	limited hazard data	High	$4.00/gallon
System 2 100% Acetone	100 % 0 F 185 mm Hg	neurotoxicity; chronic toxicity	Low	$3.00/gallon
System 3 & System 4 100% Lacquer Thinner, consisting of: 30% Methyl ethyl ketone 15% Butyl acetate 5% Methanol 20% Naphtha, light aliphatic 20% Toluene 10% Isobutyl isobutyrate	100 %	developmental toxicity; genetic toxicity?; neurotoxicity; chronic toxicity	Low Medium Low High Medium Medium	$3.50/gallon
Alternative Systems				
Alpha Aromatic solvent naphtha Propylene glycol series ethers	100 % 101 F < 4 mm Hg	developmental toxicity; neurotoxicity	Low Low/Medium	$18.18/gallon (5 gallons/ $91 55 gallons/ $850)
Beta 2-Octadecanamine, N,N-dimethyl-, N-oxide or a modified amine from unsaturated soy bean oil fatty acid Water	0 % 205 F NA[c]	limited hazard data	High	$15.10/gallon (estimated)
Chi Diethylene glycol series ethers Propylene glycol series ethers N-methyl pyrrolidone Ethoxylated nonylphenol	96 % < 200 F < 0.1 mm Hg	developmental toxicity; reproductive toxicity; neurotoxicity; chronic toxicity	Low/Medium Low/Medium Low Medium	$31.20/gallon (5 gallons/$156 55 gallons/$1,315)
Delta Dibasic esters Propylene glycol series ethers Ethoxylated nonylphenol	94 % < 200 F < 1.0 mm Hg	developmental toxicity; chronic toxicity	Medium Low/Medium Medium	$20.00/gallon (5 gallons/$100 55 gallons/$900)

Table IV-1
Hazard Summaries and Costs: Ink Removers

Formulation	% VOC Flash Pt. V.P.[a]	Hazard Summary		Purchase Cost
		Health Effects Description	Aquatic Hazard Rankings[b]	
Epsilon Cyclohexanone Methoxypropanol acetate Diethylene glycol Benzyl alcohol Diacetone alcohol Aromatic solvent naphtha Derivatized plant oil	65 % 115 F unknown	developmental toxicity; reproductive toxicity; genetic toxicity; neurotoxicity; chronic toxicity	Low Medium Low Medium Low Medium Low/High	$7.80/gallon (5 gallons/$39)
Gamma Tripropylene glycol methyl ether Diethylene glycol butyl ether acetate Dibasic esters Fatty alcohol ethers Derivatized plant oil	40 % 76 F 10.9 mm Hg	developmental toxicity; chronic toxicity	Low Medium Medium Medium/High Low/High	$10.90/gallon (25 liters/$72)
Mu Dibasic esters Methoxypropanol acetate d-Limonene Ethoxylated nonylphenol Derivatized plant oil	50 % 131 F < 0.3 mm Hg	developmental toxicity; chronic toxicity	Medium Medium Medium High Low/High	$7.76/gallon (20 liters/$41)
Phi Dibasic esters	NA < 160 F NA	developmental toxicity; chronic toxicity	Medium	$24.95/gallon
Omicron AE & Omicron AF Diethylene glycol butyl ether Propylene glycol	30 % 214 F 0.04 mm Hg	developmental toxicity; chronic toxicity	Low Low	$13.40/gallon (5 gallons/$67 55 gallons/$540)
Zeta Propylene glycol series ethers	100 % 101 F 0.4-10.5 mm Hg	developmental toxicity; neurotoxicity; chronic toxicity	Low/Medium	$23.00/gallon

[a] V.P. means vapor pressure.
[b] The hazard rankings shown identify the categories (low, medium, or high) into which the individual components of the product system fall. The aquatic hazard ranking for each chemical is listed on the same line as the chemical name. When an alternative system includes chemicals from a chemical category (see Table II-2), the hazard ranking shown is the range of the rankings of all of the individual chemicals comprising the category. This analysis did not estimate the aquatic hazard ranking of the product systems as mixtures.
[c] NA means not available.

Exposure Analysis & Risk Characterization

For specific assumptions and details of the occupational exposure, environmental releases and risk assessment, please reference Chapter III.

Table IV-2
Occupational Exposures: Ink Removers

	Inhalation Exposures, by Scenario (mg/day)				Dermal Exposures, (mg/day)	
System	**I**	**II**	**III**	**IV**	**Routine**	**Immersion**
Traditional Systems						
System 1						
Mineral spirits- light hydrotreated	26	0.1	0	0.3	1560	7280
System 2						
Acetone	539	11	5	38	1560	7280
Systems 3 & 4						
Methyl ethyl ketone	165	5.3	3	20	468	2180
Butyl acetate, normal	44	1.3	1	5.3	234	1090
Methanol	27	4.7	2	15	78	364
Naphtha, light aliphatic	98	1.6	1	6.2	312	1460
Toluene	110	2.3	1	9.2	312	1460
Isobutyl isobutyrate	7	0.4	0	1.7	156	728
Alternative Systems						
Alpha						
Aromatic solvent naphtha	13	0.1	0	0.2	1250	5820
Propylene glycol series ethers	56	0.6	0	2.6	312	1460
Beta						
2-Octadecanamine, N,N-dimethyl-, N-oxide or a modified amine from unsaturated soy bean oil fatty acid	292	4.3	3	0	1530	7130
Water	0	0	0	0	31	146
Chi						
Diethylene glycol series ethers	0	0	0	0	312	1456
Propylene glycol series ethers	0	0	0	0	858	4000
N-methylpyrrolidone	3	0	0	0.1	312	1460
Ethoxylated nonylphenol	0	0	0	0	78	364
Delta						
Dibasic esters	2	0	0	0.1	702	3280
Propylene glycol series ethers	0	0	0	0	780	3640
Ethoxylated nonylphenol	0	0	0	0	78	364

Table IV-2
Occupational Exposures: Ink Removers

	Inhalation Exposures, by Scenario (mg/day)				Dermal Exposures, (mg/day)	
System	I	II	III	IV	Routine	Immersion
Epsilon						
Cyclohexanone	39	0.3	0.2	1.4	468	2180
Methoxypropanol acetate	17	0.4	0.2	1.7	234	1090
Diethylene glycol	0	0	0	0	312	1460
Benzyl alcohol	0.1	0	0	0	101	473
Derivatized plant oil	0.1	0	0	0.2	55	255
Aromatic solvent naphtha	1.6	0.1	0	0.2	156	728
Diacetone alcohol	4.6	0.1	0.1	0.4	234	1090
Gamma						
Diethylene glycol butyl ether acetate	0	0	0	0	62	291
Tripropylene glycol methyl ether	0	0	0	0	780	3640
Derivatized plant oil	0.2	0	0	0.2	62	291
Fatty alcohol ethers	0.4	0	0	0.1	187	873
Dibasic esters	1.3	0	0	0.2	468	2184
Mu						
Dibasic esters	3	0	0	0.2	1014	4728
Methoxypropanol acetate	31	0.4	0	1.7	312	1460
d-Limonene	21	0.6	0	2.4	156	728
Ethoxylated nonylphenol	0	0	0	0	94	437
Derivatized plant oil	0	0	0	0.2	62	291
Phi						
Dibasic esters	4	0	0	0.2	1561	7270
Omicron AE & Omicron AF						
Diethylene glycol butyl ether	0	0	0	0	984	4590
Propylene glycol	17	0.1	0	0.4	576	2690
Zeta						
Propylene glycol series ethers	139	0.6	0	2.8	1560	7280
Method 5 (Automatic Screen Washer)						
Ink remover solvent (mineral spirits or lacquer thinner)[a]	266				3900	

[a] Occupational exposure from automatic screen washers are estimated to be the same for either mineral spirits or lacquer thinner. See traditional system 3 for the composition of lacquer thinner. This analysis did not consider alternative exposure routes for automatic screen washers.

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = transferring waste rags from a storage drum to a "laundry bag."

Table IV-3
Occupational Risk Conclusions and Observations:
Ink Removers

System	Observations
Traditional Systems	
System 1	Dermal exposures to workers using mineral spirits in ink removal can be very high, although the risks from mineral spirits could not be quantified because of limitations in hazard data.
System 2	Hazard quotient calculations indicate clear concerns for chronic dermal and inhalation exposures to workers using acetone in ink removal.
Systems 3 & 4	Hazard quotient calculations indicate clear concerns for both toluene and methyl ethyl ketone with respect to chronic dermal and inhalation exposures to workers using these chemicals in ink removal. Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using methanol in ink removal.
Alternative Systems	
Alpha	Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using propylene glycol series ethers in ink removal. Possible concerns also exist for chronic dermal exposure to propylene glycol series ethers based on the calculated hazard quotients, which assume 100% dermal absorption. If the actual dermal absorption rate of propylene glycol series ethers is significantly lower, this concern would be significantly reduced or eliminated. Inhalation exposures to propylene glycol series ethers also present possible concerns for developmental toxicity risks, based on margin-of-exposure calculations. Dermal exposures to other chemicals used in ink removal or haze removal can be high, although the risks could not be quantified because of limitations in hazard data.
Beta	Both inhalation and dermal exposures to workers using 2-octadecanamine, N,N-dimethyl-, N-oxide in ink removal can be high, although the risks could not be quantified because of limitations in hazard data.
Chi	Clear concerns exist for chronic dermal exposures to diethylene glycol series ethers used in ink removal based on the calculated margins-of-exposure. Concerns exist for developmental toxicity risks from dermal exposures to N-methylpyrrolidone based on the calculated margin-of-exposure. Similar calculations for inhalation exposures to N-methylpyrrolidone indicate very low concern. Inhalation exposures to other ink remover components are very low. Dermal risks from other ink remover components could not be quantified because of limitations in hazard data, but exposures can be high.
Delta	Although no risks could be quantified because of limitations in hazard data, relatively high dermal exposures to ink remover components could occur. Inhalation exposures to all components are very low.

Table IV-3
Occupational Risk Conclusions and Observations: Ink Removers

System	Observations
Epsilon	Hazard quotient calculations indicate marginal concerns for chronic dermal exposures to cyclohexanone and benzyl alcohol during ink removal. Similar calculations for inhalation exposures to cyclohexanone and benzyl alcohol indicate low concern. Margin-of-exposure calculations indicate a marginal concern for developmental toxicity risk from inhalation exposures to cyclohexanone during ink removal. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified. Hazard quotient calculations indicate marginal concerns for chronic dermal exposures and low concern for chronic inhalation exposures to methoxypropanol acetate. Risks from other ink remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
Gamma	Clear concerns exist for chronic dermal exposures to diethylene glycol butyl ether acetate used in ink removal based on the calculated margin-of-exposure. Developmental toxicity risks from dermal exposures to diethylene glycol butyl ether acetate are very low based on the calculated margin-of-exposure. Risks from other ink remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high. Inhalation exposures to all components are very low.
Mu	Concerns exist for chronic risks from both inhalation and dermal exposures to *d*-limonene during ink removal based on the calculated margins-of-exposure. Hazard quotient calculations for methoxypropanol acetate used in ink removal indicate a marginal concern for chronic dermal exposures and low concern for chronic inhalation exposures. Margin-of-exposure calculations show possible concerns for developmental toxicity risks from inhalation exposures to methoxypropanol acetate. Risks from other ink remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
Phi	Risks from ink remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high. Inhalation exposures to all components are very low.

Table IV-3
Occupational Risk Conclusions and Observations:
Ink Removers

System	Observations
Omicron AE & Omicron AF	Margin-of-exposure calculations indicate clear concerns for chronic dermal exposures to workers using diethylene glycol butyl ether in ink removal. Margin-of-exposure calculations also show possible concerns for developmental toxicity risks from dermal "immersion" exposures to diethylene glycol butyl ether. Routine dermal exposures, however, represent a very low concern for developmental toxicity risks. Hazard quotient calculations for inhalation and dermal exposures to propylene glycol during ink removal indicate very low concern. Inhalation exposures to other components are very low. Risks from other components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
Zeta	Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using propylene glycol series ethers in ink removal. Possible concerns also exist for chronic dermal exposure to propylene glycol series ethers based on the calculated hazard quotients, which assume 100% dermal absorption. If the actual dermal absorption rate of propylene glycol series ethers is significantly lower, this concern would be significantly reduced or eliminated. Inhalation exposures to propylene glycol series ethers also presents possible concerns for developmental toxicity risks, based on margin-of-exposure calculations. Inhalation exposures to other components are very low. Risks from other ink remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Table IV-3
Occupational Risk Conclusions and Observations: Ink Removers

System	Observations
Method 5 (Automatic Screen Washer)	Mineral spirits Inhalation exposures were significantly lower (reduced by about 70%) than the exposures during manual use of this system. Risks could not be quantified because of limitations in hazard data. Dermal exposures can still be relatively high. Lacquer Thinner Hazard quotient calculations indicate marginal concerns for chronic inhalation exposures to toluene, methyl ethyl ketone, and methanol. Hazard quotient calculations indicate clear concerns for chronic dermal exposures to toluene and methyl ethyl ketone and marginal concerns for dermal exposures to methanol. The risks described above are slightly lower than the corresponding risks during manual use of this system. Risks from other components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Table IV-4
Environmental Releases in Screen Cleaning Operations: Ink Removers

	Release Under Each Scenario (g/day)						
	I			II	III	IV	
System	**Air**	**Water**	**Land**	**Air**	**Air**	**Air**	**Water**
Traditional Systems							
System 1							
Mineral spirits - light hydrotreated	54	0	1050	0.2	0.1	0.6	1350
System 2							
Acetone	1120	0	0	22	11	80	1270
Systems 3 & 4							
Methyl ethyl ketone	344	0	0	11	5.7	42	363
Butyl acetate, normal	92	0	80	2.6	1.5	11	191
Methanol	57	0	0	9.8	4.1	30	37
Naphtha, light aliphatic	204	0	25	3.2	1.7	13	257
Toluene	229	0	0	4.8	2.6	19	251
Isobutyl isobutyrate	15	0	100	0.8	0.5	3.4	132
Alternative Systems							
Alpha							
Aromatic solvent naphtha	27	0	473	0.1	0.1	0.5	1080
Propylene glycol series ethers	117	0	8	1.3	0.7	5.4	265
Beta							
2-Octadecanamine, N,N-dimethyl-, N-oxide or a modified amine from unsaturated soy bean oil fatty acid	609	0	0	9.1	6.3	0	0
Water	0	0	12	0	0	0	0
Chi							
Diethylene glycol series ethers	0.1	0	138	0	0	0	270
Propylene glycol series ethers	0.1	0	381	0	0	0	742
N-methylpyrrolidone	6.8	0	132	0.1	0	0.2	270
Ethoxylated nonylphenol	0	0	35	0	0	0	67
Delta							
Dibasic esters	3.7	0	319	0	0	0.2	608
Propylene glycol series ethers	0.1	0	359	0	0	0	675
Ethoxylated nonylphenol	0	0	36	0	0	0	67

Table IV-4
Environmental Releases in Screen Cleaning Operations: Ink Removers

	Release Under Each Scenario (g/day)						
	I			**II**	**III**	**IV**	
System	**Air**	**Water**	**Land**	**Air**	**Air**	**Air**	**Water**
Epsilon							
Cyclohexanone	82	0	126	0.7	0.4	2.9	402
Methoxypropanol acetate	36	0	68	0.8	0.5	3.6	199
Diethylene glycol	0	0	138	0	0	0	270
Benzyl alcohol	0.2	0	45	0	0	0	88
Derivatized plant oil	0.2	0	24	0.1	0	0.3	47
Aromatic solvent naphtha	3.2	0	66	0.1	0.1	0.5	135
Diacetone alcohol	9.6	0	94	0.2	0.1	0.8	202
Gamma							
Diethylene glycol butyl ether acetate	0	0	28	0	0	0	54
Tripropylene glycol methyl ether	0.1	0	355	0	0	0	675
Derivatized plant oil	0.3	0	28	0.1	0	0.3	54
Fatty alcohol ethers	0.8	0	84	0	0	0.1	162
Dibasic esters	2.7	0	210	0	0	0.3	405
Mu							
Dibasic esters	5.1	0	446	0	0	0.3	877
Methoxypropanol acetate	64	0	75	0.8	0.5	3.6	266
d-Limonene	43	0	27	1.2	0.7	5.1	130
Ethoxylated nonylphenol	0	0	42	0	0	0	81
Derivatized plant oil	0.3	0	27	0.1	0	0.3	54
Phi							
Dibasic esters	8.1	0	766	0	0	0.3	1349
Omicron AE & Omicron AF							
Diethylene glycol butyl ether	0	0	440	0	0	0	852
Propylene glycol	35	0	222	0.2	0.1	0.7	497
Zeta							
Propylene glycol series ethers	290	0	375	1.4	0.8	5.8	1345
Method 5 (Automatic Screen Washer) Using Mineral Spirits							
Mineral Spirits	15.1	NA[a]	NA	NA	NA	NA	NA

Table IV-4
Environmental Releases in Screen Cleaning Operations: Ink Removers

	Release Under Each Scenario (g/day)						
	I			II	III	IV	
System	**Air**	**Water**	**Land**	**Air**	**Air**	**Air**	**Water**
Method 5 (Automatic Screen Washer) Using Lacquer Thinner							
Methyl ethyl ketone	335	NA[a]	NA	NA	NA	NA	NA
Butyl acetate, normal	27.7	NA	NA	NA	NA	NA	NA
Methanol	91.5	NA	NA	NA	NA	NA	NA
Naphtha, light aliphatic	57.7	NA	NA	NA	NA	NA	NA
Toluene	80.7	NA	NA	NA	NA	NA	NA
Isobutyl isobutyrate	4.6	NA	NA	NA	NA	NA	NA

[a] This analysis did not estimate releases to water or land from automatic screen washing.

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = transferring waste rags from a storage drum to a "laundry bag."

Ecological Risks from Water Releases of Screen Reclamation Chemicals

- Cumulative releases of mineral spirits from Traditional System 1 present a concern for risk to aquatic species. The largest contributor to these releases is the hypothetical commercial laundry that launders the shop rags used by the area's screen printers.
- None of the other components of any of the four traditional systems reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.
- None of the single facility releases of either traditional or alternative systems reach an ecotoxicity concern concentration.

General Population Exposure Conclusions and Observations

- Health risks to the general population from both air and water exposures are very low for all of the ink removers evaluated.

Emulsion Removal Function

Substitute Comparative Assessment

Table IV-5 below lists some of the chemical emulsion removers that are available to screen printers. Table IV-5 includes a summary of key physical properties, a brief hazard summary, and a list of purchase prices for each emulsion remover. For information on the chemical properties and industrial synthesis of the bulk chemicals, refer to Chapter II. Market information on the volume of specific emulsion remover products sold is not available.

Table IV-5
Hazard Summaries and Cost: Emulsion Removers

Formulation[a]	% VOC, Flash Pt., V.P.[b], (per formulation)	Hazard Summary		Purchase Cost
		Health Effects Description	Aquatic Hazard Rankings[c]	
Traditional Systems				
Systems 1, 2, & 3 12% Sodium hypochlorite (bleach) 88% Water	0 % NA NA	developmental toxicity; genetic toxicity; chronic toxicity	Medium	$1.80/gallon
System 4 1% Sodium periodate 99% Water (as applied)	0 % NA NA	NA	High	$23.00/gallon (5% sodium periodate)
Alternative Systems				
Alpha Sodium periodate Water	0 % NA	NA	High	$4.00/gallon
Chi Sodium periodate Water	0 % NA NA	NA	High	$32.00/gallon (5 gallons/$160 15 gallons/$438 55 gallons/$1,238)
Delta Sodium periodate Water	0% NA NA	NA	High	$32.00/gallon (5 gallons/$160 15 gallons/$438 55 gallons/$1,238)
Epsilon Sodium periodate Sulfate salt Water	0 % NA unknown	corrosive	High Medium	$13.54/pound (5 kg/$149)
Gamma Sodium periodate Sulfate salt Phosphate salt Water	0 % NA 23.4 mm Hg (water)	chronic toxicity; corrosive	High Medium High	$1.60/pound (15 kg/$53)

Table IV-5
Hazard Summaries and Cost: Emulsion Removers

Formulation[a]	% VOC, Flash Pt., V.P.[b], (per formulation)	Hazard Summary		Purchase Cost
		Health Effects Description	Aquatic Hazard Rankings[c]	
<u>Mu</u> Periodic acid Water	0 % NA NA	NA	High	$10.34/gallon (three 5-liter units/$41 (5 gallons/$51.73))
<u>Phi</u> Sodium periodate Ethoxylated nonylphenol Other Water	0% NA 23.4 mm Hg (water)	NA	High Medium Low	$24.95/gallon
<u>Omicron AE & Omicron AF</u> Sodium periodate Ethoxylated nonylphenol Water	0 % NA 23.4 mm Hg (water)	NA	High Medium	$11.00/gallon (5 gallons/$55 55 gallons/$530)
<u>Theta</u> Sodium periodate Water	0% NA NA	NA	High	$21.95/gallon[e]
<u>Zeta</u> Sodium periodate Water	0 % NA 20 mm Hg	NA	High	$23.00/gallon

[a] While many of these formulations may seem similar, they may vary in the composition of specific components.

[b] V.P. means vapor pressure.

[b] The hazard rankings shown identify the categories (low, medium, or high) into which the individual components of the product system fall. The aquatic hazard ranking for each chemical is listed on the same line as the chemical name. When an alternative system includes chemicals from a chemical category (see Table II-2), the hazard ranking shown is the range of the rankings of all of the individual chemicals comprising the category. This analysis did not estimate the aquatic hazard ranking of the product systems as mixtures.

[d] NA means not available.

[e] Product system also requires a fixed cost of $13,165. Reference Method 4 in Chapter V.

Exposure Analysis & Risk Characterization

For specific assumptions and details of the occupational exposure, environmental releases and risk assessment, please reference Chapter III.

Table IV-6
Occupational Exposures: Emulsion Removers

System	Inhalation Exposures, by Scenario (mg/day)				Dermal Exposures, (mg/day)	
	I	II	III	IV	Routine	Immersion
Traditional Product Systems						
Systems 1 & 3 (Bleach)[a]						
Sodium hypochlorite (12%)	0	0	0	0	187	874
Water	0	0	0	0	1370	6410
Systems 2 & 4 (Zeta diluted 1:4)						
Sodium periodate (1%)	0	0	0	0	16	73
Water	0	0	0	0	1540	7210
Alternative Systems						
Alpha (diluted to 0.8%)						
Sodium periodate	0	0	0	0	12	58
Water	0	0	0	0	1550	7220
Chi (diluted 1:4)						
Sodium periodate	0	0	0	0	16	73
Water	0	0	0	0	1540	7210
Delta (diluted 1:4)						
Sodium periodate	0	0	0	0	39	182
Water	0	0	0	0	1520	7100
Epsilon (3% chemicals, 97% water)						
Sodium periodate	0	0	0	0	23	109
Sulfate salt	0	0	0	0	23	109
Water	0	0	0	0	1510	7060
Gamma						
Sodium periodate	0	0	0	0	39	182
Sulfate salt	0	0	0	0	16	73
Phosphate salt	0	0	0	0	117	546
Other	0	0	0	0	117	546
Water	0	0	0	0	1270	5930
Mu						
Periodic acid	0	0	0	0	156	728
Water	0	0	0	0	1400	6550
Phi						
Sodium periodate	0	0	0	0	47	218
Water	0	0	0	0	1210	5640
Ethoxylated nonylphenol	0	0	0	0	123	575
Other	0	0	0	0	181	844

Table IV-6
Occupational Exposures: Emulsion Removers

	Inhalation Exposures, by Scenario (mg/day)				Dermal Exposures, (mg/day)	
System	I	II	III	IV	Routine	Immersion
Omicron AE & Omicron AF						
Sodium periodate	0	0	0	0	47	218
Ethoxylated nonylphenol	0	0	0	0	31	146
Water	0	0	0	0	1480	6920
Zeta (diluted 1:4)						
Sodium periodate	0	0	0	0	16	73
Water	0	0	0	0	1540	7210
Theta (Method 4)[b]						
Sodium periodate	0	0	0	0	1250	5820
Water	0	0	0	0	312	1460
Theta (Method 4) (diluted 1:3)						
Sodium periodate	0	0	0	0	312	1460
Water	0	0	0	0	1250	5820

[a] Dermal exposures presented are worst-case and the use of gloves is expected due to irritation and corrosive effects.

[b] This system can be used with or without diluted emulsion remover, depending on the needs of the facility.

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = transferring waste rags from a storage drum to a "laundry bag."

Occupational Risk Conclusions and Observations

All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Table IV-7
Environmental Releases in Screen Cleaning Operations: Emulsion Removers

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	Air	Water	Land	Air	Air	Air	Water
Traditional Product Systems							
Systems 1 & 3 (Bleach)							
Sodium hypochlorite	0	75	0	0	0	0	0
Water	0	546	0	0	0	0	0
System 2 & 4 (Zeta diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0
Alternative Systems							
Alpha (diluted to 0.8%)							
Sodium periodate	0	5	0	0	0	0	0
Water	0	616	0	0	0	0	0
Chi (diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0
Delta (diluted 1:4)							
Sodium periodate	0	16	0	0	0	0	0
Water	0	605	0	0	0	0	0
Epsilon (diluted to 3%)							
Sodium periodate	0	9	0	0	0	0	0
Sodium salt	0	9	0	0	0	0	0
Water	0	602	0	0	0	0	0
Gamma							
Sodium periodate	0	16	0	0	0	0	0
Sulfate salt	0	6	0	0	0	0	0
Phosphate salt	0	47	0	0	0	0	0
Other	0	47	0	0	0	0	0
Water	0	506	0	0	0	0	0
Mu							
Periodic acid	0	62	0	0	0	0	0
Water	0	559	0	0	0	0	0

Table IV-7
Environmental Releases in Screen Cleaning Operations: Emulsion Removers

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	Air	Water	Land	Air	Air	Air	Water
Phi							
Sodium periodate	0	19	0	0	0	0	0
Water	0	481	0	0	0	0	0
Ethoxylated nonylphenol	0	49	0	0	0	0	0
Other	0	72	0	0	0	0	0
Omicron AE & Omicron AF							
Sodium periodate	0	19	0	0	0	0	0
Ethoxylated nonylphenol	0	13	0	0	0	0	0
Water	0	603	0	0	0	0	0
Zeta (diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0
Theta (Method 4)							
Sodium periodate	0	177	0	0	0	0	0
Water	0	44	0	0	0	0	0
Theta (Method 4) (diluted 1:3)							
Sodium periodate	0	44	0	0	0	0	0
Water	0	177	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = transferring waste rags from a storage drum to a "laundry bag."

General Population Exposure Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for all of the emulsion removers evaluated.

Ecological Risks from Water Releases of Screen Reclamation Chemicals

○ None of the single facility releases of emulsion removers reach an ecotoxicity concern concentration.

Haze Removal Function

Substitute Comparative Assessment

Table IV-8 below lists some of the chemical haze removers that are available to screen printers. Table IV-8 includes a summary of key physical properties, a brief hazard summary, and a list of purchase prices for each emulsion remover. For information on the chemical properties and industrial synthesis of the bulk chemicals, refer to Chapter II. Market information on the volume of specific haze remover products sold is not available.

Table IV-8
Hazard Summaries and Cost: Haze Removers

Formulation	% VOC Flash Pt. V.P.[a]	Hazard Summary		Purchase Cost
		Health Effects Description	Aquatic Hazard Rankings[b]	
Traditional Product Systems				
Systems 1, 2, 3, & 4 10% Xylene 30% Acetone 30% Mineral spirits 30% Cyclohexanone	100%	developmental toxicity; reproductive toxicity; genetic toxicity; neurotoxicity; chronic toxicity	Medium Low High Low	$5.12/gallon
Alternative Systems				
Alpha Alkali/caustic Tetrahydrofurfuryl alcohol Water	< 15 % 183 F NA[c]	corrosive	Low Medium	$9.39/gallon (5 kg/$50)
Chi Diethylene glycol series ethers Propylene glycol series ethers N-methyl pyrrolidone Ethoxylated nonylphenol	94 % < 200 F < 0.1 mm Hg	developmental toxicity; reproductive toxicity; chronic toxicity	Low/Medium Low/Medium Low Medium	$31.20/gallon (5 gallons/$156 55 gallons/$1,315)
Delta Dibasic esters Propylene glycol series ethers Ethoxylated nonylphenol	94 % < 200 F < 1.0 mm Hg	developmental toxicity; chronic toxicity	Medium Low/Medium Medium	$20.00/gallon (5 gallons/$100 55 gallons/$900)

Table IV-8
Hazard Summaries and Cost: Haze Removers

		Hazard Summary		
Formulation	**% VOC Flash Pt. V.P.[a]**	**Health Effects Description**	**Aquatic Hazard Rankings[b]**	**Purchase Cost**
Epsilon Alkyl benzene sulfonates Ethoxylated nonylphenol Phosphate salt Sodium hydroxide Derivatized plant oil Cyclohexanone Methoxypropanol acetate Diethylene glycol Benzyl alcohol Diacetone alcohol Aromatic solvent naphtha Derivatized plant oil Water	unknown NA unknown	developmental toxicity; reproductive toxicity; genetic toxicity; neurotoxicity; chronic toxicity; corrosive	Medium Medium High Low Low/High Low Medium Low Medium Low Medium Low/High	$1.09/lb (15 kg/$36)
Gamma Sodium hypochlorite Alkali/caustic Sodium alkyl sulfate Water	0 % NA < 0.2 mm Hg (@ 70 F)	developmental toxicity; genetic toxicity; chronic toxicity; corrosive	Medium Low Medium	$9.39/gallon (25 liters/$62))
Mu Sodium hypochlorite Alkali/caustic Sodium alkyl sulfate Water	0 % NA NA	developmental toxicity; genetic toxicity; chronic toxicity; corrosive	Medium Low Medium	$7.57/gallon (five 5-liter units/$50))
Phi N-methyl pyrrolidone Dibasic esters	NA > 185 F 0.195	developmental toxicity; reproductive toxicity; chronic toxicity	Low Medium	$39.95/gallon
Omicron AE Ethoxylated nonylphenol Phosphate surfactant Other Water	unknown 210 F 0.1 mm Hg	limited hazard data	Medium High Low	$18.00/gallon (5 gallons/$90)
Omicron AF Ethoxylated nonylphenol Phosphate surfactant Alkali/caustic Other Water	unknown unknown < 1 mm Hg	corrosive	Medium High Low Low	$18.00/gallon 5 gallons/$90

Table IV-8
Hazard Summaries and Cost: Haze Removers

Formulation	% VOC Flash Pt. V.P.[a]	Hazard Summary		Purchase Cost
		Health Effects Description	Aquatic Hazard Rankings[b]	
<u>Theta</u>				
Alkali/caustic	unavailable	developmental toxicity; reproductive toxicity; genetic toxicity; neurotoxicity; chronic toxicity; corrosive	Medium	$43.00/gallon[d]
Cyclohexanone	171 F		Low	
Furfuryl alcohol	NA		Medium	
<u>Zeta</u>				
Alkali/caustic	100 %	corrosive	Low	$30.00/gallon
Propylene glycol	101 F		Low	
Water	0.4-10.5 mm Hg			

[a] V.P. means vapor pressure.

[b] The hazard rankings shown identify the categories (low, medium, or high) into which the individual components of the product system fall. The aquatic hazard ranking for each chemical is listed on the same line as the chemical name. When an alternative system includes chemicals from a chemical category (see Table II-2), the hazard ranking shown is the range of the rankings of all of the individual chemicals comprising the category. This analysis did not estimate the aquatic hazard ranking of the product systems as mixtures.

[c] NA means not available.

[d] Product system also requires a fixed cost of $13,165. Reference Method 4 in Chapter V.

Exposure Analysis & Risk Characterization

For specific assumptions and details of the occupational exposure, environmental releases and risk assessment, please reference Chapter III.

Table IV-9
Occupational Exposures: Haze Removers

System	Inhalation Exposures, by Scenario (mg/day)				Dermal Exposures, (mg/day)	
	I	II	III	IV	Routine	Immersion
Traditional Systems						
Systems 1, 2, 3, and 4						
Xylenes (mixed)	21	0.9	1	0	156	728
Acetone	64	11	5	0	468	2180
Mineral spirits-light hydrotreated	7	0.1	0	0	468	2180
Cyclohexanone	27	0.3	0	0	468	2180
Alternative Systems						
Alpha						
Alkali/caustic[a]	0	0	0	0	390	1820
Tetrahydrofurfuryl alcohol	1	0.1	0	0	234	1090
Water	0	0	0	0	936	4370
Chi						
Diethylene glycol series ethers	0	0	0	0	312	1456
Propylene glycol series ethers	0	0	0	0	858	4000
N-methylpyrrolidone	3	0	0	0	312	1460
Ethoxylated nonylphenol	0	0	0	0	78	364
Delta						
Dibasic esters	2	0	0	0	702	3280
Propylene glycol series ethers	0	0	0	0	780	3640
Ethoxylated nonylphenol	0	0	0	0	78	364
Epsilon						
Cyclohexanone	12	0.3	0.2	0	234	109
Methoxypropanol acetate	5.2	0.4	0.2	0	117	546
Diethylene glycol	0	0	0	0	156	728
Benzyl alcohol	0	0	0	0	51	273
Derivatized plant oil	0	0	0	0	27	127
Aromatic solvent naphtha	0.5	0.1	0	0	78	364
Diacetone alcohol	1.4	0.1	0.1	0	62	291
Alkyl benzene sulfonates	0	0	0	0	140	655
Ethoxylated nonylphenol	0	0	0	0	62	291
Phosphate salt	0	0	0	0	117	546
Alkali/caustic[a]	0	0	0	0	408	1890
Water	0	0	0	0	109	510
Gamma						
Sodium hypochlorite[a]	0	0	0	0	585	2730
Alkali/caustic[a]	0	0	0	0	39	182
Water	0	0	0	0	827	3860
Sodium alkyl sulfate	0	0	0	0	109	510

Table IV-9
Occupational Exposures: Haze Removers

	Inhalation Exposures, by Scenario (mg/day)				Dermal Exposures, (mg/day)	
Mu **System**						
Sodium hypochlorite[a]	0	0	0	0	585	2730
Alkali/caustic[a]	0	0	0	0	39	182
Water	0	0	0	0	827	3860
Sodium alkyl sulfate	0	0	0	0	109	510
Phi						
N-methylpyrrolidone	6	0	0	0	780	3640
Dibasic esters	1	0	0	0	780	3639
Omicron AE						
Other	0	0	0	0	109	510
Ethoxylated nonylphenol	0	0	0	0	16	73
Phosphate surfactant	0	0	0	0	78	364
Water	0	0	0	0	1360	6330
Omicron AF						
Ethoxylated nonylphenol	0	0	0	0	16	73
Alkali/caustic[a]	0	0	0	0	156	728
Phosphate surfactant	0	0	0	0	78	364
Other	0	0	0	0	109	510
Water	0	0	0	0	1200	5610
Zeta						
Alkali/caustic[a]	0	0	0	0	234	1090
Propylene glycol	0	0.1	0	0	62	291
Water	0	0	0	0	1260	5900
Theta (Method 4)						
Alkali/caustic[a]	0	0	0	0	515	2400
Cyclohexanone	25	0.3	0	0	515	2400
Furfural alcohol	0	0	0	0	530	2480

[a] Dermal exposures presented are worst-case and the use of gloves is expected due to irritation and corrosive effects.

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = transferring waste rags from a storage drum to a "laundry bag."

Table IV-10
Occupational Risk Conclusions and Observations: Haze Removers

System	Observations
Traditional Product Systems	
Systems 1, 2, 3, & 4	Hazard quotient calculations indicate clear concerns for chronic dermal and inhalation exposures to workers using acetone in haze removal. Hazard quotient calculations indicate marginal concerns for chronic dermal exposures to workers using xylene and cyclohexanone in haze removal. Margin-of-exposure calculations indicate very low concern for developmental and reproductive toxicity risks from inhalation of cyclohexanone. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified. Dermal exposures to workers using mineral spirits in haze removal can be very high, although the risks from mineral spirits could not be quantified because of limitations in hazard data.
Alternative Systems	
Alpha	Dermal exposures to other chemicals used in haze removal can be high, although the risks could not be quantified because of limitations in hazard data.
Chi	Clear concerns exist for chronic dermal exposures to diethylene glycol series ethers used in haze removal based on the calculated margins-of-exposure. Concerns exist for developmental toxicity risks from dermal exposures to N-methylpyrrolidone based on the calculated margin-of-exposure. Similar calculations for inhalation exposures to N-methylpyrrolidone indicate very low concern. Inhalation exposures to other haze remover components are very low. Dermal risks from other haze remover components could not be quantified because of limitations in hazard data, but exposures can be high.
Delta	Although no risks could be quantified because of limitations in hazard data, relatively high dermal exposures to haze remover components could occur. Inhalation exposures to all components are very low.
Epsilon	Hazard quotient calculations indicate marginal concerns for chronic dermal exposures to cyclohexanone and benzyl alcohol during haze removal. Similar calculations for inhalation exposures to cyclohexanone and benzyl alcohol indicate low concern. Hazard quotient calculations indicate marginal concerns for chronic dermal exposures and low concern for chronic inhalation exposures to methoxypropanol acetate. Risks from other haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Table IV-10
Occupational Risk Conclusions and Observations: Haze Removers

System	Observations
Gamma	Developmental and chronic toxicity risks from dermal exposures to sodium alkyl sulfate in haze remover are very low based on the calculated margin of exposure. Inhalation exposures to all components are very low. Risks from other haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
Mu	Developmental and chronic toxicity risks from dermal exposures to sodium alkyl sulfate in haze remover are very low based on the calculated margin of exposure. Risks from other haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
Phi	Dermal exposures to N-methylpyrrolidone during haze removal present a concern for developmental toxicity risk based on the calculated margins-of-exposure. Similar estimates for inhalation exposures to N-methylpyrrolidone indicate very low concern. Inhalation exposures to all other components are very low. Risks from other haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
Omicron AE	Inhalation exposures to components are very low. Risks from components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
Omicron AF	Inhalation exposures to components are very low. Risks from components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
Zeta	Hazard quotient calculations for chronic inhalation and dermal exposures to propylene glycol during haze removal indicate very low concern. Inhalation exposures to other components are very low. Risks from other haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Table IV-10
Occupational Risk Conclusions and Observations: Haze Removers

System	Observations
Theta (Method 4)	Hazard quotient calculations indicate marginal concerns for chronic dermal exposures and very low concern for chronic inhalation exposures to cyclohexanone during haze removal. Margin-of-exposure calculations show low concern for developmental and reproductive toxicity risks from inhalation exposures to cyclohexanone. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified. Inhalation exposures to other components are very low. Risks from other haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Table IV-11
Environmental Releases in Screen Cleaning Operations: Haze Removers

	Release Under Each Scenario (g/day)						
	I			II	III	IV	
System	**Air**	**Water**	**Land**	**Air**	**Air**	**Air**	**Water**
Traditional Product Systems							
Systems 1, 2, 3, & 4							
Xylenes (mixed isomers)	44	0	0	1.9	1.1	0	0
Acetone	133	0	0	22	11	0	0
Mineral spirits- light hydrotreated	15	119	0	0.2	0.1	0	0
Cyclohexanone	57	76	0	0.7	0.4	0	0
Alternative Systems							
Alpha							
Alkali/caustic	0	133	0	0	0	0	0
Tetrahydrofurfuryl alcohol	1.5	78	0	0.1	0.1	0	0
Water	0	319	0	0	0	0	0
Chi							
Diethylene glycol series ethers	0.1	104	0	0	0	0	0
Tripropylene glycol series ethers	0.1	286	0	0	0	0	0
N-methylpyrrolidone	6.8	97	0	0.1	0	0	0
Ethoxylated nonylphenol	0	26	0	0	0	0	0
Delta							
Dibasic esters	3.7	239	0	0	0	0	0
Tripropylene glycol series ethers	0.1	269	0	0	0	0	0
Ethoxylated nonylphenol	0	27	0	0	0	0	0
Epsilon							
Cyclohexanone	25	55	0	0.7	0.7	0.4	0
Methoxypropanol acetate	11	29	0	0.8	0.8	0.5	0
Diethylene glycol	0	53	0	0	0	0	0
Benzyl alcohol	0.1	17	0	0	0	0	0
Derivatized plant oil	0.1	9.3	0	0.1	0.1	0	0
Aromatic solvent naphtha	1	26	0	0.1	0.1	0.1	0
Diacetone alcohol	2.9	37	0	0.2	0.2	0.1	0
Alkyl benzene sulfonates	0	48	0	0	0	0	0
Ethoxylated nonylphenol	0	21	0	0	0	0	0
Alkali/caustic	0	138	0	0	0	0	0
Water	0	37	0	0	0	0	0
Phosphate salt	0	21	0	0	0	0	0

Table IV-11
Environmental Releases in Screen Cleaning Operations: Haze Removers

	Release Under Each Scenario (g/day)						
	I			II	III	IV	
System	Air	Water	Land	Air	Air	Air	Water
Gamma							
Sodium hypochlorite	0	200	0	0	0	0	0
Alkali/caustic	0	13	0	0	0	0	0
Water	0	282	0	0	0	0	0
Sodium alkyl sulfate	0	37	0	0	0	0	0
Mu							
Sodium hypochlorite	0	200	0	0	0	0	0
Alkali/caustic	0	13	0	0	0	0	0
Water	0	282	0	0	0	0	0
Sodium alkyl sulfate	0	37	0	0	0	0	0
Phi							
N-methylpyrrolidone	12	270	0	0.1	0	0	0
Dibasic esters	3.1	279	0	0	0	0	0
Omicron AE							
Other	0	43	0	0	0	0	0
Ethoxylated nonylphenol	0	6.2	0	0	0	0	0
Phosphate surfactant	0	31	0	0	0	0	0
Water	0	540	0	0	0	0	0
Omicron AF							
Ethoxylated nonylphenol	0	5.6	0	0	0	0	0
Alkali/caustic	0	56	0	0	0	0	0
Phosphate surfactant	0	28	0	0	0	0	0
Other	0	39	0	0	0	0	0
Water	0	428	0	0	0	0	0
Zeta							
Alkali/caustic	0	80	0	0	0	0	0
Propylene glycol	0.7	21	0	0.2	0.1	0	0
Water	0	431	0	0	0	0	0
Theta (Method 4)							
Alkali/caustic	0	291	0	0	0	0	0
Cyclohexanone	53	239	0	0.7	0.4	0	0
Furfural alcohol	0	300	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = transferring waste rags from a storage drum to a "laundry bag."

General Population Exposure Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for all of the haze removers evaluated.

Ecological Risks from Water Releases of Screen Reclamation Chemicals

○ None of the single facility releases of haze removal chemicals reach an ecotoxicity concern concentration.

Manufacturing of Screen Reclamation Chemical Products

Manufacturing Process

Most screen reclamation chemical products are formulated in facilities outside of the United States.[1] The basic process description that follows is based primarily on conversations with two formulation manufacturers in the United States and may not describe the range of manufacturing processes used by formulation manufacturers elsewhere.[2,3]

Screen reclamation chemical products typically consist of a mixture of two or more liquid and/or solid chemicals. In some cases, the mixture may include water used as a diluent or to dissolve solids and facilitate the spray application of the product. Regardless of whether the product is an ink remover, emulsion remover or haze remover, the basic manufacturing process is the same, as described below.

Chemical ingredients are received from a chemical manufacturer or distributor in small (55 gallon drums or 350 gallon totes) or large (tanker trucks) quantities and stored on-site. Small quantities are typically stored on pallets or racks on the process floor in a designated area without separate ventilation. Large quantities may be stored in dedicated storage tanks.

Chemicals are pumped or emptied by weight into a mixing vessel. The mixing vessel is covered and ingredients are agitated or mixed using turbine or rotary blade/propeller mixing, aeration and shear dispersion. The addition of heat or pressure is not normally required to accomplish the mixing step. Typically, mixing vessels do not have a separate ventilation system (e.g., ventilation is to the process room).

Products are usually packaged in 55 gallon drums, 15 gallon drums, 5 gallon pails and one gallon jugs, although other sizes are available if requested by the customer. Containers are filled manually with a hand-held pump and semi-automated fillers or by pouring from smaller mixing

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[1] Correspondence between Marci A. Kinter, SPAI, and Lori Kincaid, University of Tennessee, June 1994.

[2] Correspondence between Oliver Nichols, Nichols and Associates, and Dean Menke, University of Tennessee, June 1994.

[3] Correspondence between Clark King, Kiwo, and Dean Menke, University of Tennessee, June 1994.

vessels (e.g., 55 gallon drums). Employees wear gloves, goggles, and respirators when needed. Packaged products may be inventoried on the process floor, in a separate designated area or stored outside of the process area pending distribution.

Source Release Assessment: Product Formulation

Process air emissions of volatile organic compounds from product formulation processes can originate from the venting of mixing vessels. Fugitive air emissions can result when process fluid leaks from plant equipment such as pumps, compressors and process valves. Air emissions from storage and handling operations can also occur where screen reclamation products are formulated. Other potential sources of environmental releases or transfers include:

- wastewater discharges from a facility into rivers, streams or other bodies of water or transfers to a publicly-owned treatment works (POTW);

- on-site releases to landfills, surface impoundments, land treatment or another mode of land disposal; and

- transfer of wastes to off-site facilities for treatment, storage or disposal.

Energy and Natural Resources Issues

The use of different chemical products, processes or technologies in a use cluster can result in changes in the rate of energy and natural resources consumption, either in the product use stage, manufacture stage, or other life cycle stages (e.g., extraction of raw materials, transportation, disposal, etc.). The processes used to formulate traditional versus alternative screen reclamation chemical products appear to be similar, however, with no differences that would significantly influence the rate of energy or natural resources consumption during product manufacturing. The following lists potential energy and natural resources issues that should be considered when choosing among alternatives.

- The energy required to manufacture the chemical ingredients of screen reclamation products can vary substantially. For example, the energy required to manufacture solvents derived from plants using a cold-press process may be less than that required in a hot-press process.

- Products manufactured from petrochemicals have an energy equivalence, as do other products with sufficient energy content to be used as fuel. The amount of petrochemicals used to manufacture screen reclamation products, however, is small compared to other uses of petroleum-based products.

- Products manufactured from petrochemicals are also derived from a nonrenewable resource, petroleum. However, products manufactured from renewable resources, such as plants, frequently use petrochemicals at some point in the chemical manufacturing process. In either case, the amount of petrochemicals used to manufacture screen reclamation products is small compared to other uses of petroleum-based products.

- Products that are formulated using heat or pressure to dissolve product ingredients or cause a chemical reaction consume more energy than those manufactured using simple mixing processes.

- Compared to undiluted products, formulations that are diluted with water prior to shipping result in greater energy consumption during transportation of the product from the manufacturer to the printing facility.

Chapter V
Substitute Comparative Assessment, Screen Reclamation Methods

Introduction

Chapter 5 provides a comprehensive assessment of screen reclamation methods 1-4 and the automatic screen washer. When available, information is provided for each method and technology on occupational exposure and risk, population exposure and risk, performance of traditional and alternative systems, and the cost analysis of traditional and alternative systems. The discussion of the details of each method or technology includes an explanation of the particular advantages or disadvantages of that method or technology. The details, assumptions and uncertainties of each of the methodologies in this chapter are discussed in Chapter 3; referencing this chapter while reading Chapter 5 may eliminate the confusion that may occur due to the numerous exhibits.

Method 1: Traditional Reclamation

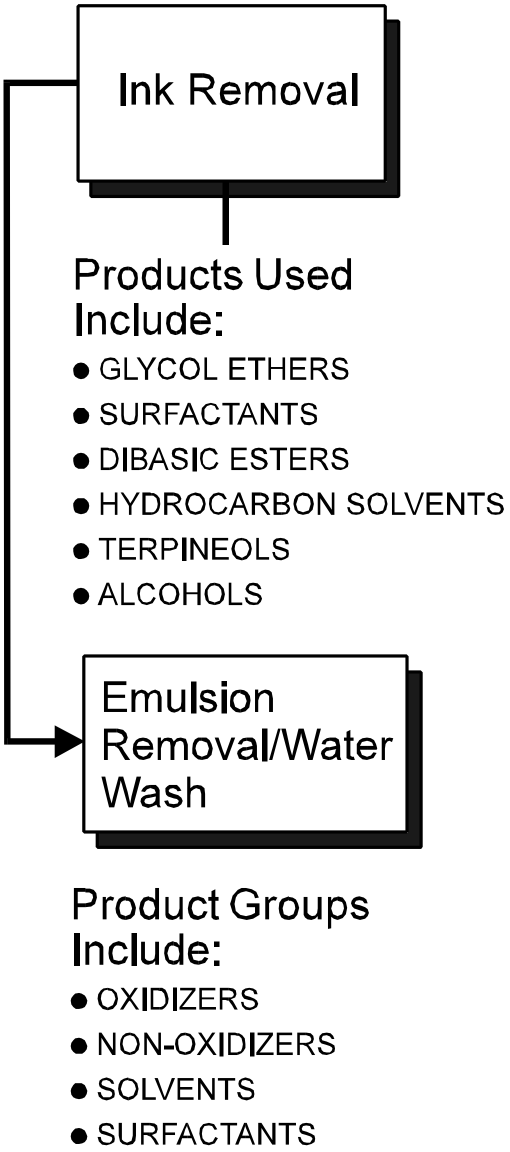
Method 1 encompasses the use of only ink removal and emulsion removal chemical products to reclaim screens. The action of these two products must eliminate the use of a haze remover. Some screen printers are able to reclaim screens without the need for a haze remover. Because a haze remover is not used in screen reclamation in Method 1, source reduction, the highest priority in the pollution prevention hierarchy, is achieved. However, simply because the haze remover is not used does not mean that occupational and population risk is low. The intrinsic hazard of the particular chemicals used in ink and emulsion remover products must be combined with worker and general exposure to the chemicals to generate a risk assessment. In the following discussion of Method 1, data detailing occupational and population exposure are presented to support overall risk conclusions for 6 systems comprised of only ink and emulsion removal products: Traditional Systems 1, 2, 3 and 4, Alternative System Chi, and Alternative Ink remover Beta. Limited performance and/or cost information is available for Traditional Systems 1, 2, 3 and 4, and Alternative System Chi. Figure V-1 provides a schematic illustration of the product groups used in the two steps required under Method 1.

Traditional System 1

Formulation

Ink Remover:	100% Mineral spirits
Emulsion Remover:	12 wt% Sodium hypochlorite/ 88% water

Figure V - 1
Process Steps Included in Method 1



Occupational Exposure

Table V-1
Occupational Exposure Estimates for Method 1, Traditional System 1

	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Mineral spirits- light hydrotreated	26	0.1	0	0.3	1560	7280
Emulsion Remover						
Sodium hypochlorite	0	0	0	0	187	874
Water	0	0	0	0	1370	6410

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Occupational Risk Estimates

Quantitative risk estimates could not be determined for this system due to insufficient data. See risk conclusions for areas of concern for this system.

Occupational Risk Conclusions and Observations

Ink Remover

○ Dermal exposures to workers using mineral spirits in ink removal can be very high, although the risks from mineral spirits could not be quantified because of limitations in hazard data.

Emulsion Removers (All Systems)

○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-2
Estimated Environmental Releases for Screen Cleaning Operations
Method 1, Traditional System 1

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	Air	Water	Land	Air	Air	Air	Water
Ink Remover							
Mineral spirits- light hydrotreated	54	0	1050	0.2	0.1	0.6	1350
Emulsion Remover							
Sodium hypochlorite	0	75	0	0	0	0	0
Water	0	546	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-3
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 1, Traditional System 1

Substance	To Air	To Water	To Landfill
Mineral Spirits	54.9 g/day	1350 g/day[a]	1050 g/day[a]
Sodium Hypochlorite		75 g/day	

[a] 1,350 g/day is estimated to be released from the rags. This release from the rags will be either to landfill or to water. If the release is to water through the laundry (launderable rags), then the landfill column is blank. If the release is to landfill (disposable rags), then the landfill column will be 1,050 g/day. This is true of all of the ink remover chemicals. For our purposes, the rest of the assessment assumes release to water only, since we are not assessing landfill releases.

Releases to Water from a Single Facility

Table V-4
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility
Screen Reclamation Method 1, Traditional System 1

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste Water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Mineral Spirits	1350 g/day at laundry	94%	81 g/day	8×10^{-2}
Sodium Hypochlorite[b]	75 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

[b] Concentrated solutions of sodium hypochlorite will kill the biota which degrade organic chemicals (the other substances listed in the table) during waste water treatment. This could cause problems at the waste water treatment plant, reducing the waste water treatment efficiency for the other compounds sent to the plant.

Releases to Water from Multiple Screen Printers

The concentrations listed in the chart above are relatively low. However, in the local area there may be many screen printers, all of which are connected to the same waste treatment facility. The concentration in the stream would be the combined amounts of all of the releases in the stream, which could be significant, even if the release from one screen printing facility is not.

To demonstrate the combined effects, the multiple screen printing facilities in St. Louis County, Missouri were picked as an example. The Dun and Bradstreet data shows 135 screen printing facilities in St. Louis County. We are assuming that the waste water from all of these is going to the St. Louis County Sewer Company, which releases into the Meramec River. Less than five kilometers downstream is the Kirkwood Water Department, and just about ten kilometers downstream is an intake for the St. Louis County Water company. These service an estimated 28 thousand people and one million people, respectively. The mean flow of the river is 7895 million liters per day (MLD), and is not any larger at the drinking water intakes than it is at the release point.

Table V-5
Estimated Cumulative Releases to Water for St. Louis County, MO
Screen Reclamation Method 1, Traditional System 1

Substance	Total Amount Released to Water from All Facilities	Waste Water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Average Concentration in Meramec River, ug/L (ppb)
Mineral Spirits	182 kg/day at laundry	94 %	11 kg/day	1
Sodium Hypochlorite	10 kg/day	100 %	0	0

Releases to Air from Individual Screen Printing Facilities

Table V-6
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Screen Reclamation Method 1, Traditional System 1

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Mineral Spirits	54.9 g/day	1 x 10^{-1} ug/m^3	7 x 10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 1, Traditional System 1.

Because of the low concentration estimate found from single source releases, multiple facility impacts are note likely to significantly raise concentration estimates. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2, and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

- ○ Cumulative releases of mineral spirits from Traditional System 1 present a concern for risk to aquatic species. The largest contributor to these releases is the hypothetical commercial laundry that launders the shop rags used by the area's screen printers.
- ○ None of the other components of Method 1, Traditional System 1 reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.
- ○ None of the single facility releases of Method 1, Traditional System 1 reach an ecotoxicity concern concentration.

The following table summarizes the exposure and risk estimates for cumulative releases of Traditional System 1. The analogous figures for single facilities show much lower exposure and risk levels.

Table V-7
Estimated Cumulative Releases to Water for St. Louis County, MO
Screen Reclamation Method 1, Traditional System 1

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Conc. in Meramec River, ug/L (ppb)	ECO CC (ug/l)	ECO Risk Indicator (Stream Conc/ ECO CC)
Mineral Spirits	16 kg/day + 182 kg/day at laundry	94 %	960 g/day 11 kg/day	1×10^{-1} 1	1	1.1
Sodium Hypochlorite	10 kg/day	100 %	0	0	<20	0

Performance

The performance of this system was not demonstrated at the Screen Printing Technical Foundation or at volunteer printing facilities. Since this system is commonly used in many screen printing shops, it was decided to use the limited resources available for a performance demonstration to evaluate alternatives to the traditionally used product systems.

Cost

Because the performance of this system was not determined in this project, the total cost of using this system was also not calculated.

Traditional System 2

Formulation

Ink Remover: 100% Acetone
Emulsion Remover: 1% Sodium periodate/ 99% water

Occupational Exposure

Table V-8
Occupational Exposure Estimates for Method 1, Traditional System 2

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Acetone	539	11	5	38	1560	7280
Emulsion Remover (Zeta diluted 1:4)						
Sodium periodate	0	0	0	0	16	73
Water	0	0	0	0	1540	7210

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Occupational Risk Conclusions and Observations

Ink Remover

○ Hazard quotient calculations indicate clear concerns for chronic dermal and inhalation exposures to workers using acetone in either ink removal or haze removal.

Emulsion Removers (All Systems)

○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Table V-9
Occupational Risk Estimates for Method 1, Traditional System 2.

Name	Hazard Quotient[b]			Margin Of Exposure[a]					
						Dermal			
		Dermal		Inhalation		Routine		Immersion	
	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
<u>Ink Remover</u>						NA	NA	NA	NA
Acetone	84	22	1,040	NA	NA	NA	NA	NA	NA
<u>Emulsion Remover (Zeta diluted 1:4)</u>									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

Environmental Releases

Table V-10
Estimated Environmental Releases in Screen Cleaning Operations
Method 1, Traditional System 2

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	Air	Water	Land	Air	Air	Air	Water
Ink Remover							
Acetone	1120	0	0	22	11	80	1270
Emulsion Remover (Zeta diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-11
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Method 1, Traditional System 2

Substance	To Air	To Water	To Landfill
Acetone	1,233 g/day	1,270[a] g/day	1,270[a] g/day
Sodium Periodate		6 g/day	

[a] 1,270 g/day is estimated to be released from the rags. This release from the rags will be either to landfill or to water. If the release is to water through the laundry, then the landfill column is blank. If the release is to landfill, then the landfill column will be 1,270 g/day and the water column will be empty. This is true of all of the ink remover chemicals. For our purposes, the rest of the assessment assumes release to water only, since we are not assessing landfill releases.

Releases to Water from a Single Facility

Table V-12
Estimated Releases to Water from Method 1, Traditional System 2

Substance	Amount Released to Water from Facility	Waste Water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1,000 MLD Receiving Water
Acetone	1270 g/day	87%	165 g/day	0.2
Sodium Periodate	6 g/day	100%	0 g/day	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Water from Multiple Screen Printers

The concentrations listed in the chart above are relatively low. However, in the local area there may be many screen printers, all of which are connected to the same waste treatment facility. The concentration in the stream would be the combined amounts of all of the releases in the stream, which could be significant, even if the release from one screen printing facility is not.

To demonstrate the combined effects, the multiple screen printing facilities in St. Louis County, Missouri were picked as an example. The Dun and Bradstreet data shows 135 screen printing facilities in St. Louis County. We are assuming that the waste water from all of these is going to the St. Louis County Sewer Company, which releases into the Meramec River. Less than five kilometers downstream is the Kirkwood Water Department, and just about ten kilometers downstream is an intake for the St. Louis County Water company. These service an estimated 28 thousand people and one million people, respectively. The mean flow of the river is 7895 million liters per day (MLD), and is not any larger at the drinking water intakes than it is at the release point.

Table V-13
Estimated Cumulative Releases to Water for St. Louis County, MO
Method 1, Traditional System 2

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Average Concentration in Meramec River, ug/L (ppb)
Acetone	171 kg/day	87%	22.3 kg/day	3
Sodium Periodate	810 g/day	>>99%	<< 8.1 g/day	<< 8 x 10^{-4}

[a] >> is very much greater than, << is very much less than.

Releases to Air from Individual Screen Printing Facilities

Table V-14
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Method 1, Traditional System 2

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Acetone	1233 g/day	3 ug/m^3	20

[a] This estimates doses for people living 100 Meters from hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 1, Traditional System 2.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2, and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the components of Method 1, Traditional System 2 reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.

○ None of the single facility releases of Method 1, Traditional System 2 reach an ecotoxicity concern concentration.

The following table summarizes the exposure and risk estimates for cumulative releases of Traditional System 2. The analogous figures for single facilities show much lower exposure and risk levels.

Table V-15
Estimated Cumulative Releases to Water for St. Louis County, MO
Screen Reclamation Method 2, Traditional System 2

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Conc. in Meramec River, ug/L (ppb)	ECO CC (ug/L)	ECO RISK INDICATOR (STREAM CONC/ ECO CC)
Acetone	171 kg/day	87%	22.3 kg/day	3	7600	$4x10^{-4}$
Sodium Periodate	810 g/day	>>99%	<< 8.1 g/day	<< 8×10^{-4}	<10	$\sim 10^{-5}$

Performance

The performance of this system was not demonstrated at the Screen Printing Technical Foundation or at volunteer printing facilities. Since this system is commonly used in many screen printing shops, it was decided to use the limited resources available for a performance demonstration to evaluate alternatives to the traditionally used product systems.

Cost

Because the performance of this system was not determined in this project, the total cost of using this system was also not calculated.

Traditional System 3

Formulation

Ink Remover: 100% Lacquer Thinner, consisting of:
30% Methyl ethyl ketone
15% n-butyl acetate
5% Methanol
20% Naphtha, light aliphatic
20% Toluene
10% Isobutyl isobutyrate
Emulsion Remover: 12 wt% Sodium hypochlorite, 88% water

Occupational Exposure

Table V-16
Occupational Exposure Estimates for Method 1, Traditional System 3

	Inhalation (mg/day)				Dermal (mg/day)	
System	I	II	III	IV	Routine	Immersion
Ink Remover						
Methyl ethyl ketone(2-butanone)	165	5.3	3	20	468	2180
Butyl acetate normal	44	1.3	1	5.3	234	1090
Methanol	27	4.7	2	15	78	364
Naphtha, light aliphatic	98	1.6	1	6.2	312	1460
Toluene	110	2.3	1	9.2	312	1460
Isobutyl isobutyrate	7	0.4	0	1.7	156	728
Emulsion Remover (Bleach)						
Sodium hypochlorite	0	0	0	0	187	874
Water	0	0	0	0	1370	874

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Occupational Risk Conclusions and Observations

Ink Remover

○ Hazard quotient calculations indicate clear concerns for both toluene and methyl ethyl ketone with respect to chronic dermal and inhalation exposures to workers using these chemicals in ink removal.

Table V-17
Occupational Risk Estimates for Method 2, Traditional System 3.

	Hazard Quotient[b]			Margin Of Exposure[a]					
						Dermal			
		Dermal		Inhalation		Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Methyl ethyl ketone (2-butanone)	9.2	22	103	NA	NA	NA	NA	NA	NA
Butyl acetate normal	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methanol	1.4	2.2	10	NA	NA	NA	NA	NA	NA
Aromatic solvent naphtha	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	17.	44.	208.	NA	NA	NA	NA	NA	NA
Isobutyl isobutyrate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover (Bleach)									
Sodium hypochlorite	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.
[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.
[c] NOAEL means No Observed Adverse Effect Level.
[d] LOAEL means Lowest Observed Adverse Effect Level.

○ Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using methanol in ink removal.

Emulsion Removers (All Systems)

○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-18
Estimated Environmental Releases in Screen Cleaning Operations
Method 1, Traditional System 3

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Methyl ethyl ketone(2-butanone)	344	0	0	11	5.7	42	363
Butyl acetate normal	92	0	80	2.6	1.5	11	191
Methanol	57	0	0	9.8	4.1	30	37
Naphtha, light aliphatic	204	0	25	3.2	1.7	13	257
Toluene	229	0	0	4.8	2.6	19	251
Isobutyl isobutyrate	15	0	100	0.8	0.5	3.4	132
Emulsion Remover (Bleach)							
Sodium hypochlorite	0	75	0	0	0	0	0
Water	0	546	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-19
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Method 1, Traditional System 3

Substance:	To Air:	To Water:	To Landfill:
Methyl ethyl ketone	403 g/day	363 g/day at laundry	
n-butyl Acetate	107 g/day	191 g/day at laundry[a]	80 g/day[a]
Methanol	101 g/day	37 g/day at laundry	
Naphtha, light aliphatic	222 g/day	257 g/day at laundry	25 g/day
Toluene	255 g/day	251 g/day at laundry	
Isobutyl isobutyrate	19.7 g/day	132 g/day at laundry	100 g/day
Sodium hypochlorite		75 g/day	

[a] The landfill number is the amount estimated to be released from the rags. This release from the rags will be either to landfill or to water. If the release is to water through the laundry, then the landfill column is blank. This is true of all of the ink remover chemicals. For our purposes, the rest of the assessment assumes release to water only, since we are not assessing landfill releases.

Releases to Water from a Single Facility

Table V-20
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility
Method 1, Traditional System 3

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Mean Daily Concentration, ug/L[a] for 1000 MLD Receiving Water
Methyl Ethyl Ketone	363 g/day at laundry	84%	58 g/day	6×10^{-2}
n-butyl acetate	191 g/day at laundry	97%	5.7 g/day	6×10^{-3}
Methanol	37 g/day at laundry	97%	1.1 g/day	1×10^{-3}
Naphtha, light aliphatic	257 g/day at laundry	94%	15 g/day	2×10^{-2}
Toluene	251 g/day at laundry	92%	20 g/day	2×10^{-2}
Isobutyl isobutyrate	132 g/day at laundry	98%	2.6 g/day	3×10^{-3}
Sodium Hypochlorite[b]	75 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

[b] Concentrated solutions of sodium hypochlorite will kill the biota which degrade organic chemicals (the other substances listed in the table) during waste water treatment. This could cause problems at the waste water treatment plant, reducing the waste water treatment efficiency for the other compounds sent to the plant.

Releases to Water from Multiple Screen Printers

The concentrations listed in the chart above are relatively low. However, in the local area there may be many screen printers, all of which are connected to the same waste treatment facility. The concentration in the stream would be the combined amounts of all of the releases in the stream, which could be significant, even if the release from one screen printing facility is not.

To demonstrate the combined effects, the multiple screen printing facilities in St. Louis County, Missouri were picked as an example. The Dun and Bradstreet data shows 135 screen printing facilities in St. Louis County. We are assuming that the waste water from all of these is going to the St. Louis County Sewer Company, which releases into the Meramec River. Less than five kilometers downstream is the Kirkwood Water Department, and just about ten kilometers downstream is an intake for the St. Louis County Water company. These service an estimated 28 thousand people and one million people, respectively. The mean flow of the river is 7895 million liters per day (MLD), and is not any larger at the drinking water intakes than it is at the release point.

Table V-21
Estimated Cumulative Releases to Water for St. Louis County, MO
Method 1, Traditional System 3

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Average Concentration in Meramec River, ug/L (ppb)
Methyl ethyl ketone	49 kg/day	84%	7.8 kg/day	1
n-butyl acetate	26 kg/day	97%	8×10^{-1} kg/day	1×10^{-1}
Methanol	5 kg/day	97%	150 g/day	2×10^{-2}
Naphtha, light aliphatic	35 kg/day	94%	2.1 kg/day	3×10^{-1}
Toluene	34 kg/day	92%	2.7 kg/day	3×10^{-1}
Isobutyl isobutyrate	18 kg/day	98%	360 g/day	4×10^{-2}
Sodium Hypochlorite	10 kg/day	>> 99%	<<100 g/day	$<<1 \times 10^{-2}$

Releases to Air from Individual Screen Printing Facilities

Table V-22
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Method 1, Traditional System 3

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Methyl Ethyl Ketone	403 g/day	8×10^{-1} ug/m^3	6
n-butyl acetate	107 g/day	2×10^{-1} ug/m^3	1
Methanol	101 g/day	2×10^{-1} ug/m^3	1
Naphtha, light aliphatic	222 g/day	4×10^{-1} ug/m^3	3
Toluene	255 g/day	5×10^{-1} ug/m^3	4
Isobutyl isobutyrate	19.7	4×10^{-2} ug/m^3	0.3

[a] This estimates doses for people living 100 Meters from hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are estimated to be very low for Method 1, Traditional System 3.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Table V-23
Risks from Potential Drinking Water Exposures
Screen Reclamation Method 1, Traditional System 3

Substance	Daily Stream Concentration in Meramec River, ug/L (ppb)	Daily dose from Drinking Water (mg/kg)	RfD (mg/kg)	Hazard Quotient (dose/RfD)
Methyl ethyl ketone	1	3x10^{-5}	0.6	5x10^{-5}
n-butyl acetate	1 x 10^{-1}	3x10^{-6}	not available	
Methanol	2 x 10^{-2}	6x10^{-7}	0.5	1x10^{-6}
Naphtha, light aliphatic	3 x 10^{-1}	9x10^{-6}	not available	
Toluene	3 x 10^{-1}	9x10^{-6}	0.2	4x10^{-5}
Isobutyl isobutyrate	4 x 10^{-2}	1x10^{-6}	not available	
Sodium Hypochlorite	<<1 x 10^{-2}	<<3x10^{-7}	not available	

Table V-24
Estimated Risks from Ambient Air Releases from a Single Model Facility
Screen Reclamation Method 1, Traditional System 3

Substance	Highest Avg Concentration 100 M away	Daily Potential Dose, (mg/kg)	RfD/RfC (mg/kg, mg/m$_3$)	Hazard Quotient(dose or conc/RfDor RfC)
Methyl Ethyl Ketone	8 x 10^{-1} ug/m^3	2x10^{-4}	1 mg/m^3	8x10^{-4}
n-butyl acetate	2 x 10^{-1} ug/m^3	4x10^{-5}	not available	
Methanol	2 x 10^{-1} ug/m^3	4x10^{-5}	0.5 mg/kg	8x10^{-5}
Naphtha,light aliphatic	4 x 10^{-1} ug/m^3	1x10^{-4}	not available	
Toluene	5 x 10^{-1} ug/m^3	2x10^{-4}	0.4 mg/m^3	1x10^{-3}
Isobutyl isobutyrate	4 x 10^{-2} ug/m^3	1x10^{-5}	not available	

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

- None of the components of Method 1, Traditional System 3 reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.

- None of the single facility releases of Method 1, Traditional System 3 reach an ecotoxicity concern concentration.

The following table summarizes the exposure and risk estimates for cumulative releases of Traditional System 3. The analogous figures for single facilities show much lower exposure and risk levels.

Table V-25
Estimated Cumulative Releases to Water for St. Louis County, MO
Screen Reclamation Method 1, Traditional System 3

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Conc. in Meramec River, ug/L (ppb)	ECO CC (ug/L)	ECO RISK INDICATOR (STREAM CONC/ ECO CC)
Methyl ethyl ketone	49 kg/day	84%	7.8 kg/day	1	4500	$2x10^{-4}$
n-butyl acetate	26 kg/day	97%	8×10^{-1} kg/day	1×10^{-1}	140	$7x10^{-4}$
Methanol	5 kg/day	97%	150 g/day	2×10^{-2}	9000	$2x10^{-6}$
Naphtha, light aliphatic	35 kg/day	94%	2.1 kg/day	3×10^{-1}	5	0.06
Toluene	34 kg/day	92%	2.7 kg/day	3×10^{-1}	110	$3x10^{-3}$
Isobutyl isobutyrate	18 kg/day	98%	360 g/day	4×10^{-2}	80	$5x10^{-4}$
Sodium Hypochlorite	10 kg/day	>> 99%	<<100 g/day	<<1×10^{-2}	<20	~0.05

Performance

The performance of a similar system was demonstrated at the Screen Printing Technical Foundation; the performance demonstration differed from this product system in that it included the use of a haze remover containing potassium hydroxide and tetrahydrofurfuryl alcohol. Reference Traditional System 3 in Method 2 for a complete description of the performance of this system with a haze remover.

Cost

Because the performance of this particular system was not determined in this project, the total cost of using this system was not determined.

Traditional System 4

Formulation

Ink Remover: 100% Lacquer Thinner, consisting of:
30% Methyl ethyl ketone
15% n-butyl acetate
5% Methanol
20% Naphtha, light aliphatic
20% Toluene
10% Isobutyl isobutyrate
Emulsion Remover: 1% Sodium periodate, 99% water

Occupational Exposure

Table V-26
Occupational Exposure Estimates for Method 1, Traditional System 4

	Inhalation (mg/day)				Dermal (mg/day)	
System	I	II	III	IV	Routine	Immersion
Ink Remover						
Methyl ethyl ketone(2-butanone)	165	5.3	3	20	468	2180
Butyl acetate normal	44	1.3	1	5.3	234	1090
Methanol	27	4.7	2	15	78	364
Naphtha, light aliphatic	98	1.6	1	6.2	312	1460
Toluene	110	2.3	1	9.2	312	1460
Isobutyl isobutyrate	7	0.4	0	1.7	156	728
Emulsion Remover (Zeta diluted 1:4)						
Sodium periodate	0	0	0	0	16	73
Water	0	0	0	0	1540	7210

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Occupational Risk Conclusions and Observations

Ink Remover

○ Hazard quotient calculations indicate clear concerns for both toluene and methyl ethyl ketone with respect to chronic dermal and inhalation exposures to workers using these chemicals in ink removal.

Table V-27
Occupational Risk Estimates for Method 1, Traditional System 4

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	**Inhalation**	**Routine**	**Immersion**	**NOAEL[c]**	**LOAEL[d]**	**NOAEL**	**LOAEL**	**NOAEL**	**LOAEL**
Ink Remover									
Methyl ethyl ketone (2-butanone)	9.29	22	103	NA	NA	NA	NA	NA	NA
Butyl acetate normal	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methanol	1.4	2.2	10.4	NA	NA	NA	NA	NA	NA
Aromatic solvent naphtha	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	17	46	210	NA	NA	NA	NA	NA	NA
Isobutyl isobutyrate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover (Zeta diluted 1:4)									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

- ○ Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using methanol in ink removal.

Emulsion Removers (All Systems)

- ○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-28
Estimated Environmental Releases in Screen Cleaning Operations
Method 1, Traditional System 4

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Methyl ethyl ketone(2-butanone)	344	0	0	11	5.7	42	363
Butyl acetate normal	92	0	80	2.6	1.5	11	191
Methanol	57	0	0	9.8	4.1	30	37
Naphtha, light aliphatic	204	0	25	3.2	1.7	13	257
Toluene	229	0	0	4.8	2.6	19	251
Isobutyl isobutyrate	15	0	100	0.8	0.5	3.4	132
Emulsion Remover (Zeta diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-29
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Method 1, Traditional System 4

Substance:	To Air:	To Water:	To Landfill:
Methyl ethyl ketone	403 g/day	363 g/day at laundry	
n-butyl Acetate	107 g/day	191 g/day at laundry[a]	80 g/day[a]
Methanol	101 g/day	37 g/day at laundry	
Naphtha, light aliphatic	222 g/day	257 g/day at laundry	25 g/day
Toluene	255 g/day	251 g/day at laundry	
Isobutyl isobutyrate	19.7 g/day	132 g/day at laundry	100 g/day
Sodium periodate		6 g/day	

[a] 191 g/day is estimated to be released from the rags if the rags are laundered. This release from the rags will be either to landfill or to water. If the release is to water through the laundry, then the landfill column is blank. If the release is to landfill, then the landfill column will be 80 g/day and the water column will be blank. This is true for all of the ink remover chemicals. For our purposes, the rest of the assessment assumes release to water only, since we are not assessing landfill releases.

Releases to Water from a Single Facility

Table V-30
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility
Method 1, Traditional System 4

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste Water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Methyl Ethyl Ketone	363 g/day at laundry	84%	58 g/day	6×10^{-2}
n-butyl acetate	191 g/day at laundry	97%	5.7 g/day	6×10^{-3}
Methanol	37 g/day at laundry	97%	1.1 g/day	1×10^{-3}
Naphtha, light aliphatic	257 g/day at laundry	94%	15.4 g/day	2×10^{-2}
Toluene	251 g/day at laundry	92%	20 g/day	2×10^{-2}
Isobutyl isobutyrate	132 g/day at laundry	98%	2.6 g/day	3×10^{-3}
Sodium periodate	6 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Water from Multiple Screen Printers

The concentrations listed in the chart above are relatively low. However, in the local area there may be many screen printers, all of which are connected to the same waste treatment facility. The concentration in the stream would be the combined amounts of all of the releases in the stream, which could be significant, even if the release from one screen printing facility is not.

To demonstrate the combined effects, the multiple screen printing facilities in St. Louis County, Missouri were picked as an example. The Dun and Bradstreet data shows 135 screen printing facilities in St. Louis County. We are assuming that the waste water from all of these is going to the St. Louis County Sewer Company, which releases into the Meramec River. Less than five kilometers downstream is the Kirkwood Water Department, and just about ten kilometers downstream is an intake for the St. Louis County Water company. These service an estimated 28 thousand people and one million people, respectively. The mean flow of the river is 7895 million liters per day (MLD), and is not any larger at the drinking water intakes than it is at the release point.

Table V-31
Estimated Cumulative Releases to Water for St. Louis County, MO
Method 1, Traditional System 4

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Average Concentration in Meramec River, ug/L (ppb)
Methyl ethyl ketone	49 kg/day	84%	7.8 kg/day	1
n-butyl acetate	26 kg/day	97%	0.8 kg/day	1×10^{-1}
Methanol	5 kg/day	97%	150 g/day	2×10^{-2}
Naphtha, light aliphatic	35 kg/day	94%	2.1 kg/day	3×10^{-1}
Toluene	34 kg/day	92%	2.7 kg/day	3×10^{-1}
Isobutyl isobutyrate	18 kg/day	98%	360 g/day	4×10^{-2}
Sodium Periodate	810 g/day	>> 99%	<< 8.1 g/day	$<<1 \times 10^{-3}$

These stream concentrations will be put into perspective in the risk integration section of this document. Please refer to that section for information on how to interpret these concentrations.

Releases to Air from Individual Screen Printing Facilities

Table V-32
Air Release, Concentration and Potential Dose Estimates for a Single Model Facility
Method 1, Traditional System 4

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Methyl Ethyl Ketone	403 g/day	8×10^{-1} ug/m^3	6
n-butyl acetate	107 g/day	2×10^{-1} ug/m^3	1
Methanol	101 g/day	2×10^{-1} ug/m^3	1
Naphtha, light aliphatic	222 g/day	4×10^{-1} ug/m^3	3
Toluene	255 g/day	5×10^{-1} ug/m^3	4
Isobutyl isobutyrate	19.7	4×10^{-2} ug/m^3	3×10^{-1}

[a] This estimates doses for people living 100 Meters from hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

- Health risks to the general population from both air and water exposures are very low for Method 1, Traditional System 4.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2, and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

- None of the components of Method 1, Traditional System 4 reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.

- None of the single facility releases of Method 1, Traditional System 4 reach an ecotoxicity concern concentration.

The following table summarizes the exposure and risk estimates for cumulative releases of Traditional System 4. The analogous figures for single facilities show much lower exposure and risk levels.

Table V-33
Estimated Cumulative Releases for St. Louis County, MO
Screen Reclamation Method 1, Traditional System 4

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Conc. in Meramec River, ug/L (ppb)	ECO CC (ug/L)	ECO RISK INDICATOR (STREAM CONC/ ECO CC)
Methyl ethyl ketone	49 kg/day	84%	7.8 kg/day	1	4500	$2x10^{-4}$
n-butyl acetate	26 kg/day	97%	0.8 kg/day	1×10^{-1}	140	$7x10^{-4}$
Methanol	5 kg/day	97%	150 g/day	2×10^{-2}	9000	$2x10^{-6}$
Naphtha, light aliphatic	35 kg/day	94%	2.1 kg/day	3×10^{-1}	5	0.06
Toluene	34 kg/day	92%	2.7 kg/day	3×10^{-1}	110	$3x10^{-3}$
Isobutyl isobutyrate	18 kg/day	98%	360 g/day	4×10^{-2}	80	$5x10^{-4}$
Sodium Periodate	810 g/day	>> 99%	<< 8.1 g/day	$<<1 \times 10^{-3}$	<10	$\sim 10^{-4}$

Performance

The performance of this system was not demonstrated at the Screen Printing Technical Foundation or at volunteer printing facilities. Since this system is commonly used in many screen printing shops, it was decided to use the limited resources available for a performance demonstration to evaluate alternatives to the traditionally used product systems.

Cost

Table V-34
Method 1: Summary of Cost Analysis for Baseline (Traditional System 4 Minus Haze Remover)

Cost Element Description		Traditional System 4 (minus Haze Remover)
Facility Characteristics		
Average screen size (in^2)		2,127
Average # screens/day		6
Cost Elements per Screen		
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	12.9 2.82
Materials and Equipment	# of rags used Cost ($)	3 0.45
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13
	Haze Remover Average Volume (oz.) Cost ($)	--- ---
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02
Totals		
Total Cost($/Screen)		3.63
Total Cost($/year)		5,446

Alternative System Chi

Formulation

Ink Remover:	Diethylene glycol series ethers Propylene glycol series ethers N-methyl pyrrolidone Ethoxylated nonylphenol
Emulsion Remover:	Sodium periodate Water

Occupational Exposure

Table V-35
Occupational Exposure Estimates for Method 1, Alternative System Chi

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Diethylene glycol series ethers	0	0	0	0	312	1456
Tripropylene glycol methyl ether	0	0	0	0	858	4000
N-methylpyrrolidone	3	0	0	0.1	312	1460
Ethoxylated nonylphenol	0	0	0	0	78	364
Emulsion Remover (diluted 1:4)						
Sodium periodate	0	0	0	0	16	73
Water	0	0	0	0	1540	7210

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Occupational Risk Conclusions and Observations

Ink Remover

- Clear concerns exist for chronic dermal exposures to the diethylene glycol series ethers used in ink removal based on the calculated margins-of-exposure.

- Concerns exist for developmental toxicity risks from dermal exposures to N-methylpyrrolidone based on the calculated margin-of-exposure. Similar calculations for inhalation exposures to N-methylpyrrolidone indicate very low concern.

Table V-36
Occupational Risk Estimates for Method 1, System CHI

Name	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
	Inhalation	Routine	Immersion			Routine		Immersion	
				NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Diethylene glycol series ethers	NA	NA	NA	NA	NA	1,800	46	380	9.8
Tripropylene glycol series ethers	NA	NA	NA	NA	NA	NA	NA	NA	NA
N-methylpyrrolidone	NA	NA	NA	3,600	NA	39	NA	8.4	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover (diluted 1:4)									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

- ○ Inhalation exposures to other ink remover components are very low.
- ○ Dermal risks from other ink remover components could not be quantified because of limitations in hazard data, but exposures can be high.

Emulsion Removers (All Systems)

- ○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-37
Estimated Environmental Releases in Screen Cleaning Operations
Method 1, Alternative System Chi

	Release Under Each Scenario (g/day)						
	I			II	III	IV	
System	air	water	land	air	air	air	water
Ink Remover							
Diethylene glycol series ethers	0.1	0	138	0	0	0	270
Tripropylene glycol series ethers	0.1	0	381	0	0	0	742
N-methylpyrrolidone	6.8	0	132	0.1	0	0.2	270
Ethoxylated nonylphenol	0	0	35	0	0	0	67
Emulsion Remover (diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-38
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 1, Alternative System Chi

Substance:	To Air:	To Water:	To Landfill:
Diethylene glycol series ethers	0.1 g/day	270 g/day at laundry	138 g/day
Propylene glycol series ethers	0.1 g/day	742 g/day at laundry	381 g/day
N-methyl pyrrolidone	7.1 g/day	270 g/day at laundry	132 g/day
Ethoxylated nonylphenol		67 g/day at laundry	35 g/day
Sodium Periodate		6 g/day	

Releases to Water from a Single Facility

Table V-39
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 1, Alternative System Chi

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Diethylene glycol series ethers	270 g/day at laundry	83%	46 g/day	4×10^{-2}
Propylene glycol series ethers	742 g/day at laundry	83-97%	126 g/day	1×10^{-1}
N-methyl pyrrolidone	270 g/day at laundry	97%	8.1 g/day	8×10^{-3}
Ethoxylated nonylphenol	67 g/day at laundry	100%	0 g/day	0
Sodium periodate	6 g/day	>>99%	<<.06 g/day	$<< 6 \times 10^{-5}$

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-40
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 1, Alternative System Chi

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Diethylene glycol series ethers	0.1 g/day	2×10^{-4} ug/m^3	1×10^{-3}
Propylene glycol series ethers	0.1 g/day	2×10^{-4} ug/m^3	1×10^{-3}
N-methyl pyrrolidone	7.1 g/day	1×10^{-2} ug/m^3	1×10^{-1}

[a] This estimates doses for people living 100 Meters from hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Alternative System Chi.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Alternative System Chi in Method 2. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 1, Alternative System Chi reach an ecotoxicity concern concentration.

Performance

The performance of System Chi, with the ink remover also in use as a haze remover, was demonstrated at the Screen Printing Technical Foundation and at two volunteer printing facilities. Reference Product System Chi in Method 2 for details of these performance evaluations. The information reported from Facility 21 will be particularly applicable to Method 1 as Facility 21 was able to use the ink remover/emulsion remover combination and achieve acceptable performance. Facility 21 noted that all screens could be reused for future jobs and that this system worked particularly well in removing metallic inks.

Cost

Table V-41
Method 1: Summary of Cost Analysis for Method 1, Alternative System Chi

Cost Element Description		Baseline (Traditional System 4-Haze Remover)	Alternative System Chi	
			Facility 3	Facility 21
Facility Characteristics				
Average screen size (in^2)		2,127	1,977	1,088
Average # screens/day		6	15	23
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	12.9 2.82	9.4 2.07	4.5 0.98
Materials and Equipment	# of rags used Cost ($)	3 0.45	1.2 0.18	1.2 0.19
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	1.1 0.21	1.1 0.21
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	2.1 0.07	1.5 0.05
	Haze Remover Average Volume (oz.) Cost ($)	--- ---	--- ---	--- ---
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	0 0	0 0
Totals				
Total Cost ($/screen)		3.63	2.53	1.43
Normalized[a]		3.63	2.83	1.95
Total Cost ($/year)		5,466	9,497	8,005
Normalized[a]		5,446	4,245	2,918

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Alternative System Beta

Unlike other manufacturers who participated in the project, this manufacturer submitted only an ink remover, rather than a product system consisting of ink remover, emulsion remover and haze remover. To accommodate the screen reclamation methods identified in this CTSA and develop a risk assessment based on a product system, an emulsion remover product was arbitrarily added to ink remover Beta to form Product System Beta. While the risk and cost assessment include this other product, the performance of the ink remover was profiled at a single facility (12) which used their standard emulsion and haze remover to completely clean their screens. Due to a lack of information about the standard emulsion and haze remover products used by Facility 12, the risk assessment for these products was not undertaken.

Formulation

Ink Remover:	2-octadecanamine, N, N-dimethyl-, N-oxide or a modified amine from unsaturated soy bean oil fatty acid/ water
Emulsion Remover:	Sodium periodate Water

Occupational Exposure

Table V-42
Occupational Exposure Estimates for Method 1, Alternative Beta

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
2-Octadecanamine, N,N-dimethyl, N-oxide	292	4.3	3	0	1530	7130
Water	0	0	0	0	31	146
Emulsion Remover (diluted 1:4)						
Sodium periodate	0	6	0	0	0	0
Water	0	615	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Occupational Risk Estimates

Quantitative risk estimates could not be determined for this system due to insufficient data. See risk conclusions for areas of concern for this system.

Occupational Risk Conclusions and Observations

Ink Remover

○ Both inhalation and dermal exposures to workers using 2-octadecanamine, N,N-dimethyl-, N-oxide in ink removal can be high, although the risks could not be quantified because of limitations in hazard data.

Emulsion Removers (All Systems)

○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-43
Estimated Environmental Releases in Screen Cleaning Operations
Method 1, Alternative System Beta

	Release Under Each Scenario (g/day)						
	I			**II**	**III**	**IV**	
System	**air**	**water**	**land**	**air**	**air**	**air**	**water**
Ink Remover							
2-Octadecanamine, N,N-dimethyl, N-oxide	609	0	0	9.1	6.3	0	0
Water	0	0	12	0	0	0	0
Emulsion Remover (Zeta diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-44
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 1, Alternative System Beta

Substance:	To Air:	To Water:	To Landfill:
2-octadecanamine, N,N-dimethyl, N-oxide	624 g/day		
Sodium periodate		5 g/day	

Releases to Water from a Single Facility

Table V-45
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 1, Alternative System Beta

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Sodium periodate	5 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-46
Air Releases, Concentrations and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 1, Alternative System Beta

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
2-Octadecanamine, N,N-dimethyl, N-oxide	624 g/day	1.3 ug/m^3	9

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 1, Alternative System Beta.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2, and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 1, Alternative System Beta reach an ecotoxicity concern concentration.

Performance

General Summary of Ink Remover Beta Performance, and Related Variables

Facility 12 used ink remover Beta during the performance demonstrations. Unlike the Product Systems submitted by other manufacturers, the manufacturer of Beta supplied the ink remover only. The facility used the alternative ink remover Beta, along with their standard emulsion remover and haze remover to reclaim their screens. During the demonstrations, the performance of ink remover Beta was recorded for 17 screens with solvent-based inks over a three week period. Facility 12 prints graphic overlays, labels, and flexible membrane switches, and all products are primarily printed on plastics.

Ink remover Beta was also sent to two other facilities who were not able to participate in the Performance Demonstrations. One facility could not use the product because they send all their screens out to be reclaimed; they only use ink removers as an in-process cleaner. Since this project is intended to evaluate ink removers used for screen reclamation, not for in-process ink removal, this facility did not participate. The second facility felt they could not use the alternative system because of an on-going EPA inspection. The printer regretted not being able to participate, however, the EPA was in the process of testing his waste water, so he did not want to add any new chemicals to his waste stream.

Facility 12 reported that the ink remover removed the ink on most screens, but it also left an oily residue on the screen. Prior to the demonstration, this facility used an acetone and toluene blend that left no residue on the screen. The printer found that the ink wiped off more easily when it was wet, however it was very time-consuming to remove dried ink. On some screens, it took 30 minutes to remove the ink.

Alternative Ink Remover Beta Profile

The manufacturer recommends applying ink remover Beta as follows:

Water Resistant Emulsions: Card off the excess ink from the screen. Using a spray bottle, apply the ink remover to the screen. After a short penetration time (only for dried inks) use high pressure water and rinse all the ink residue from the screen. For tests done at SPTF, a 1000 psi spray was used for rinsing the ink remover.

Non Water Resistant Emulsions: Card off the excess ink from the screen. Using a spray bottle, spray the ink remover directly onto the screen. Clean the screen with a cloth slightly dampened with ink remover. Dry both sides of the screen with a dry and absorbent cloth.

Alternative System Performance at SPTF

Ink remover Beta was tested at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). On all three screens, the technician reported that the ink dissolved well, however a fair amount of wiping was required. For the screen with the solvent-based ink, seven wipes were needed. Six wipes were used on the UV ink screen, and eight wipes were required to remove the ink from the water-based ink screen. On all three screens, the technician noticed that the ink remover affected the stencil image in the half tone area. The color of the stencil appeared on the rag, which also indicated that the product was deteriorating the emulsion.

Alternative System Performance Details

Performance Details from Facility 12

Facility 12 felt the ink remover Beta sufficiently removed the ink from most screens, however, it took a long time to remove the ink and the product left an oily haze on the screen. In some cases, they reported ink residue or ink stains were also left in the mesh. The oily film and the ink residue were both removed during emulsion removal and haze removal steps, and all screens were reusable for all types of printing jobs.

Unlike all of the other facilities in the Performance Demonstrations, an observer did not visit this facility to introduce them to the project and to the alternative system. This lack of in-person guidance may have affected the results. During the first week, the printer sprayed on the ink remover, rubbed it in with a brush and pressure washed the screen to remove the ink. This application method was very messy and did not effectively remove the ink. For the remainder of the demonstrations, the printer changed his application method and used rags to wipe the ink off the screen. This second method removed the ink much more easily, but took a long time (an average of 25 minutes per screen). Two or three rags were used on each screen. While wiping the screen with the rags, the printer noticed that the emulsion started to deteriorate. He also mentioned that he needed to replace his filters on the ink removal sink waste water more frequently when using the alternative system.

In reviewing the data, there did not appear to be any correlations between the product performance and the screen conditions, however, the printer felt it was much easier to remove wet ink and light colored inks, than dried on and black ink.

Alternative System Performance Table Compiled from Field Sites

The following table highlights the observed performance of the ink remover and the relevant conditions at the demonstration facility. In addition to the field demonstrations data, results of the product tests performed at SPTF are also summarized in this table.

Table V-47
Performance Summary for Ink Remover BETA

	System Component	Performance						Demonstration Conditions			
		Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
In-field Demonstrations at Volunteer Printing Facilities											
Facility 12	*Ink remover*	3.9 ± 8.2 hrs (n=15)	4.2 ± 1.5 oz. (n=17)	24.6 ± 5.4 mins (n=17)	Moderate	Removed ink but took a long time and left an oily residue.	• Not demonstrated as part of a system.	Solvent-based ink	Capillary film	Polyester, abraded; 195 - 390 threads/ inch	1089 in^2
Laboratory Testing at SPTF											
SPTF Solvent-based Ink	*Ink Remover*	15 mins	2.5 oz.	9.1 mins	Moderate	Ink dissolved well, but 7 rags were needed and the stencil started to deteriorate.		Solvent-based	Dual cure direct	Polyester; 260 threads/ inch	360 in^2
SPTF UV-curable Ink	*Ink Remover*	15 mins	2.5 oz.	6.3 mins	Moderate	Ink dissolved well, but 6 rags were needed and the stencil started to deteriorate.		UV-curable	Dual cure direct	Polyester; 390 threads/ inch	360 in^2
SPTF Water-based Ink	*Ink Remover*	15 mins	3.0 oz.	12.0 mins	Moderate	Ink dissolved well, but it took a long time (8 rags were needed) and the stencil started to deteriorate.		Water-based	Dual cure direct	Polyester; 260 threads/ inch	360 in^2

Facility Profiles

General Facility Background for Facility 12

Facility 12 prints graphic overlays, labels, and flexible membrane switches on plastics, paper, and metals. Their typical run length is one hour, and approximately 70% of their orders are repeat orders. There are about 10 employees involved in screen printing at this location, and approximately 4 are involved in screen reclamation. Solvent-based vinyl and polyester inks used at this facility. Screens with mesh counts of 195 - 390 threads/inch and capillary film emulsions were used during the demonstrations. The average screen size at this facility is 9 ft^2 and 10 - 15 screens are reclaimed daily.

Screen Reclamation Area in Facility 12

Ink removal is done in a spray booth where a local, mechanical system provides ventilation. Screen reclamation is done in a high-pressure (2700 psi) water blaster booth. Waste water from the wash of the emulsion remover and haze remover is filtered prior to discharge to the sewer. Filters and spent solvent from the ink removal area are disposed of as hazardous waste.

Current Screen Reclamation Products at Facility 12

This facility uses a solvent blend ink remover containing 50% toluene and 50% acetone. Their emulsion remover consists primarily of sodium periodate. For haze removal, they use a proprietary solvent blend which includes sodium hydroxide and cyclohexanone.

Current Screen Reclamation Practices in Facility 12

Using their standard products, this facility reclaims their screens following the procedure described below. Personal protective equipment worn by operators includes gloves, eye protection, respiratory protection, and rubber boots (for haze removal).

- <u>Ink Remover:</u> Card off the excess ink. Spray the ink remover onto the screen from a low pressure tank (60 psi). Wipe off the dissolved ink with disposable rags (one or two rags are used on each screen).

- <u>Emulsion Remover:</u> Spray the emulsion remover onto both sides of the screen. Brush the emulsion remover into the screen. Pressure rinse and allow to air dry.

- <u>Haze Remover:</u> Dip a brush into the container of haze remover and rub it into the screen. Rinse with the high-pressure water blaster.

Cost

Table V-48
Method 1: Summary of Cost Analysis for Alternative Beta

Description		Baseline (Traditional System 4 minus Haze Remover)	Alternative System Beta[a] Facility 12
Facility Characteristics			
Average screen size (in^2)		2,127	1,089
Average # screens/day		6	15
Cost Elements per Screen			
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	12.9 2.82	29.4 6.43
Materials and Equipment	# of rags used Cost ($)	3 0.45	2.2 0.34
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	4.2 0.50
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	1.8 0.06
	Haze Remover Average Volume (oz.) Cost ($)	--- ---	--- ---
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	0 0
Total Costs			
Total Cost ($/screen)		3.63	17.33
Normalized[b]		3.63	7.97
Total Cost ($/year)		5,446	27,477
Normalized[b]		5,446	11,958

[a] The emulsion removal use and cost per screen were taken from performance demonstration results for product system Zeta.

[b] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Method 2: Traditional Reclamation With Haze Remover

In a typical screen printing facility, ink remover, emulsion remover and haze remover are all used in the process of screen reclamation. Method 2 incorporates the most common practices in screen reclamation; it differs from Method 1 in that printers are assumed to use a haze remover (see Figure V-2). For the purposes of determining occupational exposure to the haze remover, it was assumed that screen reclaimers only used haze remover on 1-2 screens of the estimated six screens reclaimed daily in the average small/medium screen printing facility.

Because Method 2 is most representative of current screen reclamation practices, the majority of alternative systems are included in this category. A total of fourteen systems are assessed, including four traditional systems and ten alternative systems. The alternative systems were submitted by manufacturers who volunteered to participate in the project. These systems were named Alpha, Chi, Delta, Epsilon, Gamma, Mu, Phi, Omicron-AE, Omicron-AF and Zeta. Printers who are interested in further exploration of the merits of one of these systems should contact the manufacturers listed in the acknowledgements section of the document.

Although three chemical products are used in Method 2, as opposed to two chemical products in Method 1, pollution prevention can still be achieved through a combination of improved workplace practices and equipment modifications. Chapter 6 should be referenced to best determine which pollution prevention practices are most appropriate for a particular facility. In Chapter 6, a discussion of workplace practices reported by printers as a means of reducing or preventing pollution is followed by an overview of spray applicator systems, washout booths, filtration systems, recirculation systems and distillation units. All of these modifications can be used in combination with Method 2 to prevent pollution.

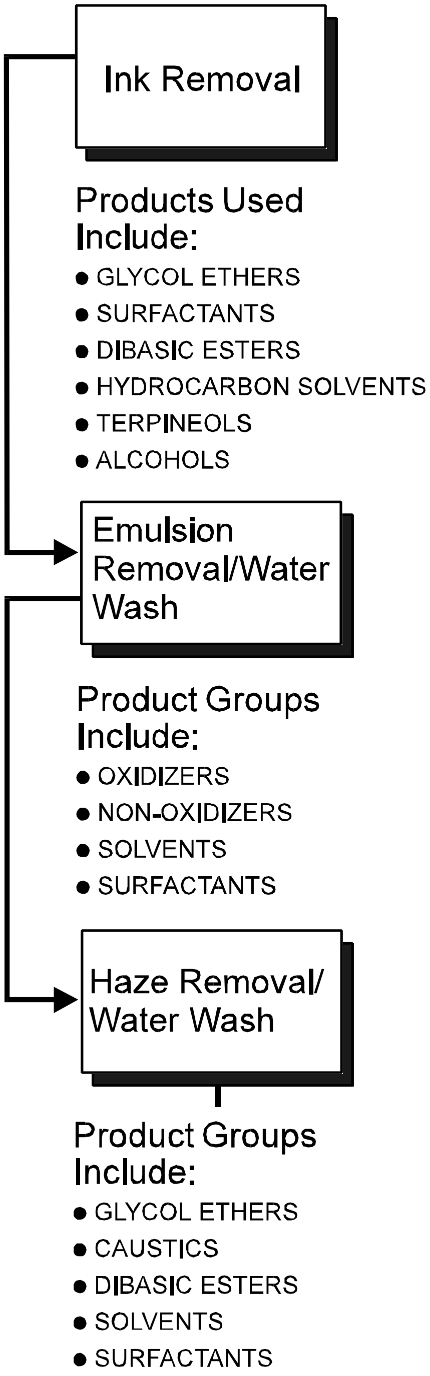
Traditional System 1

Formulation

Ink Remover: 100% Mineral spirits
Emulsion Remover: 12% Sodium hypochlorite (bleach)
Haze Remover: 10% Xylene
30% Acetone
30% Mineral spirits
30% Cyclohexanone

Figure V - 2

Process Steps Included in Method 2



Occupational Exposure

Table V-49
Occupational Exposure Estimates For Method 2, Traditional System 1

System	Inhalation Exposures, by Scenario (mg/day)				Dermal Exposures, (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Mineral spirits- light hydrotreated	26	0.1	0	0.3	1560	7280
Emulsion Remover						
Sodium hypochlorite	0	0	0	0	187	874
Water	0	0	0	0	1370	6410
Haze Remover						
Xylenes (mixed)	21	0.9	1	0	156	728
Acetone	64	11	5	0	468	2180
Mineral spirits-light hydrotreated	7	0.1	0	0	468	2180
Cyclohexanone	27	0.3	0	0	468	2180

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

- ○ Hazard quotient calculations indicate clear concerns for chronic dermal and inhalation exposures to workers using acetone in haze removal.
- ○ Hazard quotient calculations indicate marginal concerns for chronic dermal exposures to workers using xylene and cyclohexanone in haze removal.
- ○ Margin-of-exposure calculations indicate very low concern for developmental and reproductive toxicity risks from inhalation of cyclohexanone. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified.
- ○ Dermal exposures to workers using mineral spirits in ink removal can be very high, although the risks from mineral spirits could not be quantified because of limitations in hazard data.

Emulsion Removers (All Systems)

- ○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide.

Table V-50
Occupational Risk Estimates for Method 2, Traditional System 1

	Hazard Quotient			Margin Of Exposure[a]					
				Inhalation		Dermal			
		Dermal				Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[b]	LOAEL[c]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Mineral spirits- light hydrotreated	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover									
Sodium hypochlorite		NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Xylenes (mixed isomers)	0.2	1.1	5.2	NA	NA	NA	NA	NA	NA
Acetone	11	66	311	NA	NA	NA	NA	NA	NA
Mineral spirits- light hydrotreated	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexanone	0.08	1.3	6.2	180	NA	NA	NA	NA	NA

[a] NA means Not Available.
[b] NOAEL means No Observed Adverse Effect Level.
[c] LOAEL means Lowest Observed Adverse Effect Level.

The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-51
Estimated Environmental Releases in Screen Cleaning Operations
Method 2, Traditional System 1

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Mineral spirits- light hydrotreated	54	0	1050	0.2	0.1	0.6	1350
Emulsion Remover							
Sodium hypochlorite	0	75	0	0	0	0	0
Water	0	546	0	0	0	0	0
Haze Remover							
Xylenes (mixed isomers)	44	0	0	1.9	1.1	0	0
Acetone	133	0	0	22	11	0	0
Mineral spirits- light hydrotreated	15	119	0	0.2	0.1	0	0
Cyclohexanone	57	76	0	0.7	0.4	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-52
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility: Traditional System 1

Substance	To Air	To Water	To Landfill
Mineral Spirits	69.5 g/day	119 g/day 1350 g/day[a]	1053 g/day[a]
Sodium Hypochlorite		74.5 g/day	
Acetone	167 g/day		
Xylene	47.5 g/day		
Cyclohexanone	58.1 g/day	76.5 g/day	

[a] This release is either to water from the printing facility, or is sent with wastes to a waste handler to go to a landfill or to incineration. For our purposes, the rest of the assessment assumes release to water only, since we are not assessing landfill releases.

Releases to Water from a Single Facility

Table V-53
Estimated Releases to Water from Screen Reclamation at a Single Facility Traditional System 1

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Mineral Spirits	119 g/day 1350 g/day at laundry	99%	1.2 g/day 13.50 g/day	1.2×10^{-3}
Xylenes		75%		
Cyclohexanone	76.5 g/day	90%	7.6 g/day	7.6×10^{-3}
Sodium Hypochlorite[b]	74.5 g/day	>>[c] 99%	<< .7 g/day	$<< 7 \times 10^{-4}$

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

[b] Concentrated solutions of sodium hypochlorite will kill the biota which degrade organic chemicals (the other substances listed in the table) during waste water treatment. This could cause problems at the waste water treatment plant, reducing the waste water treatment efficiency for the other compounds sent to the plant.

[c] >> is very much greater than, << is very much less than.

Releases to Water from Multiple Screen Printers

The concentrations listed in the chart above are relatively low. However, in the local area there may be many screen printers, all of which are connected to the same waste treatment facility. The concentration in the stream would be the combined amounts of all of the releases in the stream, which could be significant, even though the release from one screen printing facility is not.

To demonstrate the combined effects, the multiple screen printing facilities in St. Louis County, Missouri were picked as an example. The Dun and Bradstreet data shows 135 screen printing facilities in St. Louis County. We are assuming that the waste water from all of these is going to the St. Louis County Sewer Company, which releases into the Meramec River. Less than five kilometers downstream is the Kirkwood Water Department, and just about ten kilometers downstream is an intake for the St. Louis County Water company. These service an estimated 28 thousand people and one million people, respectively. The mean flow of the river is 7895 million liters per day (MLD), and is not any larger at the drinking water intakes as it is at the release point.

Table V-54
Estimated Cumulative Releases for St. Louis County, MO
Traditional System 1

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration in Meramec River, ug/L (ppb)
Mineral Spirits	16 kg/day + 182 kg/day at laundry	99%	160 g/day 1.8 kg/day	1.6×10^{-1} 1.8
Cyclohexanone	10 kg/day	90%	1 g/day	1×10^{-3}
Sodium Hypochlorite	10 kg/day	>> 99%	<<100 g/day	$<<1 \times 10^{-1}$

Releases to Air from Individual Screen Printing Facilities

Table V-55
Air Release, Concentration and Potential Dose Estimates From a Single Model Facility
Traditional System 1

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Mineral Spirits	69.5 g/day	3 x 10^{-1} ug/m^3	1.1
Acetone	167 g/day	23 ug/m^3	2.6
Xylene	47.5 g/day	9 x 10^{-2} ug/m^3	0.7
Cyclohexanone	58.1 g/day	1 x 10^{-1} ug/m^3	0.9

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

The following graphic depicts the population near San Bernardino, CA, and the lines (isopleths) are equal average concentration of acetone from a hypothetical facility at 34° latitude and 117° longitude. The concentrations do not vary in concentric circles from the release point, but in patterns which depend on the weather and terrain.

Table V-56
Population Risk Estimates for Traditional System 1

Chemical Name	Ambient Air (Health)	Ambient Water (Health)	Ambient Water Conc/Eco CC
Mineral spirits	See note 1	See note 1	2
Sodium hypochlorite	Air releases not expected	See note 2	~ 10^{-3}
Xylene	Hazard Quotient = ~ 10^{-5}	Water releases not expected	Water releases not expected
Acetone	Hazard Quotient = ~ 10^{-3}	Water releases not expected	Water releases not expected
Cyclohexanone	Hazard Quotient = ~ 10^{-5}	Hazard Quotient = ~ 10^{-8}	~10^{-7}

Note 1: Risks resulting from exposures to mineral spirits could not be quantified.
Note 2: Human health risks from the release of hypochlorite to water are expected to be very low, but cannot be quantified because of limitations in the available hazard data. Estimated concentrations of hypochlorite in ambient water are much lower than hypochlorite concentrations in typical drinking water supplies.

General Population Risk Conclusions and Observations

- Health risks to the general population from both air and water exposures are very low for Method 2, Traditional System 1.

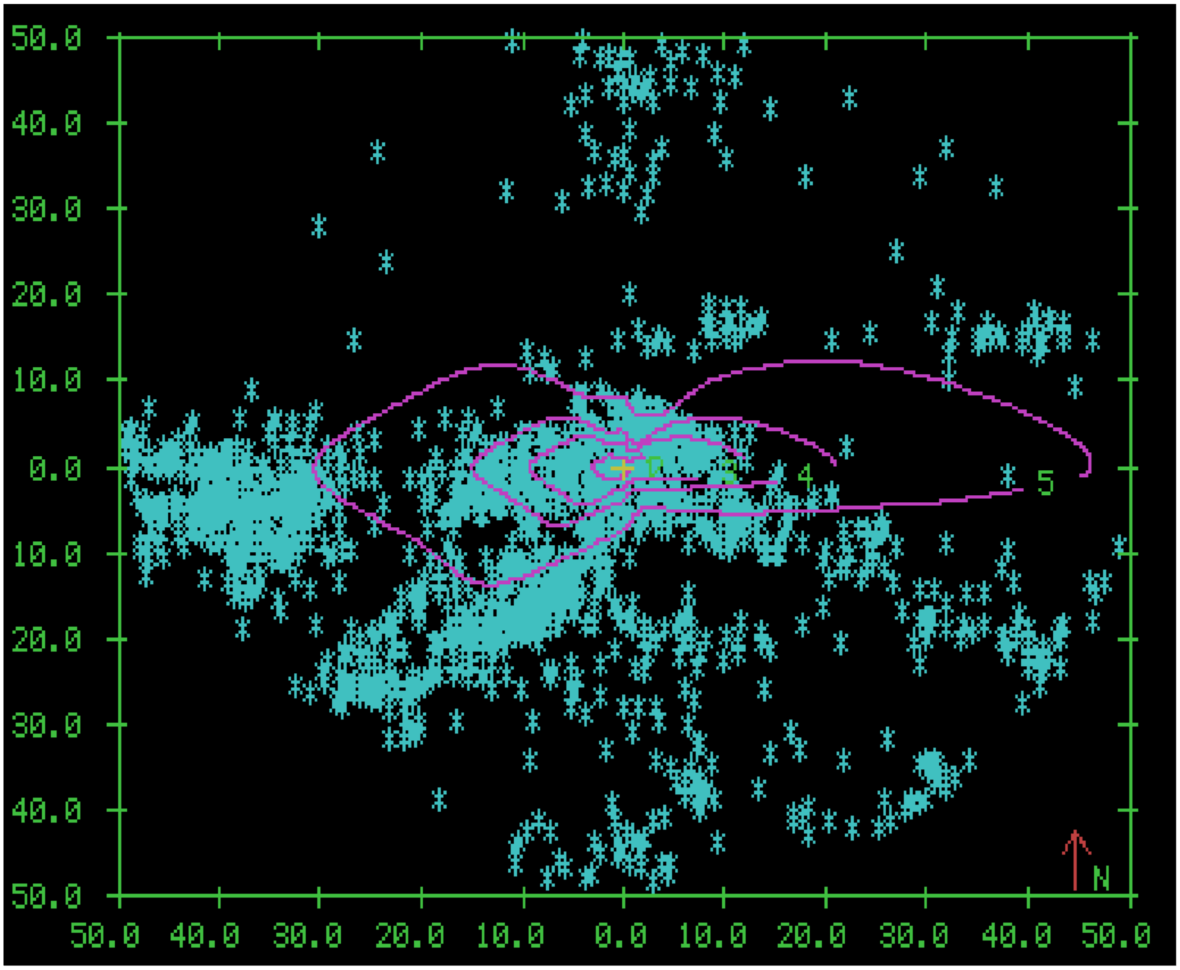
- Risks to the general population from ambient air and drinking water exposures are very low for Method 2, Traditional System 1.

- The major health impact on the general population for this type of product is probably its release of volatile organic compounds that contribute to the formation of photochemical smog in the ambient air.

- A marginal concern exists for risks to aquatic species resulting from the release of mineral spirits from a commercial laundry that launders shop rags from all of the screen printing facilities in the area. Aquatic risks from all of the chemicals are low with respect to direct water releases from the screen printing facilities.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Figure V-3
Acetone Concentration Patterns Around a "Typical" Screen Print Facility



ISOPLETH #	CONCENTRATION, ug/m^3
1	5.4×10^{-4}
2	5.0×10^{-4}
3	1.0×10^{-4}
4	5.0×10^{-5}
5	1.8×10^{-5}

* = Population Centroid - Weighted center of population of one census block group. There are roughly 800 to 1200 people represented by each centroid.

Distances are in kilometers

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

- Cumulative releases of mineral spirits from Traditional System 1 present a concern for risk to aquatic species. The largest contributor to these releases is the hypothetical commercial laundry that launders the shop rags used by the area's screen printers.
- None of the components of Method 2, Traditional System 1 reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.
- None of the single facility releases of Method 2, Traditional System 1 reach an ecotoxicity concern concentration.

The following table summarizes the exposure and risk estimates for cumulative releases of Traditional System 1. The analogous figures for single facilities show much lower exposure and risk levels.

Table V-57
Estimated Cumulative Releases for St. Louis County, MO
Screen Reclamation Method 2, Traditional System 1

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Conc. in Meramec River, ug/L (ppb)	ECO CC (ug/l)	ECO RISK INDICATOR (STREAM CONC/ ECO CC)
Mineral Spirits	16 kg/day + 182 kg/day at laundry	94 %	960 g/day 11 kg/day	1×10^{-1} 1	1	1.1
Cyclohexanone	10 kg/day	83%	1.7 kg/day	2×10^{-1}	2800	7×10^{-5}
Sodium Hypochlorite	10 kg/day	100 %	0	0	<20	0

Performance

The performance of this system was not demonstrated at the Screen Printing Technical Foundation or at volunteer printing facilities. Since this system is commonly used in many screen printing shops, it was decided to use the limited resources available for a performance demonstration to evaluate alternatives to the traditionally used product systems.

Cost

Because the performance of this system was not determined in this project, the total cost of using this system was also not calculated.

Traditional System 2

Formulation

Ink Remover	100% Acetone
Emulsion Remover	12% Sodium hypochlorite (bleach)
Haze Remover	10% Xylene
	30% Acetone
	30% Mineral spirits
	30% Cyclohexanone

Occupational Exposure

Table V-58
Occupational Exposure Estimates for Method 2, Traditional System 2

	Inhalation (mg/day)				Dermal (mg/day)	
System	I	II	III	IV	Routine	Immersion
Ink Remover						
Acetone	539	11	5	38	1560	7280
Emulsion Remover (Bleach)						
Sodium hypochlorite	0	0	0	0	187	874
Water	0	0	0	0	1370	6410
Haze Remover						
Xylenes (mixed isomers)	21	0.9	1	0	156	728
Acetone	64	11	5	0	468	2180
Mineral spirits- light hydrotreated	7	0.1	0	0	468	2180
Cyclohexanone	27	0.3	0	0	468	2180

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-59
Occupational Risk Estimates for Method 2, Traditional System 2

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Acetone	84	23	1,040	NA	NA	NA	NA	NA	NA
Emulsion Remover (Bleach)									
Sodium hypochlorite	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Xylenes (mixed isomers)	0.2	1.1	5.2	NA	NA	NA	NA	NA	NA
Acetone	11	66	311.	NA	NA	NA	NA	NA	NA
Mineral spirits- light hydrotreated	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexanone	0.07	1.3	6.2	180	NA	NA	0	0	0

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.
[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.
[c] NOAEL means No Observed Adverse Effect Level.
[d] LOAEL means Lowest Observed Adverse Effect Level.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

- Hazard quotient calculations indicate clear concerns for chronic dermal and inhalation exposures to workers using acetone in either ink removal or haze removal.

- Hazard quotient calculations indicate marginal concerns for dermal exposures to workers using xylene and cyclohexanone in haze removal.

- Margin-of-exposure calculations indicate very low concern for developmental and reproductive toxicity risks from inhalation of cyclohexanone. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified.

- Dermal exposures to workers using mineral spirits in haze removal can be high, although the risks from mineral spirits could not be quantified because of limitations in hazard data.

Emulsion Removers (All Systems)

- All of the systems that employ an emulsion remover (all systems except Beta) use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-60
Estimated Environmental Releases in Screen Cleaning Operations
Method 2, Traditional System 2

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
<u>Ink Remover</u>							
Acetone	1120	0	0	22	11	80	1270
<u>Emulsion Remover (Bleach)</u>							
Sodium hypochlorite	0	75	0	0	0	0	0
Water	0	546	0	0	0	0	0
<u>Haze Remover</u>							
Xylenes (mixed isomers)	44	0	0	1.9	1.1	0	0
Acetone	133	0	0	22	11	0	0
Mineral spirits- light hydrotreated	15	119	0	0.2	0.1	0	0
Cyclohexanone	57	76	0	0.7	0.4	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Estimated Environmental Releases from Screen Reclamation Processes Method 2, Traditional Screen Reclamation System 2

From Ink Removal Operations:
    Acetone
        1233 g/day to air
        1270 g/day to water

From Emulsion Remover:
    Sodium Hypoclorite
        75 g/day to water

From Haze Remover:
    Acetone:
        166 g/day to air
    Xylenes:
        47 g/day to air
    Mineral Spirits:
        15.3 g/day to air
        119 g/day to water
    Cyclohexanone:
        58.1 g/day to air
        76 g/day to water

Table V-61
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Method 2, Traditional System 2

Substance:	To Air:	To Water:	To Landfill:
Acetone	1,399 g/day	1270[a] g/day	1270[a] g/day
Sodium Hypoclorite		75 g/day	
Mineral Spirits	15.3 g/day	119 g/day	
Xylenes	47 g/day		
Cyclohexanone	58.1 g/day	76 g/day	

[a] 1270 g/day is estimated to be releases from the rags. This release from the rags will be either to landfill or to water. If the release is to water through the laundry, then the landfill column is blank. If the release is to landfill, then the landfill column will be 1270 g/day and the water column will be empty. This is true of all of the ink remover chemicals. For our purposes, the rest of the assessment assumes release to water only, since we are not assessing landfill releases.

Releases to Water from a Single Facility

Table V-62
Estimated Releases to Water from Method 2, Traditional System 2

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Acetone	1270 g/day	87%	165 g/day	0.2
Cyclohexanone	76 g/day	83%	12.9 g/day	1×10^{-2}
Mineral spirits	119 g/day	94%	7.14 g/day	7×10^{-3}
Sodium Hypoclorite	75 g/day	>>99%	<<1 g/day	$<<1 \times 10^{-3}$

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Water from Multiple Screen Printers

The concentrations listed in the chart above are relatively low. However, in the local area there may be many screen printers, all of which are connected to the same waste treatment facility. The concentration in the stream would be the combined amounts of all of the releases in the stream, which could be significant, even if the release from one screen printing facility is not.

To demonstrate the combined effects, the multiple screen printing facilities in St. Louis County, Missouri were picked as an example. The Dun and Bradstreet data shows 135 screen printing facilities in St. Louis County. We are assuming that the waste water from all of these is going to the St. Louis County Sewer Company, which releases into the Meramec River. Less than five kilometers downstream is the Kirkwood Water Department, and just about ten kilometers downstream is an intake for the St. Louis County Water company. These service an estimated 28 thousand people and one million people, respectively. The mean flow of the river is 7895 million liters per day (MLD), and is not any larger at the drinking water intakes than it is at the release point.

Table V-63
Estimated Cumulative Releases for St. Louis County, MO
Method 2, Traditional System 2

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Average Concentration in Meramec River, ug/L (ppb)
Acetone	171 kg/day	87%	22.3 kg/day	3
Mineral Spirits	16.1 kg/day	94%	964 g/day	0.1
Cyclohexanone	10.3 kg/day	83%	1.7 kg/day	0.2
Sodium Hypochlorite	10.1 kg/day	>>99%	<< 100 g/day	<< 1×10^{-1}

[b] >> is very much greater than, << is very much less than.

Releases to Air from Individual Screen Printing Facilities

Table V-64
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Method 2, Traditional System 2

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Mineral Spirits	15.3 g/day	3×10^{-2} ug/m^3	0.2
Acetone	1399 g/day	3 ug/m^3	20
Xylenes	47 g/day	9×10^{-2} ug/m^3	0.7
Cyclohexanone	58.1 g/day	1×10^{-1} ug/m^3	0.7

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Traditional System 2.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

- ○ None of the other components of Method 2, Traditional System 2 reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.
- ○ None of the single facility releases of Method 2, Traditional System 2 reach an ecotoxicity concern concentration.

The following table summarizes the exposure and risk estimates for cumulative releases of Traditional System 2. The analogous figures for single facilities show much lower exposure and risk levels.

Table V-65
Estimated Cumulative Releases to Water for St. Louis County, MO
Screen Reclamation Method 2, Traditional System 2

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Conc. in Meramec River, ug/L (ppb)	ECO CC (ug/L)	ECO RISK INDICATOR (STREAM CONC/ ECO CC)
Acetone	171 kg/day	87%	22.3 kg/day	3	7600	$4x10^{-4}$
Mineral Spirits	16.1 kg/day	94%	964 g/day	0.1	1	0.1
Cyclohexanone	10.3 kg/day	83%	1.7 kg/day	0.2	2800	$7x10^{-5}$
Sodium Hypochlorite	10.1 kg/day	>>99%	<< 100 kg/day	$<< 1 \times 10^{-1}$	20	$<<1 \times 10^{-2}$

Performance

The performance of this system was not demonstrated at the Screen Printing Technical Foundation or at volunteer printing facilities. Since this system is commonly used in many screen printing shops, it was decided to use the limited resources available for a performance demonstration to evaluate alternatives to the traditionally used product systems.

Cost

Because the performance of this system was not determined in this project, the total cost of using this system was also not calculated.

Traditional System 3

Formulation

Ink Remover: 100% Lacquer Thinner, consisting of:
- 30% Methyl ethyl ketone
- 15% n-butyl acetate
- 5% Methanol
- 20% Naphtha light aliphatic
- 20% Toluene
- 10% Isobutyl isobutyrate

Emulsion Remover: 12 wt% Sodium hypochlorite/88 % water

Haze Remover:
- 10% Xylene
- 30% Acetone
- 30% Mineral spirits
- 30% Cyclohexanone

Occupational Exposure

Table V-66
Occupational Exposure Estimates for Method 2, Traditional System 3

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Methyl ethyl ketone(2-butanone)	165	5.3	3	20	468	2180
Butyl acetate, normal	44	1.3	1	5.3	234	1090
Methanol	27	4.7	2	15	78	364
Naphtha, light aliphatic	98	1.6	1	6.2	312	1460
Toluene	110	2.3	1	9.2	312	1460
Isobutyl isobutyrate	7	0.4	0	1.7	156	728
Emulsion Remover (Bleach)						
Sodium hypochlorite	0	0	0	0	187	874
Water	0	0	0	0	1370	874
Haze Remover						
Xylenes (mixed isomers)	21	0.9	1	0	156	728
Acetone	64	11	5	0	468	2180
Mineral spirits- light hydrotreated	7	0.1	0	0	468	2180
Cyclohexanone	27	0.3	0	0	468	2180

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

○ Hazard quotient calculations indicate clear concerns for both toluene and methyl ethyl ketone with respect to chronic dermal and inhalation exposures to workers using these chemicals in ink removal.

○ Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using methanol in ink removal.

○ Hazard quotient calculations indicate clear concerns for chronic dermal and inhalation exposures to workers using acetone in haze removal.

Table V-67
Occupational Risk Estimates for Method 2, Traditional System 3

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	**Inhalation**	**Routine**	**Immersion**	**NOAEL[c]**	**LOAEL[d]**	**NOAEL**	**LOAEL**	**NOAEL**	**LOAEL**
Ink Remover									
Methyl ethyl ketone (2-butanone)	9.29	23	103	NA	NA	NA	NA	NA	NA
Butyl acetate normal	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methanol	1.4	2.2	10	NA	NA	NA	NA	NA	NA
Aromatic solvent naphtha	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	17	44	208	NA	NA	NA	NA	NA	NA
Isobutyl isobutyrate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover (Bleach)									
Sodium hypochlorite	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Xylenes (mixed isomers)	0.2	1.1	5.2	NA	NA	NA	NA	NA	NA
Acetone	11	66	311	NA	NA	NA	NA	NA	NA
Mineral spirits- light hydrotreated	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexanone	0.07	1.3	6.2	180	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

- ○ Hazard quotient calculations indicate marginal concerns for chronic dermal exposures to workers using cyclohexanone in haze removal.

- ○ Margin-of-exposure calculations indicate very low concern for developmental and reproductive toxicity risks from inhalation of cyclohexanone. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified.

- ○ Dermal exposures to workers using mineral spirits in haze removal can be high, although the risks from mineral spirits could not be quantified because of limitations in hazard data.

Emulsion Removers (All Systems)

- ○ All of the systems that employ an emulsion remover (all systems except Beta) use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-68
Estimated Environmental Releases in Screen Cleaning Operations
Method 2, Traditional System 3

	Release Under Each Scenario (g/day)						
	I			**II**	**III**	**IV**	
System	**air**	**water**	**land**	**air**	**air**	**air**	**water**
Ink Remover							
Methyl ethyl ketone(2-butanone)	344	0	0	11	5.7	42	363
Butyl acetate, normal	92	0	80	2.6	1.5	11	191
Methanol	57	0	0	9.8	4.1	30	37
Naphtha, light aliphatic	204	0	25	3.2	1.7	13	257
Toluene	229	0	0	4.8	2.6	19	251
Isobutyl isobutyrate	15	0	100	0.8	0.5	3.4	132
Emulsion Remover (Bleach)							
Sodium hypochlorite	0	75	0	0	0	0	0
Water	0	546	0	0	0	0	0
Haze Remover							
Xylenes (mixed isomers)	44	0	0	1.9	1.1	0	0
Acetone	133	0	0	22	11	0	0
Mineral spirits- light hydrotreated	15	119	0	0.2	0.1	0	0
Cyclohexanone	57	76	0	0.7	0.4	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-69
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Method 2, Traditional System 3

Substance:	To Air:	To Water:	To Landfill:
Methyl ethyl ketone	403 g/day	363 g/day at laundry	
n-butyl Acetate	107 g/day	191 g/day at laundry[a]	80 g/day[a]
Methanol	101 g/day	37 g/day at laundry	
Naphtha, light aliphatic	222 g/day	257 g/day at laundry	25 g/day
Toluene	255 g/day	251 g/day at laundry	
Isobutyl isobutyrate	19.7 g/day	132 g/day at laundry	100 g/day
Bleach		75 g/day	
Mineral Spirits	15.3 g/day	119 g/day	
Acetone	166 g/day		
Xylenes	47 g/day		
Cyclohexanone	58.1 g/day	76 g/day	

[a] The landfill number is the amount estimated to be releases from the rags. This release from the rags will be either to landfill or to water. If the release is to water through the laundry, then the landfill column is blank. This is true of all of the ink remover chemicals. For our purposes, the rest of the assessment assumes release to water only, since we are not assessing landfill releases.

Releases to Water from a Single Facility

Table V-70
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility
Method 2, Traditional System 3

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Mean Daily Concentration, ug/L[a] for 1000 MLD Receiving Water
Methyl Ethyl Ketone	363 g/day at laundry	84%	58 g/day	6×10^{-2}
n-butyl acetate	191 g/day at laundry	97%	5.7 g/day	6×10^{-3}
Methanol	37 g/day at laundry	97%	1.1 g/day	1×10^{-3}
Naphtha, light aliphatic	257 g/day at laundry	94%	15 g/day	2×10^{-2}
Toluene	251 g/day at laundry	92%	20 g/day	2×10^{-2}
Isobutyl isobutyrate	132 g/day at laundry	98%	2.6 g/day	3×10^{-3}
Mineral Spirits	119 g/day	94%	7.1 g/day	7×10^{-3}
Cyclohexanone	76 g/day	83%	13 g/day	1×10^{-2}
Sodium Hypochlorite[b]	75 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.
[b] Concentrated solutions of sodium hypochlorite will kill the biota which degrade organic chemicals (the other substances listed in the table) during waste water treatment. This could cause problems at the waste water treatment plant, reducing the waste water treatment efficiency for the other compounds sent to the plant.

Releases to Water from Multiple Screen Printers

The concentrations listed in the chart above are relatively low. However, in the local area there may be many screen printers, all of which are connected to the same waste treatment facility. The concentration in the stream would be the combined amounts of all of the releases in the stream, which could be significant, even if the release from one screen printing facility is not.

To demonstrate the combined effects, the multiple screen printing facilities in St. Louis County, Missouri were picked as an example. The Dun and Bradstreet data shows 135 screen printing facilities in St. Louis County. We are assuming that the waste water from all of these is going to the St. Louis County Sewer Company, which releases into the Meramec River. Less than five kilometers downstream is the Kirkwood Water Department, and just about ten kilometers downstream is an intake for the St. Louis County Water company. These service an estimated 28 thousand people and one million people, respectively. The mean flow of the river is 7895 million liters per day (MLD), and is not any larger at the drinking water intakes than it is at the release point.

Table V-71
Estimated Cumulative Releases for St. Louis County, MO
Method 2, Traditional System 3

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Average Concentration in Meramec River, ug/L (ppb)
Methyl ethyl ketone	49 kg/day	84%	7.8 kg/day	1
n-butyl acetate	26 kg/day	97%	8×10^{-1} kg/day	1×10^{-1}
Methanol	5 kg/day	97%	150 g/day	2×10^{-2}
Naphtha, light aliphatic	35 kg/day	94%	2.1 kg/day	3×10^{-1}
Toluene	34 kg/day	92%	2.7 kg/day	3×10^{-1}
Isobutyl isobutyrate	18 kg/day	98%	360 g/day	4×10^{-2}
Mineral Spirits	16 kg/day	94%	960 g/day	1×10^{-1}
Cyclohexanone	10 kg/day	83%	1.7 kg/day	2×10^{-1}
Sodium Hypochlorite	10 kg/day	>> 99%	<<100 g/day	$<<1 \times 10^{-2}$

Releases to Air from Individual Screen Printing Facilities

Table V-72
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Method 2, Traditional System 3

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Methyl Ethyl Ketone	403 g/day	8×10^{-1} ug/m^3	6
n-butyl acetate	107 g/day	2×10^{-1} ug/m^3	1
Methanol	101 g/day	2×10^{-1} ug/m^3	1
Naphtha, light aliphatic	222 g/day	4×10^{-1} ug/m^3	3
Toluene	255 g/day	5×10^{-1} ug/m^3	4
Isobutyl isobutyrate	19.7	4×10^{-2} ug/m^3	0.3
Mineral Spirits	15.3 g/day	3×10^{-2} ug/m^3	0.2
Acetone	166 g/day	3×10^{-1} ug/m^3	2
Xylenes	47 g/day	9×10^{-2} ug/m^3	0.7
Cyclohexanone	58.1 g/day	1×10^{-1} ug/m^3	0.7

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Traditional System 3.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Table V-73
Risks from Potential Drinking Water Exposures
Screen Reclamation Method 2, Traditional System 3

Substance	Daily Stream Concentration in Meramec River, ug/L (ppb)	Daily dose from Drinking Water (mg/kg)	RfD (mg/kg)	Hazard Quotient (dose/RfD)
Methyl ethyl ketone	1	$3x10^{-5}$	0.6	$5x10^{-5}$
n-butyl acetate	1×10^{-1}	$3x10^{-6}$	not available	
Methanol	2×10^{-2}	$6x10^{-7}$	0.5	$1x10^{-6}$
Naphtha, light aliphatic	3×10^{-1}	$9x10^{-6}$	not available	
Toluene	3×10^{-1}	$9x10^{-6}$	0.2	$4x10^{-5}$
Isobutyl isobutyrate	4×10^{-2}	$1x10^{-6}$	not available	
Mineral Spirits	1×10^{-1}	$3x10^{-6}$	not available	
Cyclohexanone	2×10^{-1}	$6x10^{-6}$	5	$1x10^{-6}$
Sodium Hypochlorite	$<<1 \times 10^{-2}$	$<<3x10^{-7}$	not available	

Table V-74
Risk Estimates from Ambient Air Releases from a Single Model Facility Screen Reclamation Method 2, Traditional System 3

Substance	Highest Avg Concentration 100 M away	Daily Potential Dose, (mg/kg)	RfD/RfC (mg/kg, mg/m_3)	Hazard Quotient(Dose or Conc/RfD or RfC)
Methyl Ethyl Ketone	8×10^{-1} ug/m^3	$2x10^{-4}$	1 mg/m^3	$8x10^{-4}$
n-butyl acetate	2×10^{-1} ug/m^3	$4x10^{-5}$	not available	
Methanol	2×10^{-1} ug/m^3	$4x10^{-5}$	0.5 mg/kg	$8x10^{-5}$
Naphtha, light aliphatic	4×10^{-1} ug/m^3	$1x10^{-4}$	not available	
Toluene	5×10^{-1} ug/m^3	$2x10^{-4}$	0.4 mg/m^3	$1x10^{-3}$
Isobutyl isobutyrate	4×10^{-2} ug/m^3	$1x10^{-5}$	not available	
Mineral Spirits	3×10^{-2} ug/m^3	$8x10^{-6}$	not available	
Acetone	3×10^{-1} ug/m^3	$8x10^{-5}$	0.1 mg/kg	$8x10^{-4}$
Xylenes	9×10^{-2} ug/m^3	$3x10^{-5}$	2 mg/kg	$1x10^{-5}$
Cyclohexanone	1×10^{-1} ug/m^3	$3x10^{-5}$	5 mg/kg	$6x10^{-6}$

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the other components of Method 2, Traditional System 3 reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.

○ None of the single facility releases of Method 2, Traditional System 3 reach an ecotoxicity concern concentration.

The following table summarizes the exposure and risk estimates for cumulative releases of Traditional System 3. The analogous figures for single facilities show much lower exposure and risk levels.

Table V-75
Estimated Cumulative Releases for St. Louis County, MO
Screen Reclamation Method 2, Traditional System 3

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Conc. in Meramec River, ug/L (ppb)	ECO CC (ug/L)	ECO RISK INDICATOR (STREAM CONC/ ECO CC)
Methyl ethyl ketone	49 kg/day	84%	7.8 kg/day	1	4500	$2x10^{-4}$
n-butyl acetate	26 kg/day	97%	$8 x 10^{-1}$ kg/day	$1 x 10^{-1}$	140	$7x10^{-4}$
Methanol	5 kg/day	97%	150 g/day	$2 x 10^{-2}$	9000	$2x10^{-6}$
Naphtha light aliphatic	35 kg/day	94%	2.1 kg/day	$3 x 10^{-1}$	5	0.06
Toluene	34 kg/day	92%	2.7 kg/day	$3 x 10^{-1}$	110	$3x10^{-3}$
Isobutyl isobutyrate	18 kg/day	98%	360 g/day	$4 x 10^{-2}$	80	$5x10^{-4}$
Mineral Spirits	16 kg/day	94%	960 g/day	$1 x 10^{-1}$	1	0.1
Cyclohexanone	10 kg/day	83%	1.7 kg/day	$2 x 10^{-1}$	2800	$7x10^{-5}$
Sodium Hypochlorite	10 kg/day	>> 99%	<<100 g/day	$<<1 x 10^{-2}$	<20	~0.05

Performance

General Summary of Traditional System 3 Performance

The performance of Traditional System 3 was demonstrated at SPTF. This product system consisted of an ink remover (lacquer thinner), an emulsion remover (sodium hypochlorite or bleach), and a haze remover. The ink remover and the haze remover were selected based on general chemical formulations that were identified by manufacturers as the most common types of products currently used in the screen printing industry. SPTF did not use the haze remover suggested by the manufacturers due to concerns about the volatility and hazards of the product; instead a commonly used, commercially available haze remover containing potassium hydroxide and tetrahydrofurfuryl alcohol was used. Unlike the alternative systems, Traditional Product System 3 was only tested at SPTF; no demonstrations were conducted at volunteer printing facilities. Traditional System 3 was tested following the same procedure as was used for alternative system testing at SPTF (see Appendix F for details of the testing methodology and test parameters).

Overall, SPTF described the ink remover (lacquer thinner) as very difficult to work with, and incompatible with water-based ink systems. Using bleach as an emulsion remover was also inefficient: it required a lot of time and effort to remove the stencil. The haze remover worked very well on the screens with solvent-based ink and UV ink, but it was not tested on the screen with water-based ink.

Traditional System 3 Profile

The products in Traditional System 3 were used to reclaim screens as follows:

- ○ Ink Removal Card up the excess ink from the screen with cardboard or plastic squeegees. Spray the screen surface with the ink remover and wipe up the dissolved ink and solvent with an absorbent rag or cloth. Repeat spraying on the product and wiping off the ink until the ink is removed and little comes off on the cloth.
- ○ Emulsion Removal Place the screen in the washout sink and spray both sides of the stencil area so that the product evenly covers the stencil. Use a soft brush to loosen the stencil. Scrub with the brush until the stencil is broken up in all areas. Apply more product if necessary. Wash away the stencil with a hard spray of water, preferably with a pressure washer.
- ○ Haze Removal Mix the haze remover paste thoroughly. Brush the product on the stained areas on both sides of the wet mesh. Let stand for a maximum of 8 minutes. Rinse off the residue with a gentle water spray, followed by a high pressure water spray to remove the stain.

Traditional System 3 Performance by SPTF

Traditional System 3 was tested by SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). The performance of the products varied greatly with the different ink types.

On the screen with the solvent-based ink, the lacquer thinner removed the ink, but left a gray haze over the screen. The technician noted that the lacquer thinner was very difficult to use: it required a lot of wiping effort and ten rags were used to remove the ink. The stencil was affected during ink removal, either from the lacquer thinner itself or from the excessive wiping that was required to remove the ink. The emulsion remover was also very difficult to use. Three applications of the bleach were required, along with vigorous scrubbing for over 10 minutes to remove the stencil. When the stencil finally did dissolve and the screen was pressure washed, ink residue and stain remained in the image areas. The haze remover easily removed all of the ink residue and the ink stain. The screen was then left in the laboratory testing area overnight. The next day, the technician noticed that the screen had ripped sometime after the test was complete.

The performance of the traditional system was similar on the screen with UV ink. The lacquer thinner left a gray haze on the screen and the stencil started to deteriorate during the ink removal step. The UV ink screen did not require quite as much scrubbing effort as the solvent-based ink screen, and seven rags were used. The bleach performance was the same as with the solvent-based ink screen: the stencil dissolved very slowly, and an excessive amount of scrubbing, effort, and rinsing were needed to remove the stencil. After the rinse, ink residue remained in the image areas. As with the solvent-based ink screen, the haze remover easily removed the ink residue and no latent image was visible.

On the screen with the water-based ink, the lacquer thinner proved to be completely incompatible. All of the ink on the screen solidified when the lacquer thinner was applied. At that point, the test had to be aborted and the emulsion remover and haze remover were not applied.

Traditional System 3 Performance Table

The following table highlights the observed performance of Traditional Product System 3 during the product tests performed at SPTF.

Cost

Although the performance of this system was demonstrated at SPTF, the total cost of this system was not calculated. It was determined that a cost analysis with a sodium periodate-based emulsion remover would be more representative of the products that are currently being used at screen printers. Subsequently, the traditional system cost baseline was based on Traditional System 4, not System 3.

Table V-76
Performance Summary For Traditional Product System 3

		Performance					Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Overall System Performance	Ink type	Emulsion type	Mesh type; Thread count	Average Screen Size
Laboratory Testing at SPTF										
Solvent-based Ink	*Ink Remover*	15 mins	3.5 oz.	8.7 mins	High	Removed ink with a lot of scrubbing. Gray haze remained on entire screen.	Solvent-based	Dual-cure direct	Polyester; 245 threads/inch	360 in^2
	Emulsion Remover	24 hours	3.0 oz.	22.5 mins	High	Stencil dissolved slowly with vigorous scrubbing. Heavy ink residue and stain remained in image areas.				
	Haze Remover[a]	0 mins	1.5 oz.	11.0 mins	Low	Removed all residue and stain.				
UV-curable Ink	*Ink Remover*	15 mins	2.5 oz.	7.4 mins	Moderate	Removed ink with moderate scrubbing. A gray haze remained on the screen.	UV-cured	Dual-cure direct	Polyester; 390 threads/inch	360 in^2
	Emulsion Remover	24 hours	3.0 oz.	17.7 mins	High	Stencil dissolved slowly with vigorous scrubbing and excessive rinsing. Ink residue and stain remained in image areas.				
	Haze Remover[a]	0 mins	1.0 oz.	12.0 mins	Low	Removed all residue and stain.				
Water-based Ink	*Ink Remover*	15 mins	not recorded	not recorded	not recorded	The ink solidified across the entire screen when the ink remover was applied. Testing was stopped at this point.	Water-based	Dual-cure direct	Polyester; 245 threads/inch	360 in^2
	Emulsion Remover	not used	not used	not used	not used	Test aborted after ink remover failure.				
	Haze Remover	not used	not used	not used	not used	Test aborted after ink remover failure.				

[a] A haze remover other than the formulation specified by the manufacturer and evaluated in the risk assessment for this system was used during the performance demonstration. See General Summary of Traditional System 3 Performance for details.

Traditional System 4

Formulation

Ink Remover:	100% Lacquer Thinner, consisting of:
	30% Methyl ethyl ketone
	15% n-butyl acetate
	5% Methanol
	20% Naphtha light alipahtic
	20% Toluene
	10% Isobutyl isobutyrate
Emulsion Remover:	1% Sodium periodate/ 99% water
Haze Remover:	10% Xylene
	30% Acetone
	30% Mineral spirits
	30% Cyclohexanone

Occupational Exposure

Table V-77
Occupational Exposure Estimates for Method 2, Traditional System 4

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
<u>Ink Remover</u>						
Methyl ethyl ketone(2-butanone)	165	5.3	3	20	468	2180
Butyl acetate normal	44	1.3	1	5.3	234	1090
Methanol	27	4.7	2	15	78	364
Naphtha, light aliphatic	98	1.6	1	6.2	312	1460
Toluene	110	2.3	1	9.2	312	1460
Isobutyl isobutyrate	7	0.4	0	1.7	156	728
<u>Emulsion Remover (Zeta diluted 1:4)</u>						
Sodium periodate	0	0	0	0	16	73
Water	0	0	0	0	1540	7210
<u>Haze Remover</u>						
Xylenes (mixed isomers)	21	0.9	1	0	156	728
Acetone	64	11	5	0	468	2180
Mineral spirits- light hydrotreated	7	0.1	0	0	468	2180
Cyclohexanone	27	0.3	0	0	468	2180

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Occupational Risk Conclusions and Observations

<u>Ink Remover and Haze Remover</u>

- Hazard quotient calculations indicate clear concerns for both toluene and methyl ethyl ketone with respect to chronic dermal and inhalation exposures to workers using these chemicals in ink removal.

- Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using methanol in ink removal.

- Hazard quotient calculations indicate clear concerns for chronic dermal and inhalation exposures to workers using acetone in haze removal.

- Hazard quotient calculations indicate marginal concerns for chronic dermal exposures to workers using cyclohexanone in haze removal.

Table V-78
Occupational Risk Estimates for Method 2, Traditional System 4

Name	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Methyl ethyl ketone (2-butanone)	9.3	22	103	NA	NA	NA	NA	NA	NA
Butyl acetate normal	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methanol	1.4	2.2	10	NA	NA	NA	NA	NA	NA
Aromatic solvent naphtha	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	17	44	208	NA	NA	NA	NA	NA	NA
Isobutyl isobutyrate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover (Zeta diluted 1:4)									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Xylenes (mixed isomers)	0.2	1.1	5.2	NA	NA	NA	NA	NA	NA
Acetone	11	66	310	NA	NA	NA	NA	NA	NA
Mineral spirits- light hydrotreated	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexanone	0.07	1.3	6.2	180	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

- Margin-of-exposure calculations indicate very low concern for developmental and reproductive toxicity risks from inhalation of cyclohexanone. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified.

- Dermal exposures to workers using mineral spirits in haze removal can be high, although the risks from mineral spirits could not be quantified because of limitations in hazard data.

Emulsion Removers (All Systems)

- All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-79
Estimated Environmental Releases in Screen Cleaning Operations
Method 2, Traditional System 4

	Release Under Each Scenario (g/day)						
	I			**II**	**III**	**IV**	
System	**air**	**water**	**land**	**air**	**air**	**air**	**water**
Ink Remover							
Methyl ethyl ketone(2-butanone)	344	0	0	11	5.7	42	363
Butyl acetate, normal	92	0	80	2.6	1.5	11	191
Methanol	57	0	0	9.8	4.1	30	37
Naphtha, light aliphatic	204	0	25	3.2	1.7	13	257
Toluene	229	0	0	4.8	2.6	19	251
Isobutyl isobutyrate	15	0	100	0.8	0.5	3.4	132
Emulsion Remover (Zeta diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0
Haze Remover							
Xylenes (mixed isomers)	44	0	0	1.9	1.1	0	0
Acetone	133	0	0	22	11	0	0
Mineral spirits- light hydrotreated	15	119	0	0.2	0.1	0	0
Cyclohexanone	57	76	0	0.7	0.4	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-80
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Method 2, Traditional System 4

Substance:	To Air:	To Water:	To Landfill:
Methyl ethyl ketone	403 g/day	363 g/day at laundry	
n-butyl Acetate	107 g/day	191 g/day at laundry[a]	80 g/day[a]
Methanol	101 g/day	37 g/day at laundry	
Naphtha, light aliphatic	222 g/day	257 g/day at laundry	25 g/day
Toluene	255 g/day	251 g/day at laundry	
Isobutyl isobutyrate	19.7 g/day	132 g/day at laundry	100 g/day
Sodium periodate		6 g/day	
Mineral Spirits	15.3	119 g/day	
Acetone	166 g/day		
Xylenes	47 g/day		
Cyclohexanone	58.1 g/day	76 g/day	

[a] 191 g/day is estimated to be releases from the rags if the rags are laundered. This release from the rags will be either to landfill or to water. If the release is to water through the laundry, then the landfill column is blank. If the release is to landfill, then the landfill column will be 80 g/day and the water column will be blank. This is true for all of the ink remover chemicals. For our purposes, the rest of the assessment assumes release to water only, since we are not assessing landfill releases.

Releases to Water from a Single Facility

Table V-81
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility
Method 2, Traditional System 4

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Methyl Ethyl Ketone	363 g/day at laundry	84%	58 g/day	6×10^{-2}
n-butyl acetate	191 g/day at laundry	97%	5.7 g/day	6×10^{-3}
Methanol	37 g/day at laundry	97%	1.1 g/day	1×10^{-3}
Naphtha, light aliphatic	257 g/day at laundry	94%	15.4 g/day	2×10^{-2}
Toluene	251 g/day at laundry	92%	20 g/day	2×10^{-2}
Isobutyl isobutyrate	132 g/day at laundry	98%	2.6 g/day	3×10^{-3}
Mineral Spirits	119 g/day	94%	7.1 g/day	7×10^{-3}
Cyclohexanone	76 g/day	83%	13 g/day	1×10^{-2}
Sodium periodate	6 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Water from Multiple Screen Printers

The concentrations listed in the chart above are relatively low. However, in the local area there may be many screen printers, all of which are connected to the same waste treatment facility. The concentration in the stream would be the combined amounts of all of the releases in the stream, which could be significant, even if the release from one screen printing facility is not.

To demonstrate the combined effects, the multiple screen printing facilities in St. Louis County, Missouri were picked as an example. The Dun and Bradstreet data shows 135 screen printing facilities in St. Louis County. We are assuming that the waste water from all of these is going to the St. Louis County Sewer Company, which releases into the Meramec River. Less than five kilometers downstream is the Kirkwood Water Department, and just about ten kilometers downstream is an intake for the St. Louis County Water company. These service an estimated 28 thousand people and one million people, respectively. The mean flow of the river is 7895 million liters per day (MLD), and is not any larger at the drinking water intakes than it is at the release point.

Table V-82
Estimated Cumulative Releases for St. Louis County, MO
Method 2, Traditional System 4

Substance	Total Amount Released to Water from All Facilities	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Average Concentration in Meramec River, ug/L (ppb)
Methyl ethyl ketone	49 kg/day	84%	7.8 kg/day	1
n-butyl acetate	26 kg/day	97%	0.8 kg/day	1×10^{-1}
Methanol	5 kg/day	97%	150 g/day	2×10^{-2}
Naphtha, light aliphatic	35 kg/day	94%	2.1 kg/day	3×10^{-1}
Toluene	34 kg/day	92%	2.7 kg/day	3×10^{-1}
Isobutyl isobutyrate	18 kg/day	98%	360 g/day	4×10^{-2}
Mineral Spirits	16 kg/day	94%	960 g/day	1×10^{-1}
Cyclohexanone	10 kg/day	83%	1.7 kg/day	2×10^{-1}
Sodium Periodate	810 g/day	>> 99%	<< 8.1 g/day	$<<1 \times 10^{-3}$

Releases to Air from Individual Screen Printing Facilities

Table V-83
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Method 2, Traditional System 4

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Methyl Ethyl Ketone	403 g/day	8×10^{-1} ug/m^3	6
n-butyl acetate	107 g/day	2×10^{-1} ug/m^3	1
Methanol	101 g/day	2×10^{-1} ug/m^3	1
Naphtha, light aliphatic	222 g/day	4×10^{-1} ug/m^3	3
Toluene	255 g/day	5×10^{-1} ug/m^3	4
Isobutyl isobutyrate	19.7	4×10^{-2} ug/m^3	3×10^{-1}
Mineral Spirits	15.3 g/day	3×10^{-2} ug/m^3	2×10^{-1}
Acetone	166 g/day	3×10^{-1} ug/m^3	2
Xylene	47 g/day	9×10^{-2} ug/m^3	7×10^{-1}
Cyclohexanone	58.1 g/day	1×10^{-1} ug/m^3	7×10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Traditional System 4.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

- None of the other components of Method 2, Traditional System 4 reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.

- None of the single facility releases of Method 2, Traditional System 4 reach an ecotoxicity concern concentration.

The following table summarizes the exposure and risk estimates for cumulative releases of Traditional System 4. The analogous figures for single facilities show much lower exposure and risk levels.

Table V-84
Estimated Cumulative Releases for St. Louis County, MO
Screen Reclamation Method 2, Traditional System 4

Substance	Total Amount Released to Water from All Facilities	Waste Water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Conc. in Meramec River, ug/L (ppb)	ECO CC (ug/L)	Eco Risk Indicator (Stream Conc/ ECO CC)
Methyl ethyl ketone	49 kg/day	84%	7.8 kg/day	1	4500	$2x10^{-4}$
n-butyl acetate	26 kg/day	97%	0.8 kg/day	1×10^{-1}	140	$7x10^{-4}$
Methanol	5 kg/day	97%	150 g/day	2×10^{-2}	9000	$2x10^{-6}$
Naphtha, light aliphatic	35 kg/day	94%	2.1 kg/day	3×10^{-1}	5	0.06
Toluene	34 kg/day	92%	2.7 kg/day	3×10^{-1}	110	$3x10^{-3}$
Isobutyl isobutyrate	18 kg/day	98%	360 g/day	4×10^{-2}	80	$5x10^{-4}$
Mineral Spirits	16 kg/day	94%	960 g/day	1×10^{-1}	1	0.1
Cyclohexanone	10 kg/day	83%	1.7 kg/day	2×10^{-1}	2800	$7x10^{-5}$
Sodium Periodate	810 g/day	>> 99%	<< 8.1 g/day	$<<1 \times 10^{-3}$	<10	$\sim 10^{-4}$

Performance

The performance of this system was not demonstrated at the Screen Printing Technical Foundation or at volunteer printing facilities. Since this system is commonly used in many screen printing shops, it was decided to use the limited resources available for a performance demonstration to evaluate alternatives to the traditionally used product systems.

Cost

Table V-85
Baseline (Traditional System 4)

Cost Element Description		Traditional System 4
Facility Characteristics		
Average screen size (in^2)		2,127
Average # screens/day		6
Cost Elements per Screen		
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33
Materials and Equipment	# of rags used Cost ($)	3 0.45
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02
Totals		
Total Cost ($/screen)		6.27
Total Cost ($/year)		9,399

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Alpha

Formulation

Ink Remover:	Aromatic solvent naphtha Propylene glycol series ethers
Emulsion Remover:	Sodium periodate/water
Haze Remover:	Alkali/Caustic Tetrahydrofurfuryl alcohol Water

Occupational Exposure

Table V-86
Occupational Exposure Estimates for Method 2, Alternative System Alpha

System	Inhalation (mg/day) I	II	III	IV	Dermal (mg/day) Routine	Immersion
Ink Remover						
Aromatic solvent naphtha	13	0.1	0	0.2	1250	5820
Propylene glycol series ethers	56	0.6	0	2.6	312	1460
Emulsion Remover (diluted to 0.8%)						
Sodium periodate	0	0	0	0	12	58
Water	0	0	0	0	1550	7220
Haze Remover						
Alkali/Caustic	0	0	0	0	390	1820
Tetrahydrofurfuryl alcohol	1	0.1	0	0	234	1090
Water	0	0	0	0	936	4370

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-87
Occupational Risk Estimates for Alternative System Alpha

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Aromatic solvent naphtha	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propylene glycol series ethers	1.4	7.4	34		230	NA	NA	NA	NA
Emulsion Remover (diluted to 0.8%)									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Alkali/Caustic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrahydrofurfuryl alcohol	NA	NA	NA	NA	NA	NA	NA	NA	NA
water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

○ Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using propylene glycol series ethers in ink removal. Possible concerns also exist for chronic dermal exposure to propylene glycol series ethers based on the calculated hazard quotients, which assume 100% dermal absorption. If the actual dermal absorption rate of propylene glycol series ethers is significantly lower, this concern would be significantly reduced or eliminated.

○ Inhalation exposures to propylene glycol series ethers also present possible concerns for developmental toxicity risks, based on margin-of-exposure calculations.

○ Dermal exposures to other chemicals used in ink removal or haze removal can be high, although the risks could not be quantified because of limitations in hazard data.

Emulsion Removers (All Systems)

○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-88
Estimated Environmental Releases in Screen Cleaning Operations Method 2, Alternative System Alpha

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Aromatic solvent naphtha	27	0	473	0.1	0.1	0.5	1080
Propylene glycol series ethers	117	0	8	1.3	0.7	5.4	265
Emulsion Remover (diluted to 0.8%)							
Sodium periodate	0	5	0	0	0	0	0
Water	0	616	0	0	0	0	0
Alpha - Haze Remover							
Alkali/Caustic	0	133	0	0	0	0	0
Tetrahydrofurfuryl alcohol	1.5	78	0	0.1	0.1	0	0
Water	0	319	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-89
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Alpha

Substance:	To Air:	To Water:	To Landfill:
Aromatic solvent naphtha	27.7 g/day	1080 g/day at laundry	473 g/day
Propylene glycol series ethers	124 g/day	265 g/day at laundry	8 g/day
Sodium periodate		5 g/day	
Alkali/caustic		133 g/day	
Tetrahydrofurfuryl alcohol	1.7 g/day	78 g/day	

Releases to Water from a Single Facility

Table V-90
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Alpha

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Aromatic solvent naphtha	1080 g/day at laundry	92-96 %	43 g/day	4×10^{-2}
Propylene glycol series ethers	265 g/day at laundry	83-84 %	45.1 g/day	5×10^{-2}
Sodium periodate	5 g/day	100 %	0	
Alkali/caustic	133 g/day	100 %	0	
Tetrahydrofurfuryl alcohol	78 g/day	97 %	2.3 g/day	2×10^{-3}

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-91
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Alpha

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Aromatic solvent naphtha	27.7 g/day	5.6×10^{-2} ug/m^3	4×10^{-1}
Propylene glycol series ethers	124 g/day	2.5×10^{-1} ug/m^3	2
Tetrahydrofurfuryl alcohol	1.7 g/day	3×10^{-3} ug/m^3	2×10^{-2}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Alternative System Alpha.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, Alternative System Alpha reach an ecotoxicity concern concentration.

Performance

General Summary of Alternative System Alpha Performance, and Related Variables

This product system consisted of an ink remover, emulsion remover, and a haze remover. The products were demonstrated at Facilities 8, 13, and 14. Facility 8 prints labels, nameplates, and graphic overlays. They reclaimed 48 screens over 4 weeks of demonstrations using solvent-based inks. Facility 13 prints store displays, decals, and outdoor signs, and they reclaimed 13 screens using UV-cured and solvent-based inks during the 2 weeks they participated in the demonstrations. Facility 14 prints metal nameplates, vinyl pressure sensitive decals, and signs. They used solvent-based inks during the three weeks they used Alternative System Alpha and they reclaimed 36 screens.

Facility 8 reported that the ink remover worked well most of the time, but results were inconsistent and some extra scrubbing was required to achieve the desired results. Performance was improved if the ink remover was sprayed on both the scrubbing rag and the screen. The ink remover did not seem to work at all with epoxy inks. Facility 13 also reported that the ink remover required more time and scrubbing than their usual product. Facility 14 reported that the ink remover worked as well as their usual product. One screen reclamation employee at this facility reported that the ink remover worked particularly well with their vinyl inks.

At Facility 8, the emulsion remover worked satisfactorily only if the screen was rinsed with hot water before applying the product. Facility 13 reported that the emulsion remover did not work as efficiently as their usual product, taking more time to dissolve the stencil and more scrubbing, even at full strength. Facility 14 reported that the emulsion remover worked as well as their usual product and required less effort than the regular product with the same positive results. The only negative feature mentioned by Facility 14 was that the emulsion remover left a slight green tint on the screen, but this tint was removed by the alternative haze remover.

The haze remover performance varied between the three facilities. At Facility 8, the haze remover removed the ink stain on most of the screens, however, it did not sufficiently remove haze from about 20% of the screens. These screens had to be cleaned again with their standard product. Facility 13 thought that the haze remover did not work at all, and required extra scrubbing and follow up use with their regular product. Facility 14 initially reported that the haze remover performance was average, but another reclaimer said that it did not work as well as their usual product.

Alternative System Alpha Profile

The manufacturer recommends applying Product System Alpha as follows:

○ Ink Remover. Card up as much ink as possible with plastic squeegees or cardboard. Spray the screen surface with the ink remover and wipe up the dissolved ink and solvent with an absorbent rag or cloth. Repeat spraying on the ink remover and wiping it off until the ink is removed, and little comes off on the cloth.

○ Emulsion Remover. Dilute the emulsion remover as instructed on the label and pour it into a spray bottle. Place the screen in a washout sink and spray both sides of the stencil so that the product evenly covers the stencil. Using a soft brush, scrub the stencil until it is broken up in all areas. Apply more emulsion remover if necessary. Wash away the stencil with a pressure washer (a 1000 psi pressure washer was used at SPTF).

○ Haze Remover. Thoroughly mix the haze remover paste. Wet the screen before applying the haze remover. Scoop out the paste from the container and apply the it to a brush. Brush the haze remover into the stained areas on both sides mesh. Allow the haze remover to stand for a maximum of 8 minutes. Rinse the screen with a gentle water spray, followed by a high pressure wash.

Alternative System Performance at SPTF

Alternative System Alpha was tested at SPTF on two screens (one with a solvent-based ink, and one with a UV-curable ink). This product system is not recommended for use with water-based inks. On the screen with the solvent-based ink, the ink dissolved well with moderate scrubbing. On the screen with the UV ink, the ink dissolved more easily and minimal scrubbing was needed. Four wipes were used to clean each screen.

On both screens, the emulsion remover dissolved the stencil with moderate scrubbing effort, leaving no emulsion stain. There was a moderate ink stain remaining on the solvent-based ink screen after emulsion removal, but the application of the haze remover removed the stain completely. On the screen with UV ink, a light stain remained after emulsion remover use, but the haze remover lightened the stain considerably.

Products were applied according to the manufacturer's recommended application procedure. The technician noted that the ink remover did have an unpleasant odor.

Alternative System Performance Details

Performance Details from Facility 8

Over the four week demonstration period, this facility reclaimed 48 screens with the Product System Alpha. The screen printing manager reclaimed the screens himself during the demonstration period. He was willing to experiment with different application techniques to improve the performance of the alternative system.

The printer thought the ink remover performance was satisfactory, but results were inconsistent and the product required extra scrubbing effort to achieve acceptable results. He noted that the ink remover performance was unacceptable on epoxy inks, even with the extra effort. One specific observation was that the ink remover did not stay wet on the screen which made wiping more difficult. Performance improved, however, when he sprayed the product both on the rag and on the screen. After using the ink remover, the printer evaluated each screen and reported that the ink was removed effectively on 62% of the screens.

Typically, this facility uses hot water to start the breakdown of their emulsion. When following the manufacturer's application instructions for the Alpha emulsion remover, which does not require hot water, the printer found the emulsion came off in "strings," instead of dissolving. The stringy, solid mass clogged the drain. To solve this problem, the printer rinsed the screen with hot water before applying the emulsion remover. This additional step took an extra 3 - 5 minutes, but the emulsion remover performance improved.

The haze remover did not sufficiently remove the haze on approximately 20% of the screens. The printer wiped these screens with lacquer thinner (which easily removed the haze) before reusing the screen. The observer confirmed that this supplementary wipe down was necessary and noted that the white rag with lacquer thinner on it turned black as the dark haze was removed from the screen. Overall, the printer felt the alternative haze remover performance was not acceptable.

Data from the printer's product evaluation forms was analyzed to determine if there were any correlations between variations in the product performance and changes in the demonstration conditions (e.g., ink type, emulsion type, screen condition). The printer was asked to evaluate the screen after using each product (ink remover, emulsion remover, and haze remover). In addition, the printer recorded the amount of ink remaining on the screen at the start of reclamation. In reviewing this data, it was found that for screens where the initial ink remaining on the screen was high (i.e., it was not carded off well), there was an ink stain remaining on the screen after emulsion removal (for 100% of the screens in the demonstration). When the initial ink remaining on the screen was recorded as "low", an ink stain remained after emulsion removal for only 33% of the screens. This could indicate that if the screen is effectively carded before ink removal (as the manufacturer recommends), the product performance may improve significantly. Overall, 76% of the screens had an ink stain or stencil stain after using the emulsion remover. After applying the haze remover, 20% of the screens could not be reused because of the remaining haze.

During the four week demonstration, this facility did not notice any change in screen failure rate or any deterioration of the screen mesh. The printer had no problems with print image quality while using Product System Alpha, however, he felt he avoided potential print quality problems by cleaning the screens again with his own ink remover before reusing them.

Performance Details from Facility 13

Overall, this facility was not satisfied with the performance of System Alpha. The alternative system required more time and effort than their standard products and were not as effective in cleaning the screens as their standard products. Because of the extra time required, the facility could not reclaim screens fast enough to keep up with their need to reuse the screens. The screen reclaimer also did not like the strong smells associated with the alternative system. For these reasons, the printing manager made the decision to discontinue participation in the demonstrations after two weeks. More experimenting with application methods could have lead to improved performance, but this facility did not seem willing to try. The facility contact also mentioned that the reclamation employee was not reliable and that he did not feel confident in the screen reclamation results that were provided. In analyzing the limited data from this facility, the performance of the alternative system did not seem to be affected by ink type, ink color, mesh type, or other demonstration conditions.

The ink remover did not perform as well as their usual product. It removed ink less effectively than was expected and involved more applications and rinsing (which meant more time) to get the ink out of the mesh. The only application changes attempted were to use more product and effort. The added scrubbing was considered a very negative characteristic of the ink remover.

Even at full strength the emulsion remover required more scrubbing and time to remove the emulsion from the screens than their usual product. The alternative emulsion remover did remove the stencil, however, because of the extra time required, the facility discontinued use of the emulsion remover after the first week of demonstrations.

The haze remover did not reduce stains in the mesh as effectively as the facility's usual haze remover. Almost every time the haze remover was used, the facility had to follow with their usual haze remover to get the screen clean enough for reuse. When using their standard product system, this facility needed to use a haze remover for only about 30 percent of their screens. Facility 13 did not experiment with application methods other than extra scrubbing and they stopped using the haze remover after the first week of demonstrations.

No changes were noted in the screens used with the alternative system. Longer-term use of the alternative system may have damaged the screens or reduced screen life because of the excessive scrubbing that was needed with Product System Alpha.

Performance Details from Facility 14

Performance of System Alpha was average at Facility 14. The results are complicated by the fact that three different people were involved in the demonstrations and the two original screen reclamation employees were terminated after about three weeks into the demonstration period. The initial data quality seemed good, but a lot of information was missing from the forms that were submitted from the last week(s) of employment of the terminated employees. The new screen reclaimer may not have followed the same procedures when using the alternative system.

The ink remover worked fairly well, but sometimes had to be reapplied for the screens to be thoroughly cleaned. The product worked particularly well with vinyl inks. The ink remover's performance was improved by applying the ink remover immediately after a print run and letting it sit on the screen for up to a day before it was pressure rinsed off. The manufacturer's directions do not give any recommendations of the soaking time for the ink remover.

The emulsion remover was reported to have worked well at this facility and it worked faster than their usual product. In one case, however, the emulsion remover left a slight green tint in the screens, but this was removed by their usual haze remover.

The initial screen reclaimers felt that the haze remover had average performance, but the final reclaimer felt that it left more of a haze in the mesh than she expected. This later reclaimer only used the product on a few screens and may not have applied the ink remover immediately after the press run which the original employees were doing to improve the performance of the ink remover. This may explain why the new employee thought that more haze than usual was left on the screens. The alternative haze remover and the standard haze remover used at this facility are almost identical chemically. Also, the print quality was very rarely documented by this facility, although it may be safe to assume that problems with print quality would have been reported, if obvious.

The analysis of the data from this facility did not show any correlation between the performance of the alternative system and any variations in ink type, ink color, mesh type, or other demonstration conditions. No side effects on the screens or changes in the screen failure rates were noted during the demonstrations.

Alternative System Performance Table Compiled from Field Sites

The table below highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 8

Facility 8 prints labels, nameplates, and graphic overlays, primarily on plastics, but they also do some printing on paper and metals. Their typical run length is 100 sheets, and approximately 75% of their orders are repeat orders. Of the 40 - 50 employees at this facility, approximately 3 are involved in screen reclamation. All printing is done with solvent-based inks; both vinyl and epoxy inks are used. All screens used in the Performance Demonstrations were made of a monoester mesh that was treated with a roughening paste and a degreaser when each screen was initially stretched. Mesh count during the demonstration period ranged from 195 - 330 threads/inch and an indirect stencil was used for all screens. The average screen size used at this facility is 24.5 inches x 31.75 inches (778 in^2) and 10 - 15 screens are reclaimed daily.

Screen Reclamation Area in Facility 8

The screen printing, ink removal, and screen reclamation activities are all done in the same area of the facility. Ink removal is done at the press and screen reclamation is done in a spray booth. The open plant area with high ceilings and overhead fans provide ventilation for the general area. The spray booth has an integrated ventilation fan in the hood. The average temperature during the observer's visit was 68°F (and 40% relative humidity). Rags used for clean up and for ink removal are cleaned under contract by a laundry service. Waste water from the high pressure wash of the emulsion remover and haze remover is filtered at this facility.

Table V-92
On-Site Performance Summary For System Alpha

	System Component	Performance						Demonstration Conditions			
		Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
In-field Demonstrations at Volunteer Printing Facilities											
Facility 8	*Ink remover*	10.8 ± 17.6 hrs (n=50)	1.7 ± 0.8 oz. (n=50)	5.9 ± 2.5 mins (n=32)	Moderate	Good on 40% of screens; Fair on 22%; Poor on 38%	• 20% of screens required additional cleaning before reusing them. • Needed to use hot water to get the emulsion to break down.	Solvent-based vinyl and epoxy inks	Indirect photo stencil	Monofilament Polyester; 195 - 330 threads/inch	823 in^2
	Emulsion Remover	1.8 ± 4.2 mins (n=50)	1.0 ± 0.2 oz. (n=50)	9.0 ± 3.9 mins (n=50)	Moderate	With hot water, removed stencil.					
	Haze Remover	1.1 ± 3.5 mins (n=50)	1.0 ± 0.0 oz. (n=39)	7.6 ± 2.5 mins (n=39)	Moderate	Haze was not removed from 20% of screens.					
Facility 13	*Ink Remover*	1.5 ± 3.0 hrs (n=15)	2.5 ± 0.8 oz. (n=15)	15.5 ± 8.0 mins (n=15)	Moderate	Removed the ink but required extra time and effort.	• Most screens had to be re-cleaned with the standard haze remover before the could be reused.	UV-curable and Solvent-based inks	Direct photo stencil	Abraded polyester; 155 - 390 threads/inch	1591 in^2
	Emulsion Remover	5.7 ± 5.8 mins (n=6)	3.9 ± 2.0 oz. (n=7)	11.7 ± 4.5 mins (n=7)	Moderate	Removed stencil, but required extra time and effort.					
	Haze Remover	5.7 ± 4.0 mins (n=3)	1.3 ± 0.5 oz. (n=4)	9.5 ± 2.4 mins (n=4)	Moderate	Did not effectively remove the haze.					

Table V-93
On-Site and Laboratory Performance Summary For System Alpha

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
In-field Demonstrations at Volunteer Printing Facilities											
Facility 14	*Ink Remover*	6.6 ± 39.4 hrs (n=37)	4.4 ± 2.0 oz. (n=37)	5.0 mins (n=1)	Low/ Moderate (n=37)	Worked very well with vinyl ink; acceptable on other inks by increasing the soaking time.	• Most screens could be reused, however, some had to be recleaned with other products. • Two reclaimers felt the haze remover performance was acceptable, one did not.	Solvent-based inks	Direct photo stencil	305 - 390 threads/inch	1577 in^2
	Emulsion Remover	19.9 ± 17.9 hrs (n=37)	4.1 ± 0.7 oz. (n=37)	5.0 ± 0.0 mins (n=36)	Low (n=37)	Removed stencil easily.					
	Haze Remover	5.0 ± 19.6 mins (n=37)	4.0 ± 1.0 oz. (n=15)	5.2 ± 0.8 mins (n=16)	Moderate (n=14)	Haze remaining on some screens had to be removed with their standard product.					
Laboratory Testing at SPTF											
SPTF Solvent-based Ink	*Ink Remover*	15 mins	1.5 oz.	3.9 mins	Moderate	Ink dissolved with scrubbing; has bad odor.		Solvent-based	Dual cure direct	Polyester; 255 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	3.7 mins	Moderate	Stencil dissolved completely; medium ink stain.					
	Haze Remover	0 mins	1.0 oz.	9.7 mins	Low	Removed stain completely.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	2.0 oz.	3.5 mins	Low	Ink dissolved well; has bad odor.		UV-curable	Dual cure direct	Polyester; 390 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	2.6 mins	Moderate	Stencil dissolved completely; medium ink stain remaining.					
	Haze Remover	0 mins	1.0 oz.	10.0 mins	Low	Lightened ink stain.					

Current Screen Reclamation Products at Facility 8

Facility 8 uses an ink remover that is a solvent blend of 50% toluene and 50% methyl ethyl ketone, as well as a proprietary blend of propylene glycol ethers (<30%), Stoddard Solvent (a petroleum distillate) (<5%), and d-limonene (<20%). As an emulsion remover, they use a formulation consisting primarily of sodium periodate. Information on their haze remover was not currently available.

Current Screen Reclamation Practices in Facility 8

The screen reclamation process at Facility 8 is described below:

○ Ink Remover: Card of excess ink. Pour lacquer thinner from a one-gallon can onto the screen surface with the screen lying flat. Using reusable rags, wipe the ink off the screen. After ink removal at the press, move the screen to the reclamation area.

○ Emulsion Remover: Wet the screen with hot water at low pressure. Spray an ink remover on the emulsion side of the screen. Dip a brush into the container of emulsion remover and brush it into both sides of the screen. Rinse both sides of the screen with a high pressure (2500 psi) washer to remove the emulsion.

○ Haze Remover: If an ink stain remains after emulsion removal, spray more lacquer thinner onto the screen and rub it in with a scrubber pad. After allowing the lacquer thinner to soak for 1 - 2 minutes, remove the excess ink with a high pressure wash. Haze remover is only applied to approximately 25% of the screens. When needed, apply the haze remover by pouring it from a quart container onto a brush and then rubbing it into the screen. Rinse the screen with the high pressure washer.

General Facility Background for Facility 13

Facility 13 prints store displays, decals, and outdoor signs. Their products are printed on plastics, paper, and metal. A typical run length is 500 - 1000 sheets and approximately 25% of their orders are repeat orders. There are about 70 employees at this facility and 1 - 3 employees are responsible for screen reclamation. The facility uses both UV ink and solvent-based ink. During the Performance Demonstrations they used a direct photo stencil and the screen mesh was an abraded polyester. Mesh counts ranged from 155 - 390 threads/inch. The screen size typically used in this facility is 49 inches x 41 inches, and approximately 20 screens are reclaimed daily.

Screen Reclamation Area in Facility 13

Ink removal and screen reclamation are both done within the screen printing area of the facility where local ventilation is provided. The screen reclamation area is 20 - 50 ft^2 in size. During the observer's visit, the average temperature in the area was 76°F (and 44% relative humidity). Rags used for screen reclamation activities are disposed of as hazardous waste. Waste water from emulsion and haze removal washes is not filtered at this facility.

Current Screen Reclamation Products at Facility 13

Facility 13 uses an ink remover that is a proprietary blend consisting primarily of tripropylene glycol methyl ether. Their emulsion remover consists primarily of sodium periodate. Information on their haze remover was not available.

Current Screen Reclamation Practices in Facility 13

Gloves, eye protection, aprons, and respiratory protection are available for employees during screen reclamation. At Facility 13, screens are reclaimed as follows:

- Ink Remover: Card off the excess ink at press. Dip a soft bristle brush into a five-gallon bucket of ink remover and brush it onto the screen. The dirty ink remover brush is repeatedly dipped into this bucket so the ink remover becomes diluted with ink residue. Pressure wash (1000 psi) the screen.

- Emulsion Remover: Dip a soft bristle brush into the bucket of emulsion remover and rub the product into screen. Apply enough emulsion remover to both sides of the screen to cover the stencil. Pressure wash both sides. Rinse the screen with low pressure water, vacuum it dry, wipe it dry with a disposable rag, and set it in front of an electric fan to dry.

- Haze Remover: Haze remover is used on approximately 50% of the screens, primarily when black, red, and blue inks are used. If haze remover is not needed, apply undiluted ink remover to the screen with a brush after emulsion removal. Rub into both sides of the screen, then pressure wash. Rinse both sides of the screen with low pressure water from a hose. If haze remover is used, do not apply the ink remover after emulsion removal. To apply the haze remover, dip a soft bristle brush into the paste. Rub it into both sides of the stain and wait for 5 - 15 minutes, depending on the severity of the haze. Pressure wash the screen. Vacuum the screen dry, then wipe it with a disposable wipe. Place the screen in front of a fan to dry.

General Facility Background for Facility 14

Facility 14 prints three-dimensional panels, pressure-sensitive labels, and specialty items for advertising. Primarily, they print on plastics and metals, but they also do some printing on paper. A typical run is 100 - 300 sheets and approximately 85% of their orders are repeat orders. Of the approximately 12 employees at this facility, 3 are involved in screen reclamation activities. Several different types of ink are commonly used at Facility 14, including thermal setting, vinyls, and UV-curable, and small amounts of lacquers, enamels, and epoxies. All screens used in the Performance Demonstrations were made of a monofilament polyester and a direct photo stencil emulsion was applied. Mesh count during the demonstration period ranged from 305 - 390 threads/inch. The average screen size used at this facility is 12 ft^2 and approximately 12 screens are reclaimed daily.

Screen Reclamation Area in Facility 14

This facility has two spray booths; one for ink removal and one for emulsion and haze removal. At the ink removal area, the solvent is applied with a pressure sprayer and then filtered and recycled through the system. For ventilation, there is a hood above each spray booth. The average temperature during the observer's visit was 72°F (and 45% relative humidity). Rags used for screen reclamation are washed by an industrial laundry service. Spent filters are disposed of as hazardous waste. Waste water from the high-pressure wash of the emulsion remover and haze remover is not filtered.

Current Screen Reclamation Products at Facility 14

For ink removal, Facility 14 uses either a product consisting of 99% tripropylene glycol methyl ether, or a proprietary solvent blend sold by a manufacturer not participating in the performance demonstration. MSDS information on the latter product states it contains no hazardous substances, is non-flammable, has no SARA reportable chemicals, and meets California's South Coast Air Quality Management District requirements. Their emulsion remover is a formulation consisting primarily of sodium periodate. For haze removal, they use either an aqueous blend which consists of potassium hydroxide (27%) and tetrahydrofurfuryl alcohol (11%), or an aqueous blend that contains sodium hydroxide (5%) and tetrahydrofurfuryl alcohol (17%).

Current Screen Reclamation Practices in Facility 14

The screen reclamation process at Facility 14 is described below:

○ Ink Remover: Card off the excess ink. At the press, spray on the ink remover and wipe off about 95% of the ink with reusable rags. Approximately 2 - 4 rags are used for each screen. Take the screen to the wash out sink and spray on the ink remover solvent from the recirculating tank. With a brush, scrub the ink remover into the screen, then squeegee off the excess solvent and ink. Wipe down with rags. If ink clumps are remaining, spray on more ink remover and wipe the screen again.

○ Emulsion Remover: Move the screen to the reclamation area. Spray emulsion remover on the top of the screen and use a scrubber pad to spread it out and work it into the screen. Rinse with a high pressure (2000 psi) wash to remove the emulsion. With a brush, apply a degreaser then rinse with a low pressure (200 psi) wash.

○ Haze Remover: After emulsion removal, a haze remover is used only if needed (on approximately 6% of the screens). Apply the haze remover by dipping a brush in the product and rubbing it into the screen. Rinse with a high pressure water spray.

Cost

Table V-94
Method 2: Summary of Cost Analysis for System Alpha

Cost Element Description		Baseline (Traditional System 4)	Alternative System Alpha		
			Facility 8	Facility 13	Facility 14
Facility Characteristics					
Average screen size (in^2)		2,127	823	1,591	1,577
Average # screens/day		6	12.5	20	12
Cost Elements per Screen					
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	22.5 4.92	36.7 8.02	15.3 3.34
Materials and Equipment	# of rags used Cost ($)	3 0.45	1.1 0.17	4.1 0.61	0 0
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	1.8 0.21	2.5 0.31	4.4 0.53
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	1.0 <0.01	3.9 0.01	4.1 0.01
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	1.0 0.30	1.3 0.37	4.0 1.18
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	31 0.02	60 0.04	59 0.04
Totals					
Total Cost ($/screen)		6.27	5.62	9.36	5.10
Normalized[a]		6.27	6.79	9.37	5.92
Total Cost ($/year)		9,399	17,574	46,800	15,313
Normalized[a]		9,399	10,183	14,062	8,886

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Chi

Formulation

Ink Remover:	Diethylene glycol series ethers Propylene glycol series ethers N-methyl pyrrolidone Ethoxylated nonylphenol
Emulsion Remover:	Sodium periodate Water
Haze Remover:	Diethylene glycol series ethers Propylene glycol series ethers N-methyl pyrrolidone Ethoxylated nonylphenol

Occupational Exposure

Table V-95
Occupational Exposure Estimates for Alternative System Chi

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Diethylene glycol series ethers	0	0	0	0	312	1456
Tripropylene glycol methyl ether	0	0	0	0	858	4000
N-methylpyrrolidone	3	0	0	0.1	312	1460
Ethoxylated nonylphenol	0	0	0	0	78	364
Emulsion Remover (diluted 1:4)						
Sodium periodate	0	0	0	0	16	73
Water	0	0	0	0	1540	7210
Haze Remover						
Diethylene glycol series ethers	0	0	0	0	312	1456
Tripropylene glycol methyl ether	0	0	0	0	858	4000
N-methylpyrrolidone	3	0	0	0	312	1460
Ethoxylated nonylphenol	0	0	0	0	78	364

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-96
Occupational Risk Estimates for Method 2, Alternative System Chi

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Diethylene glycol series ethers	NA	NA	NA	NA	NA	1,800	46	380	9.8
Tripropylene glycol series ethers	NA	NA	NA	NA	NA	NA	NA	NA	NA
N-methylpyrrolidone	NA	NA	NA	3,600	NA	39	NA	8.4	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover (diluted 1:4)									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Diethylene glycol series ethers	NA	NA	NA	NA	NA	1,800	46	380	9.8
Tripropylene glycol series ethers	NA	NA	NA	NA	NA	NA	NA	NA	NA
N-methylpyrrolidone	NA	NA	NA	37	NA	39	NA	8.4	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

○ Clear concerns exist for chronic dermal exposures to diethylene glycol series ethers used in ink removal based on the calculated margins-of-exposure.

○ Concerns exist for developmental toxicity risks from dermal exposures to N-methylpyrrolidone based on the calculated margin-of-exposure. Similar calculations for inhalation exposures to N-methylpyrrolidone indicate very low concern.

○ Inhalation exposures to other ink remover components are very low.

○ Dermal risks from other ink remover components could not be quantified because of limitations in hazard data, but exposures can be high.

○ The haze remover components are identical to the ink removers and present essentially the same risk profile.

Emulsion Removers (All Systems)

○ All of the systems that employ an emulsion remover (all systems except Beta) use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-97
Environmental Release Estimates in Screen Cleaning Operations
Method 2, Alternative System Chi

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Diethylene glycol series ethers	0.1	0	138	0	0	0	270
Tripropylene glycol series ethers	0.1	0	381	0	0	0	742
N-methylpyrrolidone	6.8	0	132	0.1	0	0.2	270
Ethoxylated nonylphenol	0	0	35	0	0	0	67
Emulsion Remover (diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0
Haze Remover							
Diethylene glycol series ethers	0.1	104	0	0	0	0	0
Tripropylene glycol series ethers	0.1	286	0	0	0	0	0
N-methylpyrrolidone	6.8	97	0	0.1	0	0	0
Ethoxylated nonylphenol	0	26	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Environmental Release Estimates from Screen Reclamation Processes
Screen Reclamation Method 2, Alternative System Chi

From Ink Removal Operations:
- Diethylene glycol series ethers
  - 0.1 g/day to air
  - 270 g/day to water from rags at commercial laundry
  - 138 g/day to landfill

- Propylene glycol series ethers
  - 0.1 g/day to air
  - 742 g/day to water from rags at commercial laundry
  - 381 g/day to landfill

N-methyl pyrrolidone
- 7.1 g/day to air
- 270 g/day to water at commercial laundry
- 132 g/day to landfill

Ethoxylated nonylphenol
- 67 g/day to water from rags at commercial laundry
- 35 g/day to landfill

From Emulsion Remover:

Sodium periodate
- 6 g/day to water

From Haze Remover:

Diethylene glycol series ethers
- 0.1 g/day to air
- 104 g/day to water

Propylene glycol series ethers
- 0.1 g/day to air
- 286 g/day to water

N-methyl pyrrolidone
- 6.9 g/day to air
- 97 g/day to water

Ethoxylated nonylphenol
- 26 g/day to water

Table V-98
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Chi

Substance:	To Air:	To Water:	To Landfill:
Diethylene glycol series ethers	0.2 g/day	104 g/day 270 g/day at laundry	138 g/day
Propylene glycol series ethers	0.2 g/day	286 g/day 742 g/day at laundry	381 g/day
N-methyl pyrrolidone	14 g/day	97 g/day 270 g/day at laundry	132 g/day
Ethoxylated nonylphenol		26 g/day 67 g/day at laundry	35 g/day
Sodium periodate		6 g/day	

Releases to Water from a Single Facility

Table V-99
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Chi

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Diethylene glycol series ethers	104 g/day 270 g/day at laundry	83 %	18 g/day 46 g/day	2×10^{-2} 4×10^{-2}
Propylene glycol series ethers	286 g/day 742 g/day at laundry	83-97 %	49 g/day 126 g/day	5×10^{-2} 1×10^{-1}
N-methyl pyrrolidone	97 g/day 270 g/day at laundry	97 %	3 g/day 8.1 g/day	3×10^{-3} 8×10^{-3}
Ethoxylated nonylphenol	26 g/day 67 g/day at laundry	100 %	0 g/day 0 g/day	0
Sodium periodate	6 g/day	100 %	0 g/day	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-100
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Chi

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Diethylene glycol series ethers	0.2 g/day	3.5×10^{-4} ug/m^3	3×10^{-3}
Propylene glycol series ethers	0.2 g/day	3.5×10^{-4} ug/m^3	3×10^{-3}
N-methyl pyrrolidone	14 g/day	2.9×10^{-2} ug/m^3	2×10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Product System Chi.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Alternative System Chi below. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Table V-101
Risks from Potential Drinking Water Exposures
Screen Reclamation Method 2, Alternative System Chi

Substance	Daily Stream Concentration, (ug/L)	Daily Dose from Drinking Water (mg/kg)	NOAEL or LOAEL (mg/kg)	MOE - NOAEL or LOAEL/Dose
Diethylene glycol series ethers	5.8×10^{-2}	2×10^{-6}	51 LOAEL	3×10^{7}
Propylene glycol series ethers	1.5×10^{-1}	4×10^{-6}	not available	
N-methyl pyrrolidone	1.1×10^{-2}	3×10^{-7}	175 NOAEL	6×10^{8}
Ethoxylated nonylphenol	0	0	not available	
Sodium periodate	0	0	not available	

Table V-102
Risk Estimates for Ambient Air Releases from a Single Model Facility
Screen Reclamation Method 2, Alternative System Chi

Substance	Highest Avg Concentration 100 M away	Daily Potential Dose, (mg/kg)	NOAEL or LOAEL (mg/kg)	MOE - NOAEL or LOAEL/ Dose
Diethylene glycol series ethers	3.5×10^{-4} ug/m^3	1×10^{-7}	51 LOAEL	5×10^{8}
Propylene glycol series ethers	3.5×10^{-4} ug/m^3	1×10^{-7}	not available	
N-methyl pyrrolidone	2.9×10^{-2} ug/m^3	8×10^{-6}	175 NOAEL	2×10^{7}

Ecological Risks From Water Releases Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, Product System Chi reach an ecotoxicity concern concentration.

Performance

General Summary of Product System Chi Performance, and Related Variables

This product system consisted of an ink remover and an emulsion remover. In place of a separate haze remover product, the ink remover was reapplied to remove haze. A degreaser accompanied this product system and was used by the facilities, however, detailed information on the performance of the degreaser is not included in the scope of this project. The performance of the product system was demonstrated at Facilities 3 and 21. Facility 3 prints decals and vacuum formed sheets; Facility 21 prints decals for glass and ceramics. During the four week demonstration period, Facility 3 reclaimed 47 screens and Facility 21 reclaimed 48 screens. Both facilities used only solvent-based inks during the demonstrations.

The ink remover performance was considered satisfactory by Facility 3 and was considered good at Facility 21. At Facility 3, the alternative ink remover took longer to solubilize the ink and required more physical effort than their usual product. Facility 21 reported that the Product System Chi ink remover worked very well on most of their inks, but the alternative ink remover did not work as well with cover/flux ink or clear cover coats. They have similar problems with their standard ink remover on the cover/flux and clear coats. They also found additional scrubbing was needed when using the alternative ink remover on very coarse (low mesh count) screens. Overall, they described the ink remover performance as good, but not quite as good as their standard product.

The two facilities were both quite pleased with the performance of the emulsion remover. Facility 3 reported the performance was as good as their standard product. Facility 21 thought that the emulsion remover worked much better than their usual product. Although it worked well on both direct and capillary film emulsions, Facility 21 found a little more effort was required to remove the capillary film emulsions than the direct emulsions.

This system did not include a haze remover. Instead, the manufacturer recommended that the ink remover be used a second time as a haze remover. After using the ink remover following removal of the emulsion, Facility 3 reported that an image was still left on the screen and that, when used for haze removal, the ink remover did not perform as well as their usual haze remover. At Facility 21, a haze remover was needed on only one screen of the 48 screens reclaimed.

Alternative System Chi Profile

The manufacturer recommends applying Product System Chi as follows:

○ Ink Remover: Card up the excess ink to remove as much as possible from the screen. Bring the screen to the reclaiming area and apply the ink remover as soon as possible, even if the screen is not to be cleaned until later. Use a spray bottle and apply the product to both sides of the screen, using ample product to coat the inked areas completely. Thoroughly brush the ink remover into the screen, paying close attention to print areas and heavy ink spots. Allow as much time as possible for the product to dissolve the ink. If more product is needed to loosen the ink, apply it in the needed areas and brush again. Pressure rinse the screen, beginning with the well side, from the bottom of the screen to the top. Turn the screen around and repeat the pressure rinse from bottom to top.

○ Emulsion Remover: Dilute 1 part emulsion remover in 4 - 5 parts water. Spray the emulsion remover onto the wet screen and allow enough time for the product to completely dissolve the emulsion. Use a brush to loosen the emulsion on the entire screen. Pressure wash the screen on both sides, rinsing from the top to the bottom. At SPTF, a 1000 psi pressure washer was used.

○ Additional Stain Removal Step: If stains remain in the screen, allow the screen to dry and repeat the application procedure for the ink remover and pressure rinse.

Alternative System Performance at SPTF

Product System Chi was tested at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). The ink remover performance varied, depending on the type of ink used. Performance of the emulsion remover and the haze remover was consistent for all three screens. All products were applied according to the manufacturer's recommended application procedure.

On the screen with the solvent-based ink, there was considerable ink residue remaining after spraying the screen with product, scrubbing with a brush, and rinsing with a high pressure wash. The technician also noticed that the stencil was beginning to peel off. After repeating the ink remover application process, the ink residue was still present and about half of the stencil had been removed. The ink dissolved more easily on the screen with UV ink, however, after using the ink remover, a gray haze remained on the screen, but there was no noticeable ink residue and the stencil was intact. On the screen with the water-based ink, the product dissolved the ink fairly well, however, a light ink residue remained on the screen and the stencil began to peel off.

The emulsion remover easily dissolved the stencil with only light scrubbing on all three screens, leaving no emulsion residue behind. On the screen with the solvent-based ink, the heavy ink residue was still present after using the emulsion remover. When additional ink remover was applied (used instead of a haze remover in this product system), it removed the residue and lightened the stain. After using the emulsion remover on the screen with UV ink, a moderate to heavy ink stain remained. The reapplication of the ink remover lightened this stain considerably. On the screen with water-based ink, the ink residue persisted in some areas and there was a heavy ink stain on the screen after using the emulsion remover. An additional application of ink remover lightened the stain, but did not remove it.

Alternative System Performance Details

Performance Details from Facility 3

Throughout the performance demonstration period, the facility contact was asked about the performance of the components of Product System Chi. He was generally pleased with the performance of the ink remover and emulsion remover, although the ink remover took longer to solubilize the inks than their standard product in some cases. when used as a haze remover, the ink remover usually did not remove the ghost image from the screen. Overall, the facility contact remarked that he did not think that System Chi would be a viable long-term alternative reclaiming system for his plant.

The ink remover worked acceptably on all screens, although it was somewhat slower to dissolve the inks than the facility's regular ink remover. The printer tried using the product to clean the squeegee and flood bar on the press after printing runs, but found that it was slow to break down the ink and left an oily film. After several cycles of printing and reclaiming with the demonstration screens, a noticeable ink haze began to build up in the screens, indicating that the ink remover was not removing all the ink from the mesh. The buildup was not enough to prevent successful printing of regular jobs with the screens, but the facility contact felt that the performance of the screens on a transparent ink image or a flood coat would be unacceptable. There were some variations in the time it took to remove the ink, ranging from 2 to 12 minutes. However, the recorded data does not show any correlation between the ink remover time and any of the variable screen conditions, such as ink color or number of impressions.

The emulsion remover worked well, with no notable variations in performance among the screens used for the demonstration period. The facility contact did not think the product was chemically different from what he had been using previously.

This system did not include a haze remover; instead the manufacturer recommended applying the ink remover again to remove any remaining haze. At Facility 3, the ink remover did not satisfactorily remove the haze. Ghost images continued to build on the screens throughout the demonstration period. The facility normally uses two haze remover products. One haze remover is a milder chemical, which leaves a small amount of ink haze in the screens. This product is used by itself on a regular basis until ghost images in the screen become unacceptable. The other haze remover, which is a stronger chemical, is then used to de-haze the screen to a baseline clean state, after which the screen reclaimer returns to the milder chemical for as many reclaimings as possible. The facility contact remarked that the performance of the alternative haze remover is similar to their "milder" regular haze remover, except that the ink haze built up faster using the alternative product.

Product System Chi did not appear to cause screen failure, or have any noticeable permanent effects on the screens or frames. The three squirt bottles shipped with the products started leaking around the triggers during the first week of the demonstration, and had to be replaced. It is not known if this is an effect of the products or not.

Performance Details from Facility 21

This facility was generally pleased with the performance of System Chi. Currently, the facility uses an automatic screen washer, which cleans the screens in a closed system that recycles the solvent. This was a very organized facility and the quality of the data received was probably quite high. They thoroughly documented the demonstrations and only one screen reclaimer was involved in the demonstrations. The production manager was responsible for monitoring the future print quality on screens reclaimed with the alternative system. He paid very careful attention to screen conditions and would have noticed any deleterious effects of the alternative system. No changes in the screen mesh or print quality were noted during the demonstrations.

The ink remover worked well, however it was not as efficient as their standard product. The facility particularly liked the ink remover's performance with metallic inks. When used on screens with cover (flux) coats or with other clear ink coats, the ink remover did not work well, although the facility has similar problems with their current ink remover. Added scrubbing was needed to remove ink from very coarse (low mesh count) screens. Ink color and number of impressions did not seem to affect ink remover performance.

The emulsion remover worked much better ("excellent") than the product they had been using. Although it worked very well on both emulsion types, the emulsion remover required a little more effort to remove capillary film emulsion than direct emulsion.

For Product System Chi, a second application of the ink remover was used in place of a haze remover as needed. At this facility, a haze remover was needed on only one screen. On that screen, a ghost image remained in the mesh after using the ink remover one time. After reapplying the ink remover two more times, the image was lightened enough to reuse the screen. Normally, this facility does not use a haze remover.

Alternative System Performance Table Compiled from Field Sites

The following table highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 3

Facility 3 prints decals and vacuum formed sheets on plastics and paper. A typical run is 250 sheets, and 71% of their orders are repeat orders. Of the approximately 40 employees at this facility, 1 - 3 are involved in screen reclamation. All printing is done with solvent-based inks. Screens used in the Performance Demonstrations were polyester or monoester/polyester with a mesh count of 180 - 370 threads/inch. The facility used a dual cure emulsion. The average screen size at this facility is 15 ft^2 and approximately 15 screens are reclaimed daily.

Screen Reclamation Area in Facility 3

Ink removal is done at the press where local ventilation is provided. The screen reclamation room is approximately 150 ft^2, with a large spray booth built into one wall, and is also ventilated with a local system. The average temperature during the observer's visit was 64°F (and 39% relative humidity). Rags used for clean up and for ink removal are cleaned by a laundry service. Waste water from the high-pressure wash of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 3

Facility 3 uses a proprietary solvent blend for ink removal, which consists of n-butyl acetate (81%) and toluene (19%). For emulsion removal, they use a formulation consisting of 100% sodium periodate. They use two different haze removal products at this facility. One product is a proprietary solvent blend which contains at least sodium hydroxide and cyclohexanone. Their other haze removal product, sold by a manufacturer who is not participating in the performance demonstration, contains no carcinogens, no ingredients with TLV or PELs, and no petroleum derivatives, according to the MSDS.

Current Screen Reclamation Practices in Facility 3

Using their standard products, screens are reclaimed as follows:

○ Ink Remover: Card off the excess ink. Pour the ink remover onto the screen and wipe with rags until clean. Approximately 2 - 4 rags are used for each screen. Gloves and eye protection are worn during ink removal.

○ Emulsion Remover: Dip a scrubber pad into the container of emulsion remover. Scrub both sides of the screen. Using a high pressure wash (1200 psi), rinse the screen. Gloves, eye protection, respiratory protection, and ear protection are available to employees for emulsion removal and haze removal.

Table V-103
On-Site Performance Summary For System Chi

		Performance						Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
In-field Demonstrations at Volunteer Printing Facilities											
Facility 3	*Ink remover*	7.2 ± 3.6 mins (n=50)	1.1 ± 0.4 oz. (n=50)	6.6 ± 2.3 mins (n=50)	Moderate	Dissolved ink with extra effort.	• All screens could be reused. • Printer was concerned with effect of possible haze build up over time.	Solvent-based	Dual Cure	Polyester, no treatment; 180 - 370 threads/inch	1977 in^2
	Emulsion Remover	15.1 ± 21.7 hrs (n=50)	2.1 ± 0.4 oz. (n=50)	2.9 ± 0.3 mins (n=50)	Low	Removed stencil easily.					
	Haze Remover	0.2 ± 0.2 mins (n=47)	2.1 ± 0.3 oz. (n=47)	2.9 ± 0.3 mins (n=47)	Low	Ghost images built up.					
Facility 21	*Ink Remover*	7.6 ± 12.6 hrs (n=51)	1.1 ± 0.3 oz. (n=48)	2.0 ± 1.5 mins (n=47)	Low	Dissolved ink with extra effort.	• All screens could be reused for future print jobs. • Haze removal step rarely needed. • Worked well on metallic inks.	Solvent-based	Capillary film and Direct photo stencil	Polyester, half-calendared or low elongation threads; 60 - 390 threads/inch	1088 in^2
	Emulsion Remover	4.7 ± 8.6 mins (n=51)	1.5 ± 1.4 oz. (n=48)	2.5 ± 2.2 mins (n=48)	Low	Removed stencil easily.					
	Haze Remover	15.0 mins (n=1)	2.0 oz. (n=1)	3.5 ± 0.7 mins (n=2)	Moderate	Several applications needed to remove haze.					

Table V-104
Laboratory Testing Performance Summary For System Chi

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
Laboratory Testing at SPTF											
SPTF Solvent-based Ink	*Ink Remover*	15 mins	not recorded	7.5 mins	Moderate	Heavy ink residue. Started to remove stencil.		Solvent-based	Dual cure direct	Polyester; 255 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	3.3 mins	Low	Dissolved stencil easily. Heavy ink residue remaining.					
	Haze Remover	0 mins	2.5 oz.	4.7 mins	Low	Lightened ink stain.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	1.0 oz.	4.0 mins	Low	Dissolved the ink but left a grey haze over entire screen.		UV-curable	Dual cure direct	Polyester; 390 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	4.0 mins	Low	Dissolved stencil easily.					
	Haze Remover	0 mins	1.0 oz.	4.0 mins	Low	Lightened the ink stain.					
SPTF Water-based Ink	*Ink Remover*	15 mins	2.0 oz.	4.5 mins	Moderate	Light ink residue. Stencil started peeling.		Water-based	Dual cure direct	Polyester; 255 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.5 oz.	4.1 mins	Low	Dissolved stencil easily. Heavy ink stain and light residue.					
	Haze Remover	0 mins	1.5 oz.	3.3 mins	Low	Lightened ink stain.					

- ○ Haze Remover: The facility uses two haze remover products. Apply the first product to every screen. Spray the product onto the screen, brush it into the stained area on both sides and rinse with a high pressure wash. The second product is a stronger chemical and is used only when the ghost images in the screen become unacceptable (approximately 15% of the reclamations). To apply this haze remover, dip a scrubber pad into the container of product and scrub both sides of the screen. Rinse with a high pressure wash.

General Facility Background for Facility 21

Facility 21 prints decals for glass and ceramics. Their typical run length is 1000 sheets and approximately 50% of their orders are repeat orders. There are approximately 15 -20 employees at this facility, and 1 - 3 people are responsible for screen reclamation. During the Performance Demonstration, this facility used solvent-based inks, a capillary film emulsion, and screens with mesh counts that ranged from 60 - 390 threads/inch. Their average screen size is 3 feet x 3 feet and 20 - 25 screens are reclaimed daily.

Screen Reclamation Area in Facility 21

Ink removal and screen reclamation are both done in the screen reclamation room, which is approximately 150 ft^2 in size. A fan in the hood above the reclamation sink provides ventilation for the area. During the observer's visit, the average temperature in the room was 68°F (and 56% relative humidity). Ink remover is recycled off-site, and the recycled product is returned to the facility for in-house use. Reusable shop rags are cleaned by an industrial laundry service. Waste water from the washes of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 21

The standard ink remover at Facility 21 is a proprietary product, sold by a manufacturer not participating in the performance demonstration, that contains no carcinogens, no ingredients with TLV or PELs, and no petroleum derivatives, according to the MSDS. Their emulsion remover contains primarily sodium periodate. Their standard haze remover is a proprietary solvent blend which includes sodium hydroxide and cyclohexanone.

Current Screen Reclamation Practices in Facility 21

During the screen reclamation process at Facility 21, personal protective equipment available to the employees includes gloves, eye protection, aprons, respiratory protection, ear protection, and barrier cream. Screens are reclaimed as follows:

- ○ Ink Remover: At the press, card off excess ink and wipe the screen with the in-process ink remover. Bring the screen to the screen reclamation room. Spray on the ink remover and rub it into the screen with a scrubber pad. Remove the ink by running a squeegee over the screen. Wipe off both sides of the screen with a reusable rag. One or two rags are used on each screen. Move the screen to the sink and rinse both sides of the screen with a hose to remove the blockout.

- ○ Emulsion Remover: Spray both sides of the screen with the emulsion remover. Let sit until the emulsion starts to dissolve. Rub the stencil with a reusable rag. Rinse the screen with a high pressure wash (1000 psi).

- Haze Remover: A haze remover is rarely used (on approximately 1% of the screens reclaimed). Instead, the ink remover is reapplied to about 50% of the screens. For the remaining screens, reclamation is considered complete after the emulsion removal step. When haze remover is used, apply as follows: dip a brush in the product container, rub the haze remover into the screen, and rinse with a pressure wash.

Cost

Table V-105
Method 2: Summary of Cost Analysis for Alternative System Chi

Cost Element Description		Baseline (Traditional System 4)	Alternative System Chi	
			Facility 3	Facility 21
Facility Characteristics				
Average screen size (in^2)		2,127	1,977	1,088
Average # screens/day		6	15	23
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	12.3 2.69	8.0 1.74
Materials and Equipment	# of rags used Cost ($)	3 0.45	1.2 0.18	1.2 0.19
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	1.1 0.21	1.1 0.21
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	2.1 0.07	1.5 0.05
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	2.1 0.39	2.0 0.37
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	0 0	0 0
Totals				
Total Cost ($/screen)		6.27	3.55	2.56
Normalized[a]		6.27	3.89	3.25
Total Cost ($/year)		9,399	13,312	14,413
Normalized[a]		9,399	5,829	4,879

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.
Note: For additional information regarding product performance see performance demonstration summaries.

Product System Delta

Formulation

Ink Remover:	Dibasic esters Propylene glycol series ethers Ethoxylated nonylphenol
Emulsion Remover:	Sodium periodate Water
Haze Remover:	Dibasic esters Propylene glycol series ethers Ethoxylated nonylphenol

Occupational Exposure

Table V-106
Occupational Exposure Estimates for Alternative System Delta

System	Inhalation (mg/day) I	II	III	IV	Dermal (mg/day) Routine	Immersion
Ink Remover						
Dibasic esters	2	0	0	0.1	702	3280
Propylene glycol series ethers	0	0	0	0	780	3640
Ethoxylated nonylphenol	0	0	0	0	78	364
Emulsion Remover (diluted 1:1)						
Sodium periodate	0	0	0	0	39	182
Water	0	0	0	0	1520	7100
Haze Remover						
Dibasic esters	2	0	0	0	702	3280
Propylene glycol series ethers	0	0	0	0	780	3640
Ethoxylated nonylphenol	0	0	0	0	78	364

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Occupational Risk Estimates

Quantitative risk estimates could not be determined for this system due to insufficient data. See risk conclusions for areas of concern for this system.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

- Although no risks could be quantified because of limitations in hazard data, relatively high dermal exposures to ink remover and haze remover components could occur.

- Inhalation exposures to all components are very low.

Emulsion Removers (All Systems)

- All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-107
Environmental Release Estimates in Screen Cleaning Operations
Method 2, Delta System

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
<u>Ink Remover</u>							
Dibasic esters	3.7	0	319	0	0	0.2	608
Tripropylene glycol series ethers	0.1	0	359	0	0	0	675
Ethoxylated nonylphenol	0	0	36	0	0	0	67
<u>Emulsion Remover (diluted 1:1)</u>							
Sodium periodate	0	16	0	0	0	0	0
Water	0	605	0	0	0	0	0
<u>Haze Remover</u>							
Dibasic esters	3.7	239	00	00	00	00	00
Tripropylene glycol series ethers	0.1	269	0	0	0	0	0
Ethoxylated nonylphenol	0	27	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Environmental Release Estimates from Screen Reclamation Processes Screen Reclamation Method 2, Alternative System Delta

From Ink Removal Operations:

Dibasic esters

3.9 g/day to air
608 g/day to water from rags at commercial laundry
319 g/day to landfill

Propylene glycol series ethers

0.1 g/day to air
675 g/day to water from rags at commercial laundry
359 g/day to landfill

Ethoxylated nonylphenol

67 g/day to water from rags at commercial laundry
36 g/day to landfill

From Emulsion Remover:
- Sodium periodate
  - 16 g/day to water

From Haze Remover:
- Dibasic esters
  - 3.7 g/day to air
  - 239 g/day to water
- Propylene glycol series ethers
  - 0.1 g/day to air
  - 269 g/day to water
- Ethoxylated nonylphenol
  - 27 g/day to water

Table V-108
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Delta

Substance:	To Air:	To Water:	To Landfill:
Dibasic esters	7.6 g/day	239 g/day 608 g/day at laundry	319 g/day
Propylene glycol series ethers	0.2 g/day	269 g/day 675 g/day at laundry	359 g/day
Ethoxylated nonylphenol		27 g/day 67 g/day at laundry	36 g/day
Sodium periodate		16 g/day	

Releases to Water from a Single Facility

Table V-109
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Delta

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Dibasic esters	239 g/day 608 g/day at laundry	84-97 %	22 g/day 55.1 g/day	2×10^{-2} 6×10^{-2}
Propylene glycol series ethers	269 g/day 675 g/day at laundry	83-97 %	35 g/day 88 g/day	3×10^{-2} 9×10^{-2}
Ethoxylated nonylphenol	27 g/day 67 g/day at laundry	100 %	0	0
Sodium Periodate	16 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-110
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Delta

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Dibasic esters	7.6 g/day	1.6×10^{-2} ug/m^3	1.1×10^{-1}
Propylene glycol series ethers	0.2 g/day	3.5×10^{-4} ug/m^3	3×10^{-3}

[a]This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Product System Delta.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, Product System Delta reach an ecotoxicity concern concentration.

Performance

General Summary of Product System Delta Performance, and Related Variables

The performance of the Alternative System Delta was demonstrated at Facilities 10 and 11, who both used UV-cured inks. This product system consisted of an ink remover and an emulsion remover. In place of a separate haze remover product, the manufacturer recommended that the ink remover be reapplied to remove haze. A degreaser accompanied this product system and was used by the facilities, however, detailed information on the performance of the degreaser is not included in the scope of this project. Facility 10 prints store displays and Facility 11 prints vehicle markings and pressure sensitive decals. During the demonstrations, Facility 10 reclaimed 17 screens over a 3 week period and Facility 11 reclaimed 31 screens over 4 weeks.

At Facility 10, the ink remover removed the ink efficiently on 67% of the screens. On the other 33% of the screens, a slight ink residue remained on the screen after using the ink remover. Overall, the performance of the ink remover was considered fair, however, it required extra effort and it had a strong smell and the screen reclamation employees thought it gave them headaches. Facility 11 had better results and they considered the performance of the ink remover to be very good. It consistently and efficiently removed the ink from their screens under most conditions.

The emulsion remover worked very well and both facilities expressed an interest in continuing to use the product after the demonstrations were complete. Facility 10 found the product worked best when diluted at one part emulsion remover to one part water. Facility 11 used a dilution of one part emulsion remover to three parts water.

Neither facility regularly documented the performance of the ink remover used in a second application as a haze remover. Facility 10 used it a few times and found that it did not remove the haze satisfactorily. On subsequent screens where a haze remover was needed, they used their standard haze remover product. At Facility 11, the ink remover and emulsion remover cleaned the screen well enough that a haze removal step was not needed.

Alternative System Delta Profile

The manufacturer recommends applying Alternative System Delta as follows:

○ Ink Remover Card up the excess ink to remove as much as possible from the screen. Apply the ink remover as soon as possible after the press run, even if the screen is not to be cleaned until later. Use a spray bottle and apply the product to both sides of the screen, using ample product to coat the inked areas completely. Thoroughly brush the ink remover into the screen, paying close attention to print areas and heavy ink spots. Allow as much time as possible for the product to dissolve the ink. If more product is needed to loosen the ink, apply it in the needed areas and brush again. Pressure rinse the screen, beginning with the well side, from the bottom of the screen to the top. Turn the screen around and repeat the pressure rinse from bottom to top. At SPTF, a 1000 psi pressure washer was used.

○ Emulsion Remover Dilute 1 part emulsion remover in 4 - 5 parts water. Spray the emulsion remover onto the wet screen and allow enough time for the product to completely dissolve the emulsion. Use a brush to loosen the emulsion on the entire screen. Pressure wash the screen on both sides, rinsing from the top to the bottom.

○ Additional Stain Removal Step If stains remain in the screen, allow the screen to dry and repeat the application procedure for the ink remover and pressure rinse.

Alternative System Performance at SPTF

Product System Delta was tested at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). The ink remover performance varied, depending on the type of ink used. Performance of the emulsion remover and the haze remover was more consistent for the three screens. All products were applied according to the manufacturer's recommended application procedure.

On the screen with the solvent-based ink, there was some ink residue remaining after applying the ink remover. While scrubbing the screen to remove the ink, approximately half of the emulsion was also removed. The results were similar on the screen with UV ink. Moderate ink residue remained on the screen and some of the stencil in the half-tone area peeled off while scrubbing. On the third screen (water-based ink), the ink residue was still heavy after applying the ink remover. Again, some of the stencil was lost while brushing in the ink remover. For this screen (water-based ink), the technician repeated the ink remover application process, which removed most of the residue, but also removed most of the stencil. Because two applications of ink remover were needed, the quantity of ink remover and the time it took to clean the screen were about twice as much for the screen with water-based ink.

The emulsion remover easily dissolved the stencil on all three screens, leaving no emulsion residue behind. On the screen with the solvent-based ink, a heavy ink residue was still present after using the emulsion remover. The haze remover, which is an additional application of the ink remover in this product system, was then applied. It removed the residue, but an ink stain remained on the screen. Some ink residue remained on the screen with UV ink after using the emulsion remover, but the haze remover (a second application of ink remover) removed the residue, leaving a moderate ink stain. The emulsion remover worked best on the screen with water-based ink. The stencil dissolved easily with only light scrubbing. A small amount of ink residue remained, as well as moderate ink stain. A reapplication of the ink remover removed the residue, but did not lighten the stain significantly.

Alternative System Performance Details

Performance Details from Facility 10

System Delta had average success at this facility. The ink remover performance was acceptable and the emulsion remover worked very well. A second application of the ink remover as a haze remover did not remove the haze from the screens, therefore the facility used their standard haze remover when needed. After three weeks, the print manager decided they did not want to continue their participation in the performance demonstrations because their standard ink remover and haze remover worked better than the alternative system.

The ink remover's effectiveness was considered average at this facility. Prior to the performance demonstrations, the facility was using an ink remover that had a chemical composition very similar to that of the ink remover supplied in Product System Delta. This facility cards off excess ink and also wipes the screen with a rag so there is very little ink left on the screen when the ink remover product is applied. The reclaimers did not like using this product because of its strong smell and many of the employees felt that the ink remover gave them headaches. Facility 10 did not use a pressure wash to remove the ink, as recommended by the manufacturer. Instead, they wiped off the dissolved ink with reusable rags.

The emulsion remover was very effective when diluted one part emulsion remover to one part water (the manufacturer recommends diluting with 4 - 5 parts water). At this dilution level, the reclaimers were very pleased with its performance and wanted to continue using the product. This facility also liked the emulsion remover's lack of odor. When they first started using this emulsion remover, they diluted it in 4 parts water, as recommended. They found it did not work as well as their usual emulsion remover, so they tried diluting it in two parts water, and found it worked best when one part emulsion remover was diluted in one part water.

The facility infrequently documented the performance of the ink remover as a haze remover when applied a second time. After only a few screens, they felt that their usual haze remover worked much more effectively. On most of the screens, no haze remover was needed, however, when it was required, Facility 10 used their standard haze remover after using the alternative ink remover and emulsion remover.

Facility 10 did not notice that the alternative system performed differently with screen conditions. The data did not show any correlations between screen conditions (e.g., ink color, ink drying time) and indicators of performance (e.g., time to clean, quantity of product used). The printer felt that screens that sat around for days before reclamation were more difficult to clean than screens cleaned immediately after the print run ended.

No changes were noticed in screen wear or in screen failure rates. Print image quality was good, however, since they were using their own haze remover, it is difficult to determine if there would have been any changes to the print image quality as a result of using only the alternative system.

Performance Details from Facility 11

Overall this facility felt that System Delta worked well. The printing manager felt that if the alternative system is actually safer for his workers or for the environment, then he would like to use this product system at his facility. The application procedures for the alternative system closely resembled their usual reclamation procedures and this similarity may have made Facility 11 more receptive to using System Delta.

The ink remover effectively removed the ink from the screens in all instances. A UV-cured ink system was used with all screens in the demonstrations. The printer commented that the ink remover was "less effective" when the ink dried on the screen for a long time. The data from this facility shows that screens where the reclaimer took 5 minutes or less to remove the ink had dried an average of 2.7 hours prior to ink removal. Screens where the ink removal step took longer than 5 minutes had dried an average of 21.6 hours. By applying the ink remover immediately after the press run, as recommended by the manufacturer, it appears time spent on ink removal could possibly be reduced. Facility 11 followed the manufacturers instructions and used a pressure wash to remove the ink from the screen. Before the ink removal step, most of the ink was carded off the screen.

The emulsion remover worked very well for this facility at a variety of concentrations. The initial reclamations were performed without diluting the emulsion remover and performance was very good. After trying several different dilution ratios, they found a mix of one part product to three parts water worked very well at this facility.

After applying the ink remover and emulsion remover, the screens were clean enough that a haze removing step was unnecessary. Even without a haze remover step during the reclamation process, the print quality was excellent. When using their usual products, this facility attempts to minimize their use of haze remover; they only uses haze remover to clean a screen when there is a haze that has built up over time or when much adhesive remains in the screen.

The same screen reclaimer performed all of the demonstrations and evaluated the printing performance of the reclaimed screens. However, the reclaimer was moved to the position of printer during the demonstrations period. Undoubtedly, this change reduced the number of screens that were reclaimed with the alternative system and the forms were also lacking in details. Since he was pleased with the alternative system performance, he did not take the time to record many specific details.

Overall the use of System Delta did not produce any deleterious effects of the screen mesh or subsequent print image quality. The printing supervisor noted that the alternative system may be reducing their screen failure rate.

Alternative System Performance Table Compiled from Field Sites

The following table highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 10

Facility 10 prints store displays, primarily on paper, but they also print on plastics, metal, ceramic, glass, and other materials. Their typical run length is 200 - 500 impressions and less than 5% of their orders are repeat orders. Of the approximately 25 employees at this

Table V-111
On-Site Performance Summary For System Delta

	System Component	Performance						Demonstration Conditions			
		Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
In-field Demonstrations at Volunteer Printing Facilities											
Facility 10	*Ink remover*	17.4 ± 40.9 hr (n=18)	9.9 ± 4.2 oz. (n=18)	9.2 ± 2.1 mins (n=16)	Moderate	Removed ink well on 67% of screens; Slight residue on 33%.	• This facility used their own haze remover on most screens. • Ink remover performance was considered average.	UV-curable	Direct photo stencil	Twill weave; 305 - 390 threads/ inch	7767 in^2
	Emulsion Remover	17.2 ± 32.7 hr (n=18)	8.6 ± 1.5 oz. (n=18)	4.7 ± 2.2 mins (n=18)	Moderate	Easily removed stencil.					
	Haze Remover	3.0 mins (n=1)	1.0 oz. (n=1)	17.0 mins (n=1)	Moderate	Did not remove haze.					
Facility 11	*Ink Remover*	11.4 ± 22.2 hr (n=30)	7.7 ± 3.5 oz. (n=29)	6.3 ± 3.3 mins (n=29)	Low/ Moderate	Consistently removed ink well.	• All screens were reusable. • Print image quality was excellent. • No haze remover needed.	UV-curable	Direct photo stencil	Monofilament twill weave; 390 threads/ inch	5291 in^2
	Emulsion Remover	4.7 ± 14.4 min (n=31)	8.0 ± 3.5 oz. (n=30)	6.0 ± 3.2 mins (n=31)	Low/ Moderate	Easily removed stencil.					
	Haze Remover	not needed	not needed	not needed	not needed	Not needed.					

Table V-112
Laboratory Performance Summary For System Delta

		Performance						Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
Laboratory Testing at SPTF											
SPTF UV-curable Ink	*Ink Remover*	15 mins	1.0 oz.	3.5 mins	Med	Moderate ink residue remaining. Half of stencil peeled off.		UV-curable	Dual cure direct	Polyester; 390 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	4.8 mins	Med	Removed stencil. Ink residue remaining.					
	Haze Remover	0 mins	1.5 oz.	2.5 mins	Low	Removed residue. Dark ink stain left.					
SPTF Solvent-based Ink	*Ink Remover*	15 mins	1.0 oz.	4.5 mins	Med	Moderate ink residue remaining; some stencil deterioration.		Solvent-based	Dual cure direct	Polyester; 255 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.5 oz.	3.7 mins	Med	Removed stencil completely. Ink residue remaining.					
	Haze Remover	0 mins	2.0 oz.	3.5 mins	Low	Removed residue; moderate ink stain left.					
SPTF Water-based Ink	*Ink Remover*	15 mins	2.5 oz.	7.1 mins	Med	Slight ink residue remaining. Dissolved most of the stencil.		Water-based	Dual cure direct	Polyester; 255 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	3.8 mins	Low	Removed stencil completely. Slight ink residue and some ink stain remaining.					
	Haze Remover	0 mins	1.5 oz.	2.8 mins	Low	Removed residue. Slight ink stain left.					

facility, 1 - 3 are involved in screen reclamation activities. The screens used in the Performance Demonstrations were twill mesh with mesh counts of 305 - 390 threads/inch and a direct photo stencil was applied. The average screen size at this facility is 70 inches x 100 inches and 5 - 10 screens are reclaimed daily.

Screen Reclamation Area in Facility 10

Ink removal is done near the press where plant wide ventilation is provided. Screen reclamation is done in a separate room which is ventilated to the main production area. Within the reclamation room, there is a back-lit spray booth with a vented hood. During the observer's visit, the ambient conditions in the ink removal area were 67°F and 45% relative humidity. In the screen reclamation room, the temperature averaged 63°F and the relative humidity was 60%. Reusable rags used for ink removal are cleaned by a laundry service. Waste water from the wash in emulsion removal and haze removal is filtered prior to disposal.

Current Screen Reclamation Products at Facility 10

Facility 10 uses a proprietary blend ink remover consisting of at least propylene glycol ethers and dimethyl adipate. For emulsion removal, they use a proprietary aqueous mixture which contains periodate salt (<10%). Their haze remover is a proprietary aqueous mixture which contains sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 10

Using their standard products, this facility reclaims their screens following the procedure described below:

○ Ink Remover: Immediately after the print run, card off excess ink at the press. Saturate a reusable rag in ink remover and wipe remaining ink off the screen. Approximately 2 - 4 rags are used for each screen. Gloves are worn during ink removal.

○ Emulsion Remover: Rinse the screen with a pressure washer (1500 psi). Spray emulsion remover onto both sides of the screen and scrub with a scrubber pad. Pressure rinse on both sides. Gloves, eye protection, respiratory protection, and ear protection are available to employees during emulsion removal and haze removal activities.

○ Haze Remover: If there are any ink stains or stencil stains on the screen, reapply the ink remover or the emulsion remover where needed. Pressure rinse again. If the second application does not clean the screen sufficiently, then apply the haze remover. Typically, haze remover is only required on 2 - 5% of the screens reclaimed. To apply, dip a bristle brush into the pail of haze remover. Brush the haze remover into both sides of the screen and let sit for one minute. Rinse the screen with a high pressure water spray.

General Facility Background for Facility 11

Facility 11 prints fleet graphics and pressure sensitive decals. Typically, they print about 100 units per run and 50% of their orders are repeat orders. There are approximately 35 employees at this facility, and 1 - 3 people are involved in screen reclamation activities. During the Performance Demonstrations, this facility used UV-cured inks and a direct photo stencil.

Screens with a monofilament twill weave and a mesh count of 390 threads/inch were used. The average screen frame size used in this facility is 68 inches x 88 inches and approximately 5 screens are reclaimed per day.

Screen Reclamation Area in Facility 11

Ink removal and screen reclamation are both done in the same area of the facility which is 50 - 100 ft^2 in size. Natural ventilation and a shipping door next to the back-lit reclamation spray booth provide air flow for the area. During the observer's visit, the average temperature in the area was 59°F (and 42% relative humidity). Ink removal waste is sent to an off-site recycler. Waste water from the washes of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 11

Facility 11 uses a standard ink remover that is a proprietary product, sold by a manufacturer not participating in this project. According to the MSDS, this product contains no carcinogens, no ingredients with TLVs or PELs, and no petroleum derivatives. Information on the emulsion remover used at Facility 11 was not available. Their haze remover is a proprietary aqueous mixture that contains sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 11

Screen reclamation at Facility 11 usually follows the procedure detailed below. One exception is when there is a clear coat on the screen. In this case, lacquer thinner is applied to remove the clear coat prior to the ink removal step. Haze remover is rarely used at this facility (on approximately 1 - 3% of the screens reclaimed). It is usually only required when there is excessive adhesive and block out on the screen. During the screen reclamation process at Facility 11, gloves and eye protection are worn. Screens are reclaimed as follows:

○ <u>Ink Remover</u>: At the press, card off the excess. Bring the screen to the screen reclamation area and spray on the ink remover. Remove the ink by running a squeegee across the screen. Wipe off both sides of the screen with a reusable rag (2 - 4 rags are used on each screen) and pressure rinse (1000 psi).

○ <u>Emulsion Remover:</u> Dip a scrubber pad with a handle into the container of emulsion remover and scrub the product on the stencil side of the screen. Repeat dipping and scrubbing until stencil is covered (4 - 5 dips). Turn the screen over and spray emulsion remover on the other side of the screen. Let the remover sit on the screen for one or two minutes. Pressure rinse.

○ <u>Haze Remover:</u> A haze remover is rarely used (on approximately 1 - 3% of the screens reclaimed). When haze remover is used, apply as follows: dip a brush in the product container, rub the haze remover into the screen, and rinse with a high pressure wash. Lacquer thinner is used to remove any stains remaining on the screen.

Cost

Table V-113
Method 2: Summary of Cost Analysis for Alternative System Delta

Cost Element Description		Baseline (Traditional System 4)	Alternative System Delta	
			Facility 11	Facility 10
Facility Characteristics				
Average screen size (in^2)		2,127	5,292	7,767
Average # screens/day		6	5	8
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	12.3 2.69	30.9 6.76
Materials and Equipment	# of rags used Cost ($)	3 0.45	0.0 0.0	6.5 0.97
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	7.7 0.99	9.9 1.27
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	8.0 0.28	8.6 0.30
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	not used	1.0 0.13
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	0 0	0 0
Totals				
Total Cost ($/screen)		6.27	3.96	9.43
Normalized[a]		6.27	3.28	7.66
Total Cost ($/year)		9,399	4,953	17,675
Normalized[a]		9,399	4,917	11,489

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Epsilon

Formulation

Ink Remover	Cyclohexanone
	Methoxypropanol acetate
	Diethylene glycol
	Benzyl alcohol
	Diacetone alcohol
	Aromatic solvent naphtha
	Derivatized plant oil
Emulsion Remover	Sodium periodate
	Sulfate salt
	Water
Haze Remover	Alkyl benzene sulfonates
	Ethoxylated nonylphenol
	Phosphate salt
	Sodium hydroxide
	Derivatized plant oil
	Water
	Cyclohexanone
	Methoxypropanol acetate
	Diethylene glycol
	Benzyl alcohol
	Diacetone alcohol
	Aromatic solvent naphtha
	Derivatized plant oil

Occupational Exposure

Table V-114
Occupational Exposure Estimates for Epsilon System

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Cyclohexanone	39	0.3	0.2	1.4	468	2180
Methoxypropanol acetate	17	0.4	0.2	1.7	234	1090
Diethylene glycol	0	0	0	0	312	1460
Benzyl alcohol	0.1	0	0	0	101	473
Derivatized plant oil	0.1	0	0	0.2	55	255
Aromatic solvent naphtha	1.6	0.1	0	0.2	156	728
Diacetone alcohol	4.6	0.1	0.1	0.4	234	1090
Emulsion Remover (diluted 1:4)						
Sodium periodate	0	0	0	0	23	109
Sulfate salt	0	0	0	0	23	109
Water	0	0	0	0	1510	7060
Haze Remover						
Cyclohexanone	12	0.3	0.2	0	234	109
Methoxypropanol acetate	5.2	0.4	0.2	0	117	546
Diethylene glycol	0	0	0	0	156	728
Benzyl alcohol	0	0	0	0	51	273
Derivatized plant oil	0	0	0	0	27	127
Aromatic solvent naphtha	0.5	0.1	0	0	78	364
Diacetone alcohol	1.4	0.1	0.1	0	62	291
Alkyl benzene sulfonates	0	0	0	0	140	655
Ethoxylated nonylphenol	0	0	0	0	62	291
Phosphate salt	0	0	0	0	117	546
Alkali/Caustic	0	0	0	0	408	1890
Water	0	0	0	0	109	510

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

- ○ Hazard quotient calculations indicate marginal concerns for chronic dermal exposures to cyclohexanone and benzyl alcohol during both ink removal and haze removal. Similar calculations for inhalation exposures to cyclohexanone and benzyl alcohol indicate low concern.

- ○ Margin-of-exposure calculations indicate a marginal concern for developmental toxicity risk from inhalation exposures to cyclohexanone during ink removal. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified.

- ○ Hazard quotient calculations indicate marginal concerns for chronic dermal exposures and low concern for chronic inhalation exposures to methoxypropanol acetate.

- ○ Risks from other ink remover and haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Emulsion Removers (All Systems)

- ○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Exhibit V-115
Occupational Risk Estimates for System Epsilon

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Cyclohexanone	0.12	1.3	6.2	120	NA	NA	NA	NA	NA
Methoxypropanol acetate	0.45	5.6	26	0	NA	NA	NA	NA	NA
Diethylene glycol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzyl alcohol	0.004	4.8	23	NA	NA	NA	NA	NA	NA
Derivatized plant oil	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aromatic solvent naphtha	NA	NA	NA	NA	NA	NA	NA	NA	NA
Diacetone alcohol	NA	NA	NA						
Emulsion Remover (diluted to 3%)									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate salt	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

Exhibit V-116
Occupational Risk Estimates for System Epsilon

Name	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Haze Remover									
Cyclohexanone	0.03	0.8	3.6	400	NA	NA	NA	NA	NA
Methoxypropanol acetate	0.14	2.8	13	NA	NA	NA	NA	NA	NA
Diethylene glycol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzyl alcohol	NA	1.8	8.7	NA	NA	NA	NA	NA	NA
Derivatized plant oil	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aromatic solvent naphtha	NA	NA	NA	NA	NA	NA	NA	NA	NA
Diacetone alcohol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkyl benzene sulfonates	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phosphate salt	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkali/Caustic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

Environmental Releases

Table V-117
Environmental Release Estimates in Screen Cleaning Operations
Method 2, Alternative System Epsilon

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	land	water	air	air	air	water
Ink Remover							
Cyclohexanone	82	126	00	0.7	0.4	2.9	402
Methoxypropanol acetate	36	68	0	0.8	0.5	3.6	199
Diethylene glycol	0	138	0	0	0	0	270
Benzyl alcohol	0.2	45	0	0	0	0	88
Derivatized plant oil	0.2	24	0	0.1	0	0.3	47
Aromatic solvent naphtha	3.2	66	0	0.1	0.1	0.5	135
Diacetone alcohol	9.6	94	0	0.2	0.1	0.8	202
Emulsion Remover (diluted to 3%)							
Sodium periodate	0	0	9	0	0	0	0
Sodium salt	0	0	9	0	0	0	0
Water	0	0	602	0	0	0	0
Haze Remover							
Cyclohexanone	25	0	55	0.7	0.7	0.4	0
Methoxypropanol acetate	11	0	29	0.8	0.8	0.5	0
Diethylene glycol	0	0	53	0	0	0	0
Benzyl alcohol	0.1	0	17	0	0	0	0
Derivatized plant oil	0.1	0	9.3	0.1	0.1	0	0
Aromatic solvent naphtha	1	0	26	0.1	0.1	0.1	0
Diacetone alcohol	2.9	0	37	0.2	0.2	0.1	0
Alkyl benzene sulfonates	0	0	48	0	0	0	0
Ethoxylated nonylphenol	0	0	21	0	0	0	0
Alkali/Caustic	0	0	138	0	0	0	0
Water	0	0	37	0	0	0	0
Phosphate salt	0	0	21	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Environmental Releases from Screen Reclamation Processes Screen Reclamation Method 2, Alternative System Epsilon

From Ink Removal Operations:

- Cyclohexanone
  - 86 g/day to air
  - 402 g/day to water from rags at commercial laundry
  - 126 g/day to landfill
- Methoxypropanol acetate
  - 40.9 g/day to air
  - 199 g/day to water at commercial laundry
  - 68 g/day to landfill
- Diethylene glycol
  - 270 g/day to water at commercial laundry
  - 138 g/day to landfill
- Benzyl alcohol
  - 0.2 g/day to air
  - 88 g/day to water at commercial laundry
  - 45 g/day to landfill
- Derivatized plant oil
  - 0.6 g/day to air
  - 47 g/day to water from rags at commercial laundry
  - 24 g/day to landfill
- Aromatic solvent naphtha
  - 4 g/day to air
  - 135 g/day to water from rags at commercial laundry
  - 66 g/day to landfill
- Diacetone alcohol
  - 10.7 g/day to air
  - 202 g/day to water from rags at commercial laundry
  - 94 g/day to landfill

From Emulsion Remover:

- Sodium periodate
  - 9 g/day to water
- Sulfate salt
  - 9 g/day to water

From Haze Remover:

- Cyclohexanone
  - 26.8 g/day to air
  - 55 g/day to water

Environmental Releases from Screen Reclamation Processes
Screen Reclamation Method 2, Alternative System Epsilon (cont.)

Methoxypropanol acetate
- 13.1 g/day to air
- 29 g/day to water

Diethylene glycol
- 53 g/day to water

Benzyl alcohol
- 0.1 g/day to air
- 17 g/day to water

Derivatized plant oil
- 0.3 g/day to air
- 9.3 g/day to water

Aromatic solvent naphtha
- 1.3 g/day to air
- 26 g/day to water

Diacetone alcohol
- 3.4 g/day to air
- 37 g/day to water

Alkyl benzene sulfonates
- 48 g/day to water

Ethoxylated nonylphenol
- 21 g/day to water

Phosphate salt
- 21 g/day to water

Sodium hydroxide
- 138 g/day to water

Table V-118
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Epsilon

Substance:	To Air:	To Water:	To Landfill:
Cyclohexanone	113 g/day	55 g/day 402 g/day at laundry	126 g/day
Methoxypropanol acetate	54 g/day	29 g/day 199 g/day at laundry	68 g/day
Diethylene glycol		53 g/day 270 g/day at laundry	138 g/day
Benzyl alcohol	0.3 g/day	17 g/day 88 g/day at laundry	45 g/day
Derivatized plant oil	0.9 g/day	9.3 g/day 47 g/day at laundry	24 g/day
Aromatic solvent naphtha	5.3 g/day	26 g/day 135 g/day at laundry	66 g/day
Diacetone alcohol	14.1 g/day	37 g/day 202 g/day at laundry	94 g/day
Alkyl benzene sulfonates		48 g/day	
Ethoxylated nonylphenol		21 g/day	
Phosphate salt		21 g/day	
Alkali/Caustic		138 g/day	
Sodium periodate		9 g/day	
Sulfate salt		9 g/day	

Releases to Water from a Single Facility

Table V-119
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Epsilon

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Cyclohexanone	55 g/day 402 g/day at laundry	83 %	9.4 g/day 68.3 g/day	9×10^{-3} 7×10^{-2}
Methoxypropanol acetate	29 g/day 199 g/day at laundry	97 %	9×10^{-1} g/day 6 g/day	9×10^{-4} 6×10^{-3}
Diethylene glycol	53 g/day 270 g/day at laundry	84 %	8.5 g/day 43.2 g/day	9×10^{-3} 4×10^{-2}
Benzyl alcohol	17 g/day 88 g/day at laundry	97 %	5×10^{-1} g/day 3 g/day	5×10^{-4} 3×10^{-3}
Derivatized plant oil	9.3 g/day 47 g/day at laundry	100 %	0 g/day	0
Aromatic solvent naphtha	26 g/day 135 g/day at laundry	92-96 %	2 g/day 10.8 g/day	2×10^{-3} 1×10^{-2}
Diacetone alcohol	37 g/day 202 g/day at laundry	83 %	6.3 g/day 34 g/day	6×10^{-3} 3×10^{-2}
Alkyl benzene sulfonates	48 g/day	97 %	1.4 g/day	1×10^{-3}
Ethoxylated nonylphenol	21 g/day	100 %	0 g/day	0
Phosphate salt	21 g/day	100 %	0 g/day	0
Sodium hydroxide	138 g/day	100 %	0 g/day	0
Sodium periodate	9 g/day	100 %	0 g/day	0
Sulfate salt	9 g/day	100 %	0 g/day	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-120
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Epsilon

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Cyclohexanone	113 g/day	2.3×10^{-1} ug/m^3	2
Methoxypropanol acetate	54 g/day	1.1×10^{-1} ug/m^3	8×10^{-1}
Derivatized plant oil	0.9 g/day	1.8×10^{-3} ug/m^3	1×10^{-2}
Aromatic solvent naphtha	5.3 g/day	1.1×10^{-2} ug/m^3	8×10^{-2}
Benzyl alcohol	0.3 g/day	6×10^{-4} ug/ m^3	4×10^{-3}
Diacetone alcohol	14.1 g/day	3×10^{-2} ug/m^3	2×10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter **III**. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Product System Epsilon.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, Product System Epsilon reach an ecotoxicity concern concentration.

Performance

General Summary of Product System Epsilon, Performance, and Related Variables

This product system consisted of an ink remover, emulsion remover and haze remover. It's performance was demonstrated at Facility 20 and Facility 24. Facility 20 employs approximately 10 people and prints mainly banners and displays. Facility 24 employs 15 - 20 people in their production area with 4 employees involved in the screen printing operations of their business. They print pressure sensitive labels and Lexan face plates. Over a thirty-day period, Facility 20 reclaimed 48 screens and Facility 24 reclaimed 16 screens using Product System Epsilon. Both facilities used solvent-based inks, and Facility 24 also used UV-curable inks. Facility 20 used a dual-cured emulsion and Facility 24 used a direct photo stencil.

There were some differences between the two facilities in their evaluations of the performance of Product System Epsilon. Facility 20 found the ink remover was effective, but it took longer to breakdown the ink than their standard product. Facility 24 had very good results with the ink remover. They felt it worked as well as the products they had used previously and they were using less product per screen. The ink remover worked well on both UV and solvent-based inks, but the UV ink was easier to clean than the solvent-based ink.

The alternative emulsion remover performance was very good at both facilities. The two facilities reported that the performance was even better than their standard products; it dissolved the stencil quickly and easily.

Both facilities thought that the haze remover performance was acceptable, and in most cases, it worked as well as their other products.

Alternative System Epsilon Profile

The manufacturer recommends applying Product System Epsilon as follows:

- ○ Ink Remover After carding off as much excess ink as possible, spray both sides of the screen with the ink remover. Also spray a rag and rub both sides of the screen until all ink residue is completely dissolved or emulsified and the emulsion becomes clearly visible. Rinse well with water.

- ○ Emulsion Remover Dilute the powdered emulsion remover in water as follows: 1% for photoemulsions, 2% for fast exposing solvent resistant emulsion, 3% for dual-cured and water resistant photo emulsions. Stir thoroughly until the product is dissolved. Pour the diluted mixture into a spray bottle. Spray the solution on both sides of the screen. Rub the screen gently with a brush for approximately two minutes. Rinse thoroughly with a high pressure water spray. A 1000 psi pressure wash was used at SPTF. If any ink residue remains, apply additional ink remover to the screen, brush it in for a few minutes until emulsified, and pressure rinse.

- ○ Haze Remover Create a mixture of haze remover and ink remover in a ratio of 1:4 to 1:1. Scoop out the mixture and apply it to a brush. Brush the paste into both sides of the screen. Wait for a minimum of 10 minutes up to a maximum of 30 minutes. Rinse the mixture off with running water and then spray out the dissolved and softened residue with a high pressure washer.

Alternative System Performance at SPTF

Product System Epsilon was used at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and the third with water-based ink). The ink remover dissolved the solvent-based ink well and was easy to use. A light grey haze was left on the screen. On the screen with UV ink, the ink dissolved quickly, wiped off easily, rinsed clean of residue, but left a moderate ink stain. When used on the screen with water-based ink, more time and effort were needed to remove the ink which seemed to dry in the screen. With the extra effort, the ink was removed except for a light ink stain. For each of the three screens, one rag was used to remove the ink.

On all three screens, the emulsion remover dissolved the stencil with some scrubbing. The remainder of the stencil came off easily with the pressure wash. There was no emulsion stain or residue on any of the screens. On the screen with the solvent-based ink, a moderate ink stain remained after using the emulsion remover. The UV ink screen and the water-based ink screen had light stains. On all the screens, the haze remover lightened the ink stain, but did not remove it completely; a light ink stain was still visible.

Manufacturer's instructions were followed in applying the products to the screen. The technician noted that the ink remover had an unpleasant odor, but that it was not very strong.

Alternative System Performance Details

Performance Details from Facility 20

Users of the reclaiming products were asked to evaluate the performance of the components of System Epsilon relative to the facility's regular system. The screen reclaimer thought that the products were generally better than their previously used ones. The operations manager, however, felt that the ink remover did not perform quite as well in cutting some inks as their previously used products. No evaluation sheets were received from Facility 20, although the facility reported that they sent them. Unfortunately, they did not make copies of the sheets before they were mailed. Therefore, all performance information from Facility 20 was received through the observer's on-site documentation and through weekly telephone conversations with the facility. The observer interviewed both the reclamation employee and the operations manager, who was also one of the printers who used the ink remover.

The ink remover worked acceptably in the facility, although some of the printers who used it complained that it acted slowly. Performance was not as good on catalyzed inks as on other solvent-based inks. The catalyzed inks also require more effort to remove with the facility's regular ink remover, but the alternative ink remover did not perform as well as the regular product in this case. The alternative product did eventually remove all the ink from the screens. The operations manager, who also used the product, commented that it was more of an respiratory irritant than their previously used product; he said that the alternative ink remover smelled bad and made him dizzy.

The emulsion remover worked well at this facility. One screen, with an 83 mesh screen that had been used with an aggressive ink system, required at least two applications of emulsion remover to clean. Two applications of emulsion remover are also required when using the facility's standard emulsion remover with this type of screen. The reclaimer felt that either the coarse mesh or the ink system could have made the screen more difficult to clean.

Haze remover performance was acceptable. Again, when reclaiming screens with a mesh count of 83 threads per inch, the haze remover also had to be applied 2 or 3 times.

Overall, the use of Product System Epsilon had no deleterious effects on the screen mesh or on the subsequent print quality image and the printer did not notice any change in screen failure rate over the time period that the alternative system was in use.

Performance Details from Facility 24

This facility felt the ink remover and the emulsion remover worked better than their standard system, and the haze remover performed as well as their own product. Screen printing is a relatively small part of the operations at this facility, and although they used Product System Epsilon on all the screens they reclaimed, the total number of screens over four weeks was 14.

The ink remover consistently removed the both the solvent-based and the UV-curable inks. Although the product performance was good for both ink types, this printer found the UV inks easier to clean than the solvent-based inks. In addition, the facility found the quantity of alternative ink remover used per screen was significantly less than the quantity used of standard product.

The printer felt the emulsion remover was as effective as their standard product, and it dissolved the stencil quickly.

Product System Epsilon haze remover performance was evaluated as the same as the facility's standard haze remover. Although the data from this facility indicates that there were several cases where the screen could not be reused for reverse printing or for use with transparent inks, the printer felt that these restrictions were not entirely due to the alternative system. Some of the remaining ink stains may have been on the screen prior to the start of the demonstrations.

During the four weeks the products were used in this facility, no change in the screen failure, mesh deterioration, or print quality were noted. The observer felt the facility evaluated the alternative system's performance objectively and conscientiously. At the conclusion of the demonstrations, the printer mentioned that he was interested in continuing to use the alternative ink remover and emulsion remover.

Alternative System Performance Table Compiled from Field Sites

The table below highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 20

Facility 20 prints banners and point-of-purchase displays on paper, plastic, metals, ceramics, and glass. Their typical run is 20 parts and about 20% of their orders are repeat orders. Of the approximately 10 employees at this facility, 1 - 3 are involved in screen

Table V-121
On-Site Performance Summary For System Epsilon

		Performance						Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
In-field Demonstrations at Volunteer Printing Facilities											
Facility 20	*Ink remover*	no data	3.0 oz. (n=1)	no data	Moderate	Removed ink well, but took some extra time.	• Data forms were not received from this facility. • All information is based on weekly phone calls.	Solvent-based vinyl, enamels	Dual cure	Polyester; 83 - 280 threads/inch	2538 in^2
	Emulsion Remover	no data	3.3 ± 0.6 oz. (n=3)	no data	Moderate	Easily removed stencil.					
	Haze Remover	no data	4.0 ± 1.7 oz. (n=3)	no data	Moderate	Lightened ink stain.					
Facility 24	*Ink Remover*	10.3 ± 26.1 hrs (n=14)	4.2 ± 1.7 oz. (n=14)	3.7 ± 1.5 mins (n=13)	Moderate	Removed ink well, especially UV ink.	• All screens could be reused after reclamation. • Some screens could not be used for reverse printing. • Light ink stain remained.	Solvent-based and UV-curable	Direct photo stencil	Monofilament Polyester, no treatment; 355 threads/inch	1296 in^2
	Emulsion Remover	13.8 ± 12.2 hrs (n=14)	4.2 ± 1.9 oz. (n=13)	3.7 ± 1.1 mins (n=14)	Low	Easily removed stencil.					
	Haze Remover	2.9 ± 2.1 mins (n=14)	1.5 ± 0.5 oz. (n=14)	10.9 ± 4.7 mins (n=14)	Low	Usually removed haze.					

Table V-122
Laboratory Performance Summary For System Epsilon

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
Laboratory Testing at SPTF											
SPTF Solvent-based Ink	*Ink Remover*	15 mins	1.5 oz.	3.9 mins	Low	Dissolved ink well; gray haze left on screen.		Solvent-based	Dual cure direct	Polyester; 260 threads/inch	$360\ in^2$
	Emulsion Remover	24 hours	1.0 oz.	3.4 mins	Moderate	Dissolved stencil; medium ink stain remaining.					
	Haze Remover	0 mins	1.0 oz.	31.8 mins	Low	Lightened ink stain.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	1.5 oz.	3.3 mins	Low	Dissolved ink well; has unpleasant odor.		UV-curable	Dual cure direct	Polyester; 390 threads/inch	$360\ in^2$
	Emulsion Remover	24 hours	1.5 oz.	3.8 mins	Moderate	Dissolved stencil; light ink stain remaining.					
	Haze Remover	0 mins	1.0 oz.	2.2 mins	Low	Lightened ink stain.					
SPTF Water-based Ink	*Ink Remover*	15 mins	1.5 oz.	5.6 mins	Moderate	Dissolved ink with scrubbing.		Water-based	Dual cure direct	Polyester; 260 threads/inch	$360\ in^2$
	Emulsion Remover	24 hours	1.0 oz.	3.2 mins	Moderate	Dissolved stencil; light ink stain remaining.					
	Haze Remover	0 mins	1.0 oz.	32.8 mins	Low	Lightened ink stain.					

reclamation activities. The facility uses a variety of solvent-based inks including vinyl, enamel, and a multipurpose ink. They use a dual cure emulsion. Screens used in the Performance Demonstrations were polyester (untreated) with a mesh count of 83 -280 threads/inch. The average screen size at this facility is 4 feet x 5 feet and approximately 5 - 10 screens are reclaimed daily.

Screen Reclamation Area in Facility 20

The ink removal and screen reclamation activities are done in the press room in a back-lit spray booth. A plant-wide system provides the ventilation for the screen reclamation area. The average temperature during the observer's visit was 68°F (and 36% relative humidity). Ink waste is disposed of as hazardous waste. Waste water from the high-pressure wash of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 20

The standard ink remover product at Facility 20 is an acetone blend. For emulsion removal, they use a proprietary aqueous mixture which includes periodate salt (<10%). Their standard haze remover is a proprietary aqueous mixture with sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 20

This facility uses a custom blended ink remover. The application procedure listed below is used for most screens. One exception is the 83 mesh, where two applications of the emulsion remover are required. Occasionally, a dried ink requires an initial rinse with cyclohexanone. The screen reclamation process is described below:

- Ink Remover: Card off excess ink from the screen. Apply ink remover to a reusable rag from a safety can. Gloves and eye protection are usually worn during this step. Brush the product into the screen. Wipe the screen with a reusable rag. Continue wiping with clean rags until ink no longer comes off on the rag. Typically, 2 - 4 rags are used on each screen.

- Emulsion Remover: After ink removal, rinse the screen with the hose. Apply the emulsion remover with a spray bottle. Scrub in the product with a pad brush. Rinse the screen with a pressure wash (100 psi).

- Haze Remover: To apply haze remover, dip a bristle brush into the pail of product. Brush the haze remover into both sides of the screen and let sit for one minute. Rinse the screen with a high pressure water spray. If the stain is dark, reapply the haze remover and let sit for 1 - 2 minutes and rinse again with the high pressure spray.

General Facility Background for Facility 24

The majority of the products printed by Facility 24 are pressure sensitive mylar labels and polycarbonate Lexan face plates. Run lengths are typically 500 - 1000 impressions, and approximately 50% of their business is for repeat orders. There are 15 - 20 employees involved in production operations at this facility and 2 - 3 are involved in screen reclamation operations. The facility uses both solvent-based inks and UV inks; sometimes on the same screen. They use a direct photo stencil and a monofilament (untreated) polyester mesh. All screens used in the Performance Demonstrations had a mesh count of 355 threads/inch. The average screen size at this facility is 36" x 36" and 3 - 5 screens are reclaimed each week.

Screen Reclamation Area in Facility 24

Ink removal is done at press side and screen reclamation takes place nearby in a spray booth. The high ceilings and facility-wide ventilation cover both work areas. During the observer's visit, the average temperature in the area was 68°F (and 40% relative humidity). Rags used for ink removal are cleaned under a contract with a laundry service. Waste water from screen reclamation is not recycled or filtered.

Current Screen Reclamation Products at Facility 24

Facility 24 uses a proprietary solvent blend ink remover consisting primarily of cyclohexanone, diacetone alcohol and dipropylene glycol methyl ether. Their emulsion remover is a proprietary aqueous mixture with at least sodium periodate. Their standard haze remover is an aqueous blend consisting of sodium hydroxide (5%) and tetrahydrofurfuryl alcohol (<15%).

Current Screen Reclamation Practices in Facility 24

At Facility 24, all screens are reclaimed following the application procedure below:

- <u>Ink Remover:</u> At the press, scrape the excess ink off the screen. Wearing gloves, eye protection, and an apron, pour the ink remover onto the screen from a one-gallon can. Scrub with an abrasive brush. Wipe the screen with reusable rags until ink no longer comes off on the rag. Rinse the screen with a pressure wash (500 psi).

- <u>Emulsion Remover:</u> Spray emulsion remover onto both sides of the screen. Work the product into the screen using a scrubber pad. Rinse both sides of the screen with a high pressure wash. After washing off the emulsion, spray the screen with an ink degradent. Wait for one minute. Scrub the screen with a brush and pressure rinse both sides.

- <u>Haze Remover:</u> Wearing gloves and eye protection, dip a brush into the bucket of haze remover. Brush the product into the screen on the effected area on both sides. Wait for 15 minutes. Rinse both sides of the screen with a high-pressure wash.

Cost

Table V-123
Method 2: Summary of Cost Analysis for Alternative System Epsilon

Cost Element Description		Baseline (Traditional System 4)	Alternative System Epsilon	
			Facility 20	Facility 24
Facility Characteristics				
Average screen size (in^2)		2,127	2,538	1,296
Average # screens/day		6	8	1
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	9.7 2.12	18.3 4.00
Materials and Equipment	# of rags used Cost ($)	3 0.45	7.0 1.05	3.8 0.57
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	3.0 0.18	4.2 0.26
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	3.3 0.09	4.2 0.11
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	4.0 0.27	1.5 0.10
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	112 0.08	57 0.04
Totals				
Total Cost ($/screen)		6.27	3.79	5.08
Normalized[a]		6.27	3.08	5.29
Total Cost ($/year)		9,399	7,097	1,269
Normalized[a]		9,399	4,624	7,930

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Gamma

Formulation

Ink Remover	Propylene glycol series ethers
	Diethylene glycol series ethers
	Dibasic esters
	Fatty alcohol ethers
	Derivatized plant oil
Emulsion Remover	Sodium periodate
	Sulfate salt
	Phosphate salt
	Water
Haze Remover	Sodium hypochlorite
	Alkali/Caustic
	Sodium alkyl sulfonate
	Water

Occupational Exposure

Table V-124
Occupational Exposure Estimates for Alternative System Gamma

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Diethylene glycol butyl ether acetate	0	0	0	0	62	291
Tripropylene glycol methyl ether	0	0	0	0	780	3640
Derivatized plant oil	0.2	0	0	0.2	62	291
Fatty alcohol ethers	0.4	0	0	0.1	187	873
Dibasic esters	1.3	0	0	0.2	468	2184
Emulsion Remover						
Sodium periodate	0	0	0	0	39	182
Sulfate salt	0	0	0	0	16	73
Phosphate salt	0	0	0	0	117	546
Water	0	0	0	0	1270	5930
Haze Remover						
Sodium hypochlorite	0	0	0	0	585	2730
Alkali/Caustic	0	0	0	0	39	182
Water	0	0	0	0	827	3860
Sodium alkyl sulfate	0	0	0	0	109	510

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Exhibit V-125
Occupational Risk Estimates for System Gamma

Name	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
<u>Ink Remover</u>									
Diethylene glycol butyl ether acetate	NA	NA	NA	NA	NA	2258	57	481	12
Tripropylene glycol methyl ether	NA	NA	NA	NA	NA	NA	NA	NA	NA
Derivatized plant oil	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fatty alcohol ethers	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibasic esters	NA	NA	NA	NA	NA	NA	NA	NA	NA
<u>Emulsion Remover</u>									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate salt	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phosphate salt	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.
[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.
[c] NOAEL means No Observed Adverse Effect Level.
[d] LOAEL means Lowest Observed Adverse Effect Level.

Exhibit V-126
Occupational Risk Estimates for Alternative System Gamma

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Haze Remover									
Sodium hypochlorite	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkali/Caustic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sodium alkyl sulfate	NA	NA	NA	NA	NA	192	NA	41	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

- Clear concerns exist for chronic dermal exposures to diethylene glycol butyl ether acetate used in ink removal based on the calculated margin-of-exposure.

- Developmental toxicity risks from dermal exposures to diethylene glycol butyl ether acetate are very low based on the calculated margin-of-exposure.

- Risks from other ink remover and haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

- Developmental and chronic toxicity risks from dermal exposures to sodium alkyl sulfate in haze remover are very low based on the calculated margin of exposure.

- Inhalation exposures to all components are very low.

Emulsion Removers (All Systems)

- All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-127
Environmental Release Estimate for Screen Cleaning Operations
Method 2, Gamma System

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Diethylene glycol butyl ether acetate	0	0	28	0	0	0	54
Tripropylene glycol methyl ether	0.1	0	355	0	0	0	675
Derivatized plant oil	0.3	0	28	0.1	0	0.3	54
Fatty alcohol ethers	0.8	0	84	0	0	0.1	162
Dibasic esters	3.0	0	210	0	0	0.3	405
Emulsion Remover							
Sodium periodate	0	16	0	0	0	0	0
Sulfate salt	0	6	0	0	0	0	0
Phosphate salt	0	47	0	0	0	0	0
Water	0	506	0	0	0	0	0
Haze Remover							
Sodium hypochlorite	0	200	0	0	0	0	0
Alkali/Caustic	0	13	0	0	0	0	0
Water	0	282	0	0	0	0	0
Sodium alkyl sulfate	0	37	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-128
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Gamma

Substance:	To Air:	To Water:	To Landfill:
Diethylene glycol butyl ether acetate		54 g/day from laundry	28 g/day
Tripropylene glycol methyl ether	0.1 g/day	675 g/day from laundry	355 g/day
Derivatized plant oil	0.7 g/day	54 g/day at laundry	28 g/day
Fatty alcohol ethers	0.9 g/day	162 g/day at laundry	86 g/day
Dibasic esters	3.0 g/day	405 g/day at laundry	210 g/day
Sodium periodate		16 g/day	
Sulfate salt		6 g/day	
Phosphate salt		47 g/day	
Other		47 g/day	
Sodium hypochlorite		200 g/day	
Alkali/caustic		13 g/day	
Sodium alkyl sulfate		37 g/day	

Releases to Water from a Single Facility

Table V-129
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Gamma

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Diethylene glycol butyl ether acetate	54 g/day at laundry	83 %	9.2 g/day	9×10^{-3}
Tripropylene glycol methyl ether	675 g/day at laundry	83 %	115 g/day	1×10^{-1}
Derivatized plant oil	54 g/day at laundry	100 %	0	0
Fatty alcohol ethers	162 g/day at laundry	100 %	0	0
Dibasic esters	405 g/day at laundry	84-97 %	28.3 g/day	3×10^{-2}
Sodium Periodate	16 g/day	100 %	0	0
Sulfate salt	6 g/day	100 %	0	0
Phosphate salt	47 g/day	100 %	0	0
Other	47 g/day	100 %	0	0
Sodium hypochlorite	200 g/day	100 %	0	0
Alkali/caustic	13 g/day	100 %	0	0
Sodium alkyl sulfate	37 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-130
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Gamma

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Tripropylene glycol methyl ether	0.1 g/day	2×10^{-4} ug/m^3	1×10^{-3}
Derivatized plant oil	0.7 g/day	1.4×10^{-3} ug/m^3	1×10^{-2}
Fatty alcohol ethers	0.9 g/day	2×10^{-3} ug/m^3	1×10^{-2}
Dibasic esters	3.0 g/day	5×10^{-3} ug/m^3	5×10^{-2}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Product System Gamma.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, Product System Gamma reach an ecotoxicity concern concentration.

Performance

General Summary of Product System Gamma Performance, and Related Variables

Product System Gamma, demonstrated at Facilities 16 and 25, consisted of an ink remover, an emulsion remover, and a haze remover. Facility 16 prints vehicle markings; Facility 25 prints appliance panel overlays, back-lit automotive panels, and store displays. During the four week demonstration period, Facility 16 reclaimed 55 screens although ink remover was only used on seven screens and haze remover was only used on three screens; Facility 25 reclaimed 54 screens but the ink remover and haze remover were only used on about half of these. During the demonstrations, both Facility 16 and 25 used solvent-based inks.

Facility 16 reported that the ink remover left an unacceptable amount of ink on the screen and required a lot of physical effort. Facility 25 also reported that the ink remover was not acceptable, leaving ink residue on the screen, especially in the open areas of the screen mesh. The ink remover required much more time to apply (up to more than twice as long in some cases) with much greater physical effort than the products normally used at these facilities. Leaving the ink remover to sit for 3 - 5 minutes on the screen helped improve performance on the screen areas covered with emulsion, but did not help to remove the ink on the open screen areas.

Both facilities reported that the emulsion remover worked very well. Facility 16 was able to shorten the time between application and rinse from the recommended one or two minutes to less than one minute without compromising the product performance. Facility 25 improved the emulsion remover performance by wetting the screen before applying the emulsion remover.

Neither facility found the performance of the haze remover to be acceptable. They found the haze remover did not remove the ink haze left in the screen, which resulted in ghost images in future print jobs. Both facilities had to use their standard haze remover on their screens before they could be reused.

Alternative System Gamma Profile

The manufacturer recommends applying Product System Gamma as follows:

○ Ink Remover Card up the excess ink. Spray both sides of the screen with the ink remover. Also spray a rag or brush with the product and rub both sides of the screen until all of the ink residue is completely dissolved or emulsified and the emulsion becomes clearly visible. Rinse well with water. For tests done at SPTF, a 1000 psi spray was used for rinsing the ink remover, emulsion remover, and haze remover.

○ Emulsion Remover Scoop the emulsion remover out of the container and apply it to a brush. Use the brush to distribute the product evenly on both sides of the screen. After approximately two minutes spray out with a pressure washer. If no pressure water is available, brush until the photo emulsion is completely dissolved,and rinse out with a strong water spray. Should any ink residue remain, apply additional ink remover to the screen, brush it in for a few minutes until emulsified,then pressure rinse.

○ Haze Remover Spray haze remover evenly on both sides of the screen. Distribute the product evenly using a nylon brush. Let sit for at least one hour. If the ink is dried, let it sit for up to 24 hours. Rinse off with water.

Alternative System Performance at SPTF

Product System Gamma was tested at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). The ink remover performance varied depending on the type of ink used. The emulsion remover and haze remover performance was consistent for all three screens. All products were applied according to the manufacturer's instructions.

On the screen with the solvent-based ink and the screen with UV ink, the ink remover dissolved the ink well with no effect on the stencil. On the water-based ink screen, however, heavy scrubbing and more product were needed to remove the ink. While scrubbing, the stencil started to break down in the half-tone area. For all the screens, only one rag was used for ink removal.

The emulsion remover easily dissolved the stencil with only light scrubbing on all three screens, leaving no ink or emulsion residue behind. The technician noted that most of the stencil dissolved while she was brushing, and the pressure wash took off the remainder. The screens did have a moderate ink stain remaining. Subsequent application of the haze remover lightened the ink stains so that a light to very light ink stain remained.

Alternative System Performance Details

Performance Details from Facility 16

Product System Gamma ink remover and haze remover did not work well and Facility 16 decided not to use these products during the demonstration period. The emulsion remover seemed to work very well; it was evaluated for the entire four-week demonstration period. During the demonstrations, there did not appear to be any change in the screen failure rate, or any noticeable effects on the screen mesh or frames.

The ink remover was only used to clean four screens. The printer sprayed the product on and let it sit for 30 second before wiping. In all cases it took a lot of effort to clean the screens. The ink remover left an oily film and an ink residue in the mesh. The facility decided to discontinue using the alternative ink remover based on these results.

The emulsion remover worked well, with no notable variations in performance among the screens used during the demonstration period. Although the product instructions require waiting 1 - 2 minutes after applying the product before pressure washing, the reclaimer found that the emulsion began to fall off the screen within 30 - 45 seconds after application. Screens were therefore pressure washed sooner than specified, with no noticeable effect on product performance. Facility 16 uses screens encompassing a large range of sizes, including some very large screens used for producing fleet markings for semi-trailers. The amount of emulsion remover used to clean the screens varied accordingly, although the results were consistent.

At this facility, the haze remover did not remove ghost images from the screens. After initial printing using the prescribed procedure, the screen reclaimer left the haze remover on a screen for 48 hours in an attempt to remove the ghost image, with no success. The facility had to use their regular haze remover on the screens in order to be able to reuse them in production. Use of the alternative haze remover was discontinued and the product was not included in the performance demonstration. For both the haze remover and the ink remover, an insufficient number of screens were reclaimed with these products to determine any correlations between demonstration conditions (e.g., number of impressions, ink color) and the product performance.

At Facility 16, one employee applied the ink remover, and a second reclaimed the screens and evaluated the printing quality on subsequent runs. Neither of these employees had direct contact with the observer during the performance demonstration. Three different people served as the facility contact during the course of the study. The confusion of so many different contacts probably prevented the performance demonstration from being managed as closely as it was in other facilities.

Performance Details from Facility 25

Although all three components of System Gamma were used during part of the performance demonstrations, the ink remover and haze remover did not work well enough to be used for the complete four week period. The emulsion remover worked well and was used for the entire demonstration period. During the demonstrations, the printer did not notice any changes in the screen failure rate or any detrimental effects on the screen mesh, or frame.

The ink remover did not work well at Facility 25. It should be noted that the standard ink remover used at this facility is chemically very different from the alternative ink remover supplied as part of Product System Gamma. Adverse chemical interactions may have occurred on some of the older screens due to the differences in the chemicals, and may have affected all phases of the alternative system performance. The employee who used the alternative ink remover tried several different procedures in order to improve the performance such as using presoaked rags to get more ink remover on the screen, waiting 3 - 5 minutes after application before wiping the ink, and laying rags soaked in ink remover over the screen as soon as it came off the press. Although these procedures helped remove the ink from the stencil surface, there was still a large amount of ink left in the screen; enough to completely block the mesh in some cases. The residual ink was not removed by the emulsion and haze removal steps. The facility used the alternative ink remover for a week and a half before they had to stop because of the poor performance. None of the screens cleaned with this alternative product worked well in production, so they all had to be reprocessed with the facility's regular products before acceptable printing quality was achieved. The facility used several different solvent ink systems and, in reviewing the data from the printer's observations, the ink system and the length of the ink drying time seemed to be the most influential variable in determining the level of performance of the alternative system. However, the ink remover performance was not acceptable for any of the ink systems used.

The emulsion remover performed consistently well on all screens and stencils. The reclaimer found that the product acted faster on the stencil if the screen was wetted before applying the emulsion remover.

The haze remover did not work well. The haze remover was allowed to react on the screens as long as 24 hours, without successfully removing the ink haze. The reclaimer continued to use the haze remover after use of the ink remover was suspended, to see if it would perform better if the haze was less severe. She found that the haze remover worked better if the screens were dried before the product was applied. Even so, too much ink haze was left in the screens to be able to successfully reuse them. Ink residue left in the mesh caused ghost images in subsequent jobs, and eventually solubilized in similar ink systems, which caused the inks to become discolored during the printing runs. Facility 25, therefore, discontinued the use of the alternative haze remover after the second week of demonstrations.

At Facility 25, printing quality judgements were made by the printer, along with the other employees involved in the study. The personnel involved seemed to work hard to try to get acceptable results from the products.

Alternative System Performance Table Compiled from Field Sites

The following table highlights the performance of the product system as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in Section 6.

Facility Profiles

General Facility Background for Facility 16

Facility 16 prints fleet vehicle markings on vinyl film. Their typical run length is 200 sheets, and approximately 60% of their orders are repeat orders. There are over 50 employees at this location, and 7 - 10 are involved in ink removal and 1 - 3 are involved in screen reclamation. For the performance demonstrations, all inks used were solvent-based on polyester or monoflex screens with capillary film emulsions. Screens mesh counts of 200 - 390 threads/inch were used for the demonstrations. Average screen size at this facility is 12 ft^2 and approximately 20 screens are reclaimed daily.

Screen Reclamation Area in Facility 16

After initial ink removal at the press, the remainder of the ink is removed in the same washout booth as is used for emulsion and haze removal. The reclamation area is 50 - 100 ft^2 and is ventilated via the facility-wide system. The average temperature during the observer's visit was 68°F (and 62% relative humidity). Spent solvent and ink waste are sent off-site to a recycler.

Current Screen Reclamation Products at Facility 16

Information on the chemical composition of the standard ink remover at this facility was not available for this document. For emulsion removal, they use a proprietary aqueous mixture with at least sodium periodate. Their haze remover is a formulation which contains 100% sodium periodate.

Current Screen Reclamation Practices in Facility 16

Using their standard products, this facility reclaims their screens following the procedure described below. Gloves are worn during ink removal, and during emulsion and haze removal gloves, eye protection, aprons, and respiratory protection are available as personal protective equipment for the operators.

○ Ink Remover: Card off the excess ink. At the press, apply press wash to a disposable wipe from a safety can and wipe down the screen. Bring the screen to the washout booth. Apply ink remover to both sides of the screen from a bucket with a brush. Wait for one minute, then rinse with a high pressure (2000 psi) spray. Remove the tape from the screen edges and rinse again with the high pressure washer.

○ Emulsion Remover: Dip a brush in the container of emulsion remover and brush it into both sides of the screen. Rinse with the high pressure wash and let the screen dry before applying the haze remover.

Table V-131
On-Site Performance Summary For Alternative System Gamma

		Performance						Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Avg Effort Req'd	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
In-field Demonstrations at Volunteer Printing Facilities											
Facility 16	*Ink remover*	3.0 ± 2.4 mins (n=7)	5.0 ± 2.0 oz. (n=7)	11.1 ± 6.6 mins (n=7)	Med	Ink and oily residue left in mesh.	• Did not use the ink remover or haze remover due to poor performance.	Solvent-based	Capillary film	Polyester, untreated or abraded; 200 - 390 threads/ inch	2294 in^2
	Emulsion Remover	52.4 ± 272.0 mins (n=55)	2.3 ± 1.3 oz. (n=51)	1.8 ± 1.8 mins (n=50)	Low	Easily removed stencil on all screens.					
	Haze Remover	0.0 ± 0.0 mins (n=55)	3.3 ± 1.5 oz. (n=3)	3.0 ± 0.0 mins (n=1)	Med	Did not remove ghost images.					
Facility 25	*Ink Remover*	19.2 ± 15.0 mins (n=23)	10.8 ± 4.6 oz. (n=22)	11.7 ± 5.2 mins (n=22)	High	Excessive ink residue left in screen.	• Stopped using ink remover and haze remover after 2 weeks due to poor results.	Solvent-based	Direct photo stencil	Polyester, no treatment or abraded; 175 - 420 threads/ inch	1848 in^2
	Emulsion Remover	13.2 ± 31.1 hrs (n=54)	1.2 ± 0.4 oz. (n=50)	3.0 ± 0.3 mins (n=50)	Low	Quickly, easily removed stencil.					
	Haze Remover	4.6 ± 11.8 hrs (n=54)	5.3 ± 7.2 oz. (n=23)	2.2 ± 0.4 mins (n=12)	Low	Ink haze remained in screen.					

Table V-132
Laboratory Performance Summary For Alternative System Gamma

		Performance						Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Avg Effort Req'd	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
Laboratory Testing at SPTF											
SPTF Solvent-based Ink	*Ink Remover*	15 mins	1.5 oz.	3.8 mins	Low	Ink dissolved well. No effect on stencil.		Solvent-based	Dual cure direct	Polyester; 260 threads/ inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	3.9 mins	Low	Removed stencil easily. Moderate ink stain remaining.					
	Haze Remover	0 mins	1.0 oz.	1.8 mins	Low	Lightened stain.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	1.5 oz.	3.5 mins	Low	Ink dissolved well. No effect on stencil.		UV-curable	Dual cure direct	Polyester; 390 threads/ inch	360 in^2
	Emulsion Remover	24 hours	1.5 oz.	4.8 mins	Low	Removed stencil easily. Moderate ink stain remaining.					
	Haze Remover	0 mins	0.5 oz.	1.8 mins	Low	Lightened stain.					
SPTF Water-based Ink	*Ink Remover*	15 mins	2.0 oz.	5.8 mins	Med	Heavy scrubbing required to dissolve ink. Parts of stencil deteriorated.		Water-based	Dual cure direct	Polyester; 260 threads/ inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	4.8 mins	Low	Removed stencil easily. Moderate ink stain remaining.					
	Haze Remover	0 mins	1.0 oz.	2.0 mins	Low	Lightened stain.					

- ○ Haze Remover: Dip a brush into the haze remover and apply the product to both sides of the screen. Allow the screen to air dry. Rinse the screen with the high pressure sprayer.

General Facility Background for Facility 25

Facility 25 prints point-of-purchase displays and overlays for appliances and automotive applications. Print runs at this facility average 16 hours and approximately 80% of their orders are repeat orders. During the Performance Demonstration, this facility used solvent-based inks and a direct photo stencil on polyester screens with mesh counts of 175 - 420 threads per inch. The most common screen sizes at Facility 25 are 42 inches x 42 inches and 42 inches x 50 inches. Approximately 25 screens are reclaimed daily.

Screen Reclamation Area in Facility 25

Ink removal is done at the press and screen reclamation is done in a separate reclaim room. At the press, the facility-wide system provides ventilation for the area. A local, mechanical system over the spray booth ventilates the screen reclamation area. During the observer's visit, the average temperature in the facility was 68°F (and 34% relative humidity). Spent solvent waste is recycled both on-site and off-site, and recycled product is reused in the facility. Ink waste is disposed of as hazardous waste. Waste water from the washes of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 25

This facility's standard ink remover is a solvent blend which includes the following chemicals: cyclohexanone (<60%), xylenes (<5%), ethyltoluene (<15%), trimethylbenzenes (<35%), C-10 aromatics (<5%), and cumene (<5%). They also use another solvent blend which contains methyl ethyl ketone (<35%), toluene (<55%), n-butyl acetate (<20%), and heptane (<15%). Their emulsion remover is either a proprietary aqueous mixture with at least periodate salt (<10%), or a proprietary aqueous mixture with at least an acid salt. For haze removal, this facility uses a proprietary aqueous mixture with at least sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 25

During the screen reclamation process at Facility 25, personal protective equipment available to the employees includes gloves, eye protection, aprons, and ear protection. Screens are reclaimed as follows:

- ○ Ink Remover: At the press, card off excess ink. To remove the ink, rub the screen with wipes that are saturated in ink remover. Approximately 6 - 8 wipes are used for each screen.

- ○ Emulsion Remover: Wet the screen with the hose to soften the blockout. Spray emulsion remover onto both sides of the screen and let sit for 30 seconds. Rinse from the bottom to the top of the screen with a high pressure wash (2500 psi)followed by a low pressure wash.

- ○ Haze Remover: Allow the screen to air dry before applying the haze remover. Dip a brush in the haze remover and rub into screen. Wait for one minute. Rinse with a high pressure spray. Vacuum dry the screen.

Cost

Table V-133
Method 2: Summary of Cost Analysis for Alternative System Gamma

Cost Element Description		Baseline (Traditional System 4)	Alternative System Gamma	
			Facility 16	Facility 25
Facility Characteristics				
Average screen size (in^2)		2,127	2,294	1,848
Average # screens/day		6	20	25
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	15.9 3.48	16.9 3.70
Materials and Equipment	# of rags used Cost ($)	3 0.45	5.0 0.75	7.0 1.04
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	5.0 0.43	10.8 0.92
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	2.3 0.24	1.2 0.12
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	3.3 0.24	5.3 0.39
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	0 0	0.0 0.0
Totals				
Total Cost ($/screen)		6.27	5.14	6.17
Normalized[a]		6.27	5.06	5.61
Total Cost ($/year)		9,399	25,708	38,547
Normalized[a]		9,399	7,590	8,417

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Mu

Formulation

Ink Remover	Dibasic esters Methoxypropanol acetate d-Limonene Ethoxylated nonylphenol Derivatized plant oil
Emulsion Remover	Periodic acid Water
Haze Remover	Sodium hypochlorite Alkali/Caustic Sodium alkyl sulfate Water

Occupational Exposure

Table V-134
Occupational Exposure Estimates for Alternative System Mu System

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Dibasic esters	3	0	0	0.2	1014	4728
Methoxypropanol acetate	31	0.4	0	1.7	312	1460
Limonene	21	0.6	0	2.4	156	728
Ethoxylated nonylphenol	0	0	0	0	94	437
Derivatized plant oil	0	0	0	0.2	62	291
Emulsion Remover						
Periodic acid	0	0	0	0	156	728
Water	0	0	0	0	1400	6550
Haze Remover						
Sodium hypochlorite	0	0	0	0	585	2730
Alkali/Caustic	0	0	0	0	39	182
Water	0	0	0	0	827	3860
Sodium alkyl sulfate	0	0	0	0	109	510

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-135
Occupational Risk Estimates for Alternative System Mu

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
<u>Mu - Ink Remover</u>									
Dibasic esters	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methoxypropanol acetate	0.8	7.4	35	NA	600	NA	NA	NA	NA
Limonene	NA	NA	NA	NA	432	NA	67	NA	14
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Derivatized plant oil	NA	NA	NA	NA	NA	NA	NA	NA	NA
<u>Mu - Emulsion Remover</u>									
Periodic acid	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
<u>Mu - Haze Remover</u>									
Sodium hypochlorite	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkali/Caustic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sodium lauryl sulfate	NA	NA	NA	300	NA	190	NA	41	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.
[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.
[c] NOAEL means No Observed Adverse Effect Level.
[d] LOAEL means Lowest Observed Adverse Effect Level.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

○ Concerns exist for chronic risks from both inhalation and dermal exposures to *d*-limonene during ink removal based on the calculated margins-of-exposure.

○ Hazard quotient calculations for methoxypropanol acetate used in ink removal indicate a marginal concern for chronic dermal exposures and low concern for chronic inhalation exposures.

○ Margin-of-exposure calculations show possible concerns for developmental toxicity risks from inhalation exposures to methoxypropanol acetate.

○ Developmental and chronic toxicity risks from dermal exposures to sodium alkyl sulfate in haze remover are very low based on the calculated margin of exposure.

○ Risks from other ink remover and haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Emulsion Removers (All Systems)

○ All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-136
Environmental Release Estimates in Screen Cleaning Operations
Method 2, Alternative System Mu

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Dibasic esters	5.1	0	446	0	0	0.3	877
Methoxypropanol acetate	64	0	75	0.8	0.5	3.6	266
Limonene	43	0	27	1.2	0.7	5.1	130
Ethoxylated nonylphenol	0	0	42	0	0	0	81
Derivatized plant oil	0.3	0	27	0.1	0	0.3	54
Emulsion Remover							
Periodic acid	0	62	0	0	0	0	0
Water	0	559	0	0	0	0	0
Haze Remover							
Sodium hypochlorite	0	200	0	0	0	0	0
Alkali/Caustic	0	13	0	0	0	0	0
Water	0	282	0	0	0	0	0
Sodium alkyl sulfate	0	37	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-137
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Mu

Substance:	To Air:	To Water:	To Landfill:
Dibasic esters	5.4 g/day	877 g/day at laundry	446 g/day
Methoxypropanol acetate	68.9 g/day	266 g/day at laundry	75 g/day
Limonene	50 g/day	130 g/day at laundry	27 g/day
Ethoxylated nonylphenol		81 g/day at laundry	42 g/day
Derivatized plant oil	0.7 g/day	54 g/day at laundry	27 g/day
Periodic acid		62 g/day	
Sodium hypochlorite		200 g/day	
Alkali/caustic		13 g/day	
Sodium alkyl sulfate		37 g/day	

Releases to Water from a Single Facility

Table V-138
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Mu

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Dibasic esters	877 g/day at laundry	84-97 %	42.5 g/day	5×10^{-2}
Methoxypropanol acetate	266 g/day at laundry	97 %	8 g/day	8×10^{-3}
Limonene	130 g/day at laundry	> 99 %	<1.3 g/day	$<1 \times 10^{-3}$
Ethoxylated nonylphenol	81 g/day at laundry	100 %	0	0
Derivatized plant oil	54 g/day at laundry	100 %	0	0
Periodic acid	62 g/day	100 %	0	0
Sodium hypochlorite	200 g/day	100 %	0	0
Alkali/caustic	13 g/day	100 %	0	0
Sodium alkyl sulfate	37 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-139
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Mu

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Dibasic esters	5.4 g/day	1.1×10^{-2} ug/m^3	8×10^{-2}
Methoxypropanol acetate	68.9 g/day	1.4×10^{-1} ug/m^3	1
Limonene	50 g/day	1×10^{-1} ug/m^3	7×10^{-1}
Derivatized plant oil	0.7 g/day	1.4×10^{-3} ug/m^3	1×10^{-2}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Product System Mu.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, product System Mu reach an ecotoxicity concern concentration.

Performance

General Summary of Product System Mu Performance, and Related Variables

This product system consisted of an ink remover, an emulsion remover, and a haze remover. The performance of the product system was demonstrated at Facilities 17 and 22. Facility 17 prints decals; Facility 22 prints back-lit automotive overlays. During the four week demonstration period, Facility 17 reclaimed 18 screens and Facility 22 reclaimed 44 screens.

For the performance demonstrations, Facility 17 used primarily UV-cured inks, and Facility 22 used solvent-based inks.

Facility 17 reported that the ink remover worked well, although black (UV-cured) inks were more difficult to remove than the other UV-cured inks. Facility 22 reported that the ink remover performance was unacceptable for their solvent-based ink system. Extra physical effort and time were needed, and a lot of product was applied, but an ink residue still remained on the screen. The standard ink remover used at Facility 22 is chemically very different from the alternative ink remover supplied as part of Product System Mu. These differences may have caused adverse chemicals interactions on older screens.

The emulsion remover performance was very good at both facilities. It removed the emulsion quickly, easily, and completely. Facility 22 commented that the emulsion remover performance was "excellent."

Facility 17 reported that the haze remover worked better and faster than one of their usual products, but not as well as the haze remover that they use for difficult stains. The haze remover's performance was also affected by the number of impressions in the previous test run: it did not work as well after runs with many impressions. Facility 22 reported that the haze remover did not work at all and they had to use their standard product before they could reuse the screen. There was no visible change in the haze when the haze remover was applied.

Alternative System Mu Profile

The manufacturer recommends applying Product System Mu as follows:

- Ink Remover Card up the excess ink. Spray both sides of the screen with the ink remover. Also spray a rag or brush with the product and rub both sides of the screen until all of the ink residue is completely dissolved or emulsified and the emulsion becomes clearly visible. Rinse well with water. For tests done at SPTF, a 1000 psi spray was used for rinsing the ink remover, emulsion remover, and haze remover.

- Emulsion Remover Using a spray bottle, apply the emulsion remover to both sides of the screen. Distribute the product evenly with a brush and scrub the screen gently for approximately two minutes. Rinse thoroughly with a high pressure water spray.

- Haze Remover Spray haze remover evenly on both sides of the screen. Distribute the product using a nylon brush. Let sit for at least one hour. If the ink is dried, let it sit for up to 24 hours. Rinse off with water. If stains remain in the screen, allow the screen to dry and repeat the application procedure for the ink remover and pressure rinse.

Alternative System Performance at SPTF

Product System Mu was tested at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). The ink remover and the haze remover performance varied depending on the type of ink used. The emulsion remover and the haze remover performance was consistent on all three screens.

On the screen with the solvent-based ink and the screen with UV ink, the ink remover dissolved the ink easily with little scrubbing and no effect on the emulsion. On the water-based ink screen, however, the ink dried in the screen and heavy scrubbing and more product were needed to remove the ink. While scrubbing, the stencil started to break down in the half tone area. For all three screens, one wipe was used to remove the ink.

The emulsion remover easily dissolved the stencil with only light scrubbing on all three screens, leaving no ink or emulsion residue behind. The screens did have a light-to-moderate ink stain was remaining. Subsequent application of the haze remover lightened the ink stains of the UV ink and the water-based ink screen, so that a very light ink stain remained. The haze remover did not lighten the moderate ink stain on the screen with the solvent-based ink.

Alternative System Performance Details

Performance Details from Facility 17

Facility 17 thought that Product System Mu cleaned the screens well and the screen reclaimer noted that the odors associated with the alternative system were not as bad as those produced by the facility's usual products.

The ink remover performed well. Compared to their standard product, the reclaimer noted that when using the alternative ink remover, he did not have to scrub the screens as much and did not have to use as much product to get the screens clean. The printer commented that it was more difficult to remove all of the ink from the screen when the previous print run was a long one. However, the data, although limited, do not show a change in the ink remover quantity or time corresponding to a change in the length of the previous run. Black UV-cured inks were not removed as effectively as other UV-cured ink colors.

The emulsion remover performance was very good on all screens. The haze remover worked well in most cases, except when the haze was unusually dark. This facility normally uses two haze removers: one is a weaker chemical that is used more frequently and the other, stronger chemical, is only used for stubborn stains. The Product System Mu haze remover worked better than the weaker of their two usual haze removal products, but not as well as the stronger chemical. On the one screen they reclaimed that had solvent-based ink on it, the alternative haze remover did not remove the haze and the printer had to use their stronger haze remover to clean the screen. All other screens reclaimed had been used with UV ink, and on these screens, the facility felt that the alternative haze remover performed as well as and more quickly than the weaker of their two haze removers.

Using the alternative system did not substantially change the screen cleaning routine at this facility. The printer did not notice any changes in the screen condition during the time the alternative system was in use. If less scrubbing is associated with the use of the alternative system, then screen abrasion and possibly the screen failure rate could decrease with continued use of the alternative system.

Performance Details from Facility 22

This facility found the performance of Product System Mu ink remover and haze remover was not acceptable. The printer thought the emulsion remover performance was very good.

The ink remover was applied to the screens immediately after completion of the press runs. Cleaning the screens still took a high level of effort and a long time to accomplish. All screens took at least 20 minutes to clean, and two screens took 60 minutes. Screen cleaning required 10 - 16 ounces of product; because of the large quantity required, the facility ran out of ink remover after cleaning the twentieth screen. Even with this extra effort, and extra product, an ink residue remained on the screens. The ink remover was especially ineffective on ink which built up partially dried on the edge of the screen during long runs. Overall, the facility contact commented that the product did not seem to cut the ink at all. It should be noted that the standard ink remover used by this facility contains strong hydrocarbon solvents and is chemically very different from the alternative ink remover. These chemical differences may have led to an adverse chemical interaction.

The emulsion remover worked well, with no notable variations in performance among the screens used. It required a low level of effort, and consistently removed all the emulsion from the screens. The performance of the haze remover proved to be unacceptable at Facility 22. Ghost images were not removed from the screens and the facility was not able to reuse the screens until they were treated with their standard haze remover. For this reason, use of the alternative haze remover was suspended during the first week of the demonstration.

At Facility 22 the facility contact, who was the product development manager, removed the ink, reclaimed the screens and evaluated the printing quality on subsequent runs. Although these were not tasks he usually performs, it should have ensured consistency of judgement on the product performance evaluations. Product System Mu did not appear to cause screen failure, or have any noticeable effects on the screens or frames.

Alternative System Performance Table Compiled from Field Sites

The following table highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 17

Facility 17 prints decals on paper, plastics, metals, ceramics, and glass. Their typical run length is 400 impressions, and approximately 5% of their orders are repeat orders. There are about 5 employees at this location, and 1 - 3 are involved in screen reclamation. Both solvent-based and UV-curable ink systems are used at this facility; primarily UV inks were used during the performance demonstrations. Screens with mesh counts of 280 - 390 threads/inch and direct photo stencils were used for the demonstrations. The average screen size at this facility is 16 ft^2 and approximately 25 screens are reclaimed daily.

Screen Reclamation Area in Facility 17

Ink removal is done at the press where local ventilation is provided. Emulsion and haze removal are done in a sink in the screen reclamation area, which is approximately 150 ft^2 and is ventilated via a hood above the sink. The average temperature during the observer's visit was 70°F (and 41% relative humidity). Spent solvent and ink waste are disposed of as hazardous waste. Waste water from the high-pressure wash of the emulsion remover and haze remover is not recycled or filtered at this facility.

Table V-140
On-Site Performance Summary For System Mu

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
In-field Demonstrations at Volunteer Printing Facilities											
Facility 17	*Ink remover*	13.9 ± 16.9 hrs (n=19)	2.7 ± 0.7 oz. (n=18)	7.0 ± 3.9 mins (n=19)	Moderate	Removed ink well.	• Haze remover required at least one hour of wait time. • All screens with UV ink were reusable.	UV ink (one screen with solvent-based ink)	Direct photo stencil	Mesh type not recorded; 280 - 390 threads/inch	2270 in^2
	Emulsion Remover	4.9 ± 1.7 hrs (n=19)	2.6 ± 0.6 oz. (n=18)	5.7 ± 2.0 mins (n=19)	Low	Removed stencil easily.					
	Haze Remover	21.3 ± 10.5 mins (n=19)	2.9 ± 0.7 oz. (n=18)	data not recorded	Moderate	Worked well on moderate haze.					
Facility 22	*Ink Remover*	15.6 ± 12.6 mins (n=20)	11.6 ± 1.4 oz. (n=20)	30.5 ± 12.0 mins (n=20)	High	Left ink residue in the screen.	• Used their standard haze remover before reusing screens. • Emulsion remover worked better than any other they tried.	Solvent-based	Direct photo stencil	Mono-filament polyester; 230 - 305 threads/inch	1520 in^2
	Emulsion Remover	22.5 ± 72.5 hrs (n=47)	1.1 ± 0.3 oz. (n=47)	2.8 ± 0.5 mins (n=47)	Low	Removed stencil easily.					
	Haze Remover	2.2 ± 1.2 mins (n=47)	1.3 ± 0.5 oz. (n=6)	1.3 ± 0.6 mins (n=3)	Moderate	Left ghost image in screens.					

Table V-141
Laboratory Performance Summary For System Mu

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
Laboratory Testing at SPTF											
SPTF Solvent-based Ink	*Ink Remover*	15 mins	1.0 oz.	3.5 mins	Low	Dissolved ink easily.		Solvent-based	Dual cure direct	Polyester; 260 threads/inch	360 in^2
	Emulsion Remover	24 hours	0.5 oz.	3.6 mins	Med	Dissolved stencil well. Moderate ink stain remaining.					
	Haze Remover	0 mins	1.0 oz.	2.0 mins	Low	Haze remover did not lighten ink stain.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	1.5 oz.	2.9 mins	Low	Dissolved ink very easily.		UV-curable	Dual cure direct	Polyester; 390 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	3.3 mins	Med	Dissolved stencil well. Light ink stain remaining.					
	Haze Remover	0 mins	0.5 oz.	2.0 mins	Low	Lightened ink stain.					
SPTF Water-based Ink	*Ink Remover*	15 mins	2.0 oz.	6.1 mins	High	Excessive scrubbing and product required to remove dried ink.		Water-based	Dual cure direct	Polyester; 260 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.5 oz.	3.1 mins	Med	Dissolved stencil well. Light ink stain remaining.					
	Haze Remover	0 mins	0.5 oz.	2.0 mins	Low	Lightened ink stain.					

Current Screen Reclamation Products at Facility 17

The standard ink remover used at Facility 17 is a proprietary blend consisting of at least propylene glycol ethers (<50%). Their emulsion remover is a proprietary aqueous mixture which contains periodate salt (<10%). For haze removal, they use a proprietary aqueous mixture with sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 17

Using their standard products, this facility reclaims their screens following the procedure described below. Gloves, eye protection, aprons, respiratory protection, and barrier cream are available as personal protective equipment for the operators during screen reclamation activities.

○ Ink Remover: Card off the excess ink. At the press, spray press wash onto the screen and wipe with reusable rags. Repeat if necessary. One or two rags are used for each screen. Bring the screen to the reclamation sink and spray the ink remover onto both sides of the screen from a low pressure (60 psi) sprayer. Rub the product into the screen with a brush, then pressure rinse (1200 psi) the screen.

○ Emulsion Remover: Spray the emulsion remover onto both sides of the screen from a low pressure sprayer. Brush the emulsion remover into the screen. Pressure rinse and allow to air dry.

○ Haze Remover: This facility uses two haze remover products. The weaker chemical is used for light to moderate stains. The stronger product is used only when the haze is dark. For light to moderate haze, spray the screen with the haze remover and let it sit for about 30 minutes. Scrub both sides of the screen for about one minute each and rinse with the pressure washer. Give the screen a final rinse at low pressure from a hose. For dark haze, coat both sides of the screen with the haze remover using the scoop coater (this is the same kind of coater that is used when applying emulsion to the screen and it applies a thin, even coat). Let sit for 3 - 4 minutes. Pressure wash both sides of the screen.

General Facility Background for Facility 22

Facility 22 prints back-lit automotive graphic overlays on plastics. Typically, they print about 500 sheets per run and approximately 90% of their orders are repeat orders. There are approximately 40 employees at this facility, and two people are involved in screen reclamation. During the Performance Demonstration, this facility used solvent-based inks and a direct photo stencil. Polyester screens with mesh counts of 230 - 305 threads per inch were used. The average screen size in this facility is 40 inches x 40 inches and approximately 12 screens are reclaimed daily.

Screen Reclamation Area in Facility 22

Ink removal is done both at the press and in the screen reclamation room. At the press, the plant system (facility-wide) provides ventilation. In the screen reclamation area, there is a back-lit spray booth and the area is ventilated by a fan in the hood of the booth. During the observer's visit, the average temperature in the facility was 68°F (and 44% relative humidity). Ink waste is disposed of as hazardous waste and rags are disposed of as non-hazardous waste.

Waste water from the washes of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 22

For ink removal, Facility 22 uses a custom solvent blend which consists of ethyl acetate (20% - 27%), methyl ethyl ketone (20%), and xylene (20%). As an emulsion remover, they use a proprietary aqueous mixture with at least sodium periodate. Their standard haze remover is a proprietary blend which consists primarily of tripropylene glycol methyl ether.

Current Screen Reclamation Practices in Facility 22

During the screen reclamation process at Facility 22, personal protective equipment available to the employees includes gloves, eye protection, and ear protection. Screens are reclaimed as follows:

- <u>Ink Remover:</u> At the press, card off excess ink and wipe the screen with rags that are saturated in ink remover. Bring the screen to the screen reclamation room. Saturate disposable wipes in the ink remover and wipe both sides of the screen. Four to six wipes are used on each screen. Rinse the screen with a high pressure washer (2000 psi).

- <u>Emulsion Remover:</u> Spray both sides of the screen with the emulsion remover. Wipe the screen with a scrubber pad. Rinse with a high pressure wash. If needed, spray on more product, brush and rinse again.

- <u>Haze Remover:</u> Dip a disposable wipe in the haze remover container and wipe both sides of the screen. Rub the product into the stained areas with a brush. Rinse with a high pressure wash on both sides, followed by a final, low pressure rinse with the hose. Vacuum dry the screen.

Cost

Table V-142
Method 2: Summary of Cost Analysis for Alternative System Mu

Cost Element Description		Baseline (Traditional System 4)	Alternative System Mu	
			Facility 17	Facility 22
Facility Characteristics				
Average screen size (in^2)		2,127	2,270	1,520
Average # screens/day		6	25	12
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	17.2 3.75	34.6 7.58
Materials and Equipment	# of rags used Cost ($)	3 0.45	1.0 0.15	10.8 1.61
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	2.7 0.16	11.6 0.70
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	2.6 0.21	1.1 0.09
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	2.9 0.17	1.3 0.08
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	110 0.08	73 0.05
Totals				
Total Cost ($/screen)		6.27	4.53	10.11
Normalized[a]		6.27	4.79	9.33
Total Cost ($/year)		9,399	28,295	30,338
Normalized[a]		9,399	7,185	13,997

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Phi

Formulation

Ink Remover	Dibasic esters
Emulsion Remover	Sodium periodate
	Water
	Ethoxylated nonylphenol
	Other
Haze Remover	N-methyl pyrrolidone
	Dibasic esters

Occupational Exposure

Table V-143
Occupational Exposure Estimates for Alternative System Phi

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Dibasic esters	4	0	0	0.2	1561	7270
Emulsion Remover						
Sodium periodate	0	0	0	0	47	218
Water	0	0	0	0	1210	5640
Ethoxylated nonylphenol	0	0	0	0	123	575
Other	0	0	0	0	181	844
Haze Remover						
N-methylpyrrolidone	6	0	0	0	780	3640
Dibasic esters	1	0	0	0	780	3639

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-144
Occupational Risk Estimates for Alternative System Phi

	Hazard Quotient[b]			Margin Of Exposure[a]					
						Dermal			
		Dermal		Inhalation		Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Dibasic esters	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
N-methylpyrrolidone	NA	NA	NA	2076	NA	16	NA	3.3	NA
Dibasic esters	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

- Dermal exposures to N-methylpyrrolidone during haze removal present a concern for developmental toxicity risk based on the calculated margins-of-exposure. Similar estimates for inhalation exposures to N-methylpyrrolidone indicate very low concern.
- Risks from other ink remover and haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.
- Inhalation exposures to all other components are very low.

Emulsion Removers (All Systems)

- All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-145
Environmental Release Estimates in Screen Cleaning Operations
Method 2, Alternative System Phi

	Release Under Each Scenario (g/day)						
	I			II	III	IV	
System	air	water	land	air	air	air	water
Ink Remover							
Dibasic esters	8.1	0	766	0	0	0.3	1349
Emulsion Remover							
Sodium periodate	0	19	0	0	0	0	0
Water	0	481	0	0	0	0	0
Ethoxylated nonylphenol	0	49	0	0	0	0	0
Other	0	72	0	0	0	0	0
Haze Remover							
N-methylpyrrolidone	12	270	0	0.1	0	0	0
Dibasic esters	3.1	279	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Environmental Releases from Screen Reclamation Processes Screen Reclamation Method 2, Alternative System Phi

From Ink Removal Operations:
Dibasic esters
8.4 g/day to air
1349 g/day to water from rags at commercial laundry
766 g/day to landfill

From Emulsion Remover:
Sodium periodate
19 g/day to water

Ethoxylated nonylphenol
49 g/day to water

Other
72 g/day to water

From Haze Remover:

N-methyl pyrrolidone

12.1 g/day to air

270 g/day to water

Dibasic esters

3.1 g/day to air

279 g/day to water

Table V-146
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Phi

Substance:	To Air:	To Water:	To Landfill:
Dibasic esters	11.5 g/day	279 g/day 1349 g/day at laundry	766 g/day
Sodium periodate		19 g/day	
Ethoxylated nonylphenol		49 g/day	
Other		72 g/day	
N-methyl pyrrolidone	12.1 g/day	270 g/day	

Releases to Water from a Single Facility

Table V-147
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Phi

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Dibasic esters	279 g/day 1349 g/day at laundry	84-97 %	13.8 g/day 66.4 g/day	1×10^{-2} 6×10^{-2}
Sodium periodate	19 g/day	100 %	0	0
Ethoxylated nonylphenol	49 g/day	100 %	0	0
Other	72 g/day	100 %	0	0
N-methyl pyrrolidone	270 g/day	97 %	8.1 g/day	8×10^{-3}

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-148
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Phi

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Dibasic esters	11.5 g/day	2.3×10^{-2} ug/m^3	2×10^{-1}
N-methyl pyrrolidone	12.1 g/day	2.5×10^{-2} ug/m^3	2×10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Product System Phi.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, Product System Phi reach an ecotoxicity concern concentration.

Performance

General Summary of Product System Phi, Performance, and Related Variables

This product system consisted of an ink remover, an emulsion remover, and a haze remover. It's performance was demonstrated at Facility 5 and Facility 23. Facility 5 employs approximately 15 people with 3 employees involved in the screen printing area of the business. They print interior signs, markings on parts, and identification badges. Facility 23 employs five people and prints mainly on plastics. Their products include front panels, overlays, and labels. Over a four week period, Facility 5 reclaimed 40 screens. Facility 23 used Product System Phi for two weeks and reclaimed 8 screens. During the demonstrations, both facilities primarily used solvent-based vinyl inks, but they also tried System Phi on acrylic vinyl, epoxy, and metallic inks. Facility 5 used a capillary film emulsion on a polyester screen and Facility 23 used a dual-cure emulsion on a multifilament polyester screen.

Both facilities reported similar results with Product System Phi. At Facility 5, the ink remover broke down the ink effectively but required more effort than their own ink remover. Facility 23 found that the ink remover performance was inconsistent; it worked well on metallic inks, but did not remove ink from around the edges of the stencil when using vinyl ink. Both facilities noticed that the ink remover tended to deteriorate the stencil if it was not wiped off immediately after application. For this reason, the facilities felt that this product should not be used for in-process ink removal.

The emulsion remover was very effective and it easily removed the stencil with very little scrubbing. Both facilities reported the System Phi emulsion remover performed better than the product they were using before the demonstrations.

Facility 5 reported that a haze remained on the screen after using the haze remover, but it did not affect future print image quality. Over time, the printer felt this haze could potentially deteriorate the screen mesh. Facility 23 reported that the haze remover left a ghost image and some screens could not be reused for reverse printing or for printing with transparent inks.

Alternative System Phi Profile

The manufacturer recommends applying Product System Phi as follows:

- <u>Ink Remover</u> After carding off as much excess ink as possible, apply ink remover to the screen using a spray bottle. With a soft brush or sponge, work the ink remover into the screen. Rinse or wipe both sides of the screen with a lint-free cloth.

- <u>Emulsion Remover</u> Shake the bottle well and spray emulsion remover on both sides of the screens. Work the product into the screen using a nylon mesh pad or brush. If the product is too thick to spray, pour it from the spray bottle onto the brush or screen. Wait for 2 - 3 minutes, but do not allow the emulsion remover to dry. Rinse the screen with a pressure washer (a 1000 psi washer was used at SPTF).

- <u>Haze Remover</u> Allow the screen to dry before applying the haze remover. Place the screen flat side down on a non-porous surface. Spray the haze remover on the ghost image and/or emulsion residue to be removed. Using a nylon brush or pad, work the product into the screen. Wait for 2 - 3 minutes and rinse. For dried solvent inks, lacquers, enamels, vinyls, cured plastisol, or fixed emulsions, let sit for 30 minutes and wipe clean with lint free towel.

Alternative System Performance at SPTF

Product System Phi was tested at SPTF on two screens (one with a solvent-based ink, and one with a UV-curable ink). This product is not recommended for use on water-based inks. On both screens, the ink dissolved quickly with minimal effort. There was a slight blue color on the wipe (the color of the stencil), but upon inspection the stencil did not look like it was damaged or deteriorated. On the screen with solvent-based ink, six rags were needed to remove the ink, and on the UV ink screen, five rags were used. The technician noticed a slight odor.

The emulsion remover also worked well; it completely dissolved the stencil with only light scrubbing on both screens. After using the emulsion remover, the screen with solvent-based ink had a very light stain and slight ink residue in small areas. The haze remover lightened the stain only slightly, but it removed the ink residue. The screen with UV-curable ink had a dark ink stain and the haze remover lightened it somewhat, but did not remove it completely. The technician noted that the haze remover was very easy to use and required minimal effort. There was a slight odor to the product, but it was not unpleasant.

The recommended application procedure was followed with a few slight variations. The ink remover was allowed to sit on the screen for 30 seconds before it was rubbed in with a sponge. The haze remover was removed with a pressure wash.

Alternative System Performance Details

Performance Details from Facility 5

At the conclusion of the Performance Demonstrations, the printer was asked to compare the performance of each component of Product System Phi to the system they previously used at this facility. Overall, the printer felt the emulsion remover worked better, and the ink remover and the haze remover did not work as well as their previous reclamation products.

On most screens the printer reported that the ink was removed effectively, however, there was an light to moderate ink haze remaining on 35% of the screens after using the ink remover. This facility found the ink remover performance was the same whether used on vinyl inks or on epoxies. Although not included in the Performance Demonstration protocol, the printer used this product as an in-process ink remover, not just as a reclamation ink remover. He found it would start to deteriorate the stencil if left on the screen for more than a few seconds. By spraying on the ink remover, wiping it off very quickly, and allowing the screen to dry before printing, he was able to use it in-process without affecting the print quality.

The printer was very enthusiastic about the emulsion remover, commenting that it consistently dissolved the stencil very quickly with minimal effort. After the conclusion of the Performance Demonstrations, he requested more information on the product so he could continue to use it in his facility.

The haze remover performance was not up to the standards of this printing facility. When following the manufacturer's application instructions, the haze remover did not remove the haze satisfactorily. The printer commented that he thought the haze remaining on the screen would deteriorate the screen over time. To improve the performance, the printer let the haze remover sit on the screen overnight (instead of the recommended 3 - 5 minutes), he wiped the product off with rags before pressure washing, and he tried using more ink remover hoping that there would be less ink stain later. None of these techniques improved the performance of the product. The printer did note that he preferred the very mild odor of this product to the strong, unpleasant odor of his own haze remover.

In reviewing the data from the printer's evaluation forms, there does not seem to be a correlation between any specific screen condition (e.g., ink type, ink color, number of impressions) and variations in the product performance. Overall, the use of Product System Phi had no deleterious effects on the screen mesh or on the subsequent print quality image and the printer did not notice any change in screen failure rate over the time period that the alternative system was in use.

Performance Details from Facility 23

Generally, this facility felt the emulsion remover worked well, but they were not satisfied with the ink remover and the haze remover of Product System Phi. While the actual performance of the alternative system was often adequate, the procedures involved with using the products disrupted the facility's routine. After two weeks of demonstrations, this facility discontinued their participation in the project and only submitted data on 8 screens. In addition to problems with the product application procedures, this facility experienced personnel problems that contributed to their decision to discontinue their participation after two weeks. The main screen printer/screen reclaimer involved with the demonstrations was absent for two weeks in the middle of the project. No screen reclamation with the alternative system continued during her absence. When she returned, so much work had accumulated that the facility decided they could not spare the time for the demonstrations.

The printer found the performance of the ink remover to be inconsistent. When using metallic inks, the alternative ink remover worked better than their standard product. With other ink types, the ink remover did not effectively remove the ink from the edges of the stencil and it did not remove as much ink from the screen as their standard product. Their standard ink remover is a solvent blend whose chemical composition is very different from that of the alternative ink remover. On older screens that have been reclaimed many times, adverse chemical interactions between the standard products and the alternative system could occur due to these differences.

The printer felt the emulsion remover was as effective as their standard product, and it dissolved the stencil faster than their standard emulsion remover.

Product System Phi haze remover required more contact time with the screen than this facility's usual haze remover. This additional waiting time impeded the facility's ability to reuse screens at the needed rate. In addition to the inconvenient wait time, the haze remover often did not reduce the haze sufficiently and the facility had to follow up with their usual product before the screen could be reused. The printer noted that the haze remover was less irritating to the respiratory system than their usual haze remover.

During the two weeks the products were used in this facility there was no noticeable mesh deterioration, no change in the screen failure rate, and no change in print quality.

Alternative System Performance Table Compiled from Field Sites

The table below highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 5

Facility 5 makes interior signs, marks parts, and prints identification badges. Primarily, they print on plastics and on metals. A typical run is 100 pieces, and approximately 80% of their orders are repeat orders. Of the 15 employees at this facility, approximately 3 are

Table V-149
On-Site Performance Summary For Alternative System Phi

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Inktype(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
In-field Demonstrations at Volunteer Printing Facilities											
Facility 5	*Ink remover*	2.5 ± 9.6 mins (n=40)	1.3 ± 0.5 oz. (n=40)	3.7 ± 4.2 mins (n=40)	Moderate	Light/Moderate ink haze on 35% of screens.	• Ink remover deteriorated the stencil. • Light ink stain remained after reclamation.	Solvent-based (primarily vinyl, some epoxy)	Capillary film	Polyester, no treatment; 305 threads/inch	2815 in^2
	Emulsion Remover	1.3 ± 0.6 mins (n=40)	1.7 ± 0.5 oz. (n=40)	2.6 ± 0.5 mins (n=40)	Moderate	Quickly, easily removed stencil.					
	Haze Remover	8.2 ± 37.6mins (n=40)	1.1 ± 0.5 oz. (n=40)	1.6 ± 0.5 mins (n=40)	Moderate	Did not consistently remove haze.					
Facility 23	*Ink Remover*	50.6 ± 40.6 hrs (n=9)	2.0 ± 1.9 oz. (n=9)	6.9 ± 10.6 mins (n=9)	Low	Inconsistent performance. Worked well on metallic inks; did not work well on other inks used.	• Facility stopped using the product after 2 weeks because of the additional time required for the haze remover and personnel problems. • Ink remover deteriorated the stencil and could not be used in process.	Solvent-based vinyl	Dual-cure	Multi-filament polyester; 195 - 305 threads/inch	883 in^2
	Emulsion Remover	48.0 ± 40.8 hrs (n=10)	1.0 ± 0.0 oz. (n=10)	2.9 ± 1.4 mins (n=10)	Low/ Moderate	Quickly, easily removed stencil.					
	Haze Remover	1.6 ± 0.8 mins (n=10)	1.2 ± 0.4 oz. (n=10)	12.2 ± 14.1 mins (n=10)	Moderate	30 min. wait time required caused scheduling problems at this facility.					

Table V-150
Laboratory Performance Summary For Alternative System Phi

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
Laboratory Testing at SPTF											
SPTF Solvent-based Ink	*Ink Remover*	15 mins	2.5 oz.	6.7 mins	Low	Ink dissolved easily.		Solvent-based	Dual cure direct	Polyester; 255 threads/inch	360 in^2
	Emulsion Remover	24 hours	0.5 oz.	6.4 mins	Low	Stencil dissolved easily; slight ink residue and light stain remaining.					
	Haze Remover	0 mins	1.0 oz.	5.6 mins	Low	Lightened stain slightly; removed residue.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	2.0 oz.	5.5 mins	Low	Ink dissolved very easily.		UV-curable	Dual cure direct	Polyester; 390 threads/inch	360 in^2
	Emulsion Remover	24 hours	0.5 oz.	5.5 mins	Low	Stencil dissolved easily; dark ink stain remaining.					
	Haze Remover	0 mins	0.5 oz.	6.2 mins	Low	Lightened ink stain, but did not remove it.					

involved in screen printing operations and 1 employee is responsible for screen reclamation activities. The facility uses a variety of solvent-based inks including vinyl-based inks, epoxy inks and a multipurpose ink. They use capillary film for their emulsion. All screens used in the Performance Demonstrations were polyester (no treatment) with a typical mesh count of 305 threads/inch. The average screen size at this facility is 20" x 20" and approximately 2 - 3 screens are reclaimed daily.

Screen Reclamation Area in Facility 5

The screen printing, ink removal, and screen reclamation activities are all done in the same room which is approximately 100 ft^2 in size. A fan and the door to outside provide ventilation for the room. The average temperature during the observer's visit was 68°F (and 40% relative humidity), but when an oven located in the same room is in operation, the temperature can increase significantly. Rags used for ink removal are disposed of as non-hazardous waste. Waste water from the high pressure wash of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 5

The standard ink remover used at Facility 5 is a blend which contains 55% - 56% propylene glycol ether. For emulsion removal, they use a product which contains sodium metaperiodate (5%) and their standard haze remover contains sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 5

This facility primarily uses a multipurpose ink remover, however, when using specialized inks (20% of their jobs), they use the ink remover recommended by the ink manufacturer. Emulsion remover and haze remover are used on all screens. For their standard inks, the screen reclamation process is described below:

○ Ink Remover: Immediately after the printing job is completed, card off excess ink from the screen with cardboard. Apply ink remover to a reusable rag from a safety can. Gloves are usually worn during this step. Wipe both sides of the screen with the rag. Continue wiping with clean rags until ink no longer comes off on the rag. Typically, 2 - 4 rags are used on each screen. Wipe both sides of the screen with a dry rag to remove oily film.

○ Emulsion Remover: Screen reclamation is usually done at the end of the work day for several reasons: screens that are used throughout the day can all be reclaimed at the same time for more efficient operation, the haze remover can dry overnight, and fewer employees are subject to the strong, unpleasant odor of the haze remover. To apply the emulsion remover, dip a brush into the product container, wearing gloves, and brush the emulsion remover into both sides of the screen. Wait for 1 - 5 minutes. Rinse both sides of the screen with a high pressure (1000 psi) wash. Wipe both sides of the screen with a dry rag.

○ Haze Remover: Typically, haze remover is used immediately after emulsion removal, at the end of the day. The haze remover is a two-part system. To apply, dip a nylon brush into the pail containing the first haze remover component, wearing gloves, eye protection, and a respirator (if desired). Rub the haze remover into the dry screen on both sides. Allow to dry overnight. Rinse with a high pressure wash. Apply the second part of the haze remover product with a brush. Wait for one minute. Rinse with a high pressure wash.

General Facility Background for Facility 23

The majority of the products printed by Facility 23 are front panels, overlays, and labels on plastics. They also do some printing on paper, metals, and glass. Run lengths are typically 150 impressions, and approximately 82% of their business is for repeat orders. There are less than 5 employees at this facility and two are involved in screen reclamation operations. The facility uses several types of solvent-based inks including vinyls, acrylic vinyls, and epoxy inks. They use a dual-cure emulsion and a multifilament (untreated) polyester mesh. Mesh counts used in the Performance Demonstrations ranged from 195 - 305 threads/inch. The average screen size at this facility is 1,305 in^2 and approximately 3 - 5 screens are reclaimed daily.

Screen Reclamation Area in Facility 23

Ink removal is done at press side and screen reclamation takes place nearby in a back-lit spray booth. The facility-wide ventilation covers both work areas. During the observer's visit, the average temperature in the ink removal area was 70°F (and 35% relative humidity), and the screen reclamation area temperature was 62°F (and 55% relative humidity). Rags used for ink removal are cleaned under a contract with an industrial laundry service. Spent solvent from ink removal operations and ink waste are disposed of as hazardous waste. Waste water from the washes of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 23

For ink removal, Facility 23 uses a proprietary blend which contains at least xylene, propylene glycol methyl ether, and diacetone alcohol. Their standard emulsion remover product is 100% sodium periodate, and their standard haze remover is a proprietary aqueous mixture which contains sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 23

At Facility 23, the application procedure described below is used for most screens. Usually, four screens are reclaimed at the same time. The reclamation procedure is as follows:

○ <u>Ink Remover:</u> At the press, scrape the excess ink off the screen. Wearing gloves, wipe the edges of the screen with disposable lint-free wipes. Dampen a reusable rag with ink remover from a pump can and wipe both sides of the screen. Continue dampening the rag and wiping until the ink is no longer coming off on the rag. Usually, one or two rags are used on each screen. Once the rag stops picking up the ink, use a blow dryer to evaporate the solvent from the screen.

○ <u>Emulsion Remover:</u> Put the screen in the sink and wet the screen. Wearing gloves and eye protection, spray emulsion remover onto both sides of the screen and let it sit for approximately two minutes. Rinse with a high pressure (1000 psi) water spray.

○ <u>Haze Remover:</u> Dip a brush into the bucket of haze remover, wearing gloves, eye protection, and, if desired, an apron and respirator. Rub the haze remover into the screen on the effected area on both sides. Wait for 3 - 5 minutes for screens on retensionable frames and 5 - 10 minutes for screens on fixed frames. Rinse with a low pressure water spray, followed by a high pressure wash.

Cost

Table V-151
Method 2: Summary of Cost Analysis for Alternative System Phi

Cost Element Description		Baseline (Traditional System 4)	Alternative System Phi	
			Facility 5	Facility 23
Facility Characteristics				
Average screen size (in^2)		2,127	2,815	883
Average # screens/day		6	3	4
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min)	24.4	8.0	22.0
	Cost ($)	5.33	1.74	4.81
Materials and Equipment	# of rags used	3	2.9	1.3
	Cost ($)	0.45	0.43	0.19
Reclamation Product Use	Ink Remover			
	Average Volume (oz.)	8.0	1.3	2.0
	Cost ($)	0.22	0.25	0.39
	Emulsion Remover			
	Average Volume (oz.)	3.5	1.7	1.0
	Cost ($)	0.13	0.33	0.19
	Haze Remover			
	Average Volume (oz.)	3.0	1.1	1.2
	Cost ($)	0.12	0.35	0.37
Hazardous Waste Disposal	Amount (g)	34	0	0
	Cost ($)	0.02	0	0
Totals				
Total Cost ($/screen)		6.27	3.11	5.96
Normalized[a]		6.27	6.10	7.82
Total Cost ($/year)		9,399	1,991	5,957
Normalized[a]		9,399	9,233	11,728

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Omicron-AE

Formulation

Ink Remover	Diethylene glycol butyl ether Propylene glycol
Emulsion Remover	Sodium periodate Ethoxylated nonylphenol Water
Haze Remover	Ethoxylated nonylphenol Phosphate surfactant Water Other

Occupational Exposure

Table V-152
Occupational Exposure Estimates for Alternative System Omicron-AE

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Diethylene glycol butyl ether	0	0	0	0	984	4590
Propylene glycol	17	0.1	0	0.4	576	2690
Emulsion Remover						
Sodium Periodate	0	0	0	0	47	218
Ethoxylated nonylphenol	0	0	0	0	31	146
Water	0	0	0	0	1480	6920
Haze Remover						
Other	0	0	0	0	109	510
Ethoxylated nonphenol	0	0	0	0	16	73
Phosphate surfactant	0	0	0	0	78	364
Water	0	0	0	0	1360	6330

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-153
Occupational Risk Estimates for Alternative System Omicron AE

Name	Hazard Quotient[b]			Margin Of Exposure[a]					
						Dermal			
		Dermal		Inhalation		Routine		Immersion	
	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Diethylene glycol butyl ether	NA	NA	NA	NA	NA	142	3.6	30	0.8
Propylene glycol	0.01	0.4	1.9	NA	NA	NA	NA	NA	NA
Emulsion Remover	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phosphate surfactant	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

- Margin-of-exposure calculations indicate clear concerns for chronic dermal exposures to workers using diethylene glycol butyl ether in ink removal.
- Margin-of-exposure calculations also show possible concerns for developmental toxicity risks from dermal "immersion" exposures to diethylene glycol butyl ether. Routine dermal exposures, however, represent a very low concern for developmental toxicity risks.
- Hazard quotient calculations for inhalation and dermal exposures to propylene glycol during ink removal indicate very low concern.
- Inhalation exposures to other components are very low.
- Risks from other components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Emulsion Removers (All Systems)

- All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-154
Environmental Release Estimates in Screen Cleaning Operations
Method 2, Alternative System Omicron-AE

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Diethylene glycol butyl ether	0	0	440	0	0	0	852
Propylene glycol	35	0	222	0.2	0.1	0.7	497
Emulsion Remover							
Sodium periodate	0	19	0	0	0	0	0
Ethoxylated nonylphenol	0	13	0	0	0	0	0
Water	0	603	0	0	0	0	0
Haze Remover							
Other	0	43	0	0	0	0	0
Ethoxylated nonphenol	0	6.2	0	0	0	0	0
Phosphate surfactant	0	31	0	0	0	0	0
Water	0	540	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Environmental Release Estimates from Screen Reclamation Processes Screen Reclamation Method 2, Alternative System Omicron-AE

From Ink Removal Operations:
- Diethylene glycol butyl ether
    - 852 g/day to water from rags at commercial laundry
    - 440 g/day to landfill
- Propylene glycol
    - 36 g/day to air
    - 497 g/day to water from rags at commercial laundry
    - 222 g/day to landfill

From Emulsion Remover:
- Sodium periodate
  - 19 g/day to water
- Ethoxylated nonylphenol
  - 13 g/day to water

From Haze Remover:
- Other
  - 43 g/day to water
- Ethoxylated nonylphenol
  - 6.2 g/day to water
- Phosphate surfactant
  - 31 g/day to water

Table V-155
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Omicron-AE

Substance:	To Air:	To Water:	To Landfill:
Diethylene glycol butyl ether		852 g/day at laundry	440 g/day
Propylene glycol	36 g/day	497 g/day at laundry	222 g/day
Sodium periodate		19 g/day	
Ethoxylated nonylphenol		19.2 g/day	
Other		43 g/day	
Phosphate surfactant		31 g/day	

Releases to Water from a Single Facility

Table V-156
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility
Using Screen Reclamation Method 2, Alternative System Omicron-AE

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Diethylene glycol butyl ether	852 g/day at laundry	83 %	145 g/day	1×10^{-1}
Propylene glycol	497 g/day at laundry	97 %	14.9 g/day	1×10^{-2}
Sodium periodate	19 g/day	100 %	0	0
Ethoxylated nonylphenol	19.2 g/day	100 %	0	0
Other	43 g/day	100 %	0	0
Phosphate surfactant	31 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-157
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Using Screen Reclamation Method 2, Alternative System Omicron-AE

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Propylene glycol	36 g/day	7.3×10^{-2} ug/m^3	5×10^{-1}

[a]This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Product System Omicron-AE.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, Product System Omicron-AE reach an ecotoxicity concern concentration.

Performance

General Summary of System Omicron-AE Performance, and Related Variables

Product System Omicron-AE and Product System Omicron-AF were submitted for demonstration by the same manufacturer. They have the same ink remover and the same emulsion remover, but each one has a different haze remover to complete the system. Although these systems do share a common ink remover and emulsion remover, Omicron-AE and Omicron-AF are each evaluated as a separate Product System in this documentation. It was the intention of the Performance Demonstrations to evaluate reclamation systems as a whole, not individual products, whenever possible.

The performance of Omicron-AE was demonstrated at Facilities 2 and 19. This product system consisted of an ink remover, an emulsion remover, and a haze remover. A degreaser also accompanied this product system and was used by one of the facilities, however, detailed information on the performance of the degreaser is not included in the scope of this project. Facility 2 prints signs, and displays; Facility 19 prints overlays, and membrane switches. During the demonstration, Facility 2 reclaimed 30 screens using solvent-based inks over a 4 week period. Facility 19 did not participate in the demonstrations after the observer's one day visit. During the visit, they reclaimed four screens, but based on the poor results of those first reclamations, they decided not to participate in the project. Neither facility tried alternative application techniques to improve product performance.

Facility 2 reported that the ink remover performed poorly and required a lot more scrubbing than their usual product. The chemical composition of the alternative ink remover was extremely different than the constituents of the facility's standard product. Adverse interactions may have occurred because of these chemical differences. The ink remover seemed to work better when used immediately after printing, but the performance was still not acceptable. At Facility 19, the ink remover had to be re-applied and scrubbed into the screen repeatedly, and all residual ink was still not removed.

In general, Facility 2 liked the emulsion remover better than their usual product, although it took extra time to use the hand sprayer and the emulsion remover was not as effective when thick ink residue was present. Facility 19 was not satisfied with the emulsion remover performance. They reported that the emulsion remover had to be re-applied and scrubbed into the screen repeatedly; even then residual emulsion was left on the screen.

Both facilities found the haze remover performance to be unacceptable. Facility 2 saw no reduction in haze after applying the product. At Facility 19, the haze remover did not completely remove the haze. This facility, however, had very high standards in terms of haze removal; other facilities would have been satisfied with this level of haze removal. It should be noted that both facilities used standard haze removers that were very different chemically than the alternative haze remover. On screens that were reclaimed many times, there is potential for adverse effects due to interaction of the standard and alternative systems.

Alternative System Omicron-AE Profile

The manufacturer recommends applying Product System Omicron-AE as follows:

- ○ Ink Remover Card off the extra ink left in the screen. Apply the ink remover with a spray bottle to both sides of the screen. Brush the product into the screen to loosen the ink on both sides. Wipe the screen clean. Repeat spraying and wiping until the screen is clean.

- ○ Emulsion Remover Place the screen in a washout sink and spray both sides of the stencil with the emulsion remover so that it evenly covers the stencil. Wait one minute. Use a soft brush to loosen the stencil and scrub the screen until the stencil is broken up in all areas. Apply more emulsion remover if necessary. Rinse the screen with a pressure washer (a 1000 psi pressure wash was used at SPTF).

- ○ Haze Remover Spray the haze remover on the stained areas on both sides of the screen. Brush the product in and let stand for 3 - 4 minutes. Pressure rinse from the bottom of the screen to the top on both sides.

Alternative System Performance at SPTF

Product System Omicron-AE was tested at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). Products were applied according to the manufacturer's recommended application procedure. On the screens with the solvent-based ink and with UV ink, the ink dissolved well with little effort. On the solvent-based ink screen, the stencil was affected in the half-tone area, but there was no effect on the stencil on the UV ink screen. Six wipes were used to remove the ink from each screen. On the screen with water-based ink, the ink dissolved well, however, extra scrubbing was needed. The stencil was affected in the half-tone area. Again, six wipes were used.

On all three screens, the emulsion remover dissolved the stencil effectively. On the screen with solvent-based ink and the UV ink screen, moderate scrubbing was required to break up the stencil and the pressure wash remove the stencil completely. A light to moderate ink stain remained on each screen. On the screen with water-based ink, the stencil dissolved easily with only light scrubbing, but there was a small amount of ink residue remaining in the half-tone areas, in addition to a moderate ink stain.

The haze remover lightened the stains on all three screens and removed the ink residue on the water-based ink screen. However, all screens did have some ink stain remaining after the application of the haze remover.

Alternative System Performance Details

Performance Details from Facility 2

Except for the emulsion remover, Product System Omicron-AE performed poorly at this facility. Unfortunately, this facility became very busy during the demonstration period. The excessive workload reduced the amount of time available for using the alternative system and for experimenting with the application procedures. A total of 30 screens were reclaimed with Product System Omicron-AE over a 4 week period, but the Omicron-AE ink remover and haze remover were only used on 7 of the screens, due to poor performance. The Omicron-AE emulsion remover was used on 26 screens and worked very well.

The ink remover did not work well at this facility, which used solvent-based ink during the demonstrations. The screen reclaimer scrubbed one screen for 40 minutes trying to get the ink out of the mesh, whereas no scrubbing is needed with their usual ink remover. The alternative ink remover was chemically very different than this facility's standard product and chemical interactions could have occurred. Their usual ink removing method involved spraying solvent onto a screen in a small, closed room. This was a particularly unpleasant room in that there was a high concentration of solvents in the air, and there was also a lot of build-up of ink solids on the floor and walls. No respirators were seen when the observer was on-site, although the facility reported that respirators are usually worn in the "solvent room." Use of the alternative ink remover did not require the reclaimer to be in the ink reclamation room.

Facility 2 liked the performance of the emulsion remover very much and they thought it performed better than their usual product, even when diluted at one part emulsion remover to two parts water. The manufacturers application procedure did not instruct the printer to dilute the emulsion remover. When there was a thick ink residue left in the screen, the emulsion was more difficult to remove.

The haze remover did not reduce the haze in the screen mesh at all. The standard haze remover at this facility contains some very strong chemicals such as dichloromethane and has a very different chemical composition from the alternative haze remover. These differences could result in adverse chemical interactions on the screen. to improve performance, this facility used the alternative haze remover concurrently with Comet cleanser to remove the haze. Comet is typically used at this facility as a degreaser.

No changes in screen failure rate were noted during the demonstrations, but it could be speculated that a reduced screen failure rate would result from longer term use of the alternative system at this facility because of the abrasiveness of their usual products (such as Comet). Unfortunately, the lower abrasiveness of the alternative system may be offset by the amount of scrubbing required to get the screens clean. The reclaimer noted that his scrubbing was producing visible wear in the screen mesh.

Performance Details from Facility 19

This facility did not continue using System Omicron-AE after the initial demonstration during the observer's visit. The alternative system did not clean the screens to a level at all acceptable to this facility and they were not willing to experiment with different application procedures that may have improved performance. Also, the alternative system seemed to require more time and effort than the facility's usual procedures.

This facility has one screen reclaimer per shift and neither speak English. Forms were going to be translated into Spanish and the printing manager was present for much of the demonstrations and served as an interpreter. This facility tends to wash about 24 screens at a time in groups of eight. Using the alternative system severely interrupted the reclamation process established at this facility. This facility reclaims about 60 to 80 screens per shift. Currently, they only use one product for ink removal, emulsion removal, and haze removal. It is a very effective product, but the observer noticed it is also corrosive and emits strong vapors. Other facilities that use this product try to limit its use. This facility uses no other reclamation products and expects all screens to be completely without haze when reclamation is finished. Other facilities have less stringent haze removal requirements or expectations. The alternative system performance would probably have been considered acceptable at many other facilities. Also note that there may have been adverse chemical interactions between this facility's standard haze remover and the alternative haze remover, because the two haze removers are chemically very different.

During the observer's visit, the alternative system was used with different ink systems and several application techniques were evaluated. The type of ink did not seem to affect the alternative system performance levels. No changes in the rate of screen wear or failure were noted during the product demonstration. It is likely that the alternative system would be less corrosive than their standard product in the long term.

The ink remover did not work effectively enough for this facility. Average ink removal was observed, but the ink remover often had to be applied and scrubbed into the screen multiple times. Ink often remained in the screen at the edges of the print image and stencil. This level of removal did not compare to the results this facility has using their standard product as an ink remover, where usually no scrubbing is needed.

The emulsion remover often did not remove all of the emulsion from the screen. The emulsion remover required more scrubbing than with their standard product. Often, multiple applications were required to remove all of the emulsion. Still, emulsion tended to remain in the screen around the edges of the stencil.

The haze remover worked fairly well leaving only a light haze. This haze, which would have been acceptable at many of the other facilities participating in the project, was unacceptable for this facility. Even when the haze remover was allowed to stay on the screen for longer than the directions suggested, no appreciable improvement in performance was noted. When Facility 19 uses their usual haze remover, the haze disappears from the screen.

Alternative System Performance Table Compiled from Field Sites

The following table highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 2

Facility 2 prints signs, banners, and store displays on plastics and paper. A typical run is 150 pieces and approximately 40% of their orders are repeat orders. Of the approximately

Table V-158
On-Site Performance Summary For Alternative System Omicron AE

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
In-field Demonstrations at Volunteer Printing Facilities											
Facility 2	*Ink remover*	7.1 ± 9.3 hrs (n=14)	12.6 ± 13.1 oz. (n=7)	18.6 ± 15.5 mins (n=7)	Moderate	Ink residue not removed from mesh.	• Only 7 screens reclamined w/system, due to poor performance.	Solvent-based inks	Direct photo stencil	Mesh type not specified; 230 threads/in.	5663 in^2
	Emulsion remover	1.3 ± 3.7 hrs (n=30)	7.5 ± 3.7 oz. (n=26)	6.6 ± 3.4 mins (n=26)	Low	Easily, completely removed stencil.					
	Haze remover	2.2 ± 6.7 hrs (n=30)	14.6 ± 5.1 oz. (n=7)	15.0 ± 4.1 mins (n=7)	Low	Seemed to have no effect on the haze.					
Facility 19	*Ink remover*	3.7 ± 1.5 hrs (n=3)	2.3 ± 1.2 oz. (n=3)	7.3 ± 4.5 mins (n=3)	High	Ink remained in screen after several applications.	• Did not participate after observer's visit, due to poor product performance.	Solvent-based	Direct photo stencil	PeKap; 156 - 390 threads/in.	957 in^2
	Emulsion Remover	not recorded (n=0)	1.3 ± 0.6 oz. (n=3)	3.3 ± 0.6 mins (n=3)	Moderate	Reapplication needed to remove emulsion.					
	Haze Remover	3.0 mins (n=1)	2.3 ± 2.5 oz. (n=4)	10.0 ± 9.3 mins (n=4)	High/ Moderate	Lightened the ink stain.					

Table V-159
Laboratory Performance Summary For Alternative System Omicron AE

		Performance						Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
Laboratory Testing at SPTF											
SPTF Solvent-based Ink	*Ink Remover*	15 mins	3.0 oz.	8.3 mins	Low	Dissolved ink well. Stencil affected in areas.		Solvent-based	Dual cure direct	Polyester; 260 threads/ inch	360 in^2
	Emulsion Remover	24 hours	0.5 oz.	3.8 mins	Moderate	Dissolved stencil. Light ink stain remaining.					
	Haze Remover	0 mins	0.5 oz.	5.0 mins	Low	Lightened, but did not remove, ink stain.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	2.0 oz.	7.3 mins	Low	Dissolved ink well.		UV-curable	Dual cure direct	Polyester; 390 threads/ inch	360 in^2
	Emulsion Remover	24 hours	0.5 oz.	4.2 mins	Moderate	Dissolved stencil. Medium ink stain remaining.					
	Haze Remover	0 mins	0.5 oz.	5.1 mins	Low	Lightened, but did not remove, ink stain.					
SPTF Water-based Ink	*Ink Remover*	15 mins	3.0 oz.	7.2 mins	Moderate	Dissolved ink with wiping. Stencil affected in areas.		Water-based	Dual cure direct	Polyester; 260 threads/ inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	3.5 mins	Low	Dissolved stencil. Medium ink stain and residue.					
	Haze Remover	0 mins	1.0 oz.	5.5 mins	Low	Lightened, but did not remove, ink stain.					

12 employees at this facility, 5 are involved in screen reclamation. All printing is done with solvent-based inks and the screens used in the Performance Demonstrations all had a mesh count of 230 threads/inch with a direct photo stencil. The typical screen size at this facility is 50 ft^2 and about 6 screens are reclaimed daily.

Screen Reclamation Area in Facility 2

Ink removal is done in a spray booth in the "solvent room" which is approximately 30 ft^2 in size and is not ventilated. Screen reclamation is done in a spray booth in the general plant area and is ventilated by the facility-wide system. The average temperature during the observer's visit was 65°F (and 49% relative humidity). Ink remover solvent is filtered, recycled and reused in-house. Waste water from the emulsion and haze remover booth is not recycled or filtered.

Current Screen Reclamation Products at Facility 2

Facility 2 uses a proprietary ink remover that includes at least toluene (31%), xylene (24%), methyl isobutyl ketone (19%), ethylbenzene (6%) and diacetone alcohol. Their standard emulsion remover contains at least sodium periodate. For haze removal, they use a proprietary solvent blend that contains either at least dichloromethane (90%) and isopropanol (1%), or a blend that includes sodium hydroxide and cyclohexanone.

Current Screen Reclamation Practices in Facility 2

All screen printing at this facility is done using solvent-based inks. Screen reclamation employees wear gloves and eye protection for all steps of the process; respiratory protection is also used for ink removal. The screen reclamation process is:

- <u>Ink Remover:</u> Card off excess ink at the press. Bring screen to ink removal room and soak screen with solvent spray (from the low pressure spray in the recycling tank). Wipe off the solvent and ink with a squeegee. Wipe the screen and frame with disposable rags. Repeat the application of solvent (spray, wipe and squeegee) if necessary.

- <u>Emulsion Remover:</u> In the reclamation sink, pressure wash both sides of the screen. Dip a rag in the emulsion remover and wipe down the screen with the rag. Pressure wash.

- <u>Haze Remover:</u> Haze remover is used only about once per week. To apply, scrape paste onto the screen with a card and work it into the screen. Pressure wash. On all screens, a degreaser is applied after emulsion removal. Comet cleanser is used as the degreaser. Sprinkle the Comet on the screen surface. Using the emulsion remover-soaked rag, rub the Comet into the screen. Dip the rag in the emulsion remover again and scrub areas with remaining ink. Pressure wash.

General Facility Background for Facility 19

Facility 19 prints graphic overlays, front panels, and membrane switches. They print on plastics, metals, and paper. Their jobs usually run for 5 - 1500 impressions and approximately 70% of their orders are repeat orders. This facility uses solvent-based inks and a direct photo stencil. The alternative system was used on screens with mesh counts ranging from 156 - 390 threads/inch. Typical screen size in this facility is 30 inches x 33 inches, and approximately 60 - 80 screens are reclaimed daily.

Screen Reclamation Area in Facility 19

Ink removal is done at the presses and screen reclamation is done in a separate area, approximately 35 ft^2 in size, where ventilation is provided through a hood over the back-lit spray booth. During the observer's visit, the average temperature in the facility was 70°F (and 44% relative humidity). Rags used for ink removal are cleaned weekly by a laundry service. Waste water from screen reclamation is filtered prior to disposal.

Current Screen Reclamation Products at Facility 19

At Facility 19, their standard ink remover is a proprietary solvent blend consisting of at least 20% propylene glycol ethers, and petroleum hydrocarbons (<10%). Information on the chemical constituents of their emulsion remover was not available. Their standard haze remover is a proprietary solvent blend which contains sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 19

At Facility 19, 10 - 15 screens are cleaned at the same time. The same product is used for ink removal, emulsion removal and haze removal. Screens are reclaimed as follows:

○ Ink Remover, Emulsion Remover, and Haze Remover: Card off excess ink at the press. Bring screen to the reclamation area. Rinse screen with pressure washer (2000 - 2500 psi) to remove block out. Spread the reclamation product with a brush onto both sides of the screen. Let sit for approximately 3 - 4 minutes. Pressure rinse. Reapply the product, let sit for about 10 minutes, then pressure rinse. Gloves, eye protection, ear protection and aprons are worn while using this product.

Cost

Table V-160
Method 2: Summary of Cost Analysis for Alternative System Omicron-AE

Cost Element Description		Baseline (Traditional System 4)	Alternative System Omicron-AE	
			Facility 2	Facility 19
Facility Characteristics				
Average screen size (in^2)		2,127	5,663	957
Average # screens/day		6	6	70
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	40.2 8.80	20.7 4.52
Materials and Equipment	# of rags used Cost ($)	3 0.45	16 2.43	0 0
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	12.6 0.96	2.3 0.18
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	7.5 0.56	1.3 0.10
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	12.6 0.89	2.3 0.16
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	0 0	0 0
Totals				
Total Cost ($/screen)		6.27	13.65	4.96
Normalized[a]		6.27	10.85	5.49
Total Cost ($/year)		9,399	20,470	86,787
Normalized[a]		9,399	16,278	8,240

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Omicron-AF

Formulation

Ink Remover	Diethylene glycol butyl ether Propylene glycol
Emulsion Remover	Sodium periodate Ethoxylated nonylphenol Water
Haze Remover	Ethoxylated nonylphenol Phosphate surfactant Alkali/Caustic Water

Occupational Exposure

Table V-161
Occupational Exposure Estimates for Alternative System Omicron-AF

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Ink Remover						
Diethylene glycol butyl ether	0	0	0	0	984	4590
Propylene glycol	17	0.1	0	0.4	576	2690
Omicron (Emulsion Remover)						
Sodium periodate	0	0	0	0	47	218
Ethoxylated nonylphenol	0	0	0	0	31	146
Water	0	0	0	0	1480	6920
Haze Remover						
Ethoxylated nonphenol	0	0	0	0	16	73
Alkali/Caustic	0	0	0	0	156	728
Phosphate surfactant	0	0	0	0	78	364
Other	0	0	0	0	109	510
Water	0	0	0	0	1200	5610

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-162
Occupational Risk Estimates for Alternative System Omicron AF

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	**Inhalation**	**Routine**	**Immersion**	**NOAEL[c]**	**LOAEL[d]**	**NOAEL**	**LOAEL**	**NOAEL**	**LOAEL**
Ink Remover									
Diethylene glycol butyl ether	NA	NA	NA	NA	NA	142	3.6	30	0.8
Propylene glycol	0.01	0.4	1.9	NA	NA	NA	NA	NA	NA
Emulsion Remover									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkali/Caustic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phosphate surfactant	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.
[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.
[c] NOAEL means No Observed Adverse Effect Level.
[d] LOAEL means Lowest Observed Adverse Effect Level.

Occupational Risk Conclusions and Observations

Ink Remover and Haze Remover

- Margin-of-exposure calculations indicate clear concerns for chronic dermal exposures to workers using diethylene glycol butyl ether in ink removal.

- Margin-of-exposure calculations also show possible concerns for developmental toxicity risks from dermal "immersion" exposures to diethylene glycol butyl ether. Routine dermal exposures, however, represent a very low concern for developmental toxicity risks.

- Hazard quotient calculations for inhalation and dermal exposures to propylene glycol during ink removal indicate very low concern.

- Inhalation exposures to other components are very low.

- Risks from other components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Emulsion Removers (All Systems)

- All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-163
Environmental Release Estimates in Screen Cleaning Operations
Method 2, Alternative System Omicron-AF

System	Release Under Each Scenario (g/day)						
	I			II	III	IV	
	air	water	land	air	air	air	water
Ink Remover							
Diethylene glycol butyl ether	0	0	440	0	0	0	852
Propylene glycol	35	0	222	0.2	0.1	0.7	497
Emulsion Remover							
Sodium periodate	0	19	0	0	0	0	0
Ethoxylated nonylphenol	0	13	0	0	0	0	0
Water	0	603	0	0	0	0	0
Haze Remover							
Ethoxylated nonphenol	0	5.6	0	0	0	0	0
Alkali/Caustic	0	56	0	0	0	0	0
Phosphate surfactant	0	28	0	0	0	0	0
Other	0	43	0	0	0	0	0
Water	0	428	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Environmental Release Estimates from Screen Reclamation Processes
Screen Reclamation Method 2, Alternative System Omicron-AF

From Ink Removal Operations:
- Diethylene glycol butyl ether
  - 852 g/day to water from rags at commercial laundry
  - 440 g/day to landfill
- Propylene glycol
  - 36 g/day to air
  - 497 g/day to water from rags at commercial laundry
  - 222 g/day to landfill

Environmental Release Estimates from Screen Reclamation Processes Screen Reclamation Method 2, Alternative System Omicron AF (cont.)

From Emulsion Remover:
    Sodium periodate
        19 g/day to water
    Ethoxylated nonylphenol
        13 g/day to water

From Haze Remover:
    Other
        39 g/day to water

    Ethoxylated nonylphenol
        5.6 g/day to water

    Alkali/caustic
        56 g/day to water

    Phosphate surfactant
        28 g/day to water

Table V-164
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Omicron-AF

Substance:	To Air:	To Water:	To Landfill:
Diethylene glycol butyl ether		852 g/day at laundry	440 g/day
Propylene glycol	36 g/day	497 g/day at laundry	222 g/day
Sodium periodate		19 g/day	
Ethoxylated nonylphenol		18.6 g/day	
Alkali/caustic		56 g/day	
Other		39 g/day	
Phosphate surfactant		28 g/day	

Releases to Water from a Single Facility

Table V-165
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Omicron-AF

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Diethylene glycol butyl ether	852 g/day at laundry	83 %	145 g/day	1×10^{-1}
Propylene glycol	497 g/day at laundry	97 %	14.9 g/day	1×10^{-2}
Ethoxylated nonylphenol	18.6 g/day	100 %	0	0
Sodium Periodate	19 g/day	100 %	0	0
Other	39 g/day	100 %	0	0
Phosphate surfactant	28 g/day	100 %	0	0
Alkali/caustic	56 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-166
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Omicron-AF

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Propylene glycol	36 g/day	7.3×10^{-2} ug/m^3	5×10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

○ Health risks to the general population from both air and water exposures are very low for Method 2, Product System Omicron-AF.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 2, Product System Omicron-AF reach an ecotoxicity concern concentration.

Performance

General Summary of System Omicron-AF Performance, and Related Variables

Product System Omicron-AE and Product System Omicron-AF were submitted for demonstration by the same manufacturer. They have the same ink remover and the same emulsion remover, but each one has a different haze remover to complete the system. Although these systems do share a common ink remover and emulsion remover, Omicron-AE and Omicron-AF are each evaluated as a separate Product System in this documentation. It was the intention of the Performance Demonstrations to evaluate reclamation systems as a whole, not individual products, whenever possible.

Product System Omicron-AF is a water-based system and it consisted of an ink remover, an emulsion remover, and a haze remover. A degreaser accompanied this product system, however, detailed information on the performance of the degreaser is not included in the scope of this project. The performance of the product was demonstrated at Facilities 4 and 18. Facility 4 prints decals using UV-curable inks; Facility 18 prints nameplates, panels, and graphic overlays using solvent-based inks. During the demonstration periods, Facility 4 used the alternative system to reclaim 19 screens over a 2 week period and Facility 18 reclaimed 32 screens over 4 weeks. Facility 4 discontinued use of the alternative product system after two weeks, due to the poor performance of the ink remover and the haze remover.

At Facility 4, the ink remover removed the ink from the mesh satisfactorily, however, residue remained in the stencil area on most of the screens. The printer felt the ink residue was minimal, and if he were using his standard haze remover, this residue would not have been a problem. Facility 18 reported that the ink remover worked as well as their standard products.

The emulsion remover worked very well at both facilities. It removed the stencil completely and easily. The haze remover performance was not acceptable at either facility. Facility 4 reported that the haze remover was not effective in removing any of the ink haze, even with vigorous scrubbing and procedural modifications. A ghost image appeared on subsequent print jobs, which required that the printer clean the screens again with his standard product.

At Facility 18, the haze remover left too much haze under all conditions and their standard haze remover had to be used after the alternative system before the screen could be reused. Because of this poor performance, the facility stopped using the haze remover during the first week of demonstrations.

Alternative System Omicron-AF Profile

The manufacturer recommends applying Product System Omicron-AF as follows:

- ○ Ink Remover After carding off as much excess ink as possible, use a spray bottle to apply ink remover to both sides of the screen. Brush the product on the screen surface to loosen the ink on both sides. With a clean cloth, wipe the screen clean. Repeat spraying on the ink remover and wiping it off until the screen is clean.

- ○ Emulsion Remover Place the screen in a washout sink and spray both sides of the stencil with the emulsion remover so that it evenly covers the stencil. Wait one minute. Use a soft brush to loosen the stencil and scrub the screen until the stencil is broken up in all areas. Apply more emulsion remover if necessary. Rinse the screen with a pressure washer (a 1000 psi pressure wash was used at SPTF).

- ○ Haze Remover Pour the haze remover into a bucket. Dip a brush into the bucket and scrub the product into both sides of the screen in the effected areas. Let stand for 1 - 2 minutes. Pressure rinse from the bottom of the screen to the top. Turn the screen around and repeat the pressure rinse from bottom to top on the other side of the screen.

Alternative System Performance at SPTF

Product System Omicron-AF was tested at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). On the screen with the solvent-based ink, the ink dissolved well with moderate effort (5 wipes were used). On the last rag there was a slight blue color (the color of the stencil) which may indicate that the ink remover could deteriorate the stencil. Ink remover performance on the screen with UV-curable ink was similar expect there was some red coloring on the rag as well as blue. The red tint could indicate an effect on the adhesive (which is red) that holds the screen to the frame. The UV-curable ink screen also required moderate effort to remove the ink and 6 rags were used. Compared to the other two screens, the screen with water-based ink required additional time, effort (7 rags), and product to loosen the ink. Also on the water-based ink screen, the technician noted that the ink remover started to deteriorate the stencil.

On all three screens, the emulsion remover dissolved the stencil quickly and with moderate scrubbing effort and the pressure rinse removed it completely. On the screen with solvent-based ink, a moderate ink stain remained on the screen after using the emulsion remover. The UV screen had a lighter stain. The water-based ink screen had a moderate stain with some ink residue remaining in the half-tone area. The haze remover lightened the stains on all three screens and removed the ink residue on the water-based ink screen.

Products were applied according to the manufacturer's recommended application procedure. After using the haze remover, the technician noted that there was a small hole in the screen with solvent-based ink that was not there before using the haze remover.

Alternative System Performance Details

Performance Details from Facility 4

After using Product System Omicron-AF for two weeks, Facility 4 decided they did not want to continue participation in the performance demonstrations. When using the screens reclaimed with Omicron-AF in subsequent print jobs, the printer noticed a ghost image. He cleaned the screens again using his own product to remove the haze and was then able to reuse the screens. Faced with a tight production schedule, the printer was unable to continue using Product System Omicron-AF since additional time would be required to reclean the screens with his standard product.

After using the ink remover, the printer evaluated the screen and reported that the ink was removed effectively on 80% of the screens. However, after using the emulsion remover, the printer noted that on every screen an ink residue remained in the stencil area. He felt that this ink residue normally would not have been a problem, because his haze remover could remove it. The alternative haze remover could not.

The printer was pleased with the performance of the emulsion remover. He reported that it removed the stencil completely and easily.

The performance of the haze remover was unacceptable at this facility. When following the manufacturers application instructions, the haze remover reduced the residue, but did not remove it or significantly lighten the ink stain on the mesh, even after vigorous scrubbing and a long high pressure water wash. A ghost image was clearly visible on subsequent print jobs which required the printer to clean the screen again with his standard haze remover.

To improve the product performance, the printer varied several conditions: he increased the soaking time on the screen for the ink remover and the haze remover, he increased the quantity of ink remover and haze remover, he sprayed the haze remover on a scrubber pad instead of directly onto the screen, and he tried drying the screen before using the haze remover. These techniques did not improve the performance of the product system. During the two weeks of demonstrations, product performance was quite consistent as were the demonstration conditions (e.g., ink type, emulsion type, screen condition). The printer did not think further use of the product would provide any different data.

Overall, the printer did not notice any change in screen failure rate over the time period that the alternative system was in use, however, he did need to clean each screen a second time with his own haze remover in order to be able to reuse it. The printer thought this haze would build up on the screen and would eventually prevent the emulsion from adhering to the screen.

Performance Details from Facility 18

Facility 18 used Product System Omicron-AF for four weeks. The press area supervisor was asked to comment on the performance of the system several times during the performance demonstration period. He felt that, in general, the ink remover and emulsion remover products worked as well as the products they were previously using. The haze remover, however, did not give acceptable results, and they stopped using it during the first week of the demonstrations.

The ink remover worked well in most cases. Two of their solvent-based inks which were difficult to clean with their regular products also required more effort with the alternative system. The facility's standard procedure for these inks is to apply haze remover twice after reclaiming. Ink residue left by the alternative chemicals required this practice to be continued during the performance demonstration.

The emulsion remover performed well on all screens and stencils. The reclaimer noted that the stencil dissolved easily with this product. The haze remover did not work well. After reclaiming several screens, it was determined that the screens could not be reused until the facility's regular haze remover was applied to them. Facility 18 therefore discontinued the use of the alternative haze remover.

Screen size at this facility was relatively uniform, and careful controls were placed on screen condition and tension. Retensionable frames were used exclusively. The screens were brought to the reclaiming area with most of the ink removed from them already, having been carded off at the press. Facility 18 had tried other products which were advertised as "safer", and they had one bad experience where one of the products damaged their plumbing system. The same person reclaimed the screens and evaluated the print image quality. This employee was knowledgeable about the entire screen printing process.

The products in System Omicron-AF were not observed to be detrimental to the screen mesh, the printing equipment during the performance demonstration. Print image quality was not affected.

Alternative System Performance Table Compiled from Field Sites

The table below highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 4

Facility 4 prints decals on plastic sheets. A typical run is 3,000 sheets, and approximately 50% of their orders are repeat orders. Of the 30 - 40 employees at this facility, approximately 4 are involved in screen reclamation. All printing is done with UV-curable inks. All screens used in the Performance Demonstrations were polyester (calendared) with a typical mesh count of 390 threads/inch with a direct photo stencil. The average screen size at this facility is 35 inches x 38 inches and approximately 6 screens are reclaimed daily.

Screen Reclamation Area in Facility 4

The screen printing, ink removal, and screen reclamation activities are all done in the same area of the facility. The ink removal area consists of a work table about 20 feet from the press, and screen reclamation is done in a spray booth nearby. The open plant area with high ceilings and overhead fans provide ventilation for the area. The average temperature during the observer's visit was 73°F (and 35% relative humidity). Rags used for clean up and for ink removal are cleaned by a laundry service. Waste water from the high-pressure wash of the emulsion remover and haze remover is not recycled or filtered at this facility.

Table V-167
On-Site Performance Summary for Alternative System Omicron-AF

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time BeforeUsing Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
In-field Demonstrations at Volunteer Printing Facilities											
Facility 4	*Ink remover*	46.1 ± 49.3 hrs (n=22)	1.6 ± 0.7 oz.(n=22)	5.1 ± 0.6 mins (n=12)	Moderate	Ink residue in stencil area.	• Most screens could not be reused due to a haze. • A ghost image appeared when the screens were reused. • The facility discontinued use after 2 weeks.	UV-curable	Direct photo stencil	Monofilament Polyester, calandered; 390 threads/inch	1577 in^2
	Emulsion Remover	5.5 ± 10.2 hrs (n=22)	1.4 ± 0.5 oz. (n=22)	4.9 ± 0.3 mins (n=12)	Low	Easily removed stencil.					
	Haze Remover	4.1 ± 2.0 mins (n=22)	2.1 ± 0.7 oz. (n=12)	5.0 ± 0.2 mins (n=12)	High	Did not remove ghost image from most screens.					
Facility 18	*Ink Remover*	28.5 ± 28.0 hrs (n=47)	2.2 ± 0.5 oz. (n=46)	2.7 ± 0.9 mins (n=46)	Low	Removed ink well.	• Facility was pleased with the ink and emulsion removers. • They switched back to their own haze remover after one week.	Solvent-based	Direct photo stencil and capillary film	Mono-filament polyester; 110 - 460 threads/inch	1150 in^2
	Emulsion Remover	1.2 ± 1.1 mins (n=47)	3.6 ± 1.2 oz. (n=47)	4.0 ± 1.1 mins (n=47)	Low	Easily removed stencil.					
	Haze Remover	0.8 ± 2.7 mins (n=47)	1.9 ± 0.7 oz. (n=11)	4.1 ± 1.4 mins (n=11)	Low	Did not reduce haze.					

Table V-168
Laboratory Performance Summary for Alternative System Omicron-AF

		Performance						Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
SPTF Solvent-based Ink	*Ink Remover*	15 mins	1.5 oz.	5.7 mins	Moderate	Ink dissolved well.		Solvent-based	Dual cure direct	Polyester; 260 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	4.1 mins	Moderate	Stencil dissolved easily. Moderate ink stain remaining.					
	Haze Remover	0 mins	1.0 oz.	4.0 mins	Low	Lightened the ink stain.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	1.5 oz.	6.5 mins	Low	Ink dissolved well.		UV-curable	Dual cure direct	Polyester; 390 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	4.1 mins	Low	Stencil dissolved easily. Light ink stain remaining.					
	Haze Remover	0 mins	0.5 oz.	4.5 mins	Low	Lightened the ink stain.					
SPTF Water-based Ink	*Ink Remover*	15 mins	2.5 oz.	7.8 mins	Moderate	Ink dissolved with extra effort and product.		Water-based	Dual cure direct	Polyester; 260 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	4.4 mins	Moderate	Stencil dissolved easily. Some ink residue remaining.					
	Haze Remover	0 mins	1.0 oz.	4.2 mins	Low	Removed residue; lightened stain.					

Current Screen Reclamation Products at Facility 4

As their standard screen reclamation products, Facility 4 uses two proprietary products for ink removal, and also uses proprietary products for emulsion and haze removal. These products are sold by a manufacturer not participating in the performance demonstration. The MSDSs for all of these products state that they contain no carcinogens, no ingredients with TLVs or PELs, and no petroleum derivatives.

Current Screen Reclamation Practices in Facility 4

Screen reclamation employees wear eye protection for all steps of the process; gloves and barrier cream are also available. The reclamation process is described below:

○ Ink Remover: Card off excess ink at the press. Spray on the in-process ink remover and wipe the screen with a reusable rag. Bring the screen over to the ink removal area and place the screen flat on the table. Wipe with a sponge, then, using a squeegee on both sides, pull the residue down to the bottom of the screen. Use a rag to wipe off the residue. One rag is used for every two or three screens. Bring the screen over to the pressure wash booth. From a five-gallon container, spray both sides of the screen with the ink degradent. Use a scrubber pad to rub the product into the screen. Pressure wash (1000 psi) both sides of the screen to rinse out the ink and blockout, and also to loosen the masking tape around the edges of the frame.

○ Emulsion Remover: Spray both sides of the screen with emulsion remover from a five-gallon container. Brush the stencil area on both sides with a scrubber pad. Rinse the both sides of the screen with a high pressure wash.

○ Haze Remover: Haze remover is used on all screens being reclaimed. Spray on haze remover from a 24 ounce spray bottle. Scrub the effected area with a scrubber pad. Wait for one minute and rinse with a pressure wash.

General Facility Background for Facility 18

Facility 18 prints graphic overlays for the electronics industry and nameplates and panels. All of their printing is done on plastics. Their typical run length is 16 hours and approximately 80% of their orders are repeat orders. There are approximately 40 employees at this facility, three of which are involved in screen reclamation activities. During the Performance Demonstration, this facility used solvent-based inks and they used both a direct photo stencil and a capillary film stencil. High tension monofilament polyester mesh (untreated) screens with mesh counts ranging from 110 - 460 threads/inch were used. Typical screen sizes in this facility are 1,596 in^2 or 952 in^2, and approximately 10 - 15 screens are reclaimed daily.

Screen Reclamation Area in Facility 18

Ink removal and screen reclamation operations are both done within the screen printing area of the facility where local ventilation is provided. The ink removal area consists of a work table and a spray booth. A second spray booth is used for reclamation; this booth is back-lit and is separated from the ink removal booth by a stainless steel sink. During the observer's visit, the average temperature in both areas was 65°F (and 49% relative humidity). In the ink removal area, a filtration system is used to filter and recirculate the ink remover solvent. These filters are disposed of as hazardous waste along with the used shop rags. Waste water from the washes of the emulsion remover and haze remover is not recycled or filtered at this facility.

Current Screen Reclamation Products at Facility 18

As their standard ink remover, Facility 18 uses a proprietary solvent blend that contains at least pentanedioic acid and dimethyl ester (<20%). Their standard emulsion remover is a proprietary aqueous mixture with at least sodium periodate. For haze removal, this facility uses a proprietary aqueous mixture that contains sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 18

At Facility 18, screens are reclaimed as follows:

- Ink Remover: Spray on the ink remover from the recirculation tank through a manual pressurized brush system. Rub the screen with a scrubber pad on both sides of the screen. Spray both sides of the screen with low pressure water. Gloves, eye protection, and aprons are worn during ink removal.
- Emulsion Remover: Spray on the emulsion remover and let it sit for approximately 30 seconds. Rinse with a high pressure (1500 psi) wash. Blow dry the screen with compressed air, then vacuum dry the screen, and blow with compressed air again until the screen is completely dry. Gloves, eye protection, aprons, respiratory protection, and ear protection are used during emulsion removal.
- Haze Remover: Dip a scrubber pad into the container of haze remover. Rub the product into the screen. Allow the screen to drain then bring it to another tub and let sit to dry for 30 minutes. Apply ink remover from the recirculation tank and let sit for 5 minutes. Allow the screen to drain into recirculation tank. Bring the screen over to the spray booth and spray with a low pressure spray followed by a high pressure wash.

Cost

Table V-169
Method 2: Summary of Cost Analysis for Alternative System Omicron-AF

Cost Element Description		Baseline (Traditional System 4)	Alternative System Omicron-AF	
			Facility 4	Facility 18
Facility Characteristics				
Average screen size (in^2)		2,127	1,210	1,150
Average # screens/day		6	6	13
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	15.0 3.28	10.8 2.37
Materials and Equipment	# of rags used Cost ($)	3 0.45	1.3 0.20	1.3 0.20
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	1.6 0.12	2.2 0.17
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	1.4 0.10	3.6 0.27
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	2.1 0.15	1.9 0.14
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	0 0	0 0
Totals				
Total Cost ($/screen)		6.27	3.86	3.14
Normalized[a]		6.27	4.45	3.89
Total Cost ($/year)		9,399	5,784	9,823
Normalized[a]		9,399	6,675	5,836

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Product System Zeta

Formulation

Ink Remover	Propylene glycol series ethers
Emulsion Remover	Sodium periodate Water
Haze Remover	Alkali/Caustic Propylene glycol Water

Occupational Exposure

Table V-170
Occupational Exposure Estimates for Alternative System Zeta

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
<u>Ink Remover</u>						
Propylene glycol series ethers	139	0.6	0	2.8	1560	7280
<u>Emulsion Remover (diluted 1:4)</u>						
Sodium periodate	0	0	0	0	16	73
Water	0	0	0	0	1540	7210
<u>Haze Remover</u>						
Alkali/Caustic	0	0	0	0	234	1090
Propylene glycol	0	0.1	0	0	62	291
Water	0	0	0	0	1260	5900

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Occupational Risk Conclusions and Observations

<u>Ink Remover and Haze Remover</u>

○ Hazard quotient calculations indicate marginal concerns for chronic inhalation exposure to workers using propylene glycol series ethers in ink removal. Possible concerns also exist for chronic dermal exposure to propylene glycol series ethers based on the calculated hazard quotients, which assume 100% dermal absorption. If the actual dermal absorption rate of propylene glycol series ethers is significantly lower, this concern would be significantly reduced or eliminated.

Table V-171
Occupational Risk Estimates for Alternative System Zeta

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Propylene glycol series ethers	3.2	18	87	NA	100	NA	NA	NA	NA
Emulsion Remover (diluted 1:4)									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Alkali/Caustic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propylene glycol	0.1	0.04	0.2	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.
[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.
[c] NOAEL means No Observed Adverse Effect Level.
[d] LOAEL means Lowest Observed Adverse Effect Level.

- Inhalation exposures to propylene glycol series ethers also present possible concerns for developmental toxicity risks, based on margin-of-exposure calculations.

- Hazard quotient calculations for chronic inhalation and dermal exposures to propylene glycol during haze removal indicate very low concern.

- Inhalation exposures to other components are very low.

- Risks from other ink remover and haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Emulsion Removers (All Systems)

- All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-172
Environmental Release Estimates in Screen Cleaning Operations Method 2, Alternative System Zeta

	Release Under Each Scenario (g/day)						
	I			II	III	IV	
System	air	water	land	air	air	air	water
Ink Remover							
Propylene glycol series ethers	290	0	375	1.4	0.8	5.8	1345
Emulsion Remover (diluted 1:4)							
Sodium periodate	0	6	0	0	0	0	0
Water	0	615	0	0	0	0	0
Haze Remover							
Alkali/Caustic	0	80	0	0	0	0	0
Propylene glycol	0.7	21	0	0.2	0.1	0	0
Water	0	431	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Table V-173
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 2, Alternative System Zeta

Substance:	To Air:	To Water:	To Landfill:
Propylene glycol series ethers	297.6 g/day	1345 g/day at laundry	375 g/day
Sodium periodate		6 g/day	
Alkali/caustic		80 g/day	
Propylene glycol	1 g/day	21 g/day	

Releases to Water from a Single Facility

Table V-174
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 2, Alternative System Zeta

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Propylene glycol series ethers	1375 g/day	83-97 %	222 g/day	2×10^{-1}
Sodium periodate	6 g/day	100 %	0	0
Alkali/caustic	80 g/day	100 %	0	0
Propylene glycol	21 g/day	97 %	0.6 g/day	6×10^{-4}

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-175
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 2, Alternative System Zeta

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Propylene glycol series ethers	297.6 g/day	6.1×10^{-1} ug/M3	4
Propylene glycol	21 g/day	4.3×10^{-2} ug/m^3	3×10^{-1}

[a]This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions and Observations

- Health risks to the general population from both air and water exposures are very low for Method 2, Product System Zeta.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

- None of the single facility releases of Method 2, Product System Zeta reach an ecotoxicity concern concentration.

Performance

General Summary of Product System Zeta Performance, and Related Variables

This product system consisted of an ink remover, emulsion remover, and a haze remover. The performance of the products was demonstrated at Facilities 6, 7, and 15. Facility 6 prints store displays, traffic markings, and movie posters; Facility 7 prints decals, labels, vehicle markings, and store displays; Facility 15 prints plexiglass displays, store displays, and banners. During the demonstration period, Facility 6 reclaimed seven screens, Facility 7 reclaimed four screens, and Facility 15 reclaimed eight screens. Facility 6 used solvent, ultraviolet (UV)-cured, and water-based inks; Facility 7 and Facility 15 used solvent-based and UV-cured inks.

Facility 6 reported that the performance of the alternative ink remover was poor, and they had to reclean their screens using their standard ink remover after the alternative product. Although the ink remover performed poorly with solvent and UV-cured inks in general, Facility 6 reported that the alternative ink remover worked well on one screen with water-based inks and on one with UV-cured ink. Facility 7 reported that for solvent-based inks, the ink remover seemed to dry on the screen and did not take the ink out; the alternative ink remover did work well with UV-cured inks. To improve performance of the ink remover, the screen reclamation employee needed to begin wiping the ink remover off the screen immediately after spraying instead of waiting, as recommended. If the ink remover was not wiped off immediately, it dried on the screen and then they needed to use their regular ink remover. Facility 15 reported that the ink remover did not work at all for this facility; it had to be applied a number of times and, even with more scrubbing than usual, it had to be followed with their standard product.

Both Facility 6 and Facility 7 found the emulsion remover did not work well when diluted with five parts water. When the facilities increased the emulsion remover concentration by diluting with only three parts water, the emulsion remover dissolved the stencil. At Facility 6, the performance of the emulsion remover was not consistent, even at the stronger concentration. Facility 7 was generally pleased with the performance of the emulsion remover at the stronger concentration, however, they still had problems if the emulsion remover was permitted to dry in the mesh. Facility 15 reported that the emulsion remover was passable, but the facility still preferred their own product. The alternative emulsion remover required extra scrubbing effort (even at full strength) at Facility 15.

All three facilities reported that the haze remover did not have any effect on the haze. They all had to use their own haze remover in many cases. These facilities did not reclaim many screens using the Product System Zeta for several reasons: they were disappointed and discouraged by the early results, the products arrived later then expected and the observer was not present to assist the printers with the application procedure or to offer suggestions for improving performance, and the production schedules of the shops was unusually busy. Because of these factors, none of the facilities put extensive effort into attempting to alter application techniques to make the products work at their shop.

Alternative System Zeta Profile

The manufacturer recommends applying Product System Zeta as follows:

- Ink Remover Card off the extra ink left in the screen. Using a spray bottle, apply the ink remover to both sides of the screen. Allow up to 2 minutes for penetration. Squeegee or wipe soaked ink into waste bin. Rinse with high pressure water (a pressure spray of 1000 psi was used at SPTF).

- Emulsion Remover Depending on conditions, dilute one part emulsion remover with up to 5 parts of water. Using a spray bottle, apply the emulsion remover to both sides of the screen and work it in with a nylon mesh pad or brush. Wait one minute and do not allow the mixture to dry on the screen. Rinse both sides of the screen with high pressure water.

- Haze Remover Spray the haze remover thoroughly and evenly onto both sides of screen. Allow at least 15 minutes for normal penetration. Overnight soaking will not damage the screen. Scrub with a synthetic brush or pad. Rinse both sides of screen with high pressure wash.

Alternative System Performance at SPTF

Product System Zeta was tested at SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). The ink remover performance varied depending on the type of ink used. The emulsion remover and haze remover performance was consistent for all three screens.

On all three screens, the modifications were made to the manufacturer's instructions for applying ink remover. First, the technician applied the ink remover following the recommended method (spray on both sides of the screen, wait two minutes, squeegee off ink, and rinse with pressure washer). This application method did not satisfactorily remove the ink from any of the three screens. To improve the ink remover performance, the technician reapplied the product using a different method. For the second ink remover application, the technician wiped the screen with a dry rag to remove excess water, sprayed more ink remover over the entire screen, and wiped with rags until the rag was no longer picking up the ink. On the screen with solvent-based ink, the screen had some spots of ink residue and a medium gray haze after the first ink remover application. The stencil was affected in the half-tone area and it turned a light blue color in some areas. A second application of ink remover on the solvent-based ink screen removed the ink residue, but the stencil color came up on the rag. Four rags were used. On the screen with the UV ink, after the first ink remover application procedure, there was a heavy gray stain over the entire screen, ink residue remained in some areas, and the stencil had a dull finish. After the second application of the ink remover, the screen still had some ink stains remaining, but the gray haze was removed. Three rags were used. On the water-based ink screen, after the first application of ink remover was squeegeed off, ink residue remained, mainly on the emulsion. The ink wiped off easily when the ink remover was applied again. The rag was blue with the emulsion from the half-tone areas. Two rags were used.

On all three screens, the stencil dissolved easily with moderate scrubbing. A moderate ink stain remained on all of the screens, but there was no stencil stain or ink residue. The haze remover did not appear to lighten the ink stain on any of the screens. The technician also noted that the odor of the haze remover was so strong, she felt an exhaust fan or a respirator was required. Overall, although an ink stain remained on the screens, SPTF did not think the stain would affect future print quality and therefore, evaluated the product system as acceptable.

Alternative System Performance Details

Performance Details from Facility 6

This facility had mixed success with System Zeta. The demonstrations were complicated by the fact that the screen reclaimers spoke almost no English and the forms had to be translated into Spanish. Two different reclaimers participated in the demonstrations, but another person was involved to either translate the reclaimer's forms or to write down results. Because of this situation, the observer was not confidant that all the information received was accurate. Another confounding factor was that the product arrived late at the facility and the observer was not present to assist the printer with the application instructions and with trouble-shooting, as was done at most other facilities. It is possible that better results could have been achieved had the observer been present.

At Facility 6, the ink remover did not work as well as their usual product. During the demonstrations, this facility used the alternative system on screens with solvent-based, UV-curable, and water-based inks. The alternative ink remover performed poorly with solvent-based inks, it worked well on one screen with water-based inks, and performance was mixed on screens with UV-inks. Facility 6 needed to use their regular remover to get the ink out of several of the screens after using the alternative ink remover.

This facility had mixed results with the emulsion remover. In general, when the emulsion remover was used at a strength of three parts of product to one part water, or stronger, the stencil dissolved quickly. At weaker concentrations, the emulsion remover worked much more slowly than their usual product and the printer needed to use their usual emulsion remover to get the screens clean. However, these results were not consistent, and on some screens where the stronger formulation was used, the stencil did not dissolve completely.

The haze remover worked very poorly for this facility. It did not seem to reduce haze produced by UV-cured or solvent-based inks and it was not used with water-based inks.

Performance Details from Facility 7

The alternative system arrived at Facility 7 during a very busy period. The facility's initial response to the alternative system's performance was negative. The poor initial performance combined with increased activity at the facility led to a situation where little information was collected on alternative system performance. This facility also received the alternative system shipment late and the observer did not have the opportunity to assist the printer with the application technique or to suggest procedures to improve performance. This assistance was given through telephone conversations between the observer and the facility contact, however, this may not have been as effective as in-person support.

The ink remover performance at Facility 7 was poor. The facility was particularly unhappy with the directions which said to let the ink remover sit on the screen. The ink remover dried quickly into the screens, stuck into the mesh and it was then completely ineffective at removing ink. This facility was only able to use the ink remover if they applied additional ink remover and began wiping it out of the mesh immediately. These changes improved the performance of the ink remover slightly, but often the facility used their usual ink remover to remove all ink from the screens. Facility 7 did use the ink remover on one screen with UV ink and found it worked much better. As their standard ink remover, this facility uses a lacquer thinner in some cases. Adverse interactions could occur when using the alternative ink remover because its chemical composition is very different from lacquer.

Initially, the facility diluted one part emulsion remover to five parts water. At this concentration, the emulsion remover did not dissolve the stencil unless the product was reapplied. When they changed the dilution to one part emulsion remover to three parts water, the stencil dissolved easily with little scrubbing effort. The facility did have problems with the emulsion remover drying quickly into the mesh. Wiping the emulsion remover immediately off of the screen aided the product's performance.

The haze remover was not effective at this facility; they did not think that the haze remover worked at all. Facility 7 only filled in the haze remover information on the data sheets for one screen, although they tried it on several screens and the performance was consistently disappointing.

Performance Details from Facility 15

Facility 15 did not like System Zeta compared to their usual products. Under most conditions, they were unhappy with the performance of the alternative system. Because the alternative system did not work well, the facility recleaned their screens with their usual products after each demonstration. This double cleaning greatly increased the time required for screen reclamation. Each time the facility tried the alternative system, their confidence in the product's abilities to clean the screen decreased making it even harder to convince the facility to continue with the demonstrations. They submitted data on only eight screens.

The ink remover did not effectively remove the ink from the screens unless it was applied several times. Compared to their standard product, more scrubbing was required and the facility often had to follow up with their usual ink remover to get the ink out of the screens. The standard ink remover is very different chemically than the alternative product. This difference may cause adverse chemical interactions.

At Facility 15, the emulsion remover had to be applied multiple times to effectively clean the screens. Using the emulsion remover undiluted did not eliminate the need for a second application to remove all emulsion from the screen. Even with multiple applications of the undiluted emulsion remover, Facility 15 often had to use their usual emulsion remover to get the screens to the level of cleanliness that they wanted.

The haze remover required harder scrubbing than their usual product and did not seem to reduce the haze. Once again, Facility 15 had to resort to using their usual haze remover to reduce the haze to an acceptable level.

The performance of the alternative system did not seem to be affected by the types of ink or by ink color, although there was a possibility that the alternative system worked slightly better with UV-cured inks than with solvent-based inks. Since the data available was so limited, it is not possible to draw any conclusions on correlations between product performance variations and screen conditions. No screen side effects were noticed during the performance demonstrations, although increased scrubbing will produce a greater level of mesh abrasion, which may in turn lead to higher screen failure rates.

Alternative System Performance Table Compiled from Field Sites

The following table highlights the observed performance of the product system and the relevant conditions of the demonstration, as recorded by the printers using the products at the demonstration facilities. In addition to the field demonstration performance data, results of the product tests performed at SPTF are also summarized in this table. More descriptive information on the demonstration facilities is included in the section following the table.

Facility Profiles

General Facility Background for Facility 6

Facility 6 prints store displays, transit markings, and movie posters on plastics and paper. Their typical run length is 250 - 300 sheets, and approximately 5% of their orders are repeat orders. Of the approximately 25 employees at this facility, 1 - 3 are involved in screen reclamation. Currently, they used solvent-based, water-based, and UV inks, but they are in the process of discontinuing their use of solvent-based ink systems. All screens used in the Performance Demonstrations were made of a polyester mesh with thread counts ranging from 280 - 420 threads/inch. The average screen size used at this facility is 35 ft^2 and 10 - 15 screens are reclaimed daily.

Table V-176
On-Site Performance Summary For Alternative System Zeta

		Performance						Demonstration Conditions			
	System Component	Avg Drying Time Before Using Product	Average Quantity Applied	Average Cleaning Time	Average Effort Required	Performance for Each System Component	Overall System Performance	Ink type(s)	Emulsion type	Mesh type; Thread count	Average Screen Size
Facility 6	*Ink remover*	24.0 ± 15.2 hrs (n=6)	8.3 ± 8.2 oz. (n=6)	2.8 ± 1.3 mins (n=6)	Moderate	Ink residue in screen.	• Only 7 screens were reclaimed at this facility. • They did not use the products because of poor performance.	Solvent-based, UV ink, and water-based inks	Direct photo stencil	Polyester, no treatment; 280 - 420 threads/inch	3926 in^2
	Emulsion remover	12.0 ± 13.8 hrs (n=4)	6.5 ± 2.5 oz. (n=4)	4.8 ± 3.8 mins (n=4)	Moderate/ High	Worked well sometimes, but inconsistent results.					
	Haze remover	11.5 ± 2.5 mins (n=4)	2.8 ± 1.0 oz. (n=4)	2.2 ± 0.5 mins (n=4)	Moderate	Seemed to have no effect on haze.					
Facility 7	*Ink remover*	3.6 ± 1.0 mins (n=4)	8.5 ± 4.5 oz. (n=4)	4.8 ± 1.3 mins (n=4)	Moderate	Dried into the screen mesh and did not remove ink effectively.	• Only 4 screens were reclaimed at this facility. • They did not use the products because of poor performance.	Solvent-based and UV inks	Capillary film	Polyester, abraded; 230 - 390 threads/inch	3060 in^2
	Emulsion Remover	3.8 ± 7.5 hrs (n=4)	1.3 ± 0.5 oz. (n=4)	1.2 ± 0.5 mins (n=4)	Low	Reapplication of product needed to remove stencil.					
	Haze Remover	0.0 ± 0.0 mins (n=4)	2.0 oz. (n=1)	15.0 mins (n=1)	High	Seemed to have no effect on haze.					
Facility 15	*Ink Remover*	10.2 ± 21.1 hrs (n=5)	3.0 ± 0.9 oz. (n=6)	6.2 ± 5.3 mins (n=6)	Low	A lot of product was required to remove the ink.	• This facility had to use their standard products before the screens could be reused. • They reclaimed 8 screens before dropping out of the performance demonstrations	Solvent-based and UV inks	Direct photo stencil	Polyester; 156 - 305 threads/inch	2084 in^2
	Emulsion Remover	13.3 ± 21.5 hrs (n=8)	4.1 ± 2.7 oz. (n=8)	6.5 ± 4.0 mins (n=8)	High	Stencil dissolved slowly with extra scrubbing effort.					
	Haze Remover	1.5 ± 2.0 mins (n=6)	2.3 ± 0.5 oz. (n=6)	20.2 ± 14.9 mins (n=6)	Moderate	Seemed to have no effect on haze.					

Table V-177
Laboratory Performance Summary For Alternative System Zeta

		Performance						Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Performance for Each System Component**	**Overall System Performance**	**Ink type(s)**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
SPTF Solvent-based Ink	*Ink Remover*	15 mins	2.5 oz.	6.0 mins	High	2 applications required to remove ink; stencil deteriorated in areas.		Solvent-based	Dual cure direct	Polyester; 260 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.0 oz.	4.3 mins	Moderate	Stencil dissolved easily; some ink stain left.					
	Haze Remover	0 mins	1.0 oz.	16.6 mins	Low	Did not appear to lighten haze at all; strong odor.					
SPTF UV-curable Ink	*Ink Remover*	15 mins	1.0 oz.	4.6 mins	High	2 applications required to remove ink; stains in some spots.		UV-curable	Dual cure direct	Polyester; 390 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.5 oz.	4.5 mins	Moderate	Stencil dissolved easily; some ink stain left.					
	Haze Remover	0 mins	1.0 oz.	17.3 mins	Low	Did not appear to lighten haze at all; strong odor.					
SPTF Water-based Ink	*Ink Remover*	15 mins	1.5 oz.	5.7 mins	High	2 applications required to remove ink; stencil deteriorated in areas.		Water-based	Dual cure direct	Polyester; 260 threads/inch	360 in^2
	Emulsion Remover	24 hours	1.5 oz.	4.5 mins	Moderate	Stencil dissolved easily; some ink stain left.					
	Haze Remover	0 mins	1.0 oz.	16.9 mins	Low	Did not appear to lighten haze at all; strong odor.					

Screen Reclamation Area in Facility 6

Screen reclamation is done in a reclamation room near the main production area. The open area provides ventilation for screen reclamation activities and hoods are being added over the reclamation spray booth. The average temperature during the observer's visit was 71°F (and 45% relative humidity). Waste water from ink removal activities is filtered and the filters are disposed of as hazardous waste. Waste water from the high-pressure wash of the emulsion remover and haze remover is not filtered.

Current Screen Reclamation Products at Facility 6

Facility 6 uses a proprietary blend which contains propylene glycol ethers (<50%) as their standard ink remover. Their emulsion remover is a proprietary aqueous mixture with periodate salt (<10%). For haze removal, they use a proprietary blend consisting of at least sodium hydroxide, potassium hydroxide and propylene glycol ether.

Current Screen Reclamation Practices in Facility 6

The screen reclamation process at Facility 6 is described below. Gloves, eye protection, aprons, respiratory protection, barrier cream, and ear protection are available to all employees involved in screen reclamation.

○ Ink Remover: Card off the excess ink at the press. Bring the screen to the reclamation room and spray the ink remover onto the screen at 80 psi from a 55 gallon drum with a nozzle. Squeegee off the ink. Spray the screen and squeegee it again. Pressure wash (2500 psi) both sides of the screen.

○ Emulsion Remover: Spray both sides of the screen with the emulsion remover and let sit for a few seconds. Pressure wash the screen. Spray more ink remover onto both sides of the screen and let sit for one minute. Rinse with a high pressure washer, followed by a low pressure water rinse. Allow the screen to air dry.

○ Haze Remover: Dip a brush into the container of haze remover and work it into both sides of the screen with the brush or with a scrubber pad. Let sit for three to five minutes then rinse with a high pressure wash, followed by a low pressure rinse.

General Facility Background for Facility 7

Facility 7 prints roll labels, fleet markings, point of purchase displays, and decals. A typical run length is 275 sheets. There are less than 5 screen printing employees at this facility. The facility uses both UV ink and solvent-based ink. During the Performance Demonstrations they used a capillary film emulsion and the screen mesh was an abraded polyester. Mesh counts ranged from 230 - 390 threads/inch. The screen size typically used in this facility is 60" x 52", and 10 - 12 screens are reclaimed daily.

Screen Reclamation Area in Facility 7

Ink removal and screen reclamation are done in separate spray booths located next to each other in the plant. Ventilation for both areas is provided by local overhead fans and ventilated hoods. During the observer's visit, the average temperature in the area was 71°F (and 41% relative humidity). Rags used for screen reclamation activities are cleaned by a laundry service. Used ink removal solvents are recycled on-site and the recycled product is used in-house. Filtered waste from ink removal is disposed of as a hazardous water. Waste water from emulsion removal and haze removal activity is not filtered at this facility.

Current Screen Reclamation Products at Facility 7

For ink removal, Facility 7 uses lacquer thinner, as well as a proprietary product sold by a manufacturer not participating in the performance demonstration. The MSDS states that this product contains no carcinogens, no ingredients with TLVs or PELs, and no petroleum derivatives. Their standard emulsion remover is a proprietary aqueous mixture which contains periodate salt (<10%). As a haze remover, they use a proprietary aqueous mixture with sodium hydroxide (<15%).

Current Screen Reclamation Practices in Facility 7

Employees wear gloves and eye protection during ink removal and screen reclamation. Respiratory protection is also available for haze removal. Facility 7 screens are reclaimed as follows:

○ <u>Ink Remover:</u> Card off the excess ink at the press. On screens that have been printed with clear inks, spray lacquer thinner on both sides of the screen and wipe with reusable rags (two or three rags are used on each screen). The lacquer thinner is recycled. Bring the screen to the ink removal station and spray with ink remover on the squeegee side. Wipe off ink residue with a reusable rags. Repeat application of the ink remover and wipe the screen. Bring the screen to the pressure wash station and rinse both sides of the screen.

○ <u>Emulsion Remover:</u> Spray on emulsion remover and work it into the screen with a scouring pad. Pressure rinse the screen and allow to dry in front of the fan.

○ <u>Haze Remover:</u> Haze remover is only used on approximately 1 screen per month. To apply, dip a rag or brush into the haze remover, work it into the screen, then rinse with the pressure washer.

General Facility Background for Facility 15

Facility 15 prints store fixtures, banners and point-of-purchase displays. They primarily print on plastics, but they also do some jobs on paper, metal, and wood. A typical run is 800 sheets and 70% of their orders are repeat orders. Of the approximately 5 employees involved in screen printing at this facility, 2 are involved in screen reclamation activities. Several different types of ink are commonly used at Facility 15, including vinyls, epoxies and UV-curable inks. All screens used in the Performance Demonstrations were polyester and a direct photo stencil emulsion was applied. Mesh counts during the demonstration period ranged from 156 - 305 threads/inch. The average screen size used at this facility is 35 inches x 45 inches and 4 - 5 screens are reclaimed daily.

Screen Reclamation Area in Facility 15

Ink removal is primarily done at the press and screen reclamation is done in a back-lit spray booth. The temperature during the observer's visit was 58°F (and 50% relative humidity). Rags used for ink removal and screen reclamation are washed by an industrial laundry service. Waste water from the high-pressure wash of the emulsion remover and haze remover is not filtered at this facility.

Current Screen Reclamation Products at Facility 15

For ink removal, Facility 15 uses acetone, as well as a proprietary product sold by a manufacturer not participating in the performance demonstration. The MSDS states that this product contains no carcinogens, no ingredients with TLVs or PELs, and no petroleum derivatives. For emulsion removal, they use a proprietary aqueous mixture with at least sodium periodate. Their standard haze remover is an aqueous blend consisting of potassium hydroxide (27%) and tetrahydrofurfuryl alcohol (11%).

Current Screen Reclamation Practices in Facility 15

Gloves, eye protection, and aprons are worn during screen reclamation. The screen reclamation process at Facility 15 is described below:

○ <u>Ink Remover:</u> Card off the excess ink at the press. Pour lacquer thinner onto a reusable rag and wipe the screen. Bring the screen to the sink, wet it down, and let it sit for 30 seconds to five minutes. Pressure wash (1500 psi) to remove the blockout.

○ <u>Emulsion Remover:</u> Spray product onto the screen and rub it in with a scrubber pad. Let the screen sit for 10 seconds to 5 minutes. Pressure rinse. Spray on more product where needed, rub in with the scrubber pad, pressure rinse and allow the screen to air dry. When the screen is dry, pour acetone onto a rag and wipe the screen and the frame to remove any remaining ink. Wipe again with a clean, lint-free disposable rag. Pressure wash.

○ <u>Haze Remover:</u> After emulsion removal, a haze remover is used only if needed (on approximately 5% of the screens). When haze remover is used, the acetone wash step is eliminated. Haze remover is applied using a scraper, followed by a high pressure water spray.

Cost

Table V-178
Method 2: Summary of Cost Analysis for Alternative System Zeta

Cost Element Description		Baseline (Traditional System 4)	Alternative System Zeta		
			Facility 6	Facility 7	Facility 15
Facility Characteristics					
Average screen size (in^2)		2,127	3,926	3,060	2,084
Average # screens/day		6	13	11	5
Cost Elements per Screen					
Labor	Time spent applying, scrubbing, and removing reclamation products (min)	24.4	17.6	21.0	32.8
	Cost ($)	5.33	3.85	4.59	7.18
Materials and Equipment	# of rags used	3	0.0	3.8	0.0
	Cost ($)	0.45	0.00	0.56	0.00
Reclamation Product Use	Ink Remover				
	Average Volume (oz.)	8.0	8.3	8.5	3.0
	Cost ($)	0.22	1.50	1.53	0.54
	Emulsion Remover				
	Average Volume (oz.)	3.5	6.5	1.3	4.1
	Cost ($)	0.13	0.23	0.04	0.15
	Haze Remover				
	Average Volume (oz.)	3.0	2.8	2.0	2.3
	Cost ($)	0.12	0.64	0.47	0.55
Hazardous Waste Disposal	Amount (g)	34	115	90	61
	Cost ($)	0.02	0.08	0.07	0.04
Totals					
Total Cost ($/screen)		6.27	6.31	7.26	8.46
Normalized[a]		6.27	5.39	6.51	8.99
Total Cost ($/year)		9,399	19,704	19,973	9,521
Normalized[a]		9,399	8,080	9,772	13,479

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

Note: For additional information regarding product performance see performance demonstration summaries.

Method 3: SPAI Workshop Process

Method 3 (illustrated in Figure V-4) is taught as an alternative method of screen reclamation by the technical staff at the Screen Printing Association International (SPAI) in screen printing workshops. Information provided by SPAI staff was used to document this alternative method. The process for Method 3 is detailed below:

Method 3 Process

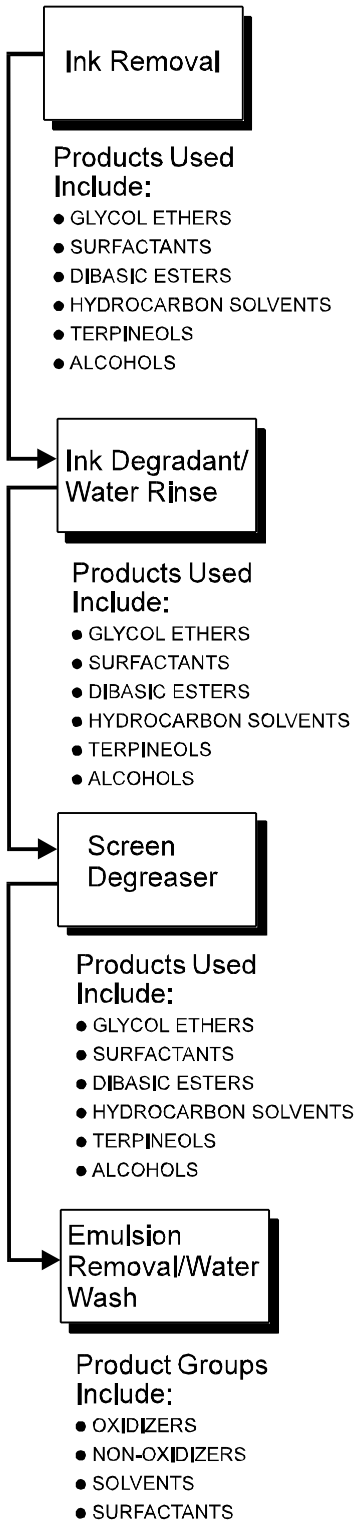
- ○ Clean the screen with the ink remover product to remove the majority of the ink residue from the screen.
- ○ Prior to the screen coming in contact with water, spray the screen on both sides of the stencil with an ink degradant or ink solubilizer.
- ○ Scrub the stencil with a soft brush on both sides to break down the components of the ink. Water wash the emulsion off the screen.
- ○ To remove the oily film that covers the screen, spray screen degreaser on both sides of the stencil and wipe off with rags.
- ○ Apply (spray) emulsion remover and rinse screen with water.

SPAI staff state that the main advantage of this method is that it eliminates the use of a haze remover; caustic haze removers can damage the screen mesh, limiting the future use of the screen. Screen printers can also avoid exposure to the harsh chemicals that can be used in haze removal.

Because the manufacturer of Alternative System Omicron supplied a screen degreaser formulation along with other product formulation information, System Omicron, minus the haze remover product, was used as the one alternative system in Method 3. In order to evaluate Method 3 as an alternative screen reclamation method, several assumptions were used in the risk and cost assessment. It was not possible to make these assumptions based on an actual performance demonstration of Method 3. Although the demonstration of the effectiveness of this method was one of the original intentions of the performance demonstration, logistical problems prevented a performance evaluation. The assumptions used in the assessment of Method 3 are as listed below:

- ○ In total, this process takes approximately the same amount of time as Screen Reclamation Method 2
- ○ For the ink degradant and the screen degreaser products, about 3 oz. of each product is used per screen size of approximately 2100 in^2.
- ○ The ink remover and the ink degradant have the same chemical composition (no ink degradant was supplied for the performance demonstration)
- ○ Some of the parameters from the Method 2 evaluation of System Omicron were used in the cost estimation, including labor costs and quantities of ink and emulsion removers used (reference Chapter 3 methodology).

Figure V - 4
Process Steps Included in Method 3



In this assessment of Method 3 using System Omicron (minus haze remover), there is no comparable assessment of a traditional system of screen reclamation products. Reference Methods 1 and 2 for a determination of the occupational and population risks, as well as performance, of a traditional screen reclamation product system.

System Omicron Formulation

Ink Remover:	Diethylene glycol butyl ether Propylene glycol
Ink Degradant:	Diethylene glycol butyl ether Propylene glycol
Screen Degreaser:	Isopropanol Ethoxylated nonylphenol Water
Emulsion Remover:	Sodium periodate Ethoxylated nonylphenol Water

Occupational Exposure

Table V-179
Occupational Exposure Estimates for Method 3, Alternative System Omicron

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
<u>Ink Remover</u>						
Diethylene glycol butyl ether	0	0	0	0	984	4590
Propylene glycol	17	0.1	0	0.4	576	2690
<u>Ink Degradant</u>						
Diethylene glycol butyl ether	0	0	0	0	984	4590
Propylene glycol	17	0.1	0	0	576	2690
<u>Degreaser</u>						
Isopropanol	2	2	1	0	16	73
Ethoxylated nonylphenol	0	0	0	0	47	218
Water	0	0	0	0	1500	6990
<u>Emulsion Remover</u>						
Sodium periodate	0	0	0	0	47	218
Ethoxylated nonylphenol	0	0	0	0	31	146
Water	0	0	0	0	1480	6920

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Occupational Risk Conclusions and Observations

Ink Remover/Ink Degradant/Screen Degreaser

- Margin-of-exposure calculations indicate clear concerns for chronic dermal exposures to workers using diethylene glycol butyl ether in ink removal.

- Margin-of-exposure calculations also show possible concerns for developmental toxicity risks from dermal "immersion" exposures to diethylene glycol butyl ether. Routine dermal exposures, however, represent a very low concern for developmental toxicity risks.

Table V-180
Occupational Risk Estimates for Method 3, Alternative System

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Diethylene glycol butyl ether	NA	NA	NA	NA	NA	140	3.6	30	0.8
Propylene glycol	0.01	0.4	1.9	NA	NA	NA	NA	NA	NA
Ink Degradant									
Diethylene glycol butyl ether	NA	NA	NA	NA	NA	140	3.6	30	0.8
Propylene glycol	0.01	0.4	1.9	NA	NA	NA	NA	NA	NA
Degreaser									
Isopropanol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethoxylated nonylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

- Hazard quotient calculations for inhalation and dermal exposures to propylene glycol during ink removal indicate very low concern.

- Inhalation exposures to other components are very low.

- Risks from other components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Emulsion Removers (All systems)

- All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-181
Environmental Release Estimates in Screen Cleaning Operations
Method 3, Alternative System Omicron

	Release Under Each Scenario (g/day)						
	I			II	III	IV	
System	air	water	land	air	air	air	water
Ink Remover							
Diethylene glycol butyl ether	0	0	440	0	0	0	852
Propylene glycol	35	0	222	0.2	0.1	0.7	497
Ink Degradant							
Diethylene glycol butyl ether	0	330	0	0	0	0	0
Propylene glycol	35	158	0	0.2	0.1	0	0
Screen Degreaser							
Isopropanol	4.2	1	0	4.1	2	0	0
Ethoxylated nonylphenol	0	16	0	0	0	0	0
Water	0	510	0	0	0	0	0
Emulsion Remover							
Sodium periodate	0	19	0	0	0	0	0
Ethoxylated nonylphenol	0	13	0	0	0	0	0
Water	0	603	0	0	0	0	0

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Environmental Release Estimates from Screen Reclamation Processes
Screen Reclamation Method 3, Alternative System Omicron

From Ink Removal Operations:

Diethylene glycol butyl ether

852 g/day to water from rags at commercial laundry
440 g/day to landfill

Propylene glycol
36 g/day to air
497 g/day to water from rags at commercial laundry
222 g/day to landfill

From Screen Degreaser Operations:
Isopropanol
10.3 g/day to air
1 g/day to water

Ethoxylated nonylphenol
16 g/day to water

From Ink Degradant Operations
Diethylene glycol butyl ether
330 g/day to water

Propylene glycol
35.3 g/day to air
158 g/day to water

From Emulsion Removal Operations
Sodium periodate
19 g/day to water
Ethoxylated nonylphenol
13 g/day to water

Table V-182
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 3, Alternative System Omicron

Substance:	To Air:	To Water:	To Landfill:
Diethylene glycol butyl ether		330 g/day 852 g/day at laundry	440 g/day
Propylene glycol	71.3 g/day	158 g/day 497 g/day at laundry	222 g/day
Isopropanol	10.3 g/day	1 g/day	
Ethoxylated nonylphenol		29 g/day	
Sodium periodate		19 g/day	

Table V-183
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 3, Alternative System Omicron

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Diethylene glycol butyl ether	330 g/day 852 g/day at laundry	83 %	56.1 g/day 145 g/day	6×10^{-2} 1×10^{-1}
Propylene glycol	158 g/day 497 g/day at laundry	97 %	4.7 g/day 14.9 g/day	5×10^{-3} 1×10^{-2}
Isopropanol	1 g/day	83 %	0.2 g/day	2×10^{-4}
Ethoxylated nonylphenol	29 g/day	100 %	0	0
Sodium periodate	19 g/day	100 %	0	0

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-184
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 3, Alternative System Omicron

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Propylene glycol	71.3 g/day	1.5×10^{-1} ug/m^3	1
Isopropanol	10.3 g/day	2×10^{-2} ug/m^3	1×10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions And Observations

○ Health risks to the general population from both air and water exposures are very low for Method 3, SPAI Workshop Process.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 3, SPAI Workshop Process reach an ecotoxicity concern concentration.

Performance

Due to resource constraints in this project, it was not possible to demonstrate the effectiveness of Method 3. However, the Screen Printing Association International can be contacted for information on how this method performs.

Cost

Table V-185
Summary of Cost Analysis for Method 3, Alternative System Omicron

Description		Baseline (Traditional System 4)	Alternative System Omicron[a]
Facility Characteristics			
Average screen size (in^2)		2,127	2,127
Average # screens/day		6	6
Cost Elements per Screen			
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	17.9 3.92
Materials and Equipment	# of rags used Cost ($)	3 0.45	2.25 0.34
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	8.0 0.22	4.87 0.37
	Emulsion Remover Average Volume (oz.) Cost ($)	3.5 0.13	4.33 0.33
	Haze Remover Average Volume (oz.) Cost ($)	3.0 0.12	--- ---
	Degreaser Average Volume (oz.) Cost ($)	--- ---	3.0 0.21
	Degradant Average Volume (oz.) Cost ($)	--- ---	3.0 0.23
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	0 0.00
Totals			
Total Cost ($/screen)		6.27	5.57
Total Cost ($/year)		9,399	8,358

[a] Alternative reclamation system costs were estimated using a combination of performance demonstration results from facilities testing product system Omicron and from SPAI on the SPAI Workshop Process.

Method 4: Alternative Screen Reclamation Technology using High-Pressure Water Blaster

Method 4 is currently in use at some screen printing facilities as an alternative to traditional screen reclamation. Method 4 utilizes the action of a high-pressure water blaster (3000 psi) so that the need for ink removal chemicals is eliminated (see Figure V-5). Emulsion and haze remover chemicals are still applied to the screen, and the water blaster also aids in removal of stencil and haze. Because an ink remover is not used in screen reclamation in Method 4, source reduction, the highest priority in the pollution prevention hierarchy, is achieved. However, simply because the ink remover is not used does not mean that occupational and population risk is low. The intrinsic hazard of the particular chemicals used in emulsion and haze remover products must be combined with worker and general exposure to the chemicals to generate a risk assessment. In the following discussion of Method 4, data detailing occupational and population exposure are presented to support overall risk conclusions for a system designated Alternative System Theta. One manufacturer supplied the actual technology and chemicals, as well as chemical formulations, for use in Method 4. The process for Method 4 is detailed below:

Method 4 Process

○ Remove excess ink from the screen surface; do not apply ink remover.

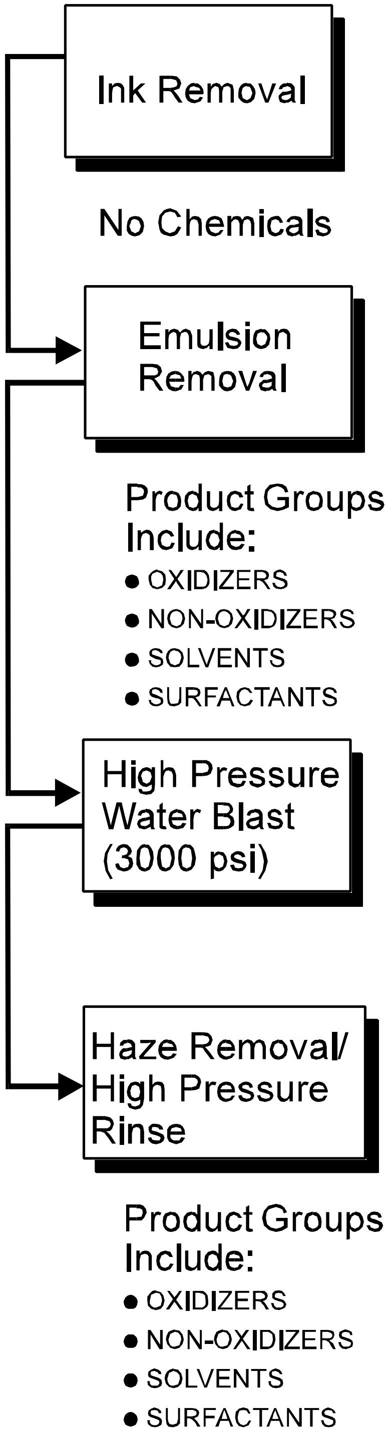
○ Spray emulsion remover on the print side of the screen. Allow to work for 10-30 seconds. Wash both sides of the screen from top to bottom with a 3000 psi pressure wash to remove ink and stencil residue.

○ Apply haze remover to screen with a rag soaked in product. Allow screen to set for 3 minutes. Rinse screen with 3000 psi water blaster from the bottom to the top on the print side of the screen. Reverse screen and rinse on the ink side.

The manufacturer suggests that the following equipment is necessary for the use of this technology: washout booth with backlight capability, high-pressure washing system, spray wand with pattern control nozzle, dual low pressure chemical applicator system. As in all screen reclamation methods, printers should consider the composition of the reclamation effluent and whether it meets federal, state and local regulations for discharges to sewer or septic tanks. Because this method involves the use of large quantities of water, energy and natural resource issues should also be considered. Reference Chapter 7 for a discussion of this topic.

In this assessment of Method 4 using Alternative Technology Theta, there is no comparable assessment of a traditional system of screen reclamation products. Reference Methods 1 and 2 for a determination of the occupational and population risks, as well as performance, of a traditional screen reclamation product system.

Figure V - 5
Process Steps Included in Method 4



Alternative Technology Theta Chemical Formulations

Ink Remover:	None
Emulsion Remover:	Sodium periodate Water
Haze remover:	Cyclohexanone Furfuryl alcohol Alkali/caustic

Occupational Exposure

Table V-186
Occupational Exposure Estimates for Method 4, Alternative System Theta

System	Inhalation (mg/day)				Dermal (mg/day)	
	I	II	III	IV	Routine	Immersion
Emulsion Remover[a]						
Sodium periodate	0	0	0	0	1250	5820
Water	0	0	0	0	312	1460
Emulsion Remover (diluted 1:3)						
Sodium periodate	0	0	0	0	312	1460
Water	0	0	0	0	1250	5820
Haze Remover						
Alkali/Caustic	0	0	0	0	515	2400
Cyclohexanone	25	0.3	0	0	515	2400
Fufural alcohol	0	0	0	0	530	2480

[a] This system can be used with or without diluted emulsion remover, depending on the needs of the facility.

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry

Occupational Risk Conclusions and Observations

Haze remover

○ Hazard quotient calculations indicate marginal concerns for chronic dermal exposures and very low concern for chronic inhalation exposures to cyclohexanone during haze removal.

Table V-187
Occupational Risk Estimates for Method 4, Alternative System Theta

Name	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Emulsion Remover									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Emulsion Remover (diluted 1:3)									
Sodium periodate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Water	NA	NA	NA	NA	NA	NA	NA	NA	NA
Haze Remover									
Alkali/Caustic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexanone	0.07	1.5	6.8	196	NA	NA	NA	NA	NA
Furfuryl alcohol	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.

[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.

[c] NOAEL means No Observed Adverse Effect Level.

[d] LOAEL means Lowest Observed Adverse Effect Level.

○ Margin-of-exposure calculations show low concern for developmental and reproductive toxicity risks from inhalation exposures to cyclohexanone. Reproductive and developmental toxicity risks from dermal exposures to cyclohexanone could not be quantified.

○ Inhalation exposures to other components are very low.

○ Risks from other haze remover components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Emulsion Removers (All systems)

All of the systems that employ an emulsion remover use either a strong oxidizer such as hypochlorite or periodate or a strong base such as sodium hydroxide. The haze removers in Alpha, Epsilon, Gamma, Mu, Omicron, and Theta also contain these compounds. All of these materials present a high concern for skin and eye irritation and tissue damage if workers are exposed in the absence of proper protective clothing. None of the emulsion removers present significant inhalation risks.

Environmental Releases

Table V-188
Environmental Release Estimates in Screen Cleaning Operations
Method 4, Alternative System Theta

	Release Under Each Scenario (g/day)						
	I			**II**	**III**	**IV**	
System	**air**	**water**	**land**	**air**	**air**	**air**	**water**
<u>Emulsion Remover</u>							
Sodium periodate	0	177	0	0	0	0	0
Water	0	44	0	0	0	0	0
<u>Emulsion Remover (diluted 1:3)</u>							
Sodium periodate	0	44	0	0	0	0	0
Water	0	177	0	0	0	0	0
<u>Haze Remover</u>							
Alkali/Caustic	0	291	0	0	0	0	0
Cyclohexanone	53	239	0	0.7	0.4	0	0
Fufural alcohol	0	300	0	0	0	0	0

Table V-188
Environmental Release Estimates in Screen Cleaning Operations
Method 4, Alternative System Theta

	Release Under Each Scenario (g/day)						
	I			**II**	**III**	**IV**	
System	**air**	**water**	**land**	**air**	**air**	**air**	**water**

Scenario I = reclaiming 6 screens per day; each screen is approximately 2100 in^2; Scenario II = pouring 1 ounce of fluid for sampling; Scenario III = transferring chemicals from a 55 gallon drum to a 5 gallon pail; Scenario IV = storing waste rags in a drum and transferring them to a laundry.

Table V-189
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Using Screen Reclamation Method 4, Alternative System Theta

Substance:	To Air:	To Water:	To Landfill:
Sodium periodate		44 g/day	
Alkali/caustic		291 g/day	
Cyclohexanone	54.1 g/day	239 g/day	
Furfural alcohol		300 g/day	

Releases to Water from a Single Facility

Table V-190
Estimated Releases to Water from Traditional Formulations from Screen Reclamation at a Single Facility Using Screen Reclamation Method 4, Alternative System Theta

Substance	Amount Released to Water from Facility	Waste water Treatment Removal Efficiency	Amount to Water After Waste water Treatment	Daily Stream Concentration, ug/L[a] for 1000 MLD Receiving Water
Sodium periodate	44 g/day	100 %	0	0
Alkali/caustic	291 g/day	100 %	0	0
Cyclohexanone	239 g/day	83 %	41 g/day	4×10^{-2}
Furfural alcohol	300 g/day	97 %	9 g/day	9×10^{-3}

[a] ug/L is Micrograms per liter, which is parts per billion for a substance in water. MLD is Million liters per day.

Releases to Air from Individual Screen Printing Facilities

Table V-191
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility Using Screen Reclamation Method 4, Alternative System Theta

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Cyclohexanone	54.1 g/day	1.1×10^{-1}	8×10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions And Observations

- Health risks to the general population from both air and water exposures are very low for Method 4, Alternative Screen Reclamation Technology using High Pressure Water Blaster.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ None of the single facility releases of Method 4, Alternative Screen Reclamation Technology using High Pressure Water Blaster.

Performance

General Summary of Alternative Reclamation Technology Theta Performance

The performance of the Alternative Technology Theta was demonstrated at Facility 1 under conditions similar to those used at SPTF for alternative system testing. This facility, however, demonstrated the performance of an alternative screen reclamation technology, instead of an alternative chemical system. The alternative technology demonstrated was a high pressure wash system with a 3000 psi spray applicator. When reclaiming screens with System Theta, an emulsion remover and a haze remover are used, but no ink remover is needed. Several different types of emulsion and haze removers are sold with this technology. The performance demonstration was conducted using the chemical products that are normally used by this volunteer facility which are supplied by the Theta equipment manufacturer. Therefore, this performance evaluation of this technology is based only on those chemicals used in the testing.

The SPTF staff felt the performance of the system was very good. During the demonstration, the ink was carded off on both sides of the screen which caused some complications during testing. Since the screen was not actually used for printing, the ink on the stencil side transferred through to the print side when the screen was carded. To remove this excess ink, the print side was also scraped. The ink on the print side of the screen was more difficult to remove and this ink also made it harder to remove the emulsion. Under normal printing operations, ink does not reach the print side of the screen, therefore SPTF staff thought this difficulty would not occur at a printing facility. The observer felt System Theta could efficiently and effectively clean the screen, while reducing the labor, effort, and quantity of chemicals required for reclamation.

Alternative Screen Reclamation Technology Theta Profile

Reclaim screens with Alternative Screen Reclamation Technology Theta as follows:

○ <u>Ink Removal and Emulsion Removal</u>. Card up excess ink from the screen. Dilute the emulsion remover as instructed. Spray the emulsion remover on the print side of the screen. Allow to sit for 10 to 30 seconds. Wash both sides of the screen from the bottom to the top with the 3000 psi spray applicator to remove the ink and stencil residue.

○ Haze Removal. With a rag soaked in haze remover, rub the screen on the ink side and allow to set for 3 minutes. Rinse from the bottom to the top on the print side of the screen with the 3000 psi applicator. Turn the screen and rinse with System Theta equipment on the ink side. For tough stains, allow the haze remover to set for up to 10 minutes.

Alternative System Performance Evaluated by SPTF

Alternative Screen Reclamation Technology Theta was tested by SPTF on three screens (one with a solvent-based ink, one with a UV-curable ink, and one with a water-based ink). Since SPTF does not have the System Theta equipment on-site, the test was performed at a volunteer printing facility that regularly uses the Theta equipment. SPTF prepared the test screens using the same parameters as were used for the testing of alternative chemical systems (these parameters are listed in the appendix). At the printing facility, the inks were applied to the stencil side of the screen, and excess ink was carded off. However, the ink was applied for testing purposes only (screens were not used for printing) and when excess ink was carded off, it transferred to the print side of the screen. When the ink on the print side was scraped off, it spread to cover the stencil. Inks were allowed to dry for 18 hours before reclamation. The ink residue on both sides of the screen does not accurately represent the conditions in typical printing operations, however, it does represent a worst case condition. SPTF thought that the presence of ink on the print side of the screen lengthened the wash time required to remove the ink and the emulsion.

On the screen with the solvent-based ink and the screen with water-based ink, the stencil dissolved easily with the application of the high pressure water; no scrubbing was needed. There was no emulsion or ink residue left in the screen, but there was a medium ink stain remaining on the screen with solvent-based ink and a very light stain on the water-based ink screen. On both screens, all of the ink and stencil did dissolve after less than four minutes of washing with the high pressure sprayer, however, the areas of the emulsion where the ink was on the print side of the screen did not dissolve as quickly as the areas where there was no ink on the print side. SPTF staff noted that these conditions did not represent an actual printing situation well and that they did not feel that the extra time was a fault of the high pressure spray system. The haze remover completely eliminated the stains. When the haze remover was applied, the product immediately dissolved the ink stain, even before the waiting period or the pressure wash.

Results were similar for the screen with UV ink. In most areas the stencil dissolved very easily without any scrubbing. After 4 minutes of water blasting, emulsion was still present in blocks where the ink was scraped on the print side of the screen. Again, SPTF staff felt that the residual emulsion was caused by the test conditions and that it did not indicate poor performance on the part of the Theta system. Some ink stain was remaining especially in areas where the emulsion was left. The haze remover removed all of the ink, leaving only a very light stain, but the emulsion was still remaining in approximately one-third of the blocks. To remove the emulsion, the emulsion remover was reapplied and allowed to sit for 20 seconds. After water blasting the screen again, the emulsion was completely removed.

Overall, the SPTF staff present at the demonstration thought System Theta was a very efficient and effective technique for screen cleaning. Use of the system could minimize the quantity of chemicals needed for screen reclamation by eliminating the ink remover and by using the high water pressure to reduce the quantity of emulsion and haze remover required. System Theta also reduces the labor time and effort needed to reclaim a screen.

Alternative Technology Performance Table

The following table highlights the observed performance of the Alternative Screen Reclamation Technology Theta during the product tests performed by SPTF.

Cost

Data collected by SPTF staff during a facility visit and equipment specifications provided by the manufacturer were used to develop the cost for this method. The capital cost of this equipment was annualized by the method described in Chapter 3, added to the recurring operating and maintenance costs and divided by the number of screens reclaimed per year to arrive at the per screen equipment costs. Water, wastewater and electrical usage costs were included in the cost estimate for this method only. As in all other cost estimations, the cost of a filtration system was not included as the analysis was focused on quantifying cost differences between reclamation systems, without accounting for filtration costs that may occur in all cases.

Table V-192
Alternative Screen Reclamation Technology Theta

		Performance					Demonstration Conditions			
	System Component	**Avg Drying Time Before Using Product**	**Average Quantity Applied**	**Average Cleaning Time**	**Average Effort Required**	**Overall System Performance**	**Ink type**	**Emulsion type**	**Mesh type; Thread count**	**Average Screen Size**
SPTF Testing at Volunteer Facility 1										
Solvent-based Ink	*Ink and Emulsion Removal*	18 hours	0.5 oz.	2.7 mins	Low	Removed stencil completely without scrubbing; where ink was put on print side of stencil, emulsion was more difficult to remove.	Solvent-based	Dual-cure direct	Polyester; 245 threads/inch	360 in^2
	Haze Remover	0 mins	1.5 oz.	1.7 mins	Low	Screen very clean; virtually no stain remaining.				
UV-curable Ink	*Ink and Emulsion Remover*	18 hours	1.0 oz.	5.5 mins	Low	Removed most of the stencil easily without scrubbing; where ink was scraped onto print side of screen, stencil residue remained.	UV-cured	Dual-cure direct	Polyester; 390 threads/inch	360 in^2
	Haze Remover	0 mins	1.5 oz.	1.5 mins	Low	No ink residue, and very light stain. Parts of emulsion remained; a second application of emulsion remover was needed.				
Water-based Ink	*Ink and Emulsion Remover*	18 hours	1.0 oz.	3.3 mins	Low	Removed stencil completely without scrubbing; where ink was put on print side of stencil, ink was more difficult to remove.	Water-based	Dual-cure direct	Polyester; 245 threads/inch	360 in^2
	Haze Remover	0 mins	1.5 oz.	1.5 mins	Low	Screen very clean; virtually no stain remaining.				

Table V-193
Method 4: Summary of Cost Analysis for Alternative Technology Theta

Cost Element Description		Baseline (Traditional System 4)	Cost Element Description	Alternative System Theta
				Facility 1
Facility Characteristics				
Average screen size (in^2)		2,127	Average screen size (in^2)	360
Average # screens/day		6	Average # screens/day	13
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min) Cost ($)	24.4 5.33	Time spent pressure washing, applying and removing removing reclamation products (min) Cost ($)	5.4 1.18
Materials and Equipment	# of rags used Cost ($)	3 0.45	Pressure Wash Equipment Cost ($)	 0.25
Reclamation Product Use	Ink Remover Average Volume (oz.) Cost ($)	 8.0 0.22	Water Use (gal.) Electricity Use (kWhr) Utility Cost ($)	10.7 0.65 0.11
	Emulsion Remover Average Volume (oz.) Cost ($)	 3.5 0.13	Emulsion Prep Product Average Volume (oz.) Cost ($)	 0.8 0.11
	Haze Remover Average Volume (oz.) Cost ($)	 3.0 0.12	Haze Remover Average Volume (oz.) Cost ($)	 1.5 0.36
Hazardous Waste Disposal	Amount (g) Cost ($)	34 0.02	Amount (g) Cost ($)	0 0
Totals				
Total Cost ($/screen)		6.27	Total Cost ($/screen)	2.02
Normalized[a]		6.27	Normalized[a]	4.53
Total Cost ($/year)		9,399	Total Cost ($/year)	6,315
Normalized[a]		9,399	Normalized[a]	6,797

[a] Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

[b] **No filtration system costs were included in this calculation.**

Note: For additional information regarding product performance see performance demonstration summaries.

Method 5: Automatic Screen Reclamation Technology

Automatic screen washers are commercially available technologies that remove ink, or in some cases, ink, emulsion and haze, by focusing appropriate reclamation products on a screen mesh surface within a fully enclosed unit. Limited information was available on this technology because those manufacturers who manufacture this type of equipment chose not to participate in the performance demonstration or other facets of the project. The system can be selective, in that it can be used to remove ink only, or to completely reclaim screens. These units employ a washout booth, pressurized sprayer/applicator, and filtration system to effectively remove ink; refer to Chapter 6 for a discussion of these equipment costs. Because these systems have a fully enclosed cleaning area, the amount of occupational exposure to the chemical reclamation system in use can potentially be minimized.

Features

Although the automatic screen washing technology can consist of any number of options, automatic screen washers have several basic components. The general shape for the entire unit is a large, fully enclosed, metal cube that can house a variety of screen sizes (see Figure V-6). The screen to be cleaned is placed inside the chamber and secured with clamps. When the screen is in place and the enclosure door closed, the cleaning process can begin.

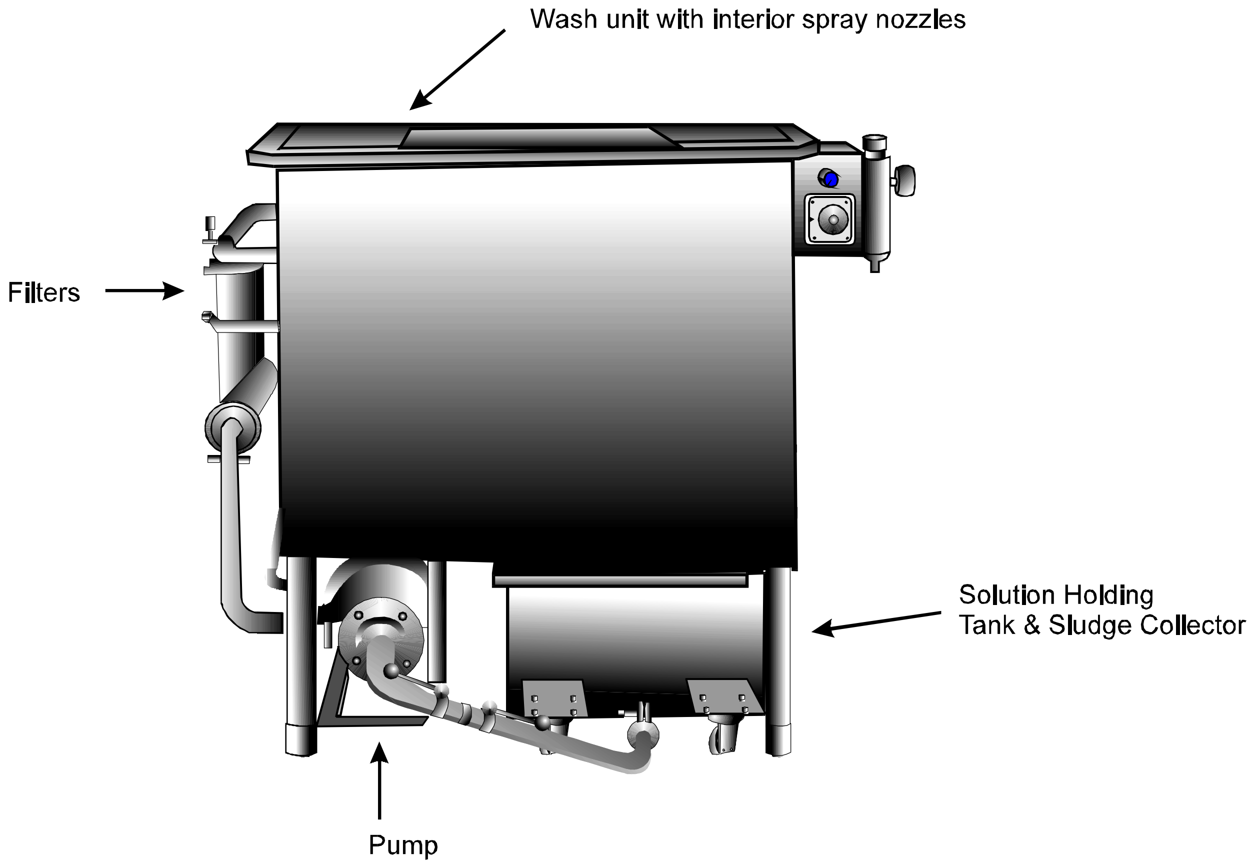
First, a mobile mechanical arm sprays solvent through one or more pressurized applicator nozzles onto the screen for any number of preset cleaning cycles. These applicator systems can operate in various ways depending on the system, but most apply the cleaner at pressures ranging from 30 psi to 150 psi (see Chapter 6 for further information on pressurized applicator systems). The used solvent then drains off the screen and usually drops directly into the filtration system. The effluent travels through the filtration system to remove the contaminants from the waste stream, and the recycled solvent can often be recirculated for subsequent use. These filtration and recirculation systems are available with various specifications and options and are discussed in more detail in Chapter 6.

While this is the generic washing system for ink removal, many other variations are currently available. One available option is multi-stage ink removal. Some automatic screen washers are equipped to remove the ink in several stages or cycles such as washing, rinsing, or blowing, and equipment employing any or all of these cycles are available. In such a system, the ink would be completely washed out in the first cycle, rinsed again to remove stubborn residue, and blown dry using air pressure. Automatic screen washers are also available to remove emulsion and haze, as well as ink, from screens. The general process for this is to apply an emulsion remover to the screen (usually with hot water and a spray applicator) after ink removal is complete; the screen is then pressure-washed and rinsed with water. A haze remover can then be applied with a spray applicator. For more specific information on automatic screen washing units, printers should consult manufacturers, product literature, and other printers.

Feasibility

The automatic screen washing systems may not be a feasible option for a large segment of the screen printing industry because they are predominantly manufactured for larger reclaiming operations. The size and speed of these systems allow a printer to remove the ink from large quantities of screens in a very short period of time; most systems can clean a screen

Figure V-6
The Typical Exterior of an Automatic Screen Washing System Used for Ink Removal



in under five minutes. In addition, the cost of an automatic screen washing system can discourage most small printers from purchasing one. Some automatic systems that remove only ink can be purchased for approximately $5,000 to 7,000; the majority of these units cost between $15,000 and 30,000. The more expensive units may include emulsion and haze removal. Such a high cost for reclamation equipment may make automated screen systems an implausible method of screen reclamation for smaller printers. On the other hand, those printers willing to pay the cost for such a technology can largely dictate the exact specifications needed; an automatic system can be created to suit the need of virtually any facility. The size of an automated system may vary to allow screens as large as 60"x 70" to be cleaned. These units may also have multiple interior cleaning areas.

Evaluation

Due to the lack of manufacturer participation, the demonstration of the performance of an automatic screen washer was not undertaken. However, a risk assessment was developed for an automatic screen washing system used by a facility that participated in the performance demonstration; this particular screen washer only removed ink. Experimental parameters used in the occupational exposure and population exposure calculations were drawn from the data available from this single site. Because the manufacturer of the ink remover product used in the screen washer did not participate in the project, the formulation for the ink remover was not available (considered proprietary). The risk assessment could not be undertaken for the actual solvents used in the screen washer because the composition of the ink remover was unknown. The experimental parameters for the screen washer were instead used with two other ink removers, mineral spirits and lacquer thinner, to develop a risk assessment. These two ink removers were also assessed in screen reclamation in Methods 1 and 2 as components of Traditional Systems 1 and 3.

Process Description

This automatic screen washer is an enclosed system used for ink removal only. It consists of two tanks, a wash tank and a rinse tank, each with 35 gallons of the same solvent. The screens are held stationary in the washer machine while an arm with spray nozzles moves up and down the stationary screens, spraying ink remover solvent. The solvent runs off the screen back into the tank from which it came. The machine is programmed to activate the pump for the appropriate tank (wash or rinse) at specific intervals for different spray cycles.

The wash tank gets dirtier at a quicker rate than the rinse tank because the rinse tank cleans off the screen for the last time. When the wash cycle solvent is eventually replaced, the spent solvent is pumped out of the tank into a drum and allowed to settle. The pumping is performed by opening and closing valves in the machine. The solvent on top of the sediment is pumped back into the wash tank after the sediment settles. The spent rinse solvent is pumped into the wash tank and fresh solvent is pumped into the rinse tank. According to one facility that uses an automatic screen washer, approximately 7-10 gallons of solvent are lost during 55 operating days and the bath is changed every 8-9 months. The settled sediment from the spent wash solvent is disposed of as hazardous waste.

Any solvent drippage from screens during screen removal is collected and returned to the tank. The trap in the reclamation sink generates a solids waste. According to the facility, about 0.5 pounds of waste is generated per year and disposed of as municipal waste.

Occupational Exposure and Environmental Releases

Assumptions

○ The amount of occupation exposure and risk depends upon the amount of cleaner released from the automatic screen washer.

○ 35 screens are cleaned per day

○ Automatic cleaning for 6 minutes per screen

○ Total machine operating time is 210 minutes per day

○ 20 oz. per day of solvent losses occur due to volatilization

○ 3 employees work with the screen washer

○ 15 minutes per employee for screen removal

The exposure/release scenario includes air releases due to volatilization of the ink remover solvent during machine operation. Dermal contact of the ink remover solvent would occur during screen removal. Spent baths and solids waste from the machine trap are periodically disposed of.

EPA has evaluated occupational exposure and risk of automatic screen washers using chemical systems based on Traditional System 1 and Traditional System 3.

Table V-194
Environmental Release Estimates from Automatic Screen Washer

Solvent System	Releases to Air (g/day)
Ink remover solvent	555

Table V-195
Occupational Exposure from Automatic Screen Washer

Solvent System	Inhalation (mg/day)	Dermal (mg/day)
Ink remover solvent	266	3,900

Estimation Methodology

In operation, the automatic screen cleaner sprays the screen with solvent and then allows the screen to drip dry. This process is repeated for the rinse cycle. Releases of the solvent to the air consist of the following:

1) Volatilization from drops of the solvent as they are being sprayed toward the screen.
2) Volatilization from the screen as it drips.
3) Volatilization from the liquid solvent pool.

The first part consists of forced-convection mass transfer past a set of spheres. The second involves free convection from a vertical plate. These processes are not described by the estimation methods in the CEB manual. If the unit were open to atmosphere, equations would be needed for all of these processes. However, the unit is closed during operation, so that the three evaporation sources merely serve to saturate the vapor space in the machine. When the machine is opened, this vapor is released to the atmosphere and the workers are exposed to it. The mass of solvent in this released vapor is (assuming complete saturation of the vapor space):

$$(\frac{V}{24.45})(\frac{P}{760})M$$

where

V is the volume of the headspace (l)
P is the vapor pressure of the solvent (mmHg)
M is the molecular weight of the solvent (g/mol)

Now, we know that 8.5 gallons of solvent is lost in this way over 55 working days. At a solvent density of 0.95 g/cc, this corresponds to 555 g/day. The vapor pressure of the solvent is 3.6 mmHg. The molecular weight is probably close to 150 g/mol. Isobutyl isobutyrate, a known component of the mixture, has a molecular weight of 144 g/mol. Other compounds with the correct volatility (and we know that the solvent consists entirely of VOCs) have molecular weights in the same range. Thus, the volatilization rate of any other solvent will be:

$$555 \times (\frac{P}{3.6})(\frac{M}{150})$$

As noted in our earlier reports, the worker exposure in mg/day equals the air release in g/day times 0.48. Thus, the worker exposure in mg/day is:

$$0.48 \times 555 \times (\frac{P}{3.6})(\frac{M}{150})$$

Thus, if the total vapor pressure of any other solvent and the average molecular weight of its vapors can be computed, the airborne releases and worker exposure can be estimated.

These are worst-case estimates which assume that all of the leakage occurs during removal of the screens, and none occurs overnight or on weekends when workers are absent.

Example 1. *Estimate the air releases and environmental exposure for ink removal from 6 screens using the automatic screen washer.*

For ink remover solvent, 555 g of ink are released to air per day during the cleaning of 20 screens. For 6 screens, the amount released to air per day will be:

$$555 \text{ x } (6/35) = 95 \text{ g/day}$$

For 6 screens, the worker exposure is:

$$0.48 \text{ x } 95 = 46 \text{ mg/day}$$

Example 2. *Estimate the air releases and environmental exposure for ink removal from 6 screens using the automatic screen washer with mineral spirits as the ink remover.*

Mineral spirits (light hydrotreated) has the following physical properties:

Molecular weight:	86
Vapor pressure:	1 mm Hg
Density:	0.78 g/L

For mineral spirits, the volatilization will be:

$$95 \text{ x } (1/3.6) \text{ x } (86/150) = 15.1 \text{ g/day}$$

The worker exposure will be:

$$0.48 \text{ x } 95 \text{ x } (1/3.6) \text{ x } (86/150) = 7.3 \text{ gm/day}$$

Example 3: *Estimate the Air Releases and Environmental Exposure for Ink Removal from 6 Screens Using the Automatic Screen Washer with Lacquer Thinner as the Ink Remover.*

Occupational Risk Estimates

Quantitative risk estimates could not be determined for this system due to insufficient data. See risk conclusions for areas of concern for this system.

Occupational Risk Conclusions

Automatic Screen Washer - Mineral spirits (ink remover only)

- ○ Inhalation exposures were significantly lower (reduced by about 70%) than the exposures during manual use of this system. Risks could not be quantified because of limitations in hazard data.
- ○ Dermal exposures can still be relatively high.

Automatic Screen Washer - Lacquer Thinner (ink remover only)

- ○ Hazard quotient calculations indicate marginal concerns for chronic inhalation exposures to toluene, methyl ethyl ketone, and methanol.

Table V-196
Occupational Risk Estimates for Auto Screen Washers Using Lacquer Thinner as the Ink Remover

	Hazard Quotient[b]			Margin Of Exposure[a]					
		Dermal		Inhalation		Dermal			
						Routine		Immersion	
Name	Inhalation	Routine	Immersion	NOAEL[c]	LOAEL[d]	NOAEL	LOAEL	NOAEL	LOAEL
Ink Remover									
Methyl ethyl ketone (2-butanone)	7.7	56		NA	NA	NA	NA	NA	NA
Butyl acetate normal	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methanol	1.2	5.6		NA	NA	NA	NA	NA	NA
Naphtha, light aliphatic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	5.6	111		NA	NA	NA	NA	NA	NA
Isobutyl isobutyrate	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] Margin of Exposure (MOE) values above 100 for a NOAEL and 1000 for a LOAEL indicate low risk.
[b] Hazard Quotient is the ratio of the estimated chronic dose/exposure level to the Reference Dose (RfD) or the Reference Concentration (RfC). Hazard Quotient values less than 1 imply that adverse effects are very unlikely to occur.
[c] NOAEL means No Observed Adverse Effect Level.
[d] LOAEL means Lowest Observed Adverse Effect Level.

Table V-197
Estimated Air Releases and Environmental Exposure for Ink Removal Screens Using the Automatic Screen Washer with Lacquer Thinner as the Ink Remover

Lacquer Thinner	wt%	Molecular Weight	Mole fraction	Vapor pressure (mm Hg)	Partial pressure (mm Hg)	Emission	Inhalation	Dermal
Methyl ethyl ketone	30	72.11	0.34	77.50	26.43	335.23	160.91	1,170
Butyl acetate	15	116.2	0.11	12.80	1.35	27.68	13.29	585
Methanol	5	32.04	0.13	126.88	16.23	91.47	43.91	195
Naphtha, light aliphatic	20	86	0.19	20.00	3.81	57.67	27.68	780
Toluene	20	92.14	0.18	28.00	4.98	80.74	38.76	780
Isobutyl isobutyrate	10	144.21	0.06	3.20	0.18	4.61	2.21	390

○ Hazard quotient calculations indicate clear concerns for chronic dermal exposures to toluene and methyl ethyl ketone and marginal concerns for dermal exposures to methanol.

○ The risks described above are slightly lower than the corresponding risks during manual use of this system.

○ Risks from other components could not be quantified because of limitations in hazard data, although dermal exposures to all components could be relatively high.

Table V-198
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility Automatic Screen Washer, Mineral Spirits

Substance:	To Air:	To Water:	To Landfill:
Mineral Spirits	15.1 g/day		

Estimated Releases to Air from Individual Screen Printing Facilities

Table V-199
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Automatic Screen Washer, Mineral Spirits

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Mineral Spirits	15.1 g/day	3 x 10^{-2}	2 x 10^{-1}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

Table V-200
Summary of Estimated Daily Environmental Releases from a Hypothetical Facility
Automatic Screen Washer, Lacquer Thinner

Substance:	To Air:	To Water:	To Landfill:
Methyl ethyl ketone	335 g/day		
n-butyl Acetate	27.7 g/day		
Methanol	91.5 g/day		
Aromatic solvent naphtha	57.7 g/day		
Toluene	80.7 g/day		
Isobutyl isobutyrate	4.6 g/day		

Table V-201
Air Release, Concentration and Potential Dose Estimates from a Single Model Facility
Automatic Screen Washer, Lacquer Thinner

Substance	Amount of Releases per day	Highest Average Concentration 100 M away	Annual Potential Dose, mg/year[a]
Methyl Ethyl Ketone	335 g/day	7×10^{-1} ug/m^3	5
n-butyl acetate	27.7 g/day	5×10^{-2} ug/m^3	4×10^{-1}
Methanol	91.5 g/day	2×10^{-1} ug/m^3	1
Naphtha, light aliphatic	57.7 g/day	1×10^{-1} ug/m^3	8×10^{-1}
Toluene	80.7 g/day	2×10^{-1} ug/m^3	1
Isobutyl isobutyrate	4.6	9×10^{-3} ug/m^3	7×10^{-2}

[a] This estimates doses for people living 100 Meters from the hypothetical facility. The actual number of people who would fall into this range can be determined from census data, if the facility location is known. The model used to calculate concentrations is more completely explained in the Overview by Media-Air Section in Chapter III. To calculate the annual potential dose, the concentration is multiplied by the amount a person will breathe (20 m^3/day) and the number of days per year (365), and the units are converted to mg/year by dividing by 1000.

General Population Risk Conclusions And Observations

○ Health risks to the general population from both air and water exposures are very low for Method 5, Automatic Screen Reclamation Technology.

Although air releases were evaluated for only a single facility, it is very unlikely that an analysis of cumulative air releases would lead to different risk conclusions. Examples of general population exposure and risk estimates are shown for Method 2, Traditional System 1 in Methods 1 and 2 and Alternative System Chi in Method 2; please reference these sections as illustrative examples. Hazard Quotient values below one indicate very low risk. Margin-of-Exposure (MOE) values above 100 for a NOAEL or above 1000 for a LOAEL indicate very low risk.

Ecological Risks From Water Releases Of Screen Reclamation Chemicals

○ Cumulative releases of mineral spirits present a concern for risk to aquatic species. The largest contributor to these releases is the hypothetical commercial laundry that launders the shop rags used by the area's screen printers.

○ None of the other components of any of the two traditional ink removers reached an ecotoxicity concern concentration, even when considering the cumulative releases from all shops in the area.

○ None of the single facility releases of the traditional ink removers reach an ecotoxicity concern concentration.

Cost

Two cost estimates were developed which reflect both the baseline facility's operations and size and the range of equipment available. Typically, automatic screen washers substitute for the ink removal step; emulsion removal and haze removal may still be required.

Automatic Screen Washer #1 is the unit used by the facility that also participated in the performance demonstration. It was a large capacity (in terms of the maximum size of screen) enclosed washer with a fully automated feed system to move the screens through separate wash and rinse areas. It was assumed that mineral spirits was present in both reservoirs. As mineral spirits are used in the ink removal step, the cost analysis of automatic screen washer #1 assumes the same emulsion and haze removal costs as in the baseline. Its original manufacturer's purchase price of $95,000 was used as a basis for the cost analysis, although in actuality, the facility purchased the equipment second-hand at auction. The only operating costs were related to solvent make-up (daily) and replacement of the reservoirs' contents 70 gallons (every eight to nine months). Time spent loading and unloading the washers was taken from manufacturer's documentation of the equipment. As the equipment's electrical rating was not available from information provided by the distributor, electrical costs were not included. The price of mineral spirits ($4.00/gallon) was taken from the Workplace Practices Questionnaire. Emulsion removal and haze removal costs were assumed to be similar to those of the baseline system.

Automatic Screen Washer #2 is a smaller unit on which some minimal information was gathered. Screens must be loaded and unloaded by hand. Because it uses a solvent with lower volatile fraction than #1, more solvent remains on the screen and must be washed off following ink removal. Time spent loading and unloading the washers was taken from manufacturer's documentation of the equipment. Two pumps operate using compressed air which is reportedly available from other sources at the facility; the cost of a generator was not included in the cost analysis. The price of the ink remover was provided by the equipment supplier. Emulsion removal costs were assumed to be similar to those of the baseline system. The manufacturer indicated that a haze remover was not required given the formulation of the ink remover.

Chapter VI
Overall Pollution Prevention Opportunities for Screen Reclamation

Screen Disposal as a Method of Pollution Prevention

Screen reclamation is typically a chemical and labor-intensive process. During the course of the assessment of various screen reclamation methods, it was proposed that disposal of imaged screens, rather than reclamation, might be a feasible alternative. It was known that some screen printers with long production runs and extremely small screens, such as those used to print on pill bottles, simply cut the screen mesh out of the frame after completion of the production run. The question arises as to whether printers who use larger screens in shorter production runs could also feasibly dispose of their screens. By simply disposing of the screen, printers could eliminate the high cost of reclamation chemicals, labor time associated with screen reclamation, and occupational and population exposure to the chemicals used in screen reclamation, thus reducing risk. Conversely, printers would have to dispose of more screens, which could be expensive if the ink and emulsion components were required to be disposed of as hazardous waste. The time involved in preparing screens for printing, especially stretching and tensioning, would also be increased.

It would be difficult to directly compare the two options in terms of pollution prevention potential due to the different types of source reduction achieved by the two methods. While screen disposal may reduce chemical usage, screen reclamation might involve less hazardous waste disposal, particularly if filtration systems are used in the reclamation process. Other areas, such as screen performance, are also not easily defined. Some screen printers claim that screen performance improves with screen use because the tension throughout the screen mesh becomes evenly distributed. Because it is experimentally difficult to assess such claims, only a cost analysis of screen reclamation versus screen disposal was undertaken. Information on screen disposal was not collected as part of the performance demonstrations.

The cost estimate of screen disposal was developed for comparison to other reclamation methods. One cost estimate was developed to reflect the baseline facility's operations and size; it is profiled in Table VI-1. It should be noted that screen disposal is most cost effective under two circumstances not assumed for the model facility's operations: where production runs approach the useful life of a screen and where the size of the screen is relatively small. A number of assumptions were used to estimate the cost of this substitute method, including:

- No other changes in operations or equipment were required.
- Waste screens do not need to be handled as hazardous waste under RCRA, which would greatly increase the estimated cost.
- The replacement of screens (after reaching the end of the useful life of the mesh) was not considered in the baseline nor in any of the other reclamation methods; it is estimated to be approximately $0.60/screen reclamation. Consequently, this value was deducted from the total cost of this method.
- The average wage rate of screen stretchers ($6.87), which is slightly higher than for screen reclaimers, was used to calculate labor costs for this method.

Table VI-1
Summary of Cost Analysis for Screen Disposal Alternative

Description		Baseline (Traditional System 4)	Description	Screen Disposal Alternative
Facility Characteristics				
Average screen size (in^2)		2,127	Average screen size (in^2)	2,127
Average # screens/day		6	Average # screens/day	6
Cost Elements per Screen				
Labor	Time spent applying, scrubbing, and removing reclamation products (min)	24.4	Time spent stretching, degreasing, and removing screen (min)	50
	Cost ($)	5.33	Cost ($)	11.50
Materials and Equipment	# of rags used	3	Screen Mesh (in^2)	2,345
	Cost ($)	0.45	Cost ($)	38.5
Reclamation Product Use	Ink Remover Average Volume (oz.)	8.0	Prep Degreasing Volume (oz.)	1.0
	Cost ($)	0.22	Cost ($)	0.02
	Emulsion Remover Average Volume (oz.)	3.5		NA[a]
	Cost ($)	0.13		NA
	Haze Remover Average Volume (oz.)	3.0		NA
	Cost ($)	0.12		NA
Waste Disposal	Amount, Hazardous (g)	34	Amount, Nonhazardous (g)	0.64
	Cost ($)	0.02	Cost ($)	< 0.01
Totals				
Total Cost ($)/screen		6.27	Total Cost/Screen[b]	49,43
Total Cost ($)/year		9,399	Total Cost/year[b]	74,141

Note: Screen disposal is cost effective only with smaller screen sizes and/or long production runs, where the number of impressions nears the expected life of the screen.

[a] Not applicable. Screen disposal does not require this cost element.

[b] The replacement of screens (after the end of the useful life of the mesh) was not considered in the baseline or other alternative reclamation methods evaluated. A value of $0.60 per screen was therefore deducted from the total cost of this method.

Printers should not view this cost estimate as a final analysis, because the operations of any one facility can be different from the assumptions used in generating this cost analysis. However, it is clear that screen disposal may not be a cost-effective option for a majority of screen printing facilities.

Pollution Prevention through Improved Workpractices

Pollution prevention is the use of materials, processes, practices or products that avoid, reduce or eliminate wastes or toxic chemical releases. Pollution prevention can be accomplished through activities such as material substitution, source reduction and closed loop recycling. This section of the CTSA focuses on ways that printers can achieve pollution prevention through improved workplace practices.

Responses to the Workplace Practices Questionnaire

Many screen printers are finding that they can save time and cut costs by improving their workplace practices to prevent pollution. This was one of the key findings of a section on pollution prevention opportunities included in the Workplace Practices Questionnaire for Screen Printers (see Appendix B). Almost 36 percent of the respondents reported that they had implemented changes in workplace practices to reduce their use of ink removal or screen cleaning/reclamation products. Almost 24 percent had made equipment changes, 26 percent had made product changes, and another 26 percent had made process changes . The majority of the respondents reported that pollution prevention, whether through improved workplace practices, or changes in equipment, products or processes, either decreased or caused no change in materials cost, the time required to clean/reclaim the screen, and disposal costs.

Almost 30 percent of the respondents to the questionnaire reported having a pollution prevention, waste minimization, or source reduction program at their facility. The concepts of pollution prevention and waste minimization are almost synonymous, except pollution prevention places more emphasis on preventing environmental releases to any media at the source. Source reduction is the highest level in the pollution prevention hierarchy, since it involves going to the source of pollution to identify prevention opportunities.

More than 75 percent of the respondents had tried an alternative ink removal or screen cleaning/reclamation product for environmental or worker safety reasons. Of these respondents, more than 50 percent reported the performance of the alternative chemical product was satisfactory, while only 19 percent found the product unsatisfactory. Others indicated they had mixed results from different products, that they were concerned about cost or that their operators were resisting any changes to alternative chemical products.

It is apparent from these results that screen printers have an excellent opportunity to prevent pollution simply by reevaluating their workplace practices with the environment in mind. Furthermore, pollution prevention through improved workplace practices results in cost savings through the reduced use of materials, reduced waste disposal costs, and other benefits. Many printers who responded to the survey reported that pollution prevention through improved workplace practices is simply a common-sense approach.

To learn more about how printers are using improved workplace practices to prevent pollution, the University of Tennessee Center for Clean Products and Clean Technologies contacted the printers responding to the survey who indicated they have a pollution prevention, source reduction, or waste minimization program that they would be willing to share with the DfE Printing Project. Using the actual experiences of screen printers and data from other sources, the following framework for pollution prevention through improved workplace practices was developed. To ensure the anonymity of printers who responded to the Workplace Practices Questionnaire for Screen Printers, no personal references are provided with this material.

Framework for Pollution Prevention

The basic framework for pollution prevention through improved workplace practices involves

- raising employee awareness
- materials management and inventory control
- process improvement
- periodic, in-house audits.

Raising employee awareness is the best way to get employees to actively participate in a pollution prevention program. Materials management and inventory control means understanding how chemicals and materials flow through a facility to identify the best opportunities for pollution prevention. Implementing these steps will help to prevent pollution through good *management* practices in the workplace. Process improvement through workplace practices means reevaluating the day-to-day operations that make up the printing and screen cleaning and reclamation processes. Implementing this step helps prevent pollution through good *operator* practices in the workplace. Finally, in-house audits are used to collect real-time data on the effectiveness of a pollution prevention program. This step gives both operators and managers the incentive to strive for continuous improvement.

Raising Employee Awareness

When asked why they do not use alternative, less polluting chemical products or methods to clean and reclaim the screen, many printers respond that press operators are reluctant to change from traditional chemicals and methods; they simply do not believe the alternatives will work. This implies that a large barrier to pollution prevention in the printing industry may be an unwillingness to try new products and new techniques due to a lack of awareness of the potential benefits. Printers need to understand that pollution prevention can result in improved worker health and safety, an improved working environment, cost savings, and reduced or less toxic waste streams leaving the plant, which means less overall impact on human health and the environment. Many printers are beginning to design and implement programs to teach employees about the benefits of pollution prevention. Table VI-2 lists some of the steps to and benefits of raising employee awareness.

Although most of the printers contacted during the follow-up survey did not have a written environmental or pollution prevention policy, several did have written operating procedures that could be used to guide pollution prevention activities. One printer in Ohio said he had recently written procedures on chemical handling and disposal to ensure that there was no misunderstanding about proper chemical handling, and to minimize the potential for an accidental discharge of potentially hazardous materials. Having procedures available also makes his job easier, since employees can first go to the procedure if they have questions about chemical handling and disposal. Another printer had begun to write operating and maintenance procedures for each process (e.g., printing process, screen cleaning/reclamation process, etc.) to control quality and materials use at his facility, and to establish environment quality goals for the facility.

Table VI-2
Benefits of Workplace Practices to Raise Employee Awareness

Workplace Practices	Benefits
Prepare a written environmental policy	Establishes environmental management goals; illustrates management commitment to pollution prevention and environmental goals
Prepare written procedures on equipment operation and maintenance, materials handling and disposal	Better informs employees of the proper procedures for using and disposing of materials
Provide employee training on health and safety issues, materials handling and disposal	Ensures that employees have proper training to understand benefits of proper materials handling and disposal, and potential consequences of improper workplace practices to their health and safety, the environment, and company profitability
Seek employee input on pollution prevention activities	Encourages the persons closest to the process, the operators, to develop the best, most creative approach to pollution prevention; employee involvement and ownership of the program is essential to a successful program
Make employees accountable for waste generation and provide incentives for reduction	Encourages employees to be aware of ways they can prevent pollution; rewards active involvement in pollution prevention activities
Provide feedback to employees on materials handling and disposal and pollution prevention performance	Re-emphasizes management commitment to pollution prevention; encourages employees to continue to improve

Materials Management and Inventory Control

Proper materials management and inventory control is a simple, cost-effective approach to prevent pollution. Several printers described materials management and inventory control as the common-sense approach to good business and pollution prevention. Keeping track of chemical usage and limiting the amount of chemicals on the process floor gives operators an incentive to use the minimum amount of chemical required to do the job. Ensuring that all chemical containers are kept closed when not in use minimizes the amount of chemical lost through evaporation to the atmosphere. Not only do these simple practices result in less overall chemical usage, and thus a cost savings, they also result in reduced worker exposure to toxic chemicals and an improved working environment. Table VI-3 lists some of the steps to and benefits of materials management and inventory control.

Process Improvements

Once the flow of materials within a facility has been documented, the next step is to analyze the process, materials logs and waste generation logs to identify workplace practices that can be adopted to prevent pollution at the source. Table VI-4 lists some workplace practices that prevent pollution and their benefits.

Table VI-3
Benefits of Workplace Practices for Materials Management and Inventory Control

Workplace Practices	Benefits
Manage inventories on a first-in, first-out basis	Reduces materials and disposal costs of expired materials
Maintain accurate logs of chemical and materials stock, chemicals and materials use, and waste generation rates	Understanding materials flow and how it relates to waste generation rates provides insights into pollution prevention opportunities
Minimize the amount of chemicals kept on the floor at any time	Gives employees an incentive to use less materials
Centralize responsibility for storing and distributing chemicals	Gives employees an incentive to use less materials
Segregate waste by waste stream and keep in marked, easily accessible, closed containers	Allows for more effective reuse or recycling of waste materials; prevents nonhazardous waste from becoming contaminated with hazardous waste; minimizes evaporation of VOCs; reduces worker exposure
Keep spent solvents in marked, easily accessible, closed containers	Promotes waste segregation, recovery and reuse; minimizes evaporation of VOCs; reduces worker exposure

A printer in Tennessee wrings excess solvent from used rags into a covered container. After allowing the heavier contaminants to settle to the bottom, he simply decants the solvent off the top for reuse and disposes of the sludge. Another printer uses a safe, explosion-proof centrifuge to recover excess solvent. Before investing in a centrifuge, however, printers should make sure that the equipment meets all health and safety requirements (e.g., protection from flammability and explosion hazards) specified by the state or local government.

A printer in Minnesota reported that he had identified chemical overspray not directed at the screen during emulsion and haze removal as one of the biggest sources of chemical loss. Employees built a simple "catching frame" to place around the screen during the chemical application steps. The catching frame is used to capture the overspray, which is then recycled or reused.

Another printer in New York said his facility keeps chemicals in safety cans or other sealed containers to minimize solvent loss from evaporation. They used to use a pump and spray unit to apply ink degradant and emulsion remover, followed by a high-pressure water wash. They only use haze remover if it is absolutely necessary. This facility has now gone to manual, spot-application of the ink degradant and manual application of the emulsion remover, followed by a low-pressure rinse. A final high-pressure water blast follows this rinse step. Results of industrial hygiene monitoring at the facility indicate that this new method of applying chemical results in no overspray of chemicals and reduced worker exposure, since the high-pressure water blaster no longer disperses the chemicals as a mist in the air. They have also reduced the accidental discharges from crimped or cracked discharge lines in the pump system. This printer estimates that the new methods for applying chemicals to the screen have resulted in a 15 percent reduction in material use.

Table VI-4
Benefits of Process Improvements to Prevent Pollution

Workplace Practices	Benefits
Keep chemicals in safety cans or covered containers between uses	Reduces materials loss; increases worker safety; reduces worker exposure
Use plunger cans, squeeze bottles or specialized spraying equipment to apply chemicals to the screen	Reduces potential for accidental spills; reduces materials use; reduces worker exposure
Consider manual, spot-application of chemicals, where applicable	Reduces materials use; reduces worker exposure if aerosol mists are avoided
Use a pump to transfer cleaning solutions from large containers to the smaller containers used at the work station	Reduces potential for accidental spills; reduces worker exposure
Reduce the size of the towel or wipe used during clean-up	More efficient use of the towel; reduces solvent use; reduces worker exposure
Reuse shop towels on the first pass with ink remover	Reduces material (shop towel and ink remover) use; reduces worker exposure
Evaluate alternative chemical: water dilution ratios (increase the amount of water)	Reduces chemical usage with no loss of efficiency; reduced worker exposure
Only apply chemicals where necessary	Reduces chemical usage; reduces worker exposure
Avoid delays in cleaning and reclaiming the screen	Simplify ink and emulsion removal; less potential for haze on the screen
Gravity-drain, wring, or centrifuge excess solvent from rags	Recovers solvent for reuse
Place catch basins around the screen during the screen cleaning/reclamation process	Captures chemical overspray for recovery and reuse
Use appropriate personal protective equipment (gloves, barrier cream, respirator, etc.)	Reduces worker exposure

Periodic, In-house Audits

Periodic, in-house audits are conducted for a number of reasons, including the following:

- ○ to ensure that each step of the pollution prevention program is being implemented
- ○ to collect data on the benefits and costs of the pollution prevention program
- ○ to identify additional pollution prevention opportunities.

Pollution prevention programs have the same goal as total quality management programs: continuous improvement. Periodic, in-house audits provide the information necessary to ensure that goal is met. The results of the audit should be shared with all employees to raise employee awareness about the benefits of the pollution prevention program, and to provide them feedback on pollution prevention progress.

Realizing Pollution Prevention Benefits

The results of the Workplace Practices Questionnaire for Screen Printers showed that there are tremendous opportunities for screen printers to reduce pollution through improved workplace practices. Below, chemical application methods, equipment and materials use, product storage and retrieval, and waste storage and disposal are four areas drawn from the questionnaire to illustrate these pollution prevention opportunities.

Printers were asked to check the method (or methods) that best describes how they apply ink removal, emulsion removal, and haze removal chemicals to the screen. Table VI-5 summarizes their responses. The majority of the respondents indicated they typically use some type of spray or specialized equipment to apply ink or emulsion remover to the screen. However, a significant percentage either poured chemical product directly from the container onto the screen or dipped a rag or brush into a container and wiped the screen. If these results are indicative of the industry as a whole, substantial pollution prevention benefits could be achieved by (1) raising employee awareness about the health, safety and environmental issues associated with excess chemicals being released to the air or washed down the drain, (2) controlling materials and inventory to reduce the unnecessary use of chemicals, (3) applying chemicals more carefully, and (4) using catchments or collection basins to capture chemical overspray for recovery and reuse.

Table VI-6 shows the types of equipment (brush, spray gun, squeegee) and materials (disposable or reusable rags) that respondents to the survey use during the three main screen cleaning and reclamation steps. The variability of these results also indicates printers have opportunities to prevent pollution by (1) identifying the optimal equipment to use during the screen cleaning/reclamation step and (2) using reusable shop towels.

Printers were also asked (1) how they retrieve ink removal and screen reclamation products from chemical storage and (2) if they keep both large and small containers in the ink removal and screen cleaning/reclamation area, how they transfer products from large containers to small containers for use. Most of the respondents either move an entire container into the press room (14 percent) or pump the contents into a smaller container (41 percent), but 26 percent pour the contents into a smaller container and 3 percent ladle the contents into a smaller container. Clearly, the latter respondents have a greater potential for accidental spills during the chemical transfer operation.

Printers who keep both large and small containers in the ink removal and screen/cleaning reclamation area were slightly more likely to pour (34 percent) or ladle (1 percent) the contents into a smaller container. Forty percent of these respondents use a pump to transfer the contents into a small container at the work station. Again, a simple change in workplace practices to using a pump, which is easier to control, instead of pouring the chemicals or using a ladle, could prevent an accidental spill.

Finally, printers were asked if they store their waste materials in a closed container, an open container, or in no specified container. Table VI-7 is a summary of their responses. Although most of the respondents indicated they store their waste materials in a closed container, there is still room for improvement, especially with waste rags and screen reclamation wastes. Printers were also asked if they pretreat their rags prior to sending them to a laundry or to a disposal facility. Almost 4 percent indicated they centrifuge their rags, while 27 percent indicated they allow the excess solvent to drain out prior to recycling or disposal. Almost 8 percent indicated they used some other form of pretreatment. Almost 50 percent of the respondents, however, indicated they do not pretreat their rags prior to recycling or disposal. Again, a successful pollution prevention program could be used to (1) raise employee awareness about the health and safety benefits of keeping waste materials in closed containers and (2) develop a simple method to recover excess solvents from rags.

Table VI-5
Prevalence of Usage of Chemical Application Methods

	Cleaning/Reclamation Step		
Method of Chemical Application	**Ink**	**Emulsion**	**Haze**
pour from container onto screen	9.3%	4.7%	5.6%
dip rag or brush into container and wipe screen	31.8	28.0	65.4
spray on w/ nozzle from tank	31.8	24.3	0.9
spray on w/ spray bottle	29.9	31.8	12.1
use specialized spraying equipment	12.1	12.1	0.9

Note: Values represent percentage of printers responding to the particular check-off category. Some printers checked more than one box; others did not respond to these sections. Therefore, numbers may not add up to 100 percent.

Table VI-6
Prevalence of Use of Reclamation Equipment and Materials

Equipment and Materials Used	Cleaning/Reclamation Step Ink	 Emulsion	 Haze
brush	40.2%	41.1%	3.7%
low-pressure water spray	NA	11.2	10.3
high-pressure water spray	NA	73.8	65.4
water blaster	NA	13.1	8.4
squeegee	1.9	NA	NA
disposable rags	16.8	5.6	0.9
reusable rags	28.0	7.5	4.7

Note: Values represent percentage of printers responding to the particular check-off category. Some printers checked more than one box; others did not respond to these sections. Therefore, numbers may not add up to 100 percent.

NA = not applicable

Table VI-7
Prevalence of Waste Management Practices

Waste Management Practices	Waste Ink Removal	 Screen Reclamation	 Rags
in closed container	71.0%	31.8%	77.6%
in open container	4.7	3.7	11.2
no specified container	2.8	15.9	5.6

Note: Values represent percentage of printers responding to the particular check-off category. Some printers checked more than one box; others did not respond to these sections. Therefore, numbers may not add up to 100 percent.

Conclusions

As can be seen by the above descriptions, a wide variety of pollution prevention opportunities exist for screen printers. The basic framework for pollution prevention through improved workplace practices is intended to be a guide or starting-point for individual printers to develop pollution prevention practices within their own facility. The specific examples given in the discussions above may not be applicable for every printer; the goals of pollution prevention are facility specific and will evolve as a program develops. Nonetheless, substantial opportunities exist for screen printers to prevent pollution through improved workplace practices, although these opportunities will vary depending on the characteristics of each facility.

Pollution Prevention through Equipment Modifications

Sprayer/Application Systems

The various systems for applying chemicals to a mesh surface offer some of the most basic methods of pollution prevention. By allowing the screen reclaimer to control the amount and direction of ink remover, emulsion remover, and/or haze remover, sprayer/application systems effectively minimize the amount of solution used and reduce chemical waste at the source. To further minimize chemical throughput, the more complex systems frequently combine solvent recirculation systems with the spray applicator systems. The use of such recirculation systems will be discussed at length in a subsequent section.

Features

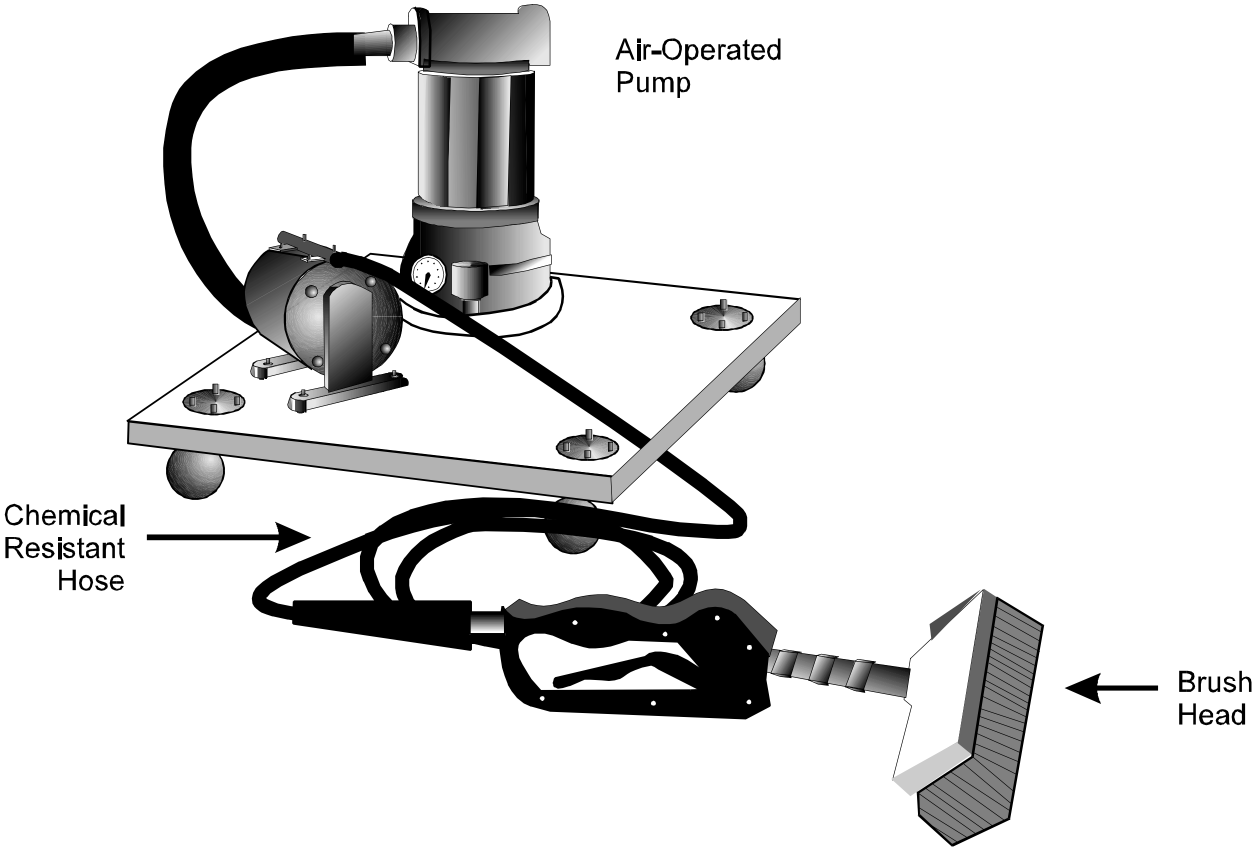
This general category encompasses a large spectrum of products ranging in cost and complexity. However, it is important to note that spray systems may not be applicable if the emulsion remover or haze remover product is a paste. Printers should consult their suppliers. Nevertheless, an applicator system at the most basic level may consist of a simple spray bottle (e.g., plant mister) that can be purchased at virtually any hardware store for several dollars. This spray bottle would substitute for simply pouring or wiping chemicals onto the screen surface.

In addition to the spray bottle, a spray applicator system consisting of a spray applicator device and a pump is an option available to screen printers (Figure VI-1). Such technologies employ a low pressure air compressor to pump solvent onto the screen at various rates. The rate of chemical flow to the screen is largely controlled by a variety of applicator attachments made for such systems. These attachments can range from a scrubber-brush head (Figure VI-1) to trigger-controlled spray guns (Figures VI-2 and VI-3). Cost for the spray applicators with pumping systems can range from several hundred to several thousand dollars. Various attachments to regulate flow are often included with such systems. Printers may purchase items separately in order to modify or update an existing system. Another type of sprayer system consists of a pressurized spray applicator and a solvent recirculation system. In addition to regulating solvent flow, the solvent recirculation system regulates the drainage and filtration of the spent solvent. Consequently, these combination systems are the most expensive of the various application methods and often cost thousands of dollars.

Issues to Consider

Although these products can allow for significant source reduction, several issues must be addressed in order to properly evaluate the method which provides the "best fit" for a particular screen shop. While the use of a spray bottle may potentially reduce solvent use compared to application with a solvent-soaked rag, the spray bottle may not provide significant advantages with respect to time or effort for a particular facility. Printers should compare their

Figure VI-1
Simple Spray Applicator System
(Note the trigger-controlled brush head used to regulate chemical flow)

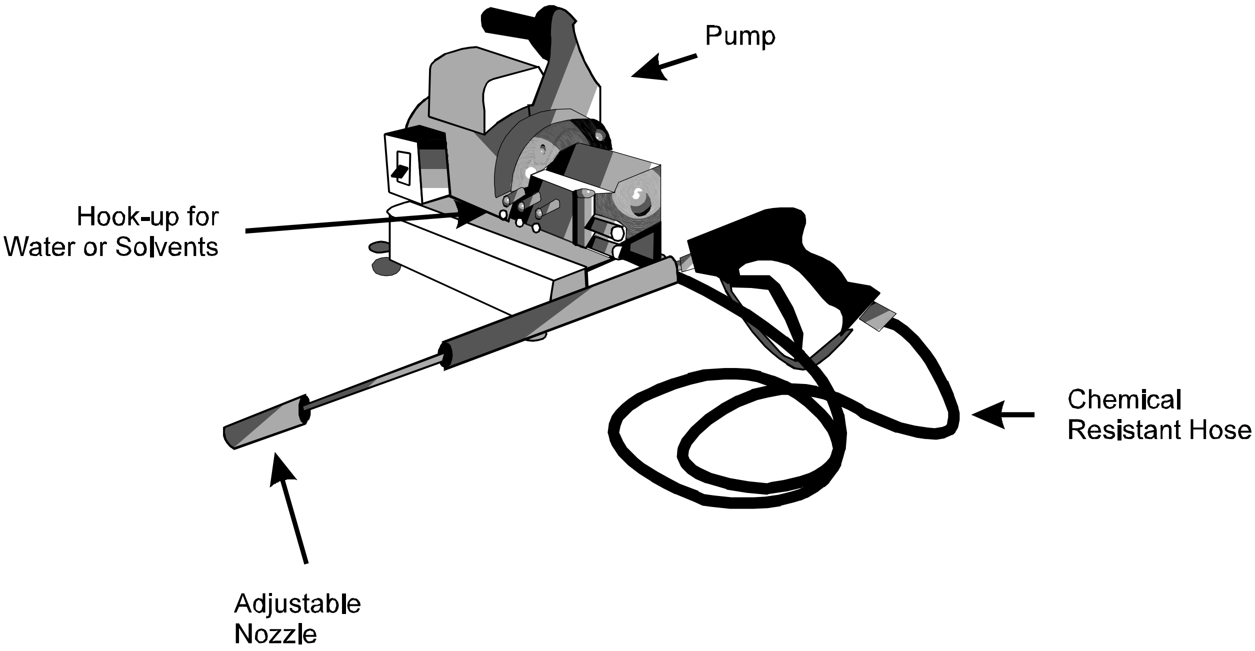


current system of applying screen reclamation chemicals with an alternative application method, such as a spray application system, keeping in mind cost, time, and effort.

Low pressure pumping systems can also reduce chemical throughput. This group represents a significant improvement in pollution prevention compared to either rags or spray bottles because they provide a greater opportunity to reduce solvent use. In addition, use of the spray applicator/pumping system can reduce the time and effort required to clean a screen. However, this group of devices does not allow for reuse of the solvents, thus, misses a pollution prevention opportunity that is present with pressurized spray application systems and solvent recirculation systems.

Conversely, while the pressurized spray applicator and recirculation system products may decrease the time, effort, and waste associated with reclaiming screens, cost can be a prohibitive factor. Since the cost for many of these technologies stretches into the thousands of dollars, one should weigh the benefits obtained by such products against the total amount of time and labor spent reclaiming screens. Additionally, there have been concerns about the

Figure VI-2
Trigger Spray Gun for Applying Solvents



effects on a screen's mesh fiber when using a high-pressure sprayer to apply chemicals to the screen. However, since the majority of products that use pressurized sprays to apply solvent do so with a relatively low pressure (50 to 300 psi), mesh damage seems unlikely.

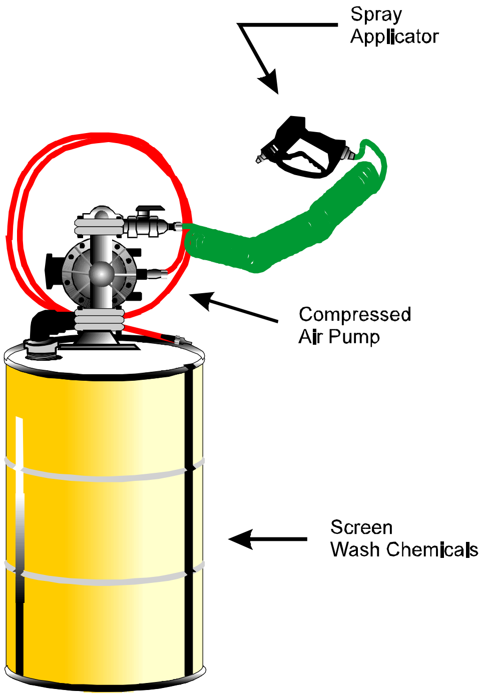
Summary

In conclusion, sprayer/application systems offer an excellent opportunity for source reduction within screen reclamation. For the smaller printer who spends minimal time in reclamation, the relatively inexpensive spray bottle might be the most cost-effective. However, companies that spend a substantial amount of time and effort in reclamation might find the more extensive spray systems a viable option. While the initial costs may be substantially higher, some or all of the cost may be recovered through decreased solvent use. Further, these systems may decrease labor costs because they tend to be quicker and easier methods for cleaning screens. In addition to surveying product literature, a printer may wish to check with several suppliers as well as other printers to determine which system would work best in his/her shop.

Washout Booths

The use of the washout bin/booth presents another basic opportunity for pollution prevention. The premise of the washout booth is that concentrating the ink and/or emulsion

Figure VI-3
A Variation of the Sprayer/Applicator with Trigger Control



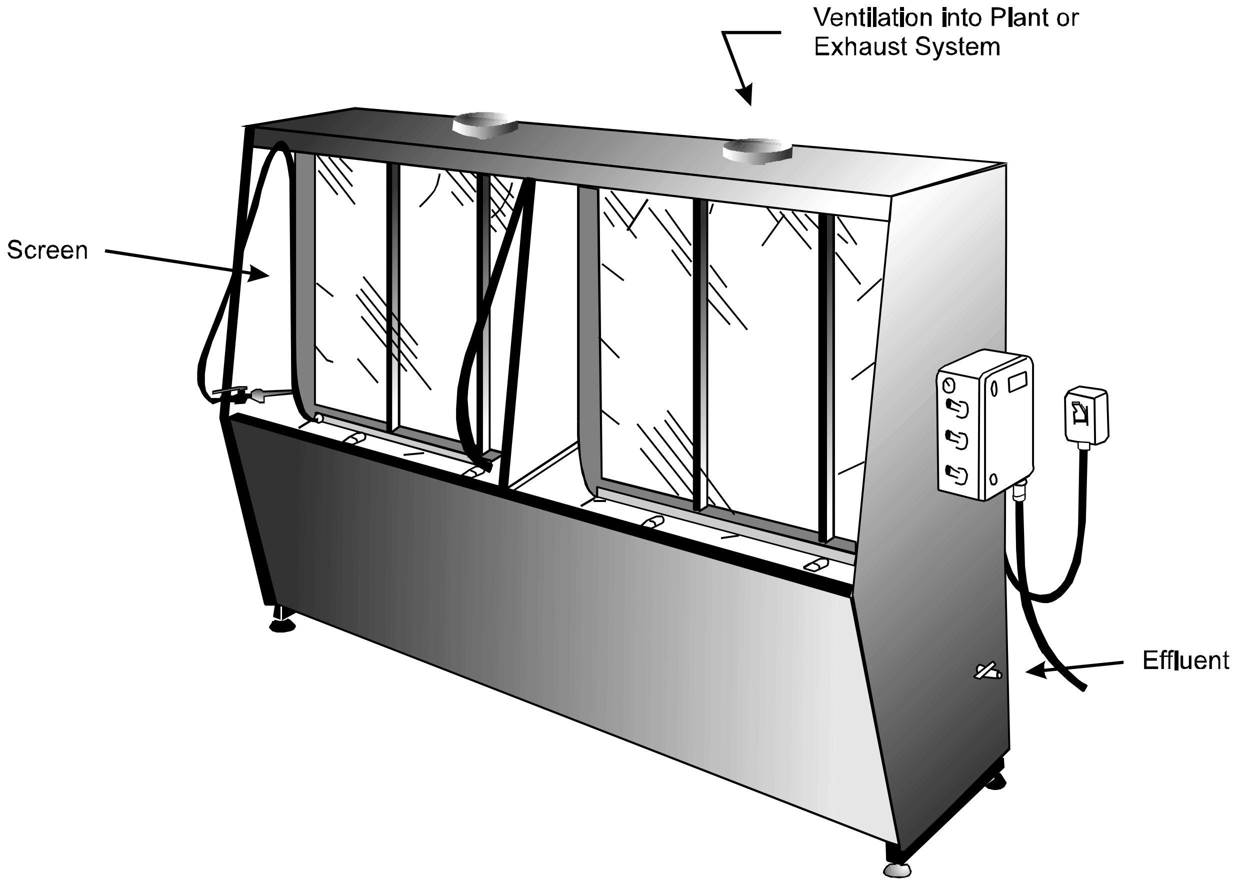
remover within a specific area will minimize the quantity of solvent necessary for reclamation, while maximizing the cleaning potential of the quantity used. Consequently, these booths are built to focus the cleaning solution in a small semi-contained area (usually box shaped). Although some booths consist of multiple cleaning areas to separate the ink and emulsion removal functions (Figure VI-4), the single unit booths are equipped to remove both ink and emulsion. The waste solution is usually funneled into a drain where it may be disposed of in several ways.

Features

Although the conventional washout booth can be made to virtually any specification, the basic design is relatively uniform. This design includes a rectangular base with a high back and sides (Figure VI-5). The base is often slanted slightly to facilitate drainage, which allows the effluent to funnel into a drain pipe.

Working from such a base unit, one can choose from a broad spectrum of options to enhance the unit design. The most common option is that of booth lighting. Lighting is critical to successful screen reclamation because it allows the reclaimer to better assess the performance of the cleaning product as well as the efforts of the reclaimer. However, since adequate shop lighting may or may not be present, washout booths are available in either lighted or unlighted models. Unlit washout booths, as the name suggests, contain no internal lighting fixtures. Depending on the size, these booths range in price from $1,000 to $3,000 or $4,000. Conversely, the lit booths are equipped with an internal lighting system through backlighting or overhead lighting. Backlighting provides a light source that emanates from directly behind the screen and would highlight any ink or emulsion residue. Overhead lighting

Figure VI-4
Washout Booth Equipped with Separate Ink and Emulsion Cleaning Areas

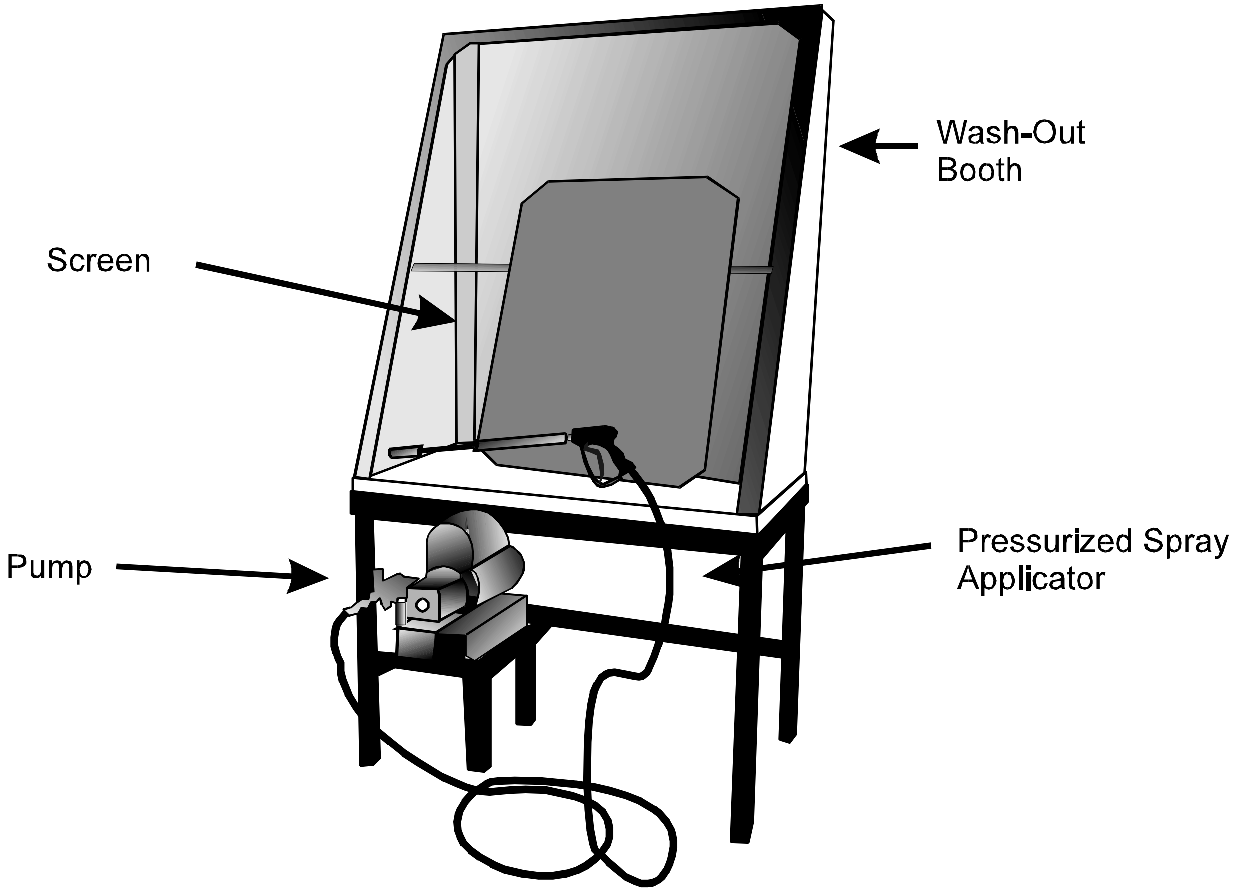


can accomplish the same goal through lighting the area from above. Generally, either type of lighting system will increase the overall cost of the booth by at least several hundred dollars.

In addition to the conventional washout booth, various other options exist that would further upgrade its screen reclamation capability. These will be explored further in other sections, but they merit mention here as well. A high pressure spray washer is a common technology that can be used in conjunction with a washout booth for screen reclamation. These washers physically blast ink and emulsion particles from the screen. High pressure washers that dispense both water and solvent at variable pressures (50 to 5000 psi) are commercially available. Depending on the pressure of the applicator, a system can cost anywhere from $1,000 to $10,000.

A washout booth can also be modified to include a filtration system. A wide variety of filtration systems are commercially available, and while some are equipped to filter solvents other than water, many cannot. However, all filtration systems generally attempt to separate out the particulates and other contaminants from the waste water. These devices connect the washout booth to the sewer system or septic tank, and they play a prominent role in the waste

Figure VI-5
A Typical Washout Booth Shown with Optional Sprayer System



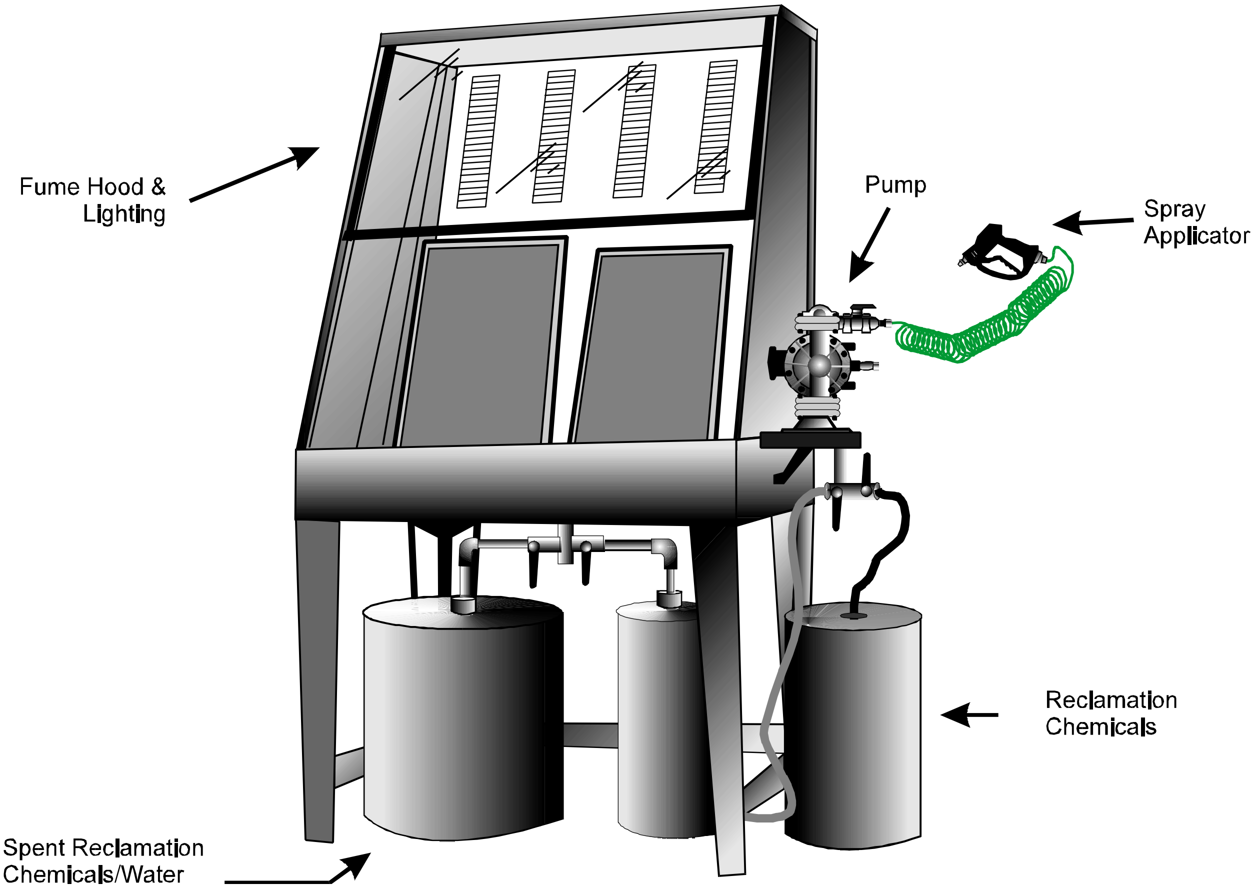
treatment process. Filtration of waste can either facilitate compliance with federal, state, or local water regulations or provide the basis for a recirculation system. The addition of a filtration system could also increase the price of the screen reclamation system by at least a thousand dollars.

The recirculation system is another major option that can be used in conjunction with the washout booth. Most recirculation units employ a filtration apparatus, holding tanks for new and used solvent, and a sprayer system. Figure VI-6 is an example of a fully equipped washout booth. In addition to the various options previously discussed, this particular booth is also equipped with a fume hood to minimize employee inhalation of volatile chemicals. This type of system costs approximately $7,000 to $10,000.

Issues to Consider

The use of a washout booth in screen reclamation increases the opportunity for pollution prevention. However, when considering the purchase of a booth, the determining factors

Figure VI-6
A More Advanced Washout Booth
(It is equipped with a sprayer system, drainage system, & fume hood)



remain cost, performance, and environmental and human risk reduction. Washout booths would reduce solvent usage relative to application with a soaked rag. Thus, a printer must examine his/her individual situation in conjunction with applicable federal, state, and local environmental regulations to determine whether such a capital expenditure is prudent. In addition, the printer should consider the time and effort spent in screen reclamation as well as the potential cost savings from reduced solvent use and excess hazardous waste disposal when considering the purchase of a washout booth.

Assuming that a printer has decided to purchase a washout booth, he/she needs to consider the lighting requirements. A non-lit booth is less expensive than a lighted booth. If substantial lighting is already available, a lighted booth may not be necessary. However, the models with lights may make cleaning easier because ink and emulsion can clearly be seen, and the potential need for re-cleaning a screen is minimized.

Finally, printers should consider the wide range of other options available for a washout booth. For a simple operation, a booth by itself may be adequate. However, if reclamation is a significant process within the shop, additions may be justifiable. Upgrading a washout booth may vastly increase one's pollution prevention potential, but this increase coincides with an equivalent rise in the cost of the system. Printers should carefully consider the size of the screen printing operation, the number of screens reclaimed, the cost associated with reclamation, and the environmental regulations with which they must comply when considering the purchase of a washout booth.

Summary

In short, a washout booth would provide another opportunity to minimize chemical throughput. The booth provides a specific area in which to reclaim screens and can minimize the potential solvent loss associated with open-area reclaiming. The booth can be made to specifications; however, the price increases according to size and level of complexity. For the small printer that reclaims very few screens, such an apparatus may not be a prudent or feasible investment. However, for printers with a sizeable reclamation operation, a washout booth may be a positive addition. Printers should consider their individual situations as well as other sources of product information to make a choice that remains consistent with good business practices.

Filtration Systems

Although they work by several different processes, filtration systems all perform essentially the same function of eliminating specific substances from the waste stream. Used independently, these products may not provide unique pollution prevention opportunities; however, when used in conjunction with a recirculator/recycler, the filtration of solvent may allow for substantial decreases in the quantity of solvent used. A filtration system's function within the solvent recirculation process is to filter out particulates, heavy metals, hydrocarbons, and other waste products. This process of treating the effluent makes it possible for conditioned solution to recirculate back for reuse in subsequent reclamation.

Features

Effluent resulting from the screen reclamation process is a mixture of liquid and particulates and can be filtered using two distinct processes: physical separation and adsorption separation. Physical separation is accomplished through the use of mechanical forces to separate the solid particles from the solution. The effluent is passed through porous materials so that the particulates are collected and separated from the liquid. However, it is only the solid particulate matter that is filtered out, and consequently, physical separation does not address other potentially hazardous substances found in solution.

Adsorption separation is another type of filtration process. Adsorption removes pollutants from an exhaust stream by the adherence of the pollutants to the surface of porous solids.[1] Given adequate time and the appropriate porous material, known as the adsorbent, removal can be highly effective.[2] Therefore, by passing waste water through a chosen material, other pollutants in solution will bond with the adsorbent and can effectively be separated from the effluent.

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[1] Geankoplis, Christie J., Transport Processes and Unit Operations, (New York:Allyn and Bacon Inc.), 1983.

[2] Geankoplis, Christie J., Transport Processes and Unit Operations, (New York:Allyn and Bacon Inc.), 1983.

The more basic filtration systems that deal only with physical separation provide a method to remove particulate matter such as ink or emulsion particles from the reclamation effluent. A typical physical separation filtration system consists of a number of filters that can vary in shape, form, and size. As the effluent travels through the filters, particulates that are too large to pass through the filter are retained on the filter media in a porous cake. As the pore space from one filter to the next decreases, particles of various size are gradually separated from the effluent. Mesh screens to trap tape, ink, and even large emulsion particles are often the coarse filters at the beginning of the process, but eventually the series of filters are able to remove even the most minuscule of particles (Figures VI-7 and VI-8). For example, it is common for many systems to filter effluent to a particle size of 1-5 microns (approximately the size of an adult human red-blood cell). Consequently, the treated effluent should ideally contain only particles of insignificant size.

Filtration systems aimed at minimizing particulate matter can have a wide range of prices depending on the system's complexity. A system that is equipped to handle less than ten gallons per minute (gpm) can be purchased for under $1,000. At the opposite end of the spectrum, systems that can handle much larger quantities of effluent can cost from $5,000 to $7,000. Additionally, a physical filtration system can increase in price depending on the desired level of filtration. The smaller the pore size within the filter media, the greater the price. Finally, a printer with this type of filtration system should also expect an added annual cost of $200 to $300 to replace the filter media.

Due to the wide variety of workpractices, inks, emulsions, and cleaning solutions, a printer may often require more extensive filtration of the reclamation effluent. For this purpose, the more advanced adsorption separation systems can be used; these systems generally begin where the physical separation stops. The effluent, instead of being disposed of or recirculated, enters an adsorption separation unit in order for any hydrocarbons, metals, or other trace impurities to be removed. A porous substance, usually activated carbon or diatomaceous earth, provides bonding sites for the impurities targeted for removal. "Activated" carbon, when used in this sense, refers simply to a carbon compound with increased pore space.[3] This media usually has a non-polar configuration in order to eliminate the potential problems that could result from attempting to filter water-based effluents.[4] Thus, as the effluent proceeds through the non-polar "activated" media, the contaminants such as hydrocarbons and metals are retained while the remaining effluent passes through (Figure VI-9).

After completion of this adsorption process, the effluent can either be circulated back to a reservoir for subsequent use in screen reclamation or sent to disposal (see Figure Vi-10). Depending on a particular operation, this filtrate may or may not represent a viable substance for reuse. Printers should realize that only the aforementioned substances have been removed (particulates, hydrocarbons, metals, and some trace contaminants), and the resulting solution may or may not be adequately treated for either recirculation or disposal.

Although these advanced filtration systems do represent a significant improvement in the quality of the resulting waste water, they are also substantially more expensive. These adsorption filtration systems start at approximately $4,000 and can cost as much as $12,000

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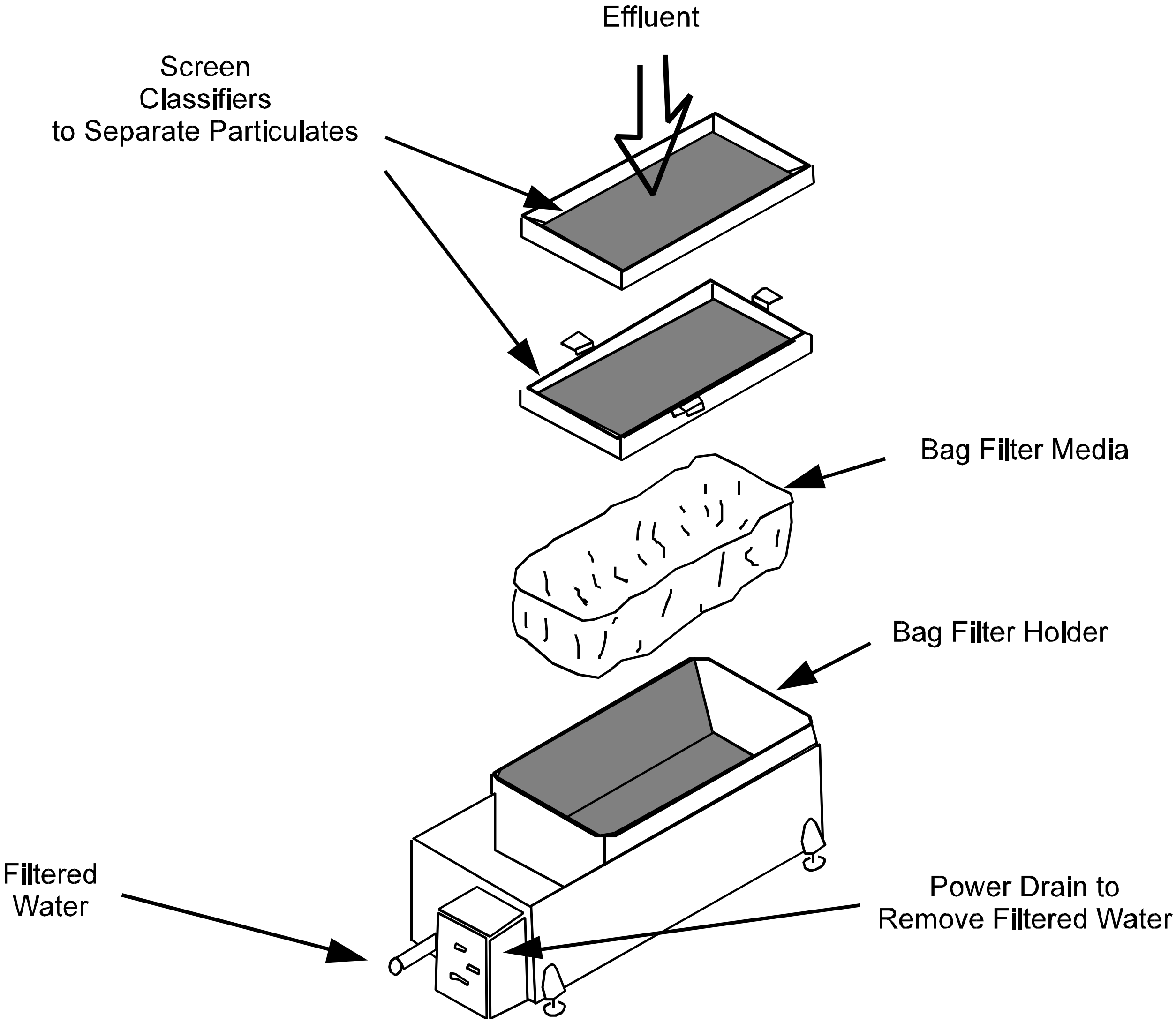
[3] Geankoplis, Christie J., Transport Processes and Unit Operations, (New York:Allyn and Bacon Inc.), 1983.

[4] If the media had a polar configuration, then the filter would exhibit a propensity towards the water molecules which are also polar. The result would be retention of the entire effluent as the filter media would act as a giant sponge.

Figure VI-7
Basic Filtration System
(Includes Both Screen & Bag Filters)

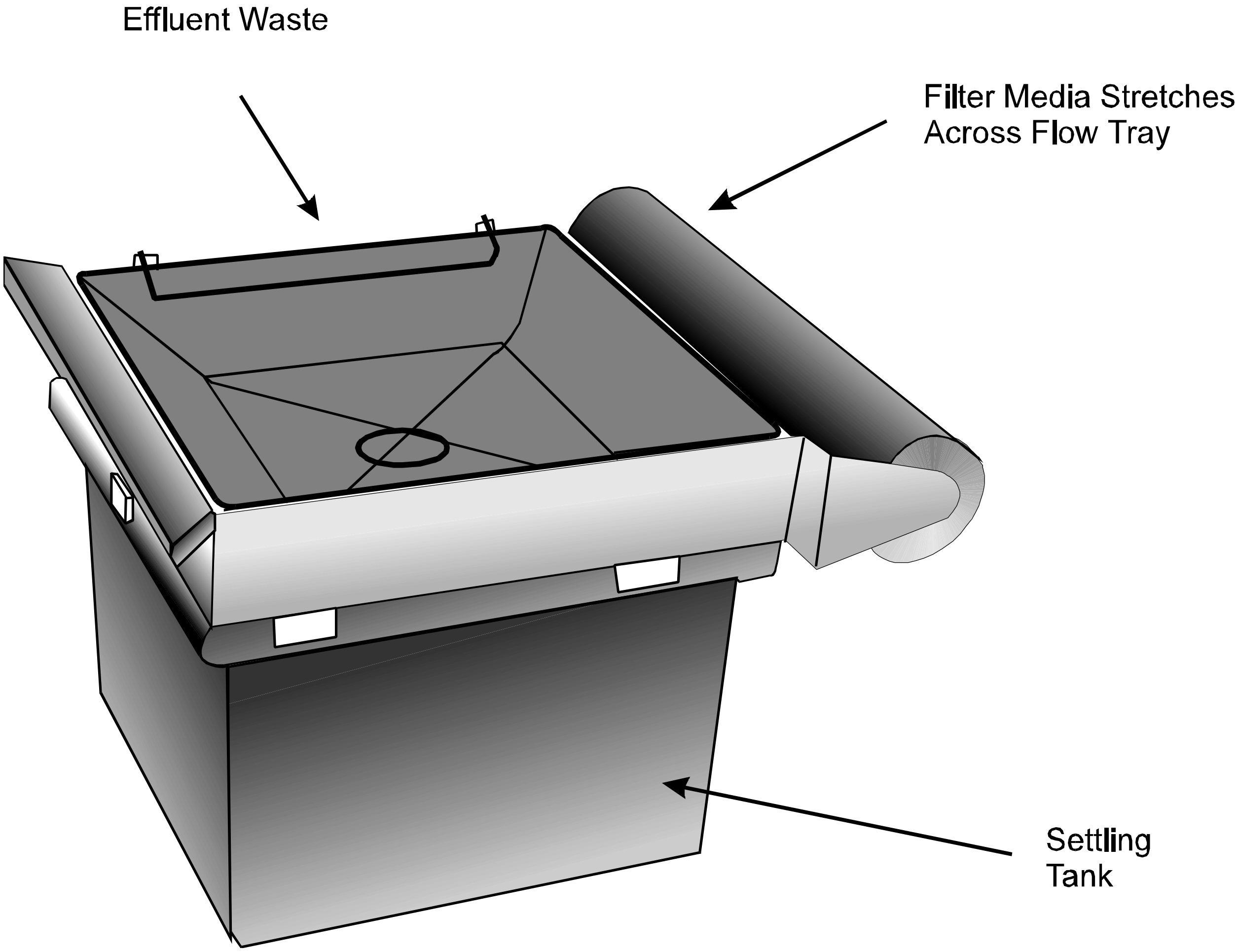


or $13,000. In addition, these systems require an annual upkeep cost of approximately $500 to $1,000 to purchase replacement filter media (diatomaceous earth or activated carbon).

Issues to Consider

One of the first major issues that a printer should consider is whether or not a filtration system would be beneficial for a given screen operation. Adding a physical separation filtering system to a reclamation process may provide a method to facilitate compliance with effluent guidelines by reducing the particulate content of the solution for discharge. Further, when used in combination with a solvent recycler or water re-circulator, a filtration device can possibly decrease the quantity of new solvent required. Thus, in addition to aiding in compliance with

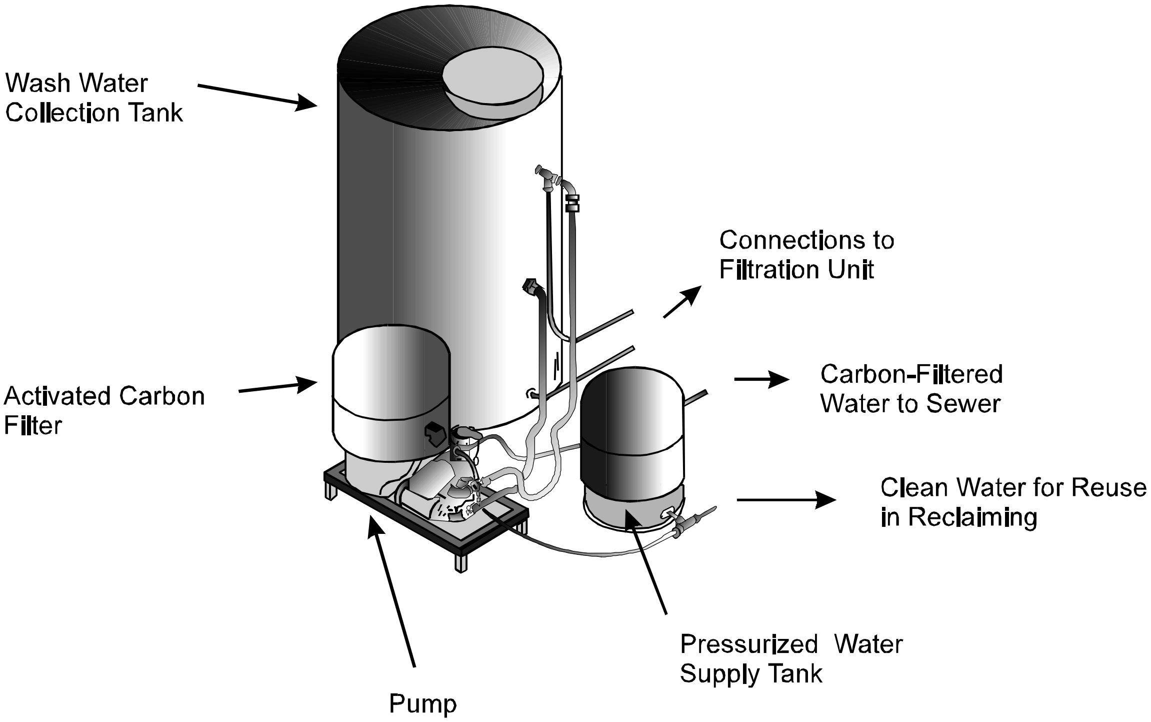
Figure VI-8
Variation of Filtration System
(Effluent Passes Through Screen and Reaches Setting Tank Below)



environmental regulations, it may provide the benefits of lower overhead costs and chemical source reduction. However, the cost of such an addition may be prohibitive. For the small printer who devotes little attention to reclaiming screens, spending hundreds or thousands of dollars may not be a practical way to simply remain in compliance. In these cases, it may be prudent to simply pay a disposal service to remove the effluent.

If a printer has decided to purchase a filtration system, he/she should consider the cost of the option and evaluate the reclamation chemicals/printing chemicals that are currently used in the print shop to determine which filtration system would perform best. By knowing the specific contaminants which can be filtered by these two types of systems and by considering the components of printing and reclaiming chemicals, the printer can better determine whether an adsorption separation system is warranted. A printer may find that, after examination of the chemicals used in the system, only physical separation is necessary.

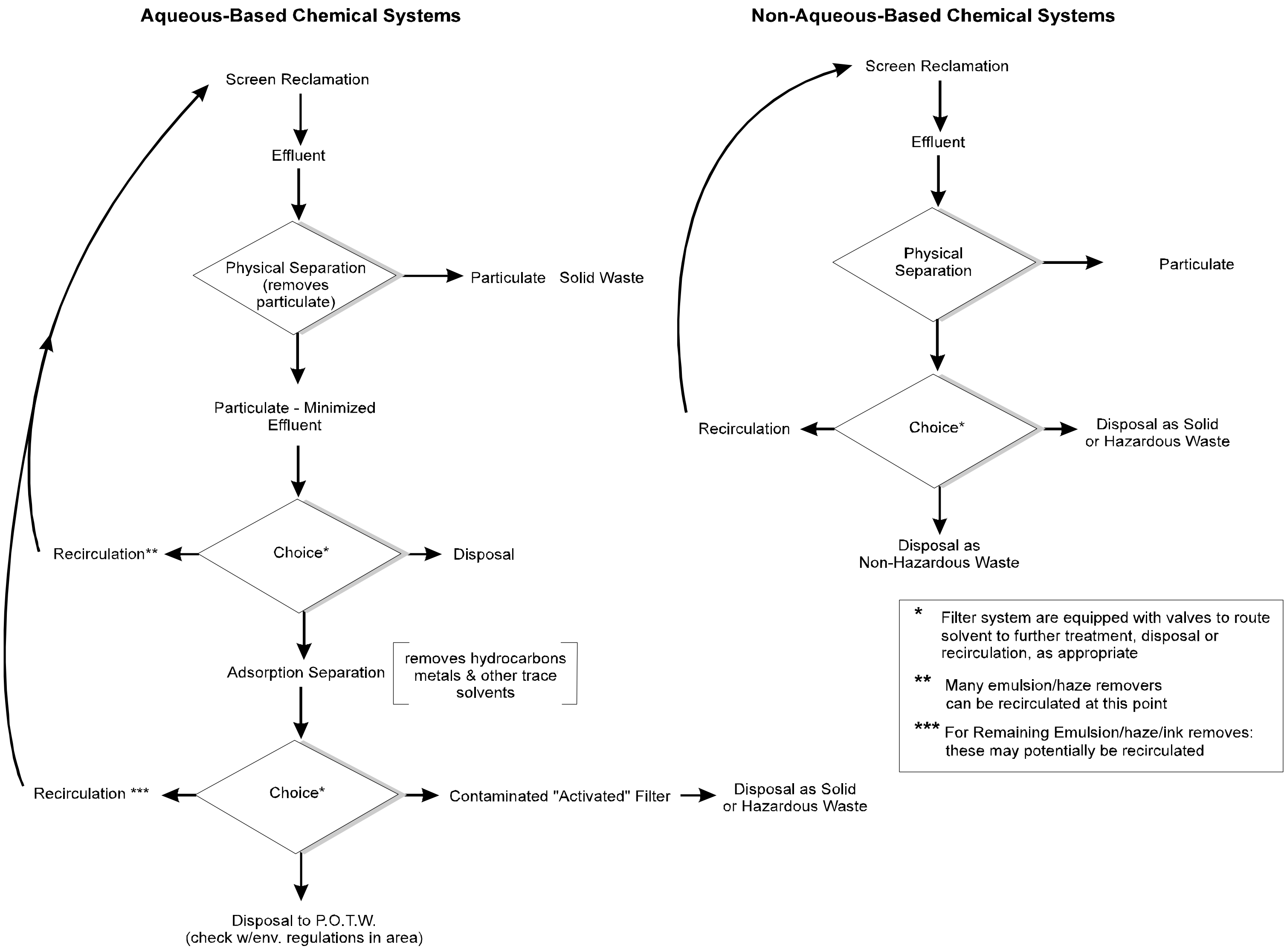
Figure VI-9
Advanced Filtration System
(These systems include an "activated" filter media to further clean the effluent)



For many aqueous-based chemical reclamation systems, the use of a physical separation system may be sufficient. After undergoing filtration to remove the particulate matter, the effluent in an aqueous-based chemical reclamation system may or may not have components that require advanced filtration. Unless these solutions have hydrocarbon compounds or metals in solution, filtering through an "activated" media probably would not provide additional benefits. For example, chemical systems that are predominantly composed of surfactants or ionic salts would probably best be served through physical separation and then recirculation. However, printers should know that some commercially available aqueous chemical systems may benefit from the use of adsorption separation, and advanced filtration may be essential for recirculating solvent or simply maintaining compliance with applicable environmental regulations.

For printers that use strictly non-aqueous chemical systems, physical separation is often the only necessary method of filtration. After passing through the physical filtration unit, what remains of a non-aqueous system would usually be a predominantly hydrocarbon solution. To process this solution by adsorption separation would result in virtually all of the solution becoming trapped within the advanced filter media. This would be costly and usually

Figure VI-10
Solvent Reuse Using Filtration Systems



* Filter system are equipped with valves to route solvent to further treatment, disposal or recirculation, as appropriate

** Many emulsion/haze removers can be recirculated at this point

*** For Remaining Emulsion/haze/ink removes: these may potentially be recirculated counterproductive. Generally, such non-aqueous systems can be recirculated for reuse in screen reclamation after physical filtration until the solution becomes sufficiently contaminated so that disposal is required as either hazardous or non-hazardous waste (consult appropriate regulations in your area).

Summary

Filtration devices, when used in conjunction with a recirculation system, offer another opportunity for pollution prevention through recycling. By screening the effluent resulting from the screen reclamation process, filtering systems also facilitate compliance with effluent guidelines. The cost of these systems should be carefully considered by a printing facility. Printers should also consider potential savings generated by reducing the use of chemicals and by avoiding fines that could result from noncompliance with federal, state, and local environmental regulations.

Recirculation Systems

A recirculation system, though a combination of several technologies, allows a printer to minimize solvent usage, and consequently, minimizes pollution at the source. Its purpose is to filter contaminants from the cleaning solution so that the filtered solution can be reapplied to future screens. Generally, a recirculation system consists of an applicator/sprayer system, a filtration unit, and a recirculating mechanism. Information on some of these products appears in previous sections.

Features

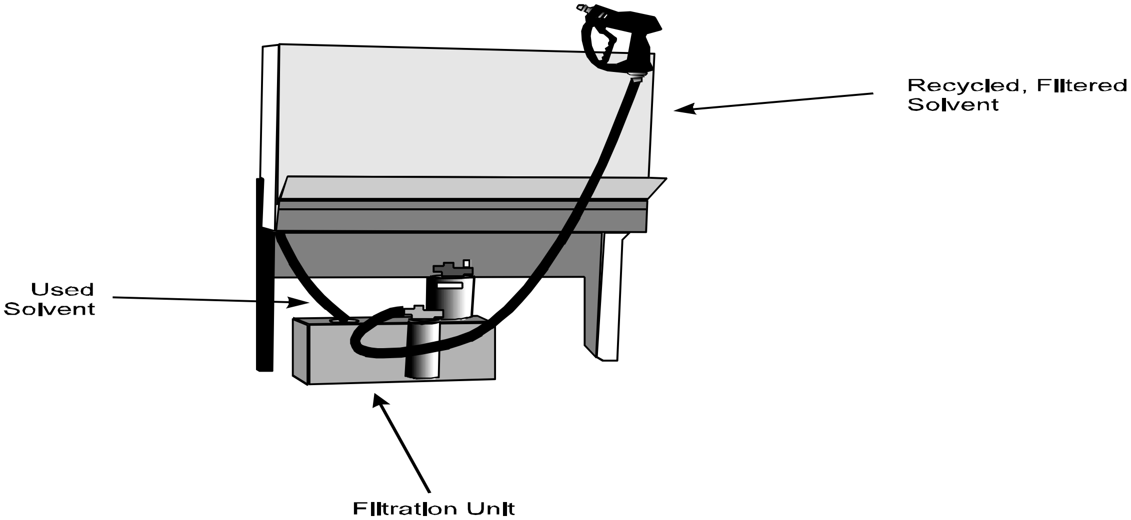
In many respects, a recirculation system represents a full commitment to pollution prevention because of its concurrent use of several different technologies. A typical recirculation system incorporates an applicator/sprayer, a filtration device, and a pump for recirculating the solvent; it is almost always used in conjunction with a washout booth/bin. Independently, each of these products may prove useful in efficiently reclaiming a screen, but together, they provide far greater pollution prevention opportunities.

At the most basic level, recirculation systems are available for ink removal only (Figure VI-11). After placing the screen in a washout booth to concentrate solvent application, the printer uses the sprayer system to apply the cleaning solvent to the mesh surface. After application, the used solvent, along with the ink sediment, drains to the filtration unit. When the effluent passes through the filtration system, the ink particulates are filtered out. The filtrate can then be recirculated by a pump to be reused in subsequent screen washing.

Printers who are interested in this type of system should expect to pay anywhere from $1,500 to $3,000 for the complete system. This would usually include the applicator, filtration unit, and recirculating pump with solvent reservoir. The price of such systems largely depends on the solvent capacity of the system (generally from 10 to 50 gallons). Lastly, printers should keep in mind that these systems only remove ink, and the emulsion/stencil must be removed separately.

In order to provide recirculating capability when removing both ink and emulsion, a printer may have to use an advanced hybrid system. This system includes several individual

Figure VI-11
Solvent Recirculating System

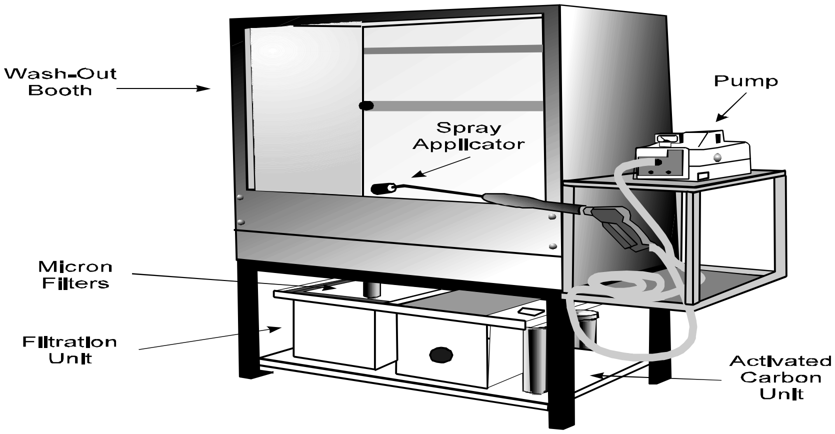


components that are linked together and may provide satisfactory screen reclamation at an economically competitive price. These individual components are essential when attempting to recirculate both ink remover and emulsion remover because of the distinct chemical function of each. The ink remover and emulsion remover must be filtered separately if successful recirculation for reuse is desired; moreover, certain options available with some equipment may provide a better match given a printer's unique operation. Printers should consider the formulation of the chemical system currently used (aqueous or non-aqueous) in addition to any other unique aspects of their operation when purchasing components for a recirculation system. The easiest and most common method for accomplishing recirculation is by using a water-based system of screen reclamation products.

Such a water-based system might include a washout booth, a pressure sprayer, a filtration unit, a recirculating pump, and an aqueous-based chemical reclaiming system, as shown in Figure VI-12. The chemical reclamation system in combination with the pressure sprayer will be responsible for removing the ink and emulsion from the screen. Depending on the chemical formulations of the cleaning products, a combined solution of water, cleaning solution, ink, and emulsion particles is then carried to the filtration system where the contaminants are removed through physical separation and possibly adsorption by an "activated" media. As noted earlier, this process must be carried out separately for both ink systems and emulsion systems; however, the end product of each filtration is a solution that could be pumped by the recirculation pump back through the pressure sprayer to clean subsequent screens.

This example is only one of many variations within the hybrid recirculation category. An assortment of other options are commercially available using both aqueous and non-aqueous based chemical reclamation systems. Interested printers should consult manufacturer's product literature, other printers, and relevant environmental regulations to obtain more information.

Figure VI-12
Advanced Reclamation System
(While this does depict may options, it could also incorporate a recirculation system)



Depending on the printer's requirements, the hybrid system could cost as little as $3,000 or as much as $15,000. The cost varies greatly because of the various kinds of equipment that could be included in the hybrid system. Printers should carefully consider which equipment best applies to their specific situation.

Issues to Consider

A printer should first and foremost determine whether a recirculation system is a necessary and useful technology in which to invest; cost of the system would be an important consideration. A small number of screens reclaimed daily or a small quantity of solvent used annually are good indicators that a recirculation system may not be the most cost-effective method for minimizing pollution.

However, for slightly larger operations, the ink remover recirculators may be an option. Such products may reduce solvent use while effectively removing ink. The cost of these systems is more moderate than the hybrid systems, but printers should keep in mind that emulsion/stencil removal is not provided for with these ink systems.

For facilities that spend significant time and resources on screen reclamation, a hybrid system may offer an excellent economic and environmental opportunity. Such systems are generally expensive ($3,000 to $15,000), but, for those printers that use large quantities of chemicals and reclaim a substantial number of screens, these systems offer several benefits. First, these recirculation systems provide ample opportunity for source reduction of reclaiming solvents. Since filtering and cleaning the used solvent for re-use can drastically reduce new solvent consumption at a facility, a printer may be able to considerably decrease the cost of doing business. Finally, these systems may, through the use of a filtration system, help maintain compliance with applicable environmental regulations.

For those printers that do choose to adopt a recirculation system, one key issue concerning pollution must be addressed. Printers should realize that although solvent use may be reduced through a recirculation device, these systems are not designed to eliminate pollution from a printing operation. Such systems merely change the form of the pollution from a bulk liquid that requires disposal to a concentrated liquid, solid, or semi-solid waste (from the filtration system) that must be dealt with as well. A printer should remember to consult applicable federal, state, and local environmental regulations concerning water and waste disposal.

Summary

A recirculation system can take on a variety of different forms. From a simple ink remover recirculator to a system that involves complete reclamation, these systems can be made to fit almost any operation. If a printer decides that this an appropriate method of pollution prevention, he/she should carefully consider the vast array of options in order to properly match the system to their facility. Further, printers should keep in mind that recirculation systems are not closed systems and that they are not designed to eliminate pollution from a printer's operation. Printers should consult applicable water and waste water disposal regulations to ensure compliance.

Distillation Equipment

Distillation devices that can be used to reclaim used solvent represent another alternative for addressing screen reclamation waste issues. These devices separate the contaminants from screen reclamation effluent and provide an effective way to recycle and reuse spent solvent. Thus, like a filtration and recirculation system, these solvent distillers provide an opportunity to reduce solvent use and operating costs.

Features

After a solvent has been used in screen reclamation, it usually contains various contaminants (resins, colorings/pigments, grease, etc.), which can either be disposed of as waste, filtered, or distilled. The distillation process involves the separation of the original solvent from the effluent's contaminants by boiling the solution. The vaporized portion of the liquid, usually the desired solvent, is withdrawn to be condensed and reused. The basic requirement for the separation of components by distillation is that at the boiling point of the liquid, the composition of the vapor must be different from the composition of the liquid with which it is in equilibrium.

The most frequently used distillation units that are commercially available operate using a specific process known as differential distillation. In differential distillation, the effluent is first placed in an enclosed heating container (Figures VI-13 and VI-14). The effluent is heated in the container to approximately 20 to 30 degrees above the desired solvent's boiling point; at this time, the solution begins to vaporize. The vapors rise and are then transported immediately to a condenser, where the condensed vapor (distilled solvent) is collected.[5] This can be accomplished by circulating cool water or air within the condenser to lower the temperature of

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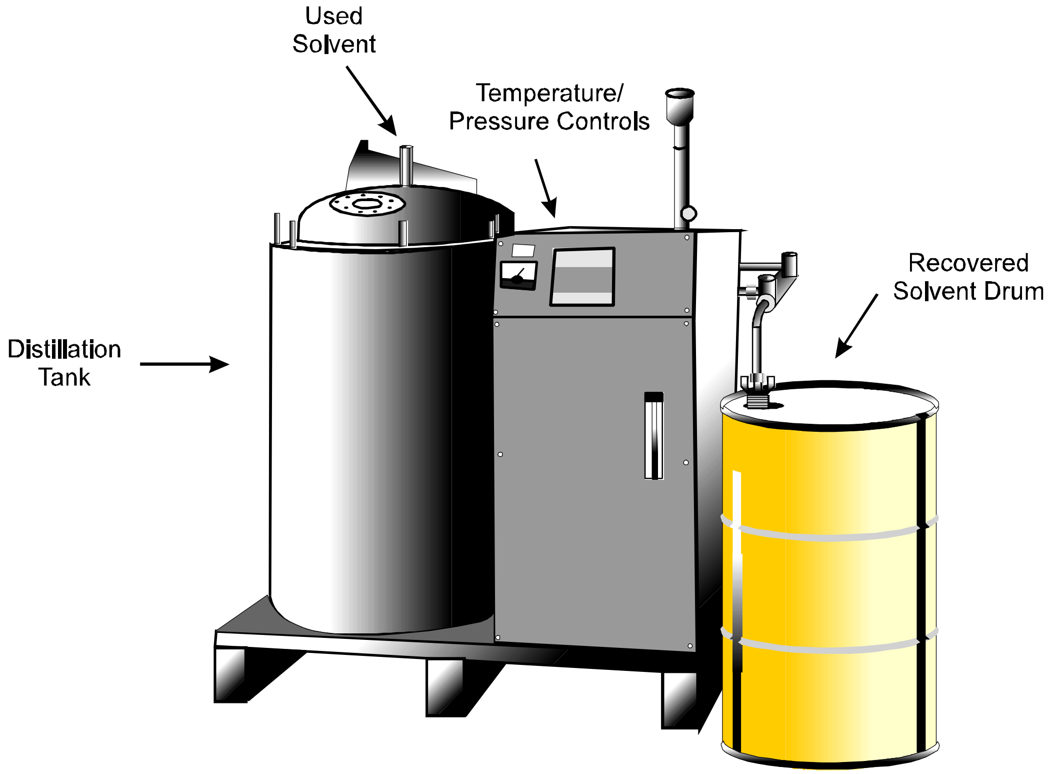
[5] Geankoplis, Christie J., Transport Processes and Unit Operations, (New York:Allyn and Bacon Inc.), 1983.

Figure VI-13

A Typical Differential Distiller Capable of Distilling Up to 110 Gallons of Used Solvent per Cycle

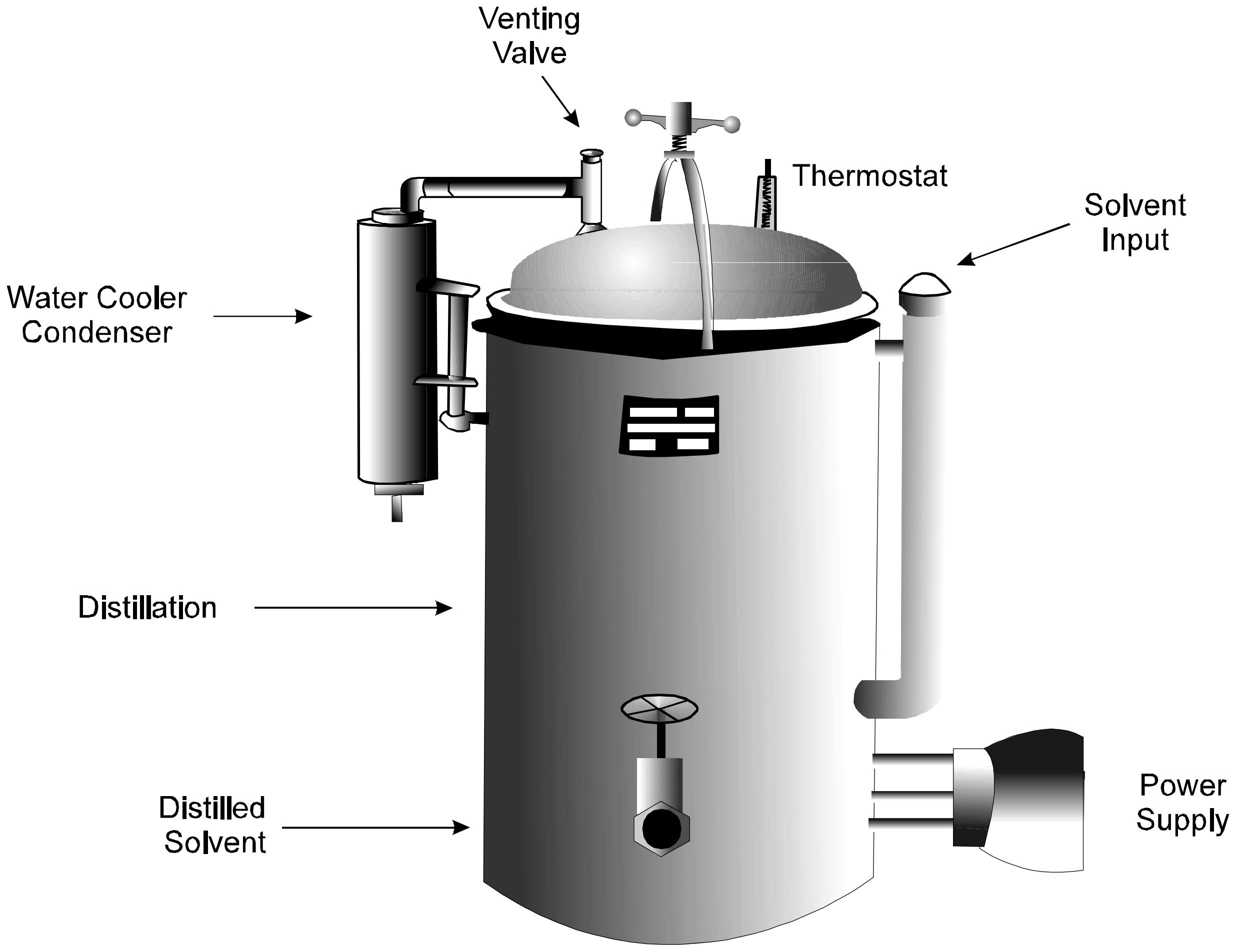
(Note the distillation unit (far left) and the drum for recovered solvent (far right))



the entering vapor. As the temperature of the vapor drops, it condenses into the desired liquid. This distillate can then be reused, while the contaminants remain in the original kettle to be disposed of as solid waste (hazardous or non-hazardous). The amount of solvent recovered largely depends on the type and concentration of the contaminants, but most distillation units can recover up to 90 percent of the remaining solvent.

Although the process generally remains the same, solvent distillers are available in a wide range of forms and sizes. A variety of distillation units that employ other methods of distillation could potentially be used for screen reclamation, but at this time, differential distillers represent well above 90 percent of the market. Most differential distillers are equipped with a heating container and a condenser with a pipe connecting the two. The heating containers can vary in size from a two gallon capacity to 250 gallon capacity, but despite this size differential, the containers are all virtually the same in function and composition. The main container is filled with a heat-transfer liquid (usually water, or polyethylene glycol), and the drum containing the used solvent is placed into this media. An air tight lid covers the apparatus, and a hose/pipe connecting the unit to the condenser is often inserted at this location. The condenser, usually less than or equal to the heating unit in size, provides the location for the vaporized solvent to recondense into liquid form. This part of the unit usually incorporates a collection chamber for the recycled solvent and an internal recirculating cooling system.

Figure VI-14
Variation of a Solvent Distillation Unit



Distillation units can vary as much in cost as they do in size. A small distiller (2 to 5 gallons) is available for several thousand dollars. As the capacity of the distiller increases, the price also begins to increase. For a distillation unit with a 15 gallon capacity, a printer should expect to pay approximately $10,000, and for the larger units (more than 100 gallons), prices can rise into the $20,000 to $100,000 range.

Issues to Consider

The main issue for printers to address is the question of need. Given a printer's individual operation, is a distillation unit the best method for reducing solvent use while maintaining compliance with relevant environmental regulations? Distillation units can provide an effective method for reclaiming used solvent for future use (these units frequently yield 90 percent recovery of available solvent). Given this effective recovery potential and the resultant decrease in new solvent use, these units may provide an extremely practical method of pollution prevention for those printers that spend significant time, money, and effort in screen reclamation. However, the costs, which range in the thousands, may prove to be too high for a smaller operation. Those printers that can not afford such an investment may wish to examine other alternatives, such as filtration and/or recirculation to maximize the pollution prevention opportunities.

Safety considerations may play a role in the decision of a printer to purchase a distillation unit. In the past year, issues concerning the explosive nature of such products have been raised. The International Fire Code Institute, an organization consisting of state fire marshals, has been investigating whether these on-site distillation units constitute an explosion hazard given the flammable nature of the solvents that are reclaimed. Consideration of changes in the Uniform Fire Code are underway (these began in Washington State and are now being considered in twelve western states), and the results of this inquiry may affect the availability of such products on the American market. Printers should consult amendments to this code as well as applicable environmental regulations when assessing distillation as a screen reclamation option.

Summary

Distillation units can provide a cost-effective method to reclaim solvent used in screen reclamation, and this may result in other benefits as well (lower cost, compliance benefits). These differential distillers can vary in size (two or three gallon capacity up to 250 gallons) as well as in cost. The relatively high cost may prohibit many small printers from utilizing this technology. When purchasing these units, printers should consider cost, relevant environmental regulations, and changes in the Uniform Fire Code affecting the availability and use of distillers.

Chapter VII
Cost/Benefit, Energy & Trade Issues

International Trade Issues

According to Marci Kinter of SPTF, screen reclamation in other parts of the world does not vary greatly from screen reclamation in the United States. There is some evidence that the size of screen printing shops in Europe may be larger; there are expensive automatic screen washers produced and sold there which were apparently unable to find a market in the US. Otherwise, screen reclamation products are basically the same as those used here. In addition, there is much growth occurring in the Asia-Pacific market.[1]

Many of the screen reclamation products used in the US are produced in Europe, including both traditional and alternative products.

Energy and Natural Resource Issues

Thus far, this CTSA has focused primarily on the trade-offs between risk, performance and cost of alternative screen reclamation chemicals and methods. When designing products or processes with the environment in mind, however, conservation of energy and natural resources (e.g., materials) should also be a goal. This section identifies the areas where energy and materials are consumed as a result of the screen reclamation process.

Screen Reclamation Processes

Table VII-1 presents the process steps performed in the four manual screen reclamation methods described in Figure I-2. Each time a process step is performed, whether it involves the application of a chemical or a water wash, it results in the use of energy or natural resources (e.g., chemicals derived from natural resources, water, disposable shop towels, etc.).

Energy is consumed when mechanized equipment is used, including hot water heaters and pressurized water-spray units. Any use of materials results in the consumption of natural resources, whether the material is water, chemicals, or shop towels. Although it is true that materials can frequently be reclaimed once used, the reclamation process results again in the use of energy and natural resources.

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[1] SPAI. 1993. Screen Print '93 International Convention and Exposition. Screen Printing Association International, Fairfax, VA. p104.

Table VII-1
Steps Performed in Manual Screen Reclamation Methods

Screen Reclamation Step	Screen Reclamation Method			
	1	2	3	4
Ink Removal Chemical	✓	✓	✓	×
Degreaser/Degradant Chemical	×	×	✓	×
Water Wash	Optional	Optional	Optional	✓
Emulsion Removal Chemical	✓	✓	✓	✓
Water Wash	✓	✓	✓	✓
Haze Removal Chemical	×	✓	×	✓
Water Wash	×	✓	×	✓

Key: ✓ - Step performed
× - Step not performed

Collecting Data on Energy and Natural Resources Consumption

The first step in an analysis of energy and natural resources consumption is to select the life cycle stages on which to focus. The life cycle of a typical product system begins with the acquisition of the raw materials used to make the product and continues on through manufacture, transportation, use, recycling, and disposal of the product. Energy and natural resources consumption can occur during each of these life cycle stages, but may be much more significant in one life cycle stage as compared to another. For example, studies of the life cycle of the automobile have shown that the vast majority of the energy consumption of a typical auto comes from the product use stage.

For screen cleaning and reclamation chemicals, the DfE Screen Printing Project elected to focus on energy and natural resource consumption during the use stage, when printers are actually cleaning and reclaiming their screens. We focused on this life cycle stage, and not the other life cycle stages, for the following reasons:

- The amount of energy and natural resources consumed during the use of the chemical products will vary depending on the relative amounts of chemical products used, the types of equipment used to apply the products and reclaim the screens, the temperatures at which the cleaning steps are conducted, and the duration of the various cleaning steps. Since this life cycle stage could be significant, it was decided to collect data on energy and natural resources consumption during the performance evaluation.

- Manufacturers of screen reclamation products indicated that the same basic process is used to formulate screen cleaning and reclamation products, regardless of the types of ingredients. Therefore, no significant differences between products were expected in energy and natural resources consumption during the product formulation process.

- Significant differences could exist in the amounts of energy and natural resources consumed when the chemical ingredients are manufactured. For example, chemical ingredients manufactured from petroleum not only use energy during the chemical manufacturing process, they also have an equivalent energy value. The amounts of each individual chemical ingredient used in screen cleaning and reclamation products is small, however, relative to the total consumption of these chemicals in other industries or products. For this reason, and because of the limited resources available to this project, no data were collected on the amounts of energy and natural resources consumed during chemical ingredient manufacturing.

- Significant differences could also exist in the amounts of energy and natural resources consumed when the raw materials used to make chemical ingredients are acquired. For example, petroleum-based chemicals require the pumping of petroleum from deep wells and transportation, usually by pipeline, to a petroleum refinery. Citrus-based products are made from fruit harvested from trees and transported, usually by truck or rail to a chemical manufacturer. For the same reasons mentioned above, however, no data were collected on the amounts of energy and natural resources consumed during the acquisition of raw materials.

- Differences may exist in the amounts of energy and natural resources required to dispose of spent screen cleaning and reclamation chemicals or water contaminated with screen cleaning chemicals. Due to limited resources, however, no data were collected on energy and natural resources use during the treatment and disposal stage of the product life cycle.

To assess energy and natural resources consumption during the performance evaluations, the following data were initially requested from the observers and the volunteer screen printing facilities:

- Equipment nameplate capacity or specifications (e.g., voltage, pressure, etc.);

- Equipment operating parameters, including operating pressure and flow rates for spray or water-blast equipment, and water temperature (if heated water is required);

- The amount (volume) of chemical product consumed during each cleaning/reclamation step, and the amount of dilution with water, if any;

- The amount (volume) of water consumed during each water wash step, calculated from the flow rate and the duration of the water wash step;

- The number of shop wipes required with the ink removal chemical; and

- The size and condition of the screen so that data could be normalized to a single screen size.

Due to the large amount of data required for the performance evaluation, however, some of the energy and natural resources data were not collected; the data requirements were taking too much of the printer's time or the extent of the data requirements were not clear. As a result, quantitative analysis of the energy and natural resources consumed with traditional and alternative products during the screen cleaning/reclamation process was not possible. Listed below, however, is a summary of the areas where energy and natural resources may be consumed as a result of the screen reclamation process.

Energy Impacts of Screen Reclamation

- The use of chemicals products and water has an energy impact. As discussed above, chemical manufacturing, distribution, recycling and disposal all require energy inputs. Chemical use requires an energy input if mechanized equipment is used. By the same token, the cycle of water treatment, distribution, and use followed by wastewater treatment also requires energy inputs.

- During a water wash, the rate of energy use is dependent on the type of equipment used to apply the water and the temperature of the water. Obviously, high-pressure spray washes require more energy and equipment than a non-pressurized water wash, however they may consume less water. Hot or warm water washes are much more energy intensive than those conducted at ambient water temperatures. In fact, it is likely that products requiring the use of heated water would have the greatest energy impact, even if a quantitative analysis was done of all stages of the product life cycle. A life cycle assessment of laundry detergents, for example, found that the greatest environmental impact from using laundry detergents came from producing the energy required to heat the water in hot-water washes.

- If a pressurized water wash is required, spray units can be used that optimize the wetting potential and minimize water flow by using a combined stream of water and air. In some cases, chemicals applied using a rag or brush can supply the abrasive action that would be provided by a pressurized water wash. If the screen is scrubbed manually, less chemical product may be required and a non-pressurized wash can be used to rinse the screen.

Materials Acquisition and Natural Resource Impacts of Screen Reclamation

- Some screen reclamation methods may require the use of greater amounts of chemical products than others, depending on the number of steps requiring chemicals and the volume of chemical used in each step. The former depends on the screen reclamation method selected; the latter depends on a number of factors, including the chemical product used, the extent of ink and stencil on the screen, employee preference, and time allowed for ink to dry before cleaning. The amount of chemicals required to reclaim a screen should be optimized to the extent possible to avoid unnecessary use of resources.

- The amount of water used during screen reclamation also depends on the screen reclamation method and chemical products used. For example, several of the alternative chemicals products evaluated during the performance testing did not require a water wash after use. If a water wash is required, the amount should be optimized to avoid unnecessary use of resources.

- ○ If a water wash is performed, the resulting wastewater should be collected separately from any chemical overspray or chemical run-off collected while the chemical is being applied. This will allow for more efficient chemical recovery and recycling, reduce the concentrations of contaminants in the wastewater, and thus, improve the treatability of the wastewater.

- ○ If the entire screen does not require cleaning or reclamation, reusable rags and brushes can be used to apply chemical products to selected areas of the screen, thus reducing the volume of chemical product used. Reusable rags and brushes save resources compared to disposable products and contribute less to the solid waste stream. The cleaning of reusable products, however, does result in a waste stream and requires inputs of energy and natural resources.

- ○ Disposable shop towels result not only in the consumption of resources, they also generate solid, potentially hazardous, waste and increased disposal cost.

Cost/Benefit Analysis of Alternative Screen Reclamation Processes

The risk assessment conducted as a part of the CTSA analyzed the risk of each alternative screen reclamation system used in each of the alternative methods as well as the screen disposal work practice and the automatic screen washer technology. A cost analysis was also performed to estimate the cost of each alternative screen reclamation method, technology, and work practice evaluated in the CTSA. This section compares the costs and benefits (in terms of reduced human health risks) of switching to alternative screen reclamation products, technologies, and work practices. In addition, this analysis looks beyond just the costs (material, labor, etc.) and benefits (reduced worker health risks) to printing operations of switching to alternative systems and considers the potential for societal benefits. Specifically, it considers the possibility that the use of screen reclamation substitutes could result in reduced health risks to the general population, lower health insurance and liability costs for the printing industry and society, and decreased adverse impacts to the environment. The costs and risk trade-offs associated with the baseline and each method are summarized in Table VII-2.

Exposed Population

Due to resource limitations, it was not possible to quantify changes in individual or population risks, i.e., changes in the incidence of associated health effects. As a result, this analysis does not provide an estimate of risk reductions nor a dollar estimate of the benefits associated with reduced health risks but makes qualitative comparisons of the estimated costs and potential benefits of switching from traditional to alternative screen reclamation methods. Estimates of the worker population potentially exposed to traditional and alternative screen reclamation chemicals, however, are provided based on data collected in the risk assessment and on estimates of numbers of printing facilities from SPAI (see Table VII-3). It has been estimated that for small to medium sized facilities one to three employees are involved in screen reclamation. Combining this information with the total number of print shops in the graphics industry (20,000, SPAI, 1994) yields an estimated exposed worker population of between 20,000 and 60,000.[2] For ink removers it is possible to further refine exposed worker population estimates based on market share data for traditional and alternative ink removers.

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[2] Estimates of the exposed general population are not available.

Table VII-2
Costs and Risk Trade-offs of Screen Reclamation Substitutes

System Evaluated		Cost/Screen	Cost/Facility	Risk Trade-offs
Baseline for Method 1 (Traditional System 4 - Haze Remover)		$3.63	$5,446	Clear concern for worker dermal risks and worker inhalation risks
Method 1: Chemical substitutes for ink removal and emulsion removal. No haze removal required.	Chi (no haze remover)	$1.95-2.83	$2,918-4,245	Moderate concern for worker dermal risks and very low concern for inhalation risks
	Beta	$7.97	$11,958	
Baseline for All Other Methods (Traditional System 4)		$6.27	$9,399	Clear concern for worker dermal risks and worker inhalation risks
Method 2: Chemical substitutes for ink removal, emulsion removal and haze removal.	Alpha	$5.92-9.37	$8,886-14,062	Moderate concern for worker dermal risks and low concern for inhalation risks
	Chi	$3.25-3.89	$4,879-5,829	
	Delta	$3.28-7.66	$4,917-11,489	
	Epsilon	$3.08-5.29	$4,624-7,930	
	Gamma	$5.06-5.61	$7,590-8,417	
	Mu	$4.79-9.33	$7,185-13,997	
	Phi	$6.10-7.82	$9,233-11,728	
	Omicron-AE	$5.49-10.85	$8,240-16,278	
	Omicron-AF	$3.89-4.45	$5,836-6,675	
	Zeta	$5.39-8.99	$8,080-13,479	
Method 3: Chemical substitutes for ink removal, degreasing and emulsion removal. No haze removal required.	Omicron	$5.57	$8,358	Moderate concern for worker dermal risks and very low concern for inhalation risks
Method 4: Technology substitute of screen disposal in lieu of reclamation.	Theta	$4.53	$6,797	Marginal concerns for worker dermal risks and very low concerns for worker inhalation risks
Technology Substitute	Automatic Screen Washer	$4.13-10.14	6,198-15,213	Moderate concern for worker dermal risks and very low concern for inhalation risks
Work Practice Substitute	Screen Disposal	$49.43	$74,141	No risks associated with screen reclamation products

Note: Costs presented are normalized costs. Ranges are presented when there was more than one facility using the method and system in the performance demonstration.

Allocating between use of traditional and alternative products suggests that between 13,120 and 39,360 workers are exposed to traditional ink removers and 6,880 and 20,640 are exposed to alternative ink removers.[3] As there are few differences among emulsion removers it is assumed that the total population of screen reclaimers are exposed to similar formulations of emulsion removers. Finally, the market share of haze removers used by printing operations that is considered to be traditional and the market share that is considered to be alternative is not known. Consequently, for this cost exercise, it was assumed that all haze removers currently used are traditional products. Not all printers, however, use haze removers. Industry figures indicate that haze removal is performed on between 27 and 80 percent of reclamations. The number of workers exposed to traditional haze removers is, therefore, estimated to be between 5,400 and 48,000.

Table VII-3 also indicates the number of workers that could potentially experience a reduction in risk (column 1) if alternative products were substituted for traditional products in their shop. It should be noted, however, that benefits may be minimized if printers switch to alternatives for some but not all screen reclamation products. A discussion of the potential benefits that might result from reductions in the incidence of an illness (hypertension) linked to exposure to chemicals typically used in screen reclamation (solvents), is presented later in this section as an example of the type and magnitude of benefits that are associated with reductions in health risks.

Table VII-3
Estimates of Exposed Worker Population

	Worker Population Exposed to Traditional Products	Worker Population Exposed to alternative products
Ink Remover	13,120 - 39,360	6,880 - 20,640
Emulsion Remover	20,000 - 60,000	
Haze Remover	5,400 - 48,000	0
Total Exposed Worker Population	20,000 - 60,000	

The following discussion is limited to ink removers and haze removers used in each method since EPA's risk assessment concluded that risks associated with traditional and alternative emulsion removers were virtually the same. Emulsion remover risks include a significant risk of skin irritation and tissue damage from the components of emulsion removers (i.e., either strong oxidizers or strong bases) if screen reclaimers are exposed in the absence of proper protective clothing. None of the traditional or alternative emulsion removers, however, presents significant inhalation risks.

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[3] Market share equals 65.6 percent for traditional ink removers and 34.4 percent for alternative ink removers.

Human Health Benefits

The benefits associated with switching to less toxic ink removers and haze removers can be described in terms of reduced risks to both printers and the general public. The results of the EPA risk assessment suggest that, in general, the alternative products are much less volatile than traditional products. While all of the traditional product systems present clear concerns for worker inhalation exposures, only one of the alternative systems (Mu) presents a concern for inhalation exposures to workers. Almost half of the alternative products, however, present clear concerns for unprotected dermal exposures to workers, as do all of the traditional products. Worker dermal exposures to all products, however, can easily be minimized by using proper protective clothing during screen reclamation.

The most significant health risk to the general population from screen reclamation products is associated with the release of volatile organic compounds that contribute to the formation of photochemical smog in the ambient air. Traditional products, due to their greater volatile fraction, are likely to have a much greater impact on ambient air quality, if released, than the alternative products. In addition, the use of an automatic screen washer technology for ink removal may significantly reduce air emissions of certain volatile ink remover components, although the amount of reduction depends on the specific components of the formulation and the type of technology employed. EPA's risk assessment indicates, however, that health impacts to the general population from screen reclamation products are very low for all traditional and alternative products, technologies and work practices evaluated. Consequently, the reduction in risks associated with switching to alternative products, technologies, or work practices are minor.

Associated Costs

Per screen costs depend on variations in labor costs, product usage, materials and equipment, and hazardous waste disposal costs (screen size and number of screens cleaned have been normalized to the baseline) at each facility in the performance demonstrations.[4] As shown in Table VII-2, the cost associated with using the baseline traditional screen reclamation system equals $3.63/screen for method 1 and $6.27/screen for all other methods (assuming reclamation of 6 screens per day and a screen size of 2,127 in^2) and total facility costs of $5,446/year and $9,399/year respectively.[5] Under the alternative systems, costs range from $1.95/screen ($2,918 per year) for Method 1 to $49.43/screen ($74,141 per year) for the Screen Disposal option. Excluding Screen Disposal, the cost of alternative methods range from $1.95/screen (Method 1) to $10.85/screen (Omicron-AE, Method 2). As such, cost savings might be realized by printers switching to any of the methods except screen disposal, depending on the operating conditions of their shop. Based on the performance demonstrations, two out of three facilities in method 1, 14 out of 22 facilities in method 2, one out of two facilities in method 3, the one facility in method 4, and one out of two facilities using the automatic screen washer would experience cost savings from switching to alternative products, technologies, and work practices. Cost savings indicated in the performance demonstrations range from as little

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[4] Normalized values adjust product usage, number of screen cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario. Labor costs, however, are not normalized. Normalization allows a comparison between the baseline and facility results.

[5] The baseline system for method 1 does not include a haze remover.

as $0.17/screen to $3.19/screen and are frequently due to differences in labor costs. Alternatively, printers could experience cost increases of between $1.39/screen and $43.16/screen ($4.58/screen excluding screen disposal). It should be noted that these cost estimates do not fully reflect the performance of product systems demonstrated. For example, while performance characteristics such as volume of product and time to clean were considered, other important characteristics such as whether the facility continued using the alternative product and whether the product shortened the life of or destroyed the screen were not considered.

Costs and Benefits by Method

The costs and benefits associated with each method are discussed separately below. For each comparison, traditional system 4 is used as the baseline system. Briefly, human health concerns for the baseline system are related to toluene, methyl ethyl ketone, and methanol for ink removers and acetone, cyclohexanone, and mineral spirits for haze removers. Risks are linked to chronic dermal and inhalation exposures to workers during both ink removal and haze removal. Dermal exposures to workers using mineral spirits in haze removal can be quite high but were not quantified in the risk assessment due to limitations in the data and the fact that these risks are easily mitigated through the use of gloves.

Method 1: Chemical Substitutes for Ink Removal and Emulsion Removal. No Haze Remover Required

The use of Chi and Beta in method 1 significantly reduced worker inhalation risks and moderate worker dermal risks. Clear concern exists, however, for chronic dermal exposures to diethylene glycol series ethers used in ink removal. Moderate concern exists for developmental toxicity risks from dermal exposures to N-methylpyrrolidone. Concern for inhalation exposures to other ink removal chemicals used in this system, however, is very low. Haze remover is not used in this method. Dermal and inhalation risks associated with haze removers are, therefore, completely avoided under this method. In terms of costs, two printers switching to method 1 incurred cost savings of $0.80/screen ($1,201/year) and $1.68/screen ($2,528/year), however, one facility experienced a cost increase of $4.34/screen ($6,512/year).

Method 2: Chemicals Substitutes for Ink Removal, Emulsion Removal and Haze Removal

Ten product systems are included in Method 2. Overall, this method, except for Mu, has significantly reduced worker inhalation risks and moderate worker dermal risks as compared to the baseline system. Concern does exist, however, for chronic dermal exposures to diethylene glycol series ethers, cyclohexanone, benzyl alcohol, d-limonene, and propylene glycol methyl ether used in ink removal. Marginal concerns exist for chronic inhalation exposure to workers using propylene glycol series ethers and d-limonene in ink removal. Moderate concern also exists for developmental toxicity risks from dermal exposures to N-methylpyrrolidone and inhalation exposures to methoxypropanol acetate, propylene glycol series ethers, and cyclohexanone.

Risks associated with other chemicals in product systems Alpha, Beta, Delta, Epsilon, Gamma, Mu, Phi, Zeta, and Omicron could not be quantified due to limitations in the hazard data. It is possible, however, that inhalation and dermal exposures to these chemicals could be high.

Fourteen of the 22 printing facilities using method 2 experienced cost savings of as much as $3.19/screen ($4,775 per year). The remaining eight printing facilities experienced cost increases from $0.24/screen ($373/year) to $4.58/screen ($6,879/year).

Method 3: SPAI Workshop Process -- Chemical Substitutes for Ink Removal, Ink Degradent, Degreasing, and Emulsion Removal. No Haze Removal Required

Similar to methods 1 and 2 above, method 3 has significantly reduced worker inhalation risks and moderate worker dermal risks. Clear concern does exist, however, for chronic dermal exposures to workers using diethylene glycol series ethers in ink removal. In addition, there are possible concerns for developmental toxicity risks from dermal "immersion" exposures to diethylene glycol series ethers. Switching from the baseline system to Method 3 resulted in a cost savings of $0.70/screen ($1,041/year).

Method 4: Technology Substitute of High Pressure Wash for Ink Removal, Technology Substitute and Reclamation Products used for Emulsion and Haze Removal

Using a high pressure wash results in only marginal concerns for worker dermal risks and very low concerns for worker inhalation risks. Specifically, there is a marginal concern for chronic dermal exposures and a very low concern for chronic inhalation exposures to cyclohexanone during haze removal. In addition, there is minimal concern for developmental and reproductive toxicity risks from inhalation exposures to cyclohexanone. In terms of costs, the printing facility in the performance demonstration switching to method 4 incurred a cost savings of $1.74/screen ($2,602/year).

Technology Substitute of Automatic Screen Washer for Ink Removal.

Risks from the automatic screen washer were evaluated assuming use of the ink removers from traditional system 1 and traditional system 3. Using traditional system 1 ink remover, inhalation exposures were significantly lower (approximately 70% reduction) than the exposures during the manual use of this ink remover. Using traditional system 3, marginal concerns are for chronic inhalation exposures to toluene, methyl ethyl ketone and methanol are indicated. Additionally, clear concerns for chronic dermal exposures to toluene and methyl ethyl ketone and marginal concerns for dermal exposures to methanol are indicated. While the automatic screen washer was not used by printing facilities in the performance demonstrations estimates of the cost to printers of using the automatic screen washer technology were generated. Based on these estimates, it is expected that printers switching from the baseline product to a low cost ($5,000) automatic screen washer for ink removal would experience a cost savings of $2.14/screen ($3,201/year). Printing operations similar to the model facility switching to a high cost ($95,000) automatic screen washer (more automated than the $5,000 washer) would experience a cost increase of $3.87/screen ($5,814/year).

Work Practice Substitute of Screen Disposal in Lieu of Reclamation.

Under this approach, reclamation does not occur. Rather, the screen is cut out of the frame and disposed. As such, it is considered to be a pollution prevention activity and is discussed more fully in Chapter Six: *Overall Pollution Prevention Opportunities for Screen Reclamation*. It should be noted, however, that the costs associated with this approach are quite high at $49.43/screen and represent a very significant cost increase to printers. Based on discussions with the Screen Printing Technical Foundation, it is suggested that screen disposal is probably only cost effective with smaller screen sizes and/or long production runs, where the number of impressions nears the expected life of the screen.

Additional and Societal Benefits

Potential Benefit of Reducing Hazardous Waste Disposal

In addition to reducing human health risks to screen reclamation workers, switching to alternative products will create social benefits in the form of reducing the amount and toxicity of hazardous wastes which are transported and disposed of in landfills and reducing releases of volatile organic compounds (VOCs) that contribute to the formation of photochemical smog in the ambient air. These benefits include the benefit to society of 1) reduced risk from exposure to hazardous wastes during transport to landfills and in the event of migration of contaminants from the landfill into groundwater and 2) reduced human health risk from exposure to VOCs released into the atmosphere. Because the risk assessment did not link exposures of concern to adverse health outcomes, however, it was not possible to estimate the dollar value of these social benefits. It should also be noted that a reduction in the quantity of hazardous waste generated could reduce the likelihood that a landfill or the generator's facility will require a hazardous waste clean-up in the future, a cost that could ultimately be borne by society.

Printing companies may also receive benefits in the form of reduced hazardous waste disposal costs since, for most of these product systems, there would be no hazardous waste associated with disposal of the product, although hazardous constituents in contaminated ink may affect disposal of spent ink remover. Comparing the current cost of disposing of hazardous waste estimated for the baseline facility and for facilities using alternative products in the cost analysis, an estimate of the potential hazardous waste disposal benefit can be estimated. Assuming 20,000 screen printing facilities involved in the graphics industry in the U.S. (SPAI, 1994), the total annual current cost of disposing of hazardous waste is approximately $600,000/year ($0.02/screen x 6 screens/day x 250 work days x 20,000 printing facilities). Because the performance demonstrations were meant to be representative of small and medium size facilities, this hazardous waste disposal cost does not account for any unit cost differences attributed to disposal of hazardous wastes by large printing operations.

For 19 of the 28 printing facilities in the performance demonstrations, the cost of disposing of hazardous waste would fall to $0/screen under an alternative method. It should be noted that determination of hazardous wastes was based on ignitability of chemical constituents and did not include toxicity testing. Where toxicity testing results in classification of the wastes as hazardous, disposal costs would be incurred. In addition, there may be costs associated with State and local regulations. The remaining nine facilities would incur hazardous waste disposal costs of as much as $0.08/screen. The variation in per screen disposal costs ($0.02 versus $0.08) is due to differences in the amount of hazardous waste generated per screen under different options.

Total hazardous waste disposal costs for the entire industry, based on the results of this cost analysis, range from $0/year to $2.4 million/year if printing facilities switch to alternative systems ($0 - 0.08/screen x 6 screens/day x 250 work days x 20,000 printing facilities). Within this range, the resulting cost savings or benefit could amount to as much as $600,000/year. Alternatively, if all printers faced higher waste disposal costs, a total cost of $1.8 million/year would result. As mentioned above, however, more than two thirds of the facilities in the performance demonstrations would experience disposal costs of $0 and only one tenth of facilities would experience disposal costs as high as $0.08/screen if they switched to an alternative system. As such, it is unlikely that total costs would be as high as $1.8 million/year.

Potential Benefit of Avoiding Illnesses Linked to Exposure to Chemicals Commonly Used in Screen Reclamation

As mentioned above, the risk assessment did not link exposures of concern to adverse health outcomes. Data do exist, however, on the cost of avoiding or mitigating certain illnesses that are linked to exposures to screen reclamation chemicals. Such cost estimates indicate potential benefits associated with switching from traditional screen reclamation products to less toxic products. For example, one disease associated with exposures to solvents typically used in screen reclamation is hypertension. Hypertension (persistent high blood pressure) increases the risk of heart attacks and stroke, particularly when coupled with high blood cholesterol levels and enlargement of the heart's left ventricle. Hypertension has also been linked to early mortality and short or long-term damage to the heart, kidneys, brain, eyes, and circulatory system. Treatment for hypertension is largely focused on decreasing blood pressure and controlling other risk factors in an attempt to avoid these more serious health effects. Per-patient lifetime estimates of the direct medical costs of treating hypertension were developed in a previous analysis titled *The Medical Costs of Five Illnesses Related to Exposure to Pollutants* (Abt Associates, 1993). The results of this analysis suggest that avoiding one case of hypertension would result in the avoidance of an average lifetime cost of treating hypertension of between $3,654 to $11,551 (1993 dollars, updated from 1978 dollars using the Consumer Price Index for medical care costs) for men and between $3,094 to $10,186 (1993 dollars, updated from 1978 dollars using the CPI for medical care costs) for women. It should be noted that this estimate is not inclusive of the non-medical direct costs or indirect costs of illness. For example, child care and housekeeping expenses required due to illness considered to be non-medical direct costs are not included. Similarly, indirect costs that reflect both the decreased productivity of patients suffering a disability or death and the value of pain and suffering borne by the afflicted individual and/or family and friends are not included. This estimate does suggest, however, the minimum benefit per affected person that would accrue to society if switching to an alternative screen reclamation product system reduced hypertension cases among workers and other individuals exposed to screen reclamation chemicals. In addition, reductions in illness benefits paid by printing operations may directly affect individual companies through a reduction in liability and health care insurance costs. While reductions in insurance premiums as a result of pollution prevention are not currently widespread, the opportunity exists for changes in the future.

Appendix A
Glossary of Terms Used in the Environmental Fate Summaries

This Appendix defines the following terms, which are used in the environmental fate summaries:

- acclimation
- activated sludge
- beta-oxidation
- bioconcentration factor (BCF)
- biodegradation
  - primary degradation
  - ultimate degradation
- biochemical oxygen demand (BOD)
- gravitational settling
- Henry's Law constant (H_C)
- hydrolysis
- hydrophile/hydrophobe
- hydroxyl radical
- leaching
- mobility
- octanol/water partition coefficient (K_{OW})
- persistence
- photolysis
  - direct photolysis
  - indirect photolysis
- photooxidation
- screening test
- soil sorption constant (Kj
- STP fugacity model
- transformation
- transport
- vapor pressure
- volatilization
- water solubility
- wet deposition

Acclimation: process in which exposure of a microbial population to a chemical results in a more rapid transformation of the chemical than initially observed

Activated sludge: the flocculated mixture of microorganisms and inert organic and inorganic mated ' al normally produced by aeration of sewage. Constitutes the biological treatment process most frequently employed for purification of domestic sewage

Beta-oxidation: microbial degradation pathway in which fatty alkyl groups are enzymatically degraded two carbons at a time, eventually resulting in total biodegradation of the alkyl group

Bioconcentration factor (BCF): equilibrium ratio of the concentration of a chemical in an exposed aquatic organism to the concentration of the chemical in the surrounding water

Biodegradation: the transformation of chemical compounds by living organisms. Not confined to microorganisms (e.g., bacteria, fungi), but chiefly a microbial process in nature

Primary degradation: any biologically induced structural transformation of the parentcompound that changes its molecular identity

Ultimate degradation: any biologically mediated conversion of an organic compound to inorganic compounds (e.g., CO, and H,O) and products associated with normal metabolic processes.

Similar to **Mineralization**

Biochemical oxygen demand (BOD): the amount of oxygen consumed by microorganisms when metabolizing a chemical compound

Gravitational settling: process by which particulate matter reaches land surfaces or water bodies via deposition from the atmosphere

Henry's Law constant (H_c): the air/water partition coefficient, usually estimated by dividing the vapor pressure of a sparingly water soluble chemical substance by its water solubility. H. , provides a measure of the volatility (see volatilization) of the chemical from soil or water

Hydrolysis: transformation process in which a molecule, abbreviated RX, reacts with water, forming a new chemical bond between R and oxygen derived from water, and cleaving the bond between R and X. Webster's says "a chemical process of decomposition involving splitting of a bond and addition of the elements of water"

Hydrophile: a molecular fragment that imparts increased water solubility**,** usually a polyethoxylate, sulfonate, sulfate, quaternary ammonium, phosphate, or other hydrophilic ("water-loving") group

Hydrophobe: a molecular fragment that imparts increased fat solubility and decreased water solubility, usually an alkyl group with at least 10 carbons or a similarly hydrophobic ("water hating") substituted benzene group

Hydroxyl radical: a strong oxidizing agent consisting of one oxygen atom and one hydrogen atom, which is generated naturally by the action of sunlight and is the chief oxidizing agent in the atmosphere (see photolysis/photooxidation)

Leaching: transport process by which dissolved chemical substances move through soil with the percolation of water

Mobility: ability of a chemical substance to move through soil with the percolation of water

Octanol/water partition coefficient (K_{ow}): equilibrium ratio of a chemical's concentration in the octanol phase to its concentration in the aqueous phase of a two-phase octanol/water system. K_{ow} is an important parameter because it provides an indication of a chemical=s water solubility and its propensity to bioconcentrate in aquatic organisms and sorb to soil and sediment

Persistence: ability of a chemical substance to remain in a particular environment in an unchanged form

Photolysis: transformation of a chemical induced by light energy

Direct photolysis: a photolytic process in which a chemical Itself absorbs solar radiation and is subsequently transformed

Indirect photolysis: a photolytic process, also referred to as sensitized photolysis, in which some other chemical absorbs solar radiation initially but then transfers that energy to the chemical of interest, which is subsequently transformed

Photooxidation: a photolytic process in which solar radiation generates an oxidizing agent (such as hydroxyl radicals) that reacts with the chemical, resulting in its transformation

Screening test: broadly, a test in which the main goal is to gather preliminary. often qualitative information for the purpose of making a decision as to the need for further, more sophisticated testing. Most often used in connection with biodegradability testing

Soil sorption constant (K_{oc}): a measure of the extent to which a chemical partitions between the solid and solution phases of a two-phase system, especially soil, sediment or activated sludge. Usually expressed on an organic carbon basis, as the equilibrium ratio of the amount of chemical sorbed per unit weight of organic carbon (oc) in the soil, sediment or sludge to the concentration of the chemical in solution

STP fugacity model: a mathematical model of a typical sewage treatment plant (STP) employing primary treatment, activated sludge secondary treatment, and secondary settling, used to predict the fate of chemical substances of interest in treatment. The STP model is based on the chemical principle of fugacity, which is a measure of the tendency of a chemical to "flee" from one phase to another (e.g., from water to air)

Transformation: any environmentally induced change in the molecular structure of a chemical that includes the breaking or formation of a covalent chemical bond

Transport: movement of a chemical through one environmental phase or from one phase to another

Treatability: the amenability of a chemical substance or waste stream to removal during biological wastewater treatment, without adversely affecting the normal operation of the treatment plant

Vapor pressure: the pressure that is exerted by a chemical substance in the vapor phase when that phase is in equilibrium with its solid or liquid form

Volatilization: transport process by which a chemical substance enters the atmosphere by evaporation from the solid or solution phase on land or in a water body

Water solubility: the maximum amount of a chemical that will dissolve in pure water at a specified temperature, usually 25N C

Wet deposition: process by which a chemical that is dissolved in water in the atmosphere reaches land or a water body via precipitation (synonym: atmospheric washout)

Appendix B
Workplace Practices Questionnaire for Screen Printers

This Appendix provides a reproduction of the blank questionnaire on workplace practices used for evaluating workplace exposure as it appeared when sent to the screen printers for completion.[1]

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[1] 'University of Tennessee, Center for Clean Products and Clean Technologies, "Summary of Responses: Workplace Practices Questionnaire for Screen Printers," Prepared for the Design for the Environment Printing Project, (February 1994), Appendix A.

WORKPLACE PRACTICES QUESTIONNAIRE
FOR
SCREEN PRINTERS

Prepared by
Screen Printing Association International
in cooperation with
University of Tennessee
Center for Clean Products and Clean Technologies,
and EPA Design for the Environment Staff

This questionnaire is designed to characterize typical screen printing facilities and workplace practices associated with the screen printing/reclamation process. The results of the questionnaire will be used to estimate exposure and characterize risk from this process and to help identify pollution prevention opportunities. Pollution Prevention is the use of materials, processes, practices or products that avoid, reduce or eliminate wastes or toxic releases, through activities such as material substitution, source reduction and closed loop recycling. *This information is being developed for industry use to help printers make informed choices about the environmental attributes of alternative cleaning and reclamation products and technologies.*

Please, mail completed questionnaires to:

Marcia Y. Kinter
Director of Government Affairs
Screen Printing Association International
10015 Main Stract
Fairfax, VA 22031-3489

If you have questions about the questionnaire or would like a copy of the summary of results, please contact Lori Kincaid from the Center for Clean Products and Clean Technologies, University of Tennessee at 615/974-4251 (fax 6151974-1838).

Respondents to this questionnaire are guaranteed anonymity. Responses will not be attributed to any individual or company in reports or other written documentation of the results of this research. Company name and other information requested below are optional.

Company Name ______________________
Address ______________________
____
Questionnaire Completed by ______________________
Title ______________________
Telephone Number ______________________

The purpose of this questionnaire is to characterize typical screen printing facilities and workplace practices associated with the screen printing/reclamation process. The business profile and general facility information requested below allows us to understand your workplace practices within the context of your overall printing business.

1) **Business Profile**

Approximately what percentage of your products are printed on the following substrates? (Please check the boxes that apply.)

	<50%	50-95%	95-100%
Plastics (rigid/flexible)	☐	☐	☐
Paper (coated or uncoated)	☐	☐	☐
Metal	☐	☐	☐
Ceramic	☐	☐	☐
Glass	☐	☐	☐
Other (specify below)	☐	☐	☐

2) **Please list the major products produced at your facility.**

3) **General Facility Information**

How many staff do you employ? How many hours per day does your staff spend removing ink and cleaning/reclaiming screens? Ink removal is the removal of the bulk of the ink from the screens prior to further cleaning/reclamation. Screen cleaning/reclamation activities include residual ink removal, emulsion removal, and haze removal. Questions about ink removal do not pertain to press-side operations, unless this is the only site used for ink removal. Please assume a 5-day work week with one 8-hour shift each day. (Please check the boxes that apply.)

Number of Employees at this Location	Number of Employees Involved in Ink Removal	Number of Employees Involved in Screen Cleaning/Reclamation	Average time (hr/day) a single individual is involved w/ ink removal	Average time (hr/day) a single individual is involved w/ cleaning/reclaiming screens
0-5 ☐	1-3 ☐	1-3 ☐	<1 ☐	<1 ☐
6-10 ☐	4-6 ☐	4-6 ☐	1-2 ☐	1-2 ☐
11-15 ☐	7-10 ☐	7-10 ☐	2-4 ☐	2-4 ☐
16-30 ☐	>11 ☐	>11 ☐	4-6 ☐	4-6 ☐
31-50 ☐	specify ____	specify ____	6-8 ☐	6-8 ☐
>50 ☐			other ☐	other ☐

4) **Equipment and Materials Use**

A) **What types of and how much ink do you use in your printing process? What do you use as a reducer/retarder? What is the primary substrate you use with each ink type? (<u>Please check or list all that apply</u>)**

n=115

Type of Ink	Volume of Ink Used/Year[b] (gallons)	Type of Reducer/Retarder	Primary Substrate
Traditional solvent-based 106 respondents (92.2%) NA = 9 (7.8%)	See Table 2A		Plastic 89 (77.4%) Paper 43 (37.4%) Metal 33 (28.7%) Glass 5 (4.3%) Ceramic 4 (3.5%) Other (specify) 26 (22.6%) various types of vinyl, cloth, wood NR=0
UV Curable 81 respondents (70.4%) NA = 34 (29.6%)	See Table 2B		Plastic 66 (57.4%) Paper 38 (33.0%) Metal 15 (13.0%) Glass 2 (1.7%) Ceramic 0 Other (specify) 17 (14.8%) vinyl (100%), wood, cloth NR=3 (2.6%)
Water-based 15 respondents (13.0%) NA = 100 (87.0%)	See Table 2C	Water 9 (7.8%) Solvent 1 (0.9%) Water/Solvent Mixture 8 (7.0%) (specify trade name) NazDar/KC glycolether butylcellusolve AquaSafe	Plastic 10 (8.7%) Paper 7 (6.1%) Metal 1 (0.9%) Glass 0 Ceramic 0 Other (specify) 4 (3.5%) wood, textile, vinyl NR=1 (0.9%)
Other (specify)[a] 26 respondents (22.6%) NA = 89 (77.4%)	See Table 2D		Plastic 9 (7.8%) Paper 6 (5.2%) Metal 10 (8.7%) Glass 1 (0.9%) Ceramic 1 (0.9%) Other (specify) 8 (7.0%) textiles NR=1 (0.9%)

[a] Other types of ink include metallic inks, etc.

[b] If you do not use a type of ink, enter "0"

See Table 2E - Total Ink Use

The remaining questions are only in reference to solvent- or UV-based inks printed on plastic/vinyl substrates. If your facility does not primarily use these types of substrates or inks, please do not complete the rest of the questionnaire.

B) What is the average number of screens cleaned/reclaimed each day for future use?
(Please check the appropriate box)

☐ 0 - 5
☐ 5 -10
☐ 10 -15
☐ > -15 Specify _

C) Please specify the average size of frame used at your facility? ________
(Please specify units; e.g. ft x ft or in x in, ect.)

D) Do you have separate areas for ink removal and screen reclamation activities? ☐ yes ☐ no
If yes, please check all that apply in the following table.

Separate areas for ink removal and screen cleaning/reclamation activities*			
Size of Ink Removal Area (ft²)	Type of Ventilation	Size of Screen Reclamation Area (ft²)	Type of Ventilation
<20 ☐	local (mechanical) ☐	<20 ☐	local (mechanical) ☐
20-50 ☐	plant (facility-wide) ☐	20-50 ☐	plant (facility-wide) ☐
50-100 ☐	natural ☐	50-100 ☐	natural ☐
100-200 ☐	other (specify below) ☐	100-200 ☐	other (specify) ☐
>200 ☐		>200 ☐	
Specify size ____		Specify size ____	

* Screen cleaning/reclamation activities include residual ink removal, emulsion removal, and haze removal.

E) Do you have a combined area for ink removal and screen reclamation? ☐ yes ☐ no
If yes, please check all that apply in the following table.

Combined area for ink removal and screen reclamation activities	
Size of Combined Area (ft2)	Type of Ventilation
<20 ☐	local (mechanical) ☐
20-50 ☐	plant (facility-wide) ☐
50-100 ☐	natural ☐
100-200 ☐	other (specify) ☐
>200 ☐	
Specify Size ____	

4

5) Ink Removal Procedures (NOT press-side/process cleaning) See Table 4

A) If you recycle ink removal products in-house, how much material was recycled in 1992? ____gal.

n=107
18 respondents (16.8%)
See Table 4

B) What ink removal products do you purchase? What type of personal protective equipment do you typically use when you remove ink? What are typical ink removal procedures at your facility? These questions do not apply to process cleaning (e.g., press-side operations such as ink removal before going to lunch.) (Please check all that apply.)

n=107

Ink Removal Product (Trade Name)	Annual Volume of Ink Removal Product Purchased (gallons)	Cost of Ink Removal Product ($/gallon)	Type of Ink with which Product Works Best	Personal Protective Equipment Used	Method of Applying Ink Removal Product	Equipment or Materials Used to Loosen Ink	Ave. No. of Rags Used Per Screen to Remove Ink
98 respondents (91.6%) 128 products listed	See Table 5		Solvent-based 39 (30.5%)	Gloves 96 (89.7%)	Pour from container onto screen surface 10 (9.3%)	Brush 43 (40.2%)	0-2 41 (38.3%) (8 specified zero)
			UV Curable 8 (6.3%)	Eye protection79 (73.8%)	Dip rag or brush into container and wipe screen 34 (31.8%)	Squeegee 2 (1.9%)	2-4 31 (29.0%)
			Either* 73 (57.0%)	Aprons 67(62.6%)	Spray on with nozzle from tank 34 (31.8%)	Disposable Rag 18 (16.8%)	4-6 12 (11.2%)
			NR=8 (7.5%) See Note Below				
				Respiratory protection33 (30.8%)	Spray on with spray bottle 32 (29.9%)	Reusable Rag 30 (28.0%)	6-8 3 (2.8%)
				Barrier Cream 15 (14.0%)	Use specialized spraying equipment (specify) 13 (12.1%)	Other (specify) 5 (4.7%) fibermat brush high pres. hose	8-10 5 (4.7%)
				None Used 2 (1.9%)	Other (specify) 9 (8.4%) plunger can safety can recirculation tanks screen scrubber pour flow turn brush		Other 1 (0.9%)
				Other (specify) 7 (6.5%) boots) earplugs			(specify number) range = 20 average = 20
				NR=9 (8.4%)	NR=9 (8.4%)	NR=13 (12.1%)	NR=14 (13.1%)

* e.g., ink removal product works equally well with either type of ink.

Note. Respondents reported 128 products. "Works Best" numbers and percentages here are based on the 128 products. (i.e. n=128 for this column alone. Numbers and percentages for all other columns in this table are based on a sample size of 107 respondents.

6) **Emulsion Removal Procedures**

A) What percent of the time do you use the following types of stencils?

	<50%	50-95%	95-100%	Are these dual cured?	
Direct photo stencils	☐	☐	☐	yes ☐	no ☐
Indirect photo stencils	☐	☐	☐	yes ☐	no ☐
Capillary film	☐	☐	☐	yes ☐	no ☐

B) What emulsion removal products do you use? What type of personal protective equipment do you typically use when you remove emulsion? What are typical emulsion removal procedures at your facility? (Please check all that apply.)

Emulsion Removal Product (Trade Name)	Annual Volume of Emulsion Removal Product Used (gallons)	Cost of Emulsion Removal Product ($/gallon)	Personal Protective Equipment Used	Method of Applying Emulsion Removal Product	Equipment or Materials Used to Remove Emulsion	Ave. No. of Rags Used Per Screen to Remove Emulsion
			Gloves ☐	Pour from container onto screen surface ☐	Brush ☐	0-2 ☐
			Eye protection ☐	Dip rag or brush into container and wipe screen ☐	Low-pressure Water-spray ☐	2-4 ☐
			Aprons ☐	Spray on with nozzle from tank ☐	High-pressure Water-spray ☐	4-6 ☐
			Respiratory protection ☐	Spray on with spray bottle ☐	Water-blaster ☐	6-8 ☐
			None Used ☐	Use specialized spraying equipment (specify) ☐	Automatic Screen Cleaning System ☐	8-10 ☐
			Other (specify) ☐	Other (specify) ☐	Disposable Rag ☐	Other ☐
					Reusable Rag ☐	(Specify number _____)
					Other (specify) ☐	

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7) **Haze Removal Procedures**

A) Please complete the following chart if you use haze remover to remove ghost images.

Haze Removal Product (Trade Name)	Annual Volume of Haze Removal Product Used (gallons)	Cost of Haze Removal Product ($/gallon)	Percent of Time Haze Remover Used	Personal Protective Equipment Used	Method of Applying Haze Removal Product	Equipment or Materials Used to Remove Haze	Ave. No. of Rags Used Per Screen to Remove Haze
			0-5 ☐	Gloves ☐	Pour from container onto screen surface ☐	Brush ☐	0-2 ☐
			5-25 ☐	Eye protection ☐	Dip rag or brush into container and wipe screen ☐	Low-pressure Water-spray ☐	2-4 ☐
			25-50 ☐	Aprons ☐	Spray on with nozzle from tank ☐	High-pressure Water-spray ☐	4-6 ☐
			>50 ☐	Respiratory protection ☐	Spray on with spray bottle ☐	Water blaster ☐	6-8 ☐
			(specify ____)	Barrier Cream ☐	Use specialized spraying equipment (specify) ☐	Squeegee ☐	8-10 ☐
				None Used ☐	Other (specify) ☐	Disposable Rag ☐	Other (specify) ☐
				Other (specify) ☐		Reusable Rag ☐	
						Other (specify) ☐	

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8) **Screen Cleaning/Reclamation Alternatives**

A) Do you use a screen degreaser? ☐ yes ☐ no
Trade Name of Product ____________________

B) Do you use a separate ink degradant before applying emulsion remover? (Answer yes only if the ink degradant is different than the primary ink removal product)? ☐ yes ☐ no
Trade Name of Product ____________________

9) **Materials Storage**

A) Where do you store ink removal and screen reclamation products and in what quantity? (Please check all that apply.)

Ink Removal and Screen Cleaning Area(s)	Ink/Chemical Storage Room
30- or 55-gallon drum with bung hole kept open ☐	30- or 55-gallon drum with bung hole kept open ☐
30- or 55-gallon drum with bung hole kept closed ☐	30- or 55-gallon drum with bung hole kept closed ☐
30- or 55-gallon drum with top removed ☐	30- or 55-gallon drum with top removed ☐
Open pail ☐	Open pail ☐
Closed pail ☐	Closed pail ☐
Quart or smaller squirt bottle ☐	Quart or smaller squirt bottle ☐
Safety can ☐	Safety can ☐
Safety cabinet ☐	Safety cabinet ☐
Not kept in the press room ☐	No separate storage area ☐
	Other (specify below) ☐
Other (specify below) ☐	Size of storage room ___ ft x ___

B) How do you retrieve ink removal and screen reclamation products from ink/chemical storage? If you keep both large and small containers in the ink removal and screen cleaning/reclamation areas, how do you transfer the products from large containers to small containers for use?

Retrieval from Storage Room	Transfer from Large to Small Container for Use
Entire container moved to press room ☐	Pumped into small container used at work station ☐
Pumped into smaller container ☐	Poured into smaller container ☐
Poured into smaller container ☐	Ladled into smaller container ☐
Ladled into smaller container ☐	Other (specify below) ☐
Other (specify below) ☐	

C) Waste Disposal

2) Please indicate the quantity of waste you dispose of annually as __hazardous__ waste for:
n=107 90 respondents (84.1%)
spent solvent waste ________ Number of 55 gal. drums) OR ________ (gal. in bulk)

ink waste ________ (Number of 55 gal. drums) OR ________ (gal. in bulk) See Table 10

used shop rag waste ________ (Number of 55 gal. drums) OR ________ (gal. in bulk)

3) What quantity of wastes from ink removal and screen cleaning/reclamation operations do you generate annually? How are these waste materials treated or disposed of? (__Please check all that apply.__)
n=107 92 respondents (86.0%)

Ink Removal Wastes			Screen Cleaning/Reclamation Wastes		
Quantity Generated Annually (gallons)	Method of Storage Prior to Treatment and/or Disposal	Method of Treatment or Disposal	Quantity Generated Annually	Method of Storage Prior to Treatment or Disposal	Method of Treatment and/or Disposal
See Table11A	In closed containers 76 (71.0%)	Filter or treat prior to disposal or recycle 6 (5.6%)	See Table 11A	In open containers 4 (3.7%)	Filter or treat prior to disposal or recycle 11 (10.3%)
	In open containers 5 (4.7%)	Send to recycler 22 (20.6%)		In closed containers 34 (31.8%)	Discharge to sewer 47 (43.9%)
56 respondents gave values	No specified container 3 (2.8%)	Recycle on site 6 (5.6%)	31 respondents gave values	No specified containers 17 (15.9%)	Discharge to septic tank 7 (6.5%)
	Other (specify) 7 (6.5%)	Discharge to sewer 11 (10.3%)		Other (specify) 16 (15.0%)	Hazardous Waste 13 (12.1%)
		Dispose as hazardous waste 46 (43.0%)			Non-Hazardous waste 19 (17.8%)
		Dispose as non-hazardous waste 18 (16.8%)			
	NR=20 (17.8%)	Other (specify) 5 (4.7%) towel service		NR=32 (29.9%) NA=6 (5.6%)	NR=24 (22.4%) NA=6 (5.6%)
		NR=16 (15.0%)			

See Table 11B - Ink and Screen C/R Wastes Generated
See Table 11C - Products Purchased and Wastes Disposed

C) How are waste rags contaminated with ink removal and screen cleaning/reclamation products stored, treated or disposed of? (Please check all that apply.)

Method of Storage Prior to Pretreatment or Disposal	Method of Pretreatment	Method of Recycle or Disposal
In open containers ☐	Centrifuge ☐	On-site water laundry ☐
In closed containers ☐	Allow liquid to drain out ☐	On-site dry cleaner ☐
No specified containers ☐	Other (specify) ☐	Off-site water laundry ☐
	None ☐	Off-site dry cleaner ☐
		Hazardous waste ☐
		Non-hazardous waste ☐
		Do not use rags ☐
		Other (specify) ☐

11) **Pollution Prevention Opportunities**

Please use the following table to describe the experiences at your facility with pollution prevention techniques. Pollution prevention is the use of materials, processes, practices or products that avoid, reduce or eliminate wastes or toxic releases, through activities such as toxic use reduction, source reduction, and closed loop recycling

Do you have a pollution prevention, waste minimization, or source reduction program?		yes ☐ no ☐	**If you answered yes, would you be willing to share a description of your program with the DFE Printing Project?**	yes ☐ no ☐
Have you tried any different chemical products for environmental or worker safety reasons to replace your current ink removal or screen cleaning/reclamation products?		yes ☐ no ☐	**If you answered yes, please list the product name:**	
If you have tried a different chemical product, please check the box that best describes your experience with the product:*	**Cleaner worked well:** **Cleaner was OK** but not as good as old cleaner: **Cleaner was not** satisfactory: Other (please explain below):	☐ ☐ ☐ ☐	**If you have not tried a different chemical product, please check the box that best describes your reason for not** trying alternatives:	**Lack adequate information to evaluate environmental performance of alternatives:** ☐ **Operators do not believe alternatives will work** ☐ **Not impressed with product descriptions:** ☐ **Cost is prohibitive:** ☐ Other (please explain below) ☐
Besides different chemical products, have you implemented any changes in equipment ☐, products ☐, processes ☐, or work practices ☐ that reduced your use of ink removal or screen cleaning/reclamation products? (If you have implemented changes, please check all boxes that apply.)		yes ☐ no ☐	If you answered yes, would you be willing to share the changes with the DFE Printing Project?	yes ☐ no ☐

		increased	decreased	no change
If you have implemented changes that reduced your use of **ink removal or screen cleaning/reclamation products, how have these changes affected:**	materials cost:	☐	☐	☐
	time required to clean the screen:	☐	☐	☐
	disposal costs:	☐	☐	☐

If you should decide or have decided to implement changes in your screen cleaning/reclamation process to incorporate pollution prevention opportunities, which of the following factors would have the greatest priority in this decision? Please rank these factors from 1 to 6, with 1 indicating the highest priority.

_______ cost
_______ regulations
_______ environmental hazard
_______ performance
_______ health hazard
_______ other (specify

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* If you have tried more than one different chemical product, please fill out a copy of this section for each product.

Appendix C

Summary of Responses to Workplace Practices Questionnaire for Screen Printers

This Appendix provides a summary of the information on workplace practices used to evaluate workplace exposures to screen reclamation chemicals.[1]

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[1] University of Tennessee, Center for Clean Products and Clean Technologies, "Summary of Responses: Workplace Practices Questionnaire for Screen Printers," Prepared for the Design for the Environment Printing Project, (February 3, 1994), Appendix B.

Presentation of Results

The Workplace Practices Questionnaire for Screen Printers included check-off type questions where respondents could check the response that best described their facility, and fill-in-the-blank type questions where respondents were asked to list specific information. The summary of responses to questions with check-off categories is presented directly on the questionnaire, instead of on a separate series of tables. This makes the results easier to read and interpret for the screen printers and others who have requested a copy of the summary of results. Responses to fill-in-the-blank questions are listed in a series of tables attached to the questionnaire.

The total sample size (n) for the questionnaire was 115 respondents. This sample size was used to calculate the percentages shown on pages two, three and 11. Of the 115 respondents, 107 were screen printers who primarily use solvent or UV-based inks printed on plastic/vinyl substrates. Thus, n=107 was used to calculate the percentages shown on the remainder of the questionnaire.

"NR" is used in the questionnaire to indicate the number of respondents who did not respond to a question. "NA" is used to indicate the number of respondents for whom a question was not applicable. A question was considered not applicable when:

1) the respondent indicated that a question is not applicable to his or her facility, or

2) the respondent did not complete a question because his or her facility did not meet the criteria specified for the question.

An example of the second case is Table 4-D) on page 4 of the questionnaire. If respondents answered "no" to the question, "Do you have separate areas for ink removal and screen cleaning/reclamation activities?", then "NA" was entered for each of the columns in the following table.

Several sections of the questionnaire are in table format with each column of a table representing a different question. At the top of these tables, we have listed the sample size that pertains to that section of the questionnaire (e.g., n=115 or n=107) followed by the number of respondents who responded to at least part of the table. The number who did not respond (NR) to any single column in the table is indicated at the bottom of the column. (Sections 1 and 6-A are examples of exceptions to this rule, since the columns in these tables do not represent different questions. For these sections, the no response rate, NR, is shown above or to the side of the table instead of at the bottom of each column.) For example, Section 3, General Facility Information, combines five related questions on the number of employees and the average time an employee spends in ink removal or screen cleaning into a single table of five columns. The sample size for this table is 115, but only 114 respondents (99.1%) of the sample completed at least part of the table. Furthermore, only 113 respondents (98.3%) completed column 1, "Number of Employees at this Location." Thus, NR=2 (115-113) for this column.

WORKPLACE PRACTICES QUESTIONNAIRE
FOR
SCREEN PRINTERS

Prepared by
Screen Printing Association International
in cooperation with
University of Tennessee
Center for Clean Products and Clean Technologies,
and EPA Design for the Environment Staff

This questionnaire is designed to characterize typical screen printing facilities and workplace practices associated with the screen printing/reclamation process. The results of the questionnaire will be used to estimate exposure and characterize risk from this process and to help identify pollution prevention opportunities. Pollution Prevention is the use of materials, processes, practices or products that avoid, reduce or eliminate wastes or toxic releases, through activities such as material substitution, source reduction and closed loop recycling. ***This information is being developed for industry use to help printers make informed choices about the environmental attributes of alternative cleaning and reclamation products and technologies.***

Please mail completed questionnaires to:

Marcia Y. Kinter
Director of Government Affairs
Screen Printing Association International
10015 Main Street
Fairfax, VA 22031-3489

If you have questions about the questionnaire or would like a copy of the summary of results, please contact Lori Kincaid from the Center for Clean Products and Clean Technologies, University of Tennessee at 615/974-4251 (fax 615/974-1838).

Respondents to this questionnaire are guaranteed anonymity. Responses will not be attributed to any individual or company in reports or other written documentation of the results of this research. Company name and other information requested below are optional.

Company Name ____________________
Address ____________________
____

Questionnaire Completed by ____________________
Title ____________________
Telephone Number ____________________

The purpose of this questionnaire is to characterize typical screen printing facilities and workplace practices associated with the screen printing/reclamation process. The business profile and general facility information requested below allows us to understand your workplace practices within the context of your overall printing business.

1) Business Profile

Approximately what percentage of your products are printed on the following substrates? (Please check the boxes that apply.)

n=115
114 respondents (99.1%)
NR=1 (0.9%)

	<50%	50-95%	95-100%
Plastics (rigid/flexible)	31(27.2%)	50(43.5%)	27(23.5%)
Paper (coated or uncoated)	54(47.0%)	13(11.3%)	3(2.6%)
Metal	46(40.0%)	6(5.2%)	3(2.6%)
Ceramic	8(7.0%)	0	0
Glass	12(10.4%)	2(1.7%)	0
Other (specify below)	20(17.4%)	8(7.0%)	2(1.7%)

2) **Please list the major products produced at your facility.**

See Table 1

3) **General Facility Information**

How many staff do you employ? How many hours per day does your staff spend removing ink and cleaning/reclaiming screens? Ink removal is the removal of the bulk of the ink from the screens prior to further cleaning/reclamation. Screen cleaning/reclamation activities include residual ink removal, emulsion removal, and haze removal. Questions about ink removal do not pertain to press-side operations, unless this is the only site used for ink removal. Please assume a 5-day work week with one 8-hour shift each day. (Please check the boxes that apply.)

n=115 114 respondents (99.1%)

Number of Employees at this Location	Number of Employees Involved in Ink Removal	Number of Employees Involved in Screen Cleaning/Reclamation	Average time (hr/day) a single individual is involved w/ ink removal	Average time (hr/day) a single individual is involved w/ cleaning/reclaiming screens
0-5 21 (18.3%)	1-3 62 (53.9%)	1-3 102 (88.7%)	<1 44 (38.9%)	<1 16 (13.9%)
6-10 10 (8.7%)	4-6 22 (19.1%)	4-6 7 (6.1%)	1-2 44 (38.9%)	1-2 24 (20.9%)
11-15 10 (8.7%)	7-10 15 (13.0%)	7-10 3 (2.6%)	2-4 11 (9.7%)	2-4 24 (20.9%)
16-30 21 (18.3%)	>11 15 (13.0%)	>11 1 (0.9%)	4-6 6 (5.3%)	4-6 20 (17.4%)
31-50 18 (15.7%)	specify range: 0 to 35 average: 22.5	specify range: 12 average: 12	6-8 7 (6.2%)	6-8 26 (22.6%)
>50 33 (28.7%)			other 0)	other 1 (0.9%)
NR=2 (1.7%)	NR=1 (0.9%)	NR = 1 (0.9%) NA = 1 (0.9%)	NR = 2 (1.8%) NA = 1 (0.9%)	NR = 4 (3.5%)

~~4) Equipment and Materials Use~~

A) What types of and how much ink do you use in your printing processes? What do you use as a reducer/retarder? What is the primary substrate you use with each ink type? (Please check or list all that apply)

Type of Ink	Volume of Ink Used/Year[b] (gallons)	Type of Reducer/Retarder	Primary Substrate
Traditional solvent-based			Plastic ☐ Paper ☐ Metal ☐ Glass ☐ Ceramic ☐ Other (specify) ☐
UV Curable			Plastic ☐ Paper ☐ Metal ☐ Glass ☐ Ceramic ☐ Other (specify) ☐
Water-based		Water ☐ Solvent ☐ Water/Solvent ☐ Mixture (specify trade name)	Plastic ☐ Paper ☐ Metal ☐ Glass ☐ Ceramic ☐ Other (specify) ☐
Other (specify)[a]			Plastic ☐ Paper ☐ Metal ☐ Glass ☐ Ceramic ☐ Other (specify) ☐

[a] Other types of ink include metallic inks, etc.

[b] If you do not use a type of ink, enter "0"

The remaining questions are only in reference to solvent- or UV-based inks printed on plastic/vinyl substrates. If your facility does not primarily use these types of substrates or inks, please do not complete the rest of the questionnaire. Eight respondents did not satisfy these criteria and thus did not complete the rest of the questionnaire. Therefore, the data base responses are based on n=107

B) What is the average number of screens cleaned/reclaimed each day for future use? (Please check the appropriate box) n=107
103 respondents (96.3%)

0 - 5	26 (24.3%)
5 - 10	23 (21.5%)
10 - 15	29 (27.1%)
> 15	25 (23.4%)
Specify	range =2 to 90 average = 43 NR=4 (3.7%)

C) Please specify the average size of frame used at your facility? See Table 3
(Please specify units; e.g. ft x ft or in x in, ect.)

D) Do you have separate areas for ink removal and screen reclamation activities? yes 72 (67.3%) NR=7 (6.5%) no 28 (26.2%)
If yes, please check all that apply in the following table. n = 107

Separate areas for ink removal and screen cleaning/reclamation activities[a]			
Size of Ink Removal Area (ft²)	Type of Ventilation	Size of Screen Reclamation Area (ft²)	Type of Ventilation
<20 16 (15.0%)	local(mechanical) 43 (40.2%)	<20 6 (5.6%)	local (mechanical) 58 (55.1%)
20-50 22 (20.6%)	plant(facility-wide) 28 (26.2%)	20-50 20 (18.7%)	plant (facility-wide) 15 (14.0%)
50-100 10 (9.3%)	natural 6 (5.6%)	50-100 13 (12.1%)	natural 8 (7.5%)
100-200 10 (9.3%)	other (specify below) 6 (5.6%)	100-200 22 (20.6%)	other (specify) 2 (1.9%)
>200 11 (10.3%)	vent, outdoors,, dryer vent, fan	>200 12 (11.2%)	outdoors vent
Specify size range=300-3500 average=1370	NR=9 (8.4%) NA=28 (26.2%)	Specify size: range=250 to 400 average=310	NR=7 (6.5%) NA=28 (26.2%)
NR=10 (9.3%) NA=28 (26.2%)		NR=7(6.5%) NA=28 (26.2%)	

[a] Screen cleaning/reclamation activities include residual ink removal, emulsion removal, and haze removal.

E) Do you have a combined area for ink removal and screen reclamation? yes 41 (38.3%) NR=7(6.5%) no 59 (55.1%)
If yes, please check all that apply in the following table. n=107

Combined area for ink removal and screen reclamation activities	
Size of Combined Area (ft2)	Type of Ventilation
<20 3 (2.8%)	local (mechanical) 32 (29.0%)
20-50 14 (13.1%)	plant (facility-wide) 9 (8.4%)
50-100 7 (6.5%)	natural 3 (2.8%)
100-200 6 (5.6%)	other (specify) 2 (1.9%)
>200 11 (10.3%)	
Specify Size: range=216 to 500 average=300	NR=8 (7.5%) NA=59 (55.1%)
NR=7 (6.5%) NA=59 (55.1%)	

Thirteen respondents answered yes to both questions 4-D) and 4-E).

4

5) **Ink Removal Procedures** (NOT press-side/process cleaning)

A) If you recycle ink removal products in-house, how much material was recycled in 1992? ____________gal.

B) **What ink removal products do you purchase? What type of personal protective equipment do you typically use when you remove ink? What are typical ink removal procedures at your facility? These questions do not apply to process cleaning (e.g., press-side operations such as ink removal before going to lunch.)** (Please check all that apply.)

Ink Removal Product (Trade Name)	Annual Volume of Ink Removal Product Purchased (gallons)	Cost of Ink Removal Product ($/gallon)	Type of Ink with which Product Works Best	Personal Protective Equipment Used	Method of Applying Ink Removal Product	Equipment or Materials Used to Loosen Ink	Ave. No. of Rags Used Per Screen to Remove Ink
			Solvent-based ☐	Gloves ☐	Pour from container onto screen surface ☐	Brush ☐	0-2 ☐
			UV Curable ☐	Eye protection ☐	Dip rag or brush into container and wipe screen ☐	Squeegee ☐	2-4 ☐
			Either[a] ☐	Aprons ☐	Spray on with nozzle from tank ☐	Disposable Rag ☐	4-6 ☐
			Solvent-based ☐	Respiratory protection ☐	Spray on with spray bottle ☐	Reusable Rag ☐	6-8 ☐
			UV Curable ☐	Barrier Cream ☐	Use specialized spraying equipment (specify) ☐	Other (specify) ☐	8-10 ☐
			Either[a] ☐	None Used ☐	Other (specify) ☐		Other ☐
			Solvent-based ☐	Other (specify) ☐			(specify number_____)
			UV Curable ☐				
			Either[a] ☐				

[a] e.g., ink removal product works equally well with either type of ink.

Emulsion Removal Procedures

What percent of the time do you use the following types of stencils?

n = 107   102 respondents (95.3%) NR – 5 (4.7%)

	< 50%	50-95%	95-100%	Are these dual cured?	
Direct photo stencils	9 (8.4%)	24 (22.4%)	52 (48.6%)	yes 43(40.2%) one with both	no 3[illegible](3[illegible])
Indirect photo stencils	10 (9.3%)	4 (3.7%)	5 (4.7%)	yes 2 (1.9%)	no 1[illegible] (11.2[illegible])
Capillary film	31 (29.0%)	9 (8.4%)	10 (9.3%)	yes 17 (15.9%)	no 28 (26.[illegible])

What emulsion removal products do you use? What type of personal protective equipment do you typically use when you remove emulsion? What are typical emulsion removal procedures at your facility? (Please check all that apply.)

n = 107

Emulsion Removal Product (Trade Name)	Annual Volume of Emulsion Removal Product Used (gallons)	Cost of Emulsion Removal Product ($/gallon)	Personal Protective Equipment Used	Method of Applying Emulsion Removal Product	Equipment or Materials Used to Remove Emulsion	Ave No. of Rags Used Per Screen to Remove Emulsion
103 respondents (96.3%)	See Table 6		Gloves 101 (94.4%) Eye protection 83 (77.6%) Aprons 66 (61.7%) Respiratory protection 42 (39.3%) None Used 1 (0.9%) Other (specify) 12 (11.2%) earplugs boots face shield polysleeves	Pour from container onto screen surface 5 (4.7%) Dip rag or brush into container and wipe screen 30 (28.0%) Spray on with nozzle from tank 26 (24.3%) Spray on with spray bottle 34 (31.8%) Use specialized spraying equipment (specify) 13 (12.1%) Other (specify) 8 (7.5%)	Brush 44 (41.1%) Low-pressure Water-spray 12 (11.2%) High-pressure Water-spray 79 (73.8%) Water-blaster 14 (13.1%) Automatic Screen Cleaning System 1 (0.9%) Disposable Rag 6 (5.6%) Reusable Rag 8 (7.5%) Other (specify) 1 (0.9%) vacuum	0-2 89 (83.[illegible]) (21 specified zero) 2-4 4 (3.[illegible]) 4-6 1 (0.[illegible]) 6-8 8-10 1 (0.[illegible]) Other 1 (0.[illegible]) reuse 20 or 30 times
			NR – 4(3.7%)	NR – 6 (5.6%)	NR – 7 (6.5%)	NR – 14 (13.1%)

7) **Haze Removal Procedures**

A) **Please complete the following chart if you use haze remover to remove ghost images.**
n = 107

Haze Removal Product (Trade Name)	Annual Volume of Haze Removal Product Used (gallons)	Cost of Haze Removal Product ($/gallon)	Percent of Time Haze Remover Used	Personal Protective Equipment Used	Method of Applying Haze Removal Product	Equipment or Materials Used to Remove Haze	Ave. No. of Rags Used Per Screen to Remove Haze
92 respondents (86.0%)	See Table 7		0-5 20 (18.7%) 5-25 23 (21.5%) 25-50 9 (8.4%) >50 36 (33.6%) specify range: 50 to 100 average: 90	Gloves 91 (85.0%) Eye protection 88 (82.2%) Aprons 69 (64.5%) Respiratory protection 47 (43.9%) Barrier Cream 10 (9.3%) None Used 0 Other (specify) 7 (6.5%)	Pour from container onto screen surface 6 (5.6%) Dip rag or brush into container and wipe screen 70 (65.4%) Spray on with nozzle from tank 1 (0.9%) Spray on with spray bottle 13 (12.1%) Use specialized spraying equipment (specify) 1 (0.9%) Other (specify) 3 (2.8%)	Brush 4 (3.7%) Low-pressure Water-spray 11 (10.3%) High-pressure Water-spray 70 (65.4%) Water-blaster 9 (8.4%) Squeegee 0 Disposable Rag 1 (0.9%) Reusable Rag 5 (4.7%) Other (specify) 0	0-2 81 (16 specified zero) 2-4 1 (0.9%) 4-6 1 (0.9%) 6-8 8-10 1 (0.9%) Other (specify)
			NR = 18 (16.8%)	NR = 16 (15.0%)	NR = 18 (16.8%)	NR = 18 (16.8%)	NR = 23 (21.5%)

Screen Cleaning/Reclamation Alternatives

Do you use a screen degreaser? yes 85 (79.4%) no 22 (20.6%)
Trade Name of Product ___See Table 8-A___

Do you use a separate ink degradant before applying emulsion remover? (Answer yes only if the ink degradant is different than the primary ink removal product)? yes 29 (27.1%) no 78 (72.9%)
Trade Name of Product ___See Table 8-B___

Materials Storage

Where do you store ink removal and screen reclamation products and in what quantity? (Please check all that apply.)
n=107 102 respondents (95.3%)

Ink Removal and Screen Cleaning Area(s)		Ink/Chemical Storage Room	
30- or 55-gallon drum with bung hole kept open	9 (8.4%)	30- or 55-gallon drum with bung hole kept open	3 (2.8%)
30- or 55-gallon drum with bung hole kept closed	40 (37.4%)	30- or 55-gallon drum with bung hole kept closed	50 (46.7%)
30- or 55-gallon drum with top removed	1 (0.9%)	30- or 55-gallon drum with top removed	0
Open pail	4 (3.7%)	Open pail	1 (0.9%)
Closed pail	32 (29.9%)	Closed pail	23 (21.5%)
Quart or smaller squirt bottle	20 (18.7%)	Quart or smaller squirt bottle	10 (9.3%)
Safety can	30 (28.0%)	Safety can	17 (15.9%)
Safety cabinet	16 (15.0%)	Safety cabinet	16 (15.0%)
Not kept in the press room	9 (8.4%)	No separate storage area	15 (14.0%)
Other (specify below) special 5 gal. systems: pour spout, recycle stray tank, disperser 30 gal. recirc. tank, outside	15 (14.%0)	Other (specify below) outside, plastic gal. jugs, drums w/ pumps	7 (6.5%)
		Size of storage room See Table 9	___ ft x ___
NR=5 (4.7%)		NR=14 (13.1%)	

How do you retrieve ink removal and screen reclamation products from ink/chemical storage? If you keep both large and small containers in the ink removal and screen cleaning/reclamation areas, how do you transfer the products from large containers to small containers for use?
n=107 99 respondents (92.5%)

Retrieval from Storage Room		Transfer from Large to Small Container for Use	
Entire container moved to press room	15 (14.0%)	Pumped into small container used at work station	43 (40.2%)
Pumped into smaller container	44 (41.1%)	Poured into smaller container	36 (33.6%)
Poured into smaller container	28 (26.2%)	Ladled into smaller container	1 (0.9%)
Ladled into smaller container	3 (2.8%)	Other (specify below)	7 (6.5%)
Other (specify below) pumped directly from store room, entire container to ink removal room.	4 (3.7%)		
NR=9 (8.4%)		NR=16 (15.0%)	

10) **Waste Disposal**

A) Please indicate the quantity of waste you dispose of annually as hazardous waste for:

spent solvent waste ________ (Number of 55 gal. drums) OR ________ (gal. in bulk)

ink waste ________ (Number of 55 gal. drums) OR ________ (gal. in bulk)

used shop rag waste ________ (Number of 55 gal. drums) OR ________ (gal. in bulk)

B) **What quantity of wastes from ink removal and screen cleaning/reclamation operations do you generate annually? How are these waste materials treated or disposed of?** (Please check all that apply.)

Ink Removal Wastes			Screen Cleaning/Reclamation Wastes		
Quantity Generated Annually (gallons)	**Method of Storage Prior to Treatment and/or Disposal**	**Method of Treatment or Disposal**	Quantity Generated Annually	**Method of Storage** Prior to Treatment or Disposal	**Method of Treatment and/or Disposal**
	In closed containers ☐ In open containers ☐ No specified container ☐ Other (specify) ☐	Filter or treat prior to disposal or recycle ☐ Send to recycler ☐ Recycle on site ☐ Discharge to sewer ☐ Dispose as hazardous waste ☐ Dispose as non-hazardous waste ☐ Other (specify) ☐		In open containers ☐ In closed containers ☐ No specified containers ☐ Other (specify) ☐	Filter or treat prior to disposal or recycle ☐ Discharge to sewer ☐ Discharge to septic tank ☐ Hazardous Waste ☐ Non-Hazardous waste ☐

C) How are waste rags contaminated with ink removal and screen cleaning/reclamation products stored, treated or disposed of? (Please check all that apply.)

n = 107 103 respondents (96.3%)

Method of Storage Prior to Pretreatment or Disposal		Method of Pretreatment		Method of Recycle or Disposal	
In open containers	12 (11.2%)	Centrifuge	4 (3.7%)	On-site water laundry	0
In closed containers	83 (77.6%)	Allow liquid to drain out	29 (27.1%)	On-site dry cleaner	0
No specified containers	6 (5.6%)	Other (specify)	8 (7.5%)	Off-site water laundry	40 (37.4%)
		None evaporation rung out	53 (49.5%)	Off-site dry cleaner	23 (21.5%)
				Hazardous waste	14 (13.1%)
				Non-hazardous waste	25 (23.4%)
				Do not use rags	2 (1.9%)
				Other (specify) paper towels - to garbage service	12 (11.2%)
NR=5 (4.7%)		NR=12 (11.2%)		NR=5 (4.7%)	

1) Pollution Prevention Opportunities

Please use the following table to describe the experience at your facility with pollution prevention techniques. Pollution prevention is the use of materials, processes, practices or products that avoid, reduce or eliminate wastes or toxic releases, through activities such as toxic use reduction, source reduction, and closed loop recycling.
Total database n=115

Do you have a pollution prevention, waste minimization, or source reduction program?		yes 33 (28.7%)	**If you answered yes, would you be willing to share a description of your program with the DFE Printing Project?**	yes	23 (20.0%)
Have you tried any **alternative chemical products** for environmental or worker safety reasons to replace your current blanket wash?		yes 87 (75.7%)	If you answered yes, please list the product name: See Table 12		

If you have tried an **alternative** chemical product, **please check** the box that best **describes your** experience with the product:'	**Cleaner worked well:**	28 (24.3%)	If you have not tried an alternative chemical product, please check the box that best describes your reason for not trying alternatives:	**Lack adequate information to evaluate environmental performance of alternatives:**	5 (4.3%)
	Cleaner was OK but not as good as old cleaner:	33 (28.7%)		**Operators do not believe alternatives will work:**	1 (0.9%)
	Cleaner was not satisfactory:	22 (19.1%)		**Not impressed** with product **descriptions:**	2 (1.7%)
	Other (please explain below)	14 (12.2%)		**Cost is prohibitive:**	1 (0.9%)
				Other (please explain below)	3 (2.6%)
	Many products tested-some worked well, **some didn't** operator-resistance cost			NR-18 (15.7%)	

Besides alternative **chemical** products, **have you implemented any changes** in equipment 27 (23.5%), products 30 (**26.1%**), processes 30 (26.1%), or **work practices** 41 (35.7%) that reduced your use of blanket washes? (If you have implemented changes, please check all boxes that apply.)	yes 63 (54.8%)	If you answered yes, would you be willing to share the changes with the DFE Printing Project?	yes	36 (31.3%)

		increased	decreased	no change
If you have implemented changes that reduced your **use of blanket** wash, how have these changes affected	**materials cost:**	26 (22.6%)	30 (26.1%)	16 (13.9%)
	time required to clean the blanket:	18 (15.7%)	29 (25.2%)	21 (18.3%)
	waste-run required to reach acceptable print quality:	9 (7.8%)	17 (14.8%)	43 (37.4%)

If you should decide or have decided to implement changes in your screen cleaning/reclamation process to incorporate pollution prevention opportunities, which of the following factors would have the greatest priority in this decision? Please rank these factors from 1 to 6, with 1 indicating the highest priority.	_____ cost _____ regulations _____ environmental hazard	_____ performance _____ health hazard _____ other (specify) See Table 13

If you have tried more than one alternative chemical product, please fill out a copy of this section for each product.

Appendix D
Densities of Solutes in Aqueous Mixtures

In this report, the densities of solvents in nonaqueous mixtures are assumed to be the same as their density as pure components. These values of density are then used to compute the amount of each component in a given volume of mixture. For aqueous solutions, however, all components of the mixture are assumed to have a density of 1 $g.cc^{-1}$. This assumption is made because of the difficulty of determining appropriate values for the densities of solutes on polar solvents such as water. This Appendix describes the relationships between component densities and intermolecular forces in liquid mixtures, and indicates the problems associated with estimation of the density.

The density of a component i in solution at a given mole fraction x_i can be related to a quantity called the partial molar volume, V_i:

$$\rho_i(x_i)=\frac{M_i}{V_i(x_i)}$$

where M_i is the molecular weight of the component. The partial molar volume is defined by:

$$V_i=(\frac{\partial V}{\partial n_i})_{n_j}$$

n_i being the number of moles of i and V the volume of one mole of the mixture. V and V_i are also related by:

$$V=\Sigma x_i V_i$$

which allows us to determine the amount of component i in the mixture once V_i is known.

Now, it is shown in standard texts on thermodynamics (e.g., J.M. Smith and H.C. Van Ness, *Introduction to Chemical Engineering Thermodynamics*) that the partial molar volume V_i is related to the chemical potential μ_i:

$$V_i=(\frac{\partial \mu_i}{\partial P})_T$$

and the chemical potential can be divided into two parts, one part representing the chemical potential of i in an ideal mixture (*IM*), and the other part representing the excess (*E*) chemical potential due to the interaction of molecules of component i with other components of the solution:

$$\mu_i = \mu_i^{IM} + \mu_i^E$$

Substituting into eq. (4) gives:

$$V_i(x_i,T,P) = V_i(x_i=1,T,P) + \left(\frac{\partial \mu_i^E}{\partial P}\right)_T$$

The first term on the right is simply the molar volume of pure liquid i. The second term can be related to the activity coefficient γ_i of i in solution:

$$V_i(x_i,T,P) = V_i(x_i=1,T,P) + RT\left(\frac{\partial \ln\gamma_i}{\partial P}\right)_T$$

In an ideal solution, such as those formed by mixtures of nonpolar solvents, the activity coefficient of each component is approximately 1 and the pure component molar volume (or density) can be used to find the amount of i in a given volume of the mixture. In polar solvents such as water, the activity coefficients are usually far from 1, especially when the mole fraction of i is small. In this case, we can replace the activity coefficient with the Henry's constant:

$$V_i(x_i,T,P) = V_i(x_i=1,T,P) + RT\left(\frac{\partial \ln(H_i/P_i^{sat})}{\partial P}\right)_T$$

where P_i^{sat} is the saturation vapor pressure of i at the temperature of interest. Henry's constants are generally assumed to be independent of pressure, making evaluation of the derivative impossible. Alternatively, we can use an activity coefficient correlation such as the Wilson equation, which is generally valid for homogenous mixtures:

$$\ln\gamma_i = 1 - \ln(\Sigma_j x_j G_{ij}) - \Sigma_k\left(\frac{x_k G_{ki}}{\Sigma_j x_j G_{kj}}\right)$$

where

$$G_{ij} = \frac{V_j(x_j=1)}{V_i(x_i=1)}\exp\left(\frac{-a_{ij}}{RT}\right)$$

the a_{ij} terms being related to the energy of interaction of components i and j. In principle, the effect of pressure on the activity coefficients can be taken into account by using the isothermal compressibility β

$$\beta = \frac{1}{V}\frac{\partial V}{\partial P}$$

to alter the pure-component molar volumes in eq. (10). However, the Wilson equation, and most other activity coefficient correlations in current use, are derived from rigid-lattice models that do not account for pressure effects. Therefore, partial molar volumes derived on this basis are not likely to be correct. In a liquid, changes in external pressure result in changes in the radial distribution function *g(r)*:

$$\frac{P}{kT} = \frac{N}{V} - \frac{1}{6kT}\left(\frac{N}{V}\right)^2 \int_0^\infty \frac{\partial u(r)}{\partial r} g(r) 4\pi r^3 dr$$

where *u(r)* is the energy of two molecules separated by a distance *r* and *g(r)* is the probability of finding two particles separated by that distance (L.E. Reichl, *A Modern Course in Statistical Physics*).

Increasing pressure will cause the molecules to assume more and more energetically unfavorable configurations, both by moving closer together and by twisting internally and externally. The chemical potential of solute *i* is the work associated with bringing a molecule of *i* into the solution from an infinite distance away (this is similar to the definition of electrostatic potential). This can be mathematically represented by "hiding" the molecule's force field from the surrounding liquid and then slowly making it visible, using a factor λ that is varied from 0 to 1:

$$u_i(r)_{apparent} = \lambda u_i(r)$$

The chemical potential is then:

$$\mu_i = \mu_i^{IdealGas} - \frac{N}{V}\int_0^1 \int_0^\infty u_i(r) g_i(r,\lambda) 4\pi r^3 dr d\lambda$$

Since water and most solutes of interest are not spherically symmetric, use of this equation requires a series of molecular mechanics simulations over the range λ = 0→1. In practice, it is found that for λ = 0→0.25, the solute molecule hardly interacts with the solvent at all and drifts through it like a particle in a slightly nonideal gas. A relatively simple angle-averaged calculation gives the contribution to the chemical potential in this region. However, at least one or two simulations must still be performed at or near λ = 1 with the complete molecular geometry taken into account. At present, these types of calculations are too compute-intensive to run on personal computers and must be run on workstations or mainframes. Such simulations are used fairly widely in the pharmaceutical industry to study the behavior of new drugs, but they are not yet routinely used to predict physical properties for engineering purposes.

In addition to the issues noted above, two other problems arise in dealing with many aqueous solutions. The first is that, in the case of weakly dissociating compounds such as acetic acid, it is difficult to know what the mole fraction of each component in solution actually is. The second problem is that, in the case of salts such as sodium chloride, one would need to know the molar volume of pure liquid NaCl ($V_i(x_i=1,T,P)$). However, sodium chloride is a solid below 804 °C and the properties of the hypothetical liquid state are not available.

Appendix E
Review of Air Release Models

NIOSH has studied exposure to solvents at a number of screen printing facilities over the past three decades. Some of the highest solvent concentrations were found in the screen washing area at Impressions Handprinters in Chicago, in June 1984 (NIOSH Health Hazard Evaluation Report 84-299-1543). The toluene concentrations in the screen-washing area during the ink removal process ranged from 181-727 ppm. These concentrations exceed the OSHA STEL for toluene (150 ppm). At other screen printing sites, NIOSH investigators observed similar concentrations of organic solvents in the air. NIOSH observed airborne toluene concentrations of 115-239 ppm during screen cleaning operations at the main U.S. Post Office in Chicago in July 1981 (NIOSH Health Hazard Evaluation Report 81-383-1151). NIOSH observed airborne cyclohexanone concentrations of 10-25 ppm during screen cleaning at Downing Displays in Cincinnati, Ohio (NIOSH Health Hazard Evaluation Report 82-330-1252). The CEB model predicts C_v = 22 ppm. NIOSH investigations are generally triggered by union or management concern about working conditions, and therefore NIOSH data generally reflects worst-case exposures. Thus, it appears that use of the "typical case" parameters in the CEB model provides estimates of occupational exposure which are high, but within the range of the observed data. Use of the "worst-case" parameters in the CEB model generates estimates which are an order of magnitude greater than the field data.

SAIC reviewed the theoretical basis for CEB's air release model and compared it to other mass transfer relationships in order to determine whether it might be possible to obtain even better agreement with the NIOSH data, especially for the worst-case ventilation scenario. SAIC also reviewed the results of Pace Laboratories' experimental measurements of liquid volatilization, which were performed for CEB. These measurements mainly relate to high-vapor pressure compounds evaporating under turbulent airflow conditions. For practical reasons, Pace was unable to run the apparatus at airspeeds less than 100 ft.min^{-1}, and therefore could not obtain correlations specific to the laminar flow regime.

SAIC identified two problems that may cause eqs. (1) and (2) to overestimate airborne concentrations. The first is that CEB's default assumptions for Q, the volumetric air flow rate, may be inconsistent. CEB uses v_z = 100 ft.min^{-1} in eq. (1). An air velocity of 100 ft.min^{-1} through a screen cleaning room 8 ft wide x 10 ft long x 10 ft high would imply Q = 8,000 $\text{ft}^3.\text{min}^{-1}$. The actual flowrate would be lower than this, since the maximum velocity would not be reached in the corners of the room nor immediately adjacent to the walls. However, CEB uses a typical air flow rate of Q = 3,000 $\text{ft}^3.\text{min}^{-1}$, which may be too low. Changing Q to 8,000 $\text{ft}^3.\text{min}^{-1}$ would reduce the predicted airborne concentrations in Example 1 by a factor of 2.3, bringing the exposure estimates down to about 560 mg.m^{-3}. The second source of possible error identified by SAIC in the standard CEB approach seems to lies in the theoretical basis of eq. (1).

The derivation of eq. (1) is given in Appendix K of the CEB Manual for the Preparation of Engineering Assessments. The following general equation governs all mass transfer processes in unreacting systems:

$$\rho \frac{\partial c}{\partial t} = -\mathbf{v}.\nabla c + D_{ab}\nabla^2 c$$

where

c = Concentration, mol.m^{-3}
t = Time, s
$\mathbf{v}$ = Velocity vector, m.s^{-1}
D_{ab} = Diffusivity in air, m^2.s^{-1}
ρ = Air density, kg.m^{-3}

For steady, unidirectional flow of air over a pool of liquid as shown in Figure 1, this can be simplified to:

$$v_z \frac{\partial c}{\partial x} = D_{ab} \frac{\partial^2 c}{\partial x^2}$$

where

υ_z = Velocity in the z direction, m.s^{-1}

If υ_z is assumed not to vary with height above the liquid pool, this equation can be solved analytically to yield eq. (1). However, this assumption is flawed. Because of viscous drag, a laminar boundary layer develops when air begins to flow over a flat surface. This is illustrated in Figure 2. The velocity varies vertically within this layer from zero at the surface to the undisturbed flow velocity at the edge of the layer. The boundary layer construct is an approximation to the truth, originally developed to simplify the analysis of airflow close to and far from the surface of airfoils. However, the results of a boundary layer analysis can be made as accurate as required. The flow regime within the layer is characterized by a boundary-layer Reynolds number, Re_x, computed as follows:

$$Re = \frac{\rho v z}{\mu}$$

where

Re_x = Reynolds number, dimensionless
ρ = Air density, kg.m^{-3}
z = Length along surface from leading edge, m
μ = Air viscosity, kg.m^{-1}.s^{-1}

If the value of Re_x is less than about 10^5, the flow in the layer will be laminar. Above this value, the flow will become turbulent. For the case of a 100 ft.min^{-1} air stream flowing over a 2127 in^2 silk screen, the Reynolds number is about 4,000 and the flow regime is laminar. If a chemical is diffusing from the surface of the liquid pool, a concentration profile will develop that has the same shape as the velocity profile within the boundary layer. However, the diffusive boundary layer is thinner than the velocity boundary layer, meaning that, if one moves vertically away from the pool surface, the concentration will be found to reach zero before the air velocity has quite reached its free stream value. The thicknesses of the flow and mass transfer boundary layers are related by the Schmidt number, *Sc*:

$$Sc=\frac{\mu}{\rho D_{ab}}$$

which is the ratio of the diffusion rates for mass and momentum. The mass transfer boundary layer is thinner than the velocity boundary layer by a factor of $Sc^{-1/3}$. The rate of mass transfer can be expressed in terms of another dimensionless group, the Sherwood number:

$$Sh=\frac{Fz}{cD_{ab}}$$

where:

Sh = Sherwood number, dimensionless
F = Mass flux, mol.m^{-2}.s^{-1}
c = Concentration at the pool surface, mol.m^{-3}

Both experimentally and theoretically, these three dimensionless groups are found to be related as follows for the case of laminar flow over a surface (R.E. Treybal, *Mass-Transfer Operations*, 3rd ed., p.66; J.M. Coulson, *Chemical Engineering, vol.1*, 3rd ed., p.332):

$$\frac{Sh}{Re_x Sc^{1/3}}=\frac{0.332}{\sqrt{Re_x}}$$

This equation is analogous to the following equation for heat transfer:

$$\frac{\mathrm{N}}{Re_x Pr^{1/3}}=\frac{0.332}{\sqrt{Re}}$$

where:

Nu = Nusselt number, dimensionless heat transfer coefficient
Pr = Prandtl number, ratio of heat and momentum diffusivities

The latter equation can be tested very simply by placing thermocouples in the airflow over a heated plate, thus providing additional validation for eq. (A-6). Equation (A-6) should work best for low rates of volatilization, where the mass flux does not affect the airflow and the latent heat of vaporization does not cause appreciable temperature changes in the liquid or air. This corresponds to the case of a low-vapor pressure chemical, which is often the case of greatest interest to CEB. According to eq. (A-6), the mass flux varies from place to place along the pool. The average value is:

$$\frac{\mathrm{N}}{Re_x Pr^{1/3}}=\frac{0.664}{\sqrt{Re}}$$

In deriving Eq. (1), the author states that an analogy may be drawn to a derivation in §17.5 of Bird, Stewart, and Lightfoot's *Transport Phenomena*. However, in that example, the chemical is being absorbed from the air into the boundary layer. The velocity at the outside edge of the boundary layer, where most of the absorption occurs, is practically the same as the free stream velocity. In the present case, most of the concentration gradient lies within a thin layer right next to the surface of the liquid pool, where the air velocity is very much lower than the free stream velocity.

Example 1. *Estimate the vapor generation rate and worker exposure during removal of ink from a printing screen using 100% toluene. The worker cleans screens for 1 hour each day in a room with a ventilation rate of 3,000* $ft^3.min^{-1}$*. The screen area is 2,217* in^2*. Assume a mixing factor of* $k = 0.5$*.*

Toluene has the following physical properties:

Molecular weight: 92.14 $g.mol^{-1}$
Vapor pressure: 28 mmHg at 25 °C
Diffusion coefficient: 0.076 $cm^2.sec^{-1}$

Using these values in eq. (1) gives:

Generation rate G: 0.28 $g.s^{-1}.m^{-2}$
Airborne concentration: 141 ppm (C_v)
534 $mg.m^{-3}$ (C_m)
Exposure over 1 hour: 667 mg

If the CEB worst-case parameters are used in eq. (2), i.e., a mixing factor of $k = 0.1$ and a ventilation rate of 500 $ft^3.min^{-1}$, then the estimated airborne concentration is $C_v = 4{,}216$ ppm. Exposures and volatilization rates are calculated by multiplying the pure-component values from Table 1 by the mole fraction of that component in the liquid phase. A typical screen has an area of 2127 $in^2 = 1.37\ m^2$. Each worker cleans screens for 1 hour per day. Amounts released should be checked against amount used to ensure mass balance.

Example 2. *Recalculate the vapor generation rate and worker exposure for Example 1 using the laminar boundary-layer model.*

The results are:

Re_x = 3662
Sc = 21.35
Sh = 111.5

The concentration at the pool surface can be estimated from the vapor pressure of toluene, which is 28 mmHg:

$$c = \frac{28}{760} \times \frac{1}{24.45} \times 92.14$$

giving $c = 0.139\ kg.m^{-3}$. Substituting into the expression for Sh gives

$F = 0.0995\ g.s^{-1}.m^{-2}$

Using this vapor generation rate and an air flow rate of 8,000 $ft^3.min^{-1}$ gives:

C_v = 19 ppm
C_m = 71 mg.m^{-3}

resulting in a total worker exposure of 88 mg.

If the calculations are repeated with the air velocity set to v = 6.25 ft.min^{-1}, corresponding to a volumetric flowrate into an 8 x 10 x 10 ft room of 500 ft^3.min^{-1}, the results are:

C_v = 379 ppm
C_m = 1428 mg.m^{-3}

and the total worker exposure is 1785 mg.day^{-1} inhaled. This result more closely approximates the highest concentrations found by NIOSH in the field.

The CEB model was compared to the results of the PACE experiments and found to be in moderately good agreement. This is not surprising, because most of the PACE data was collected in the turbulent flow mode. In turbulent boundary layers, the velocity is almost equal to the free stream value everywhere except in a very thin layer adjacent to the pool surface. In this case the assumptions used in deriving eq. (1) are correct. In laminar boundary layers, this is not the case, and eq. (A-7) should, in principle, provide a better representation of the physical situation.

Appendix F
Screen Printers Technical Foundation (SPTF) Testing Methodology

Purpose of Testing

Performance data will be collected for each product system in a laboratory setting at the Screen Printing Technical Foundation (SPTF) and also in production runs at 23 volunteer facilities. The testing methodology for the both phases of the demonstrations was developed by consensus with the involvement of EPA, product manufacturers, and screen printers. The protocol was designed to allow the evaluation of the maximum number of product systems given the resources available to the project.

The intent of the SPTF evaluations is to assure that the product systems sent to printers would provide an acceptable level of performance. Screening at SPTF will also provide another set of observations to compare with in-facility demonstration results. All evaluations will be conducted under consistent screen conditions (e.g., tension, mesh type, emulsion type, thread count, image) and each product system will be tested on three imaged screens; one with solvent-based ink, one with UV-cured ink and one with water-based ink.

Testing Methodology

Evaluate each product system as follows:

- ❍ Prepare three screens for printing according to the parameters listed in section C.

- ❍ Place a sufficient quantity of the solvent-based ink in the stenciled screen and thoroughly work into the screen with a squeegee. Card out extra ink and allow the screen to sit for approximately 15 minutes. Remove the ink from the screen following the instructions provided to SPTF by the manufacturer. Wipe or wash off the ink (depending on instructions) until it appears that no more ink is coming off on the cloth or in the rinse. Use only enough product to accomplish ink removal to this degree. Record the application procedure, the time it takes to complete the ink removal (time using a digital stop watch), the amount of product used (measure to the nearest 0.5 ounce), the temperature, humidity, product dilution ratio, number of wipes used, ease of use, and comment on the product performance.

- ❍ Repeat step 2 on the second screen using UV-cured ink and on the third screen using water-based ink.

- Allow each screen to sit for approximately 8 hours to simulate a shop situation. Record the time delay for each screen. Apply the emulsion remover to the screen according to the manufacturers instructions. Record the application procedure, the time it takes to complete the emulsion removal (time using a digital stop watch), the amount of product used (measure to the nearest 0.5 ounce), product dilution ratio, number of wipes used, and ease of use. Also document if the stencil dissolved easily or slowly, an evaluation of how much scrubbing was needed, if any emulsion was still present, and if any ink haze or stencil stain remained on the mesh. If an initial attempt to remove all the stencil fails, record the screen condition and apply the product again.

- Apply the haze remover product according to the instructions supplied by the manufacturer. Record the application procedure, the time it takes to complete the haze removal (time using a digital stop watch), the amount of product used (measure to the nearest 0.5 ounce), product dilution ratio, number of wipes used, and ease of use. Also report if any ink haze or stencil stain is present on the mesh. If an initial attempt to remove the haze fails, document the screen condition, and apply the product to the screen again.

- Based on the testing method described above, SPTF will determine the effectiveness of all of the products submitted. This will include evaluating the manufacturer's application instructions for each product and ensuring that the application technique specified for that product will enable the product to work effectively. If the application technique specified for a particular product is determined to limit the effectiveness of the product or in any other way negatively affect performance, a second application technique will be chosen and tested. **Only products deemed effective by SPTF will be used in the field demonstration portion of the project.**

Testing Parameters

For each ink type tested (solvent-based, UV-cured, and water-based), use the following screen parameters:

Mesh Count per Inch/Thread Diameter:	390/34 LE for UV ink 260/40 LE for solvent- and water-based ink
Supplier/Manufacturer:	Tetko/Swiss Silk of Switzerland
Brand Name of Fabric:	PeCap LE (Low Elongation)
Mesh Opening:	26 microns
Fabric Thickness:	60 microns
Twill or Plain Weave:	Twill Weave
Suggested Tension:	26 N/cm for UV ink 20 N/cm for solvent- and water-based ink
Frame Type:	Aluminum

Frame Size: 18" × 20" Outside Dimensions
Tensioning System: Tetko SST Pneumatic Clamp System
Adhesive: KIWO Kiwobond 1000 HMT
Tensioning Procedure:

- Bring screen directly up to tension using predetermined pressure settings on pneumatic gauges.
- Let screen set 5 minutes.
- Check tension, and retension if necessary.
- Adhere with frame adhesive.
- Check final tension and record.

Stencil Brand and Type: KIWO Poly Plus SRX dual cure direct emulsion
Scoop Coater Brand and Edge: Tetko Pro-EM round edged coater 12" length
Coating Method: 2 coats on print side, 3 coats on squeegee side, wet on wet.
Image Description: A 10" × 8" pattern of ½" checkers and a ByChrome halftone exposure image
Exposure System Description: Olec 5KW Metal Halide lamp with 36" distance and light integrator
Wipe Type: Molnlycke brand P-Tork made from rayon and pure cellulose.

Ink Types

- Solvent-based Ink: Naz-Dar 9700 Series All Purpose Ink 9724 Black
- UV Ink: Nor-Cote CD 1019 Opaque Black
- Water-based Ink: TW Graphics WB-5018 Black

Appendix G
Facility Background Questionnaire

This Appendix provides a reproduction of the blank questionnaire on facility background as it appeared when sent to the printers for completion.

FACILITY BACKGROUND QUESTIONNAIRE

Design for the Environment Screen Printing Project

1. Business Profile

a. Products

Approximately what percentage of your products are printed on the following substrates? (Please check all boxes that apply).

	< 50%	50 - 95%	95 - 100%
Plastics (rigid/flexible)			
Paper (coated or uncoated)			
Metal			
Ceramic			
Glass			
Other (specify)			

b. Please list the major products produced at your facility:

____

____

____

c. Approximately what percentage of your shippable product, by sales dollars, is produced through screen printing? _______________________

d. Approximately how long is your typical run? _______________________

e. Approximately what percentage of your orders are repeat orders? _______________________

2. Screen Reclamation Operations

a. Screen Size: Specify the average size frame used at your facility: ______________ *(ft^2 or in^2)*

b. Tracking: Describe how your screens are tracked or numbered in the facility:

____

____

____

c. Volume:
What is the average number of screens cleaned/reclaimed each day for future use?
(Please check the appropriate box)
0 - 5….. 5 - 10….. 10 - 15….. > 15….. *(specify ______)*

d. Employees
Please fill in the table below. For the purposes of this questionnaire, "Ink Removal" is not defined as press-side operations, unless this is the only site used for ink removal. Assume a 5-day work week with one 8-hour shift each day. Please check all boxes that apply.

Number of Employees at this Location	Number of Employees Involved in Ink Removal	Number of Employees Involved in Screen Cleaning/Reclamation	Average time (hr/day) a single individual is involved w/ ink removal	Average time (hr/day) a single individual is involved w/screen cleaning/reclaiming
0 - 5	1 - 3	1 - 3	< 1	< 1
6 - 10	4 - 6	4 - 6	1 - 2	1 - 2
11 - 15	7 - 10	7 - 10	3 - 4	3 - 4
16 - 30	> 11 specify _________	> 11 specify _________	5 - 6	5 - 6
31 - 50			7 - 8	7 - 8
> 50			other, specify ______	other, specify ______

e. Ink Removal and Screen Reclamation Areas
Do you have separate areas for ink removal and screen reclamation activities? ("Ink removal" is defined as activities after excess ink is carded off. It does not refer to ink removal activities *during* the process).
Yes….. No…..

- If "yes", check all that apply in the first four columns of the table below.
- If "no", check all boxes that apply in the last two columns of the table below.

Separate areas for ink removal and screen cleaning/reclamation activities				***Combined Ink Removal/ Screen Reclamation Areas***	
Ink Removal Area (ft^2)	**Type of Ventilation**	**Screen Reclamation Area (ft^2)**	**Type of Ventilation**	**Size of Combined Area (ft^2)**	**Ventilation**
< 20	local (mechanical)	< 20	local (mechanical)	< 20	local
20 - 50	plant (facility-wide)	20 - 50	plant (facility-wide)	20 - 50	plant
50 - 100	natural	50 - 100	natural	50 - 100	natural
100 - 200	other (specify):	100 - 200	other (specify):	100 - 200	other (specify):
> 200 (specify): _________		> 200 (specify): ___________		> 200 (specify): _________	

3. *Rates*

a. Record the electric rate: _______________

b. Record the water rate: ________________

c. Record the sewer rate: ________________

d. Record the screen reclamation employee's wage rate: _______________

e. Record the printer's wage rate: ____________________ *(Use the rate for the printer who would determine if the print image quality is acceptable).*

4. *Current Ink Remover Procedures* (NOT process cleaning)

a. What type of ink(s) do you use?

____

____

b. Do you recycle ink removal products? Yes..... No.....
- Do you recycle on-site or off-site?
- Do you use the recycled product in-house? Yes..... No.....
  If so, how much do you use annually? _________ gallons
- If recycled off-site, does the recycler sell the recycled product?
- What are the costs and income associated with recycling ink removal products?

c. What is the average number of screens/day where ink remover is applied? ___________________

d. Describe the current method of applying ink remover:

____

____

____

e. Do you use a pressure washer (or other equipment) for ink removal?

- If so, specify the type of equipment, and the manufacturer and model (from nameplate):

- Specify the pressure (psi) and flowrate (gpm):

- What are the equipment energy use specifications (from nameplate):

- How long is it in use for each screen?

f. Fill in the table on the next page for each of your ink remover products.

Current Ink Removal Practices

Ink Removal Product (trade name and description)	**Annual Volume of Product Purchased** (gallons)	**Cost of Ink Removal Product** ($/gallon)	**Type of Ink with which Product Works Best**	**Personal Protective Equipment Used**	**Method of Applying Ink Removal Product**	**Materials Used to Loosen Ink**	**Avg # of Rags Used/Screen to Remove Ink**
			Solvent-based UV Curable Water-based Any	Gloves Eye Protection Aprons Respiratory protection Barrier Cream None Used	Pour from container onto screen surface Dip rag or brush into container and wipe screen Spray on w/ nozzle from tank Spray on with spray bottle Use specialized spraying equipment (specify) Other (specify)	Brush Squeegee Disposable rag Reusable rag Other (specify):	0-2 2-4 4-6 6-8 8-10 Other (specify):

f. List the types of materials used in ink removal that are frequently replaced (such as brushes, squeegees, wipes and filters) and their costs. Note how often they are replaced and how much of your time does it take to order replacements?

____

____

5. Current Emulsion Remover Practices

a. Fill in the following information and the table below for each type of emulsion removal product you currently use:

Trade Name ___________________________

Volume purchased in 1993 (gal.) ____________

Generic product description ______________________

Purchase Price ($/gal.) ____________

Average # of screens/day where emulsion remover is applied: ____________________________

Personal Protective Equipment Used	**Method of Applying Emulsion Removal Product**	**Equipment or Materials Used to Remove Emulsion**	**Equipment or Materials Description** *(Include manufacturer, model #, pressure (psi) and flow rate (gpm) if applicable, frequency of replacement, equipment energy requirements)*
Gloves Eye Protection Aprons Respiratory protection Barrier cream Ear Protection None Used Other (specify):	Pour from container onto screen surface Dip rag or brush into container and wipe screen Spray on with nozzle from tank Spray on with spray bottle Use specialized spraying equipment (specify) Other (specify)	Brush	
		Low pressure	

		water spray	
		High-pressure water spray	
		Water-blaster	
		Automatic Screen Cleaning System	
		Disposable Rag	
		Reusable Rag	
		Other (specify):	

6. Current Haze Remover Practices

a. Fill in the following information and the table below for each type of haze removal product you currently use:

Trade Name ___________________________
Volume purchased in 1993 (gal.) ____________
Generic product description ______________________
Purchase Price ($/gal.) ____________
Average % of screens reclaimed where haze remover is applied: ____________________________

Personal Protective Equipment Used	**Method of Applying Haze Removal Product**	**Equipment or Materials Used to Remove Haze**	**Equipment or Materials Description** *(Include manufacturer, model #, pressure (psi) and flow rate (gpm) if applicable, frequency of replacement, equipment energy requirements)*
Gloves Eye Protection Aprons Respiratory protection Barrier cream None Used Other (specify):	Pour from container onto screen surface Dip rag or brush into container and wipe screen Spray on with nozzle from tank Spray on with spray bottle Use specialized spraying equipment (specify) Other (specify)	Brush	
		Low pressure water spray	
		High-pressure water spray	
		Water-blaster	

		Automatic Screen Cleaning System	
		Disposable Rag	
		Reusable Rag	
		Other (specify):	

7. *Materials Storage*

a. Where do you store your ink removal and screen reclamation products and in what quantity? Please check one box for each column.

Storage Method	**How is ink removal stored in the application area?** *(check all that apply)*	**How is ink removal stored in the storage room?** *(check all that apply)*	**How is emulsion remover stored in screen cleaning area?** *(check all that apply)*	**How is emulsion remover stored in storage area?** *(check all that apply)*	**How is haze remover stored in the cleaning area?** *(check all that apply)*	**How is haze remover stored in storage area?** *(check all that apply)*
30- or 55-gallon drum with bung hole kept open						
30- or 55-gallon drum with bung hole kept closed						

30- or 55-gallon drum with top removed						
Open pail						
Closed pail						
Quart or smaller squirt bottle						
Safety can						
Safety cabinet						
Not kept in the press room						
Other (specify)						

8. Waste Disposal

a. Please indicate the quantity of waste you dispose of annually as hazardous waste for:
spent solvent waste: ____________ (gal. in bulk) OR ____________ (# of 55 gal. drums)
ink waste: ____________ (gal. in bulk) OR ____________ (# of 55 gal. drums)
used shop rag waste ____________ (gal. in bulk) OR ____________ (# of 55 gal. drums)

b. Ink Removal and Screen Cleaning Wastes
Fill in the table below to describe the treatment and disposal methods used for waste (not only *hazardous* wastes) generated by the ink removal and screen cleaning/reclamation operations:

Ink Removal Area Wastes			**Screen Cleaning/Reclamation Wastes**		
Quantity Generated Annually (gal)	**Method of Storage Prior to Treatment/ Disposal**	**Method of Treatment or Disposal**	**Quantity Generated Annually (gal)**	**Method of Storage Prior to Treatment/ Disposal**	**Method of Treatment or Disposal**
	In closed containers	Filter or treat prior to disposal or recycle		In closed containers	Filter or treat prior to disposal or recycle
	In open containers	Send to recycler		In open containers	Send to recycler
	No specified container	Recycle on site		No specified container	Recycle on site
	Other (specify):	Discharge to sewer		Other (specify):	Discharge to sewer
		Dispose as hazardous waste			Dispose as hazardous waste
		Dispose as non-hazardous waste			Dispose as non-hazardous waste
		Other (specify)			Other (specify)

9. Drying

a. Are screens dried between ink removal and emulsion removal?

- If yes, how are they dried? (air dried or dried with equipment such as fans, heater, etc.) - If drying equipment is used, note:
  - Duration of drying step:
  - Manufacturer and model of the equipment:
  - Energy use specifications:

b. Are screens dried between emulsion removal and haze removal?
- If yes, how are they dried? (air dried or dried with equipment such as fans, heater, etc.)
    - If drying equipment is used, note:
        - Duration of drying step:
        - Manufacturer and model of the equipment:
        - Energy use specifications:

Appendix H
Observers' Evaluation Sheet

This Appendix provides a reproduction of the blank evaluation sheet filled out by the observers during the screen reclamation products performance demonstration.

Observer's Evaluation Sheet
Screen Reclamation Products Performance Demonstrations

Facility name: ____________________ Location: ________________________________

Date: _____ Time: ______ Facility contact name/phone:________________________________

Screen reclamation employees(s):____

1. Type of Demonstration:

check one: Products curently used at facility _____ Alternative Products _____

2. Operating Conditions

Record the information on the screen being cleaned on the table below:

Screen Information

SCREEN CONDITION	*Fill in the blank or circle the appropriate characteristic. Make any notes or comments in the space to the right.*
Screen identification and history	*Enter the identification marking code that is on the screen:* *Estimate the number of impressions printed over the life of this screen:* *Estimate how much ink was left on the screen? (< avg., avg., > avg.)*
Screen size	_______________ x _________________ (specify units; in^2 or ft^2)
Number of impressions of the screen's last run	
Screen degreaser	*Specify manufacturer and series # or name:*
Ink type	*Circle one:* Solvent-based, UV, or water-based

Observer's Evaluation Sheet
Screen Reclamation Products Performance Demonstrations

	Specify manufacturer and series # or name:
Ink color	*Circle one:* Blue, Black, Other (specify):
Emulsion type	*Circle one:* Capillary film, Direct photo stencil, Dual cured, Other (specify): *Specify manufacturer and series # or name:*
Ink coverage	*Check one:* 0 - 25%... 25 - 50%... 50 - 75%... 75 - 100%...
Screen condition	*Note any rips, holes, corrosion*
Screen mounting	Is a retensionable frame used? Is the screen glued to the frame?
Thread count **Thread diameter**	_______________ threads/inch _______________ (specify units)
Tension level *(measure both major axes; specify units)*	major axis: _________________________ N/cm minor axis: _________________________ N/cm
Mesh type *(record type of mesh material)*	
Mesh treatment *(has*	

the mesh been abraded? calendared? or treated?)	
Calibration of measurements	_______ scoop(s) of haze remover = _______ ounces
Temperature *(in the work area)*	Ink removal area: _______________ F Emulsion/Haze removal area: _______________ F
Humidity *(in the work area)*	Ink removal area: ________________ % Emulsion/Haze removal area: ________________ %

3. Cleaning Procedure

Clean the screen using the application technique designated by SPTF for alternative products or follow your typical screen reclamation procedure if demonstrating the currently used products.

Observe all actions taken by the employee in reclaiming the screen and record any differences between the technique used and the technique specified by SPTF for alternative products or the technique documented in the facility questionnaire for products currently used at the facility.

Cleaning Procedure:

For currently used products, are any variations of the reclamation procedure used, and if so, under what circumstances? For what percentage of screens, or how often are these method variations used?

Describe any temperature or humidity controls in the ink removal or reclamation area.

____
____

4. Performance

Complete the performance evaluation table on the next page for alternative products and for currently used products.

Performance Evaluation

	Enter quantity, comments, and notes
Drying Time *(specify units; hours or mins.)*	Time from end of press run to start of **ink removal** with product: ___________ Time from ink removal completed to start of **emulsion removal**: ___________ Time from emulsion removal completed to start of **haze removal**: ___________
Dilution *(record dilution ratio or enter "None")*	Ink Remover _______________ *(enter ratio)* or *"none"* Emulsion Remover _______________ *(enter ratio)* or *"none"* Haze Remover _______________ *(enter ratio)* or *"none"*
Quantity of Product Used	Ink Remover _______________ *(enter # of ounces)* Emulsion Remover _______________ *(enter # of ounces)* Haze Remover _______________ *(enter # of ounces or scoops)*
Time to clean *(do not include screen positioning or equipment clean up time)*	Ink Remover ______________ *minutes* Emulsion Remover ______________ *minutes* Haze Remover ______________ *minutes*
Physical effort required *(circle one for each step and describe effort used)*	Ink Remover: *circle one:* Low, Moderate, High. *Describe:* Emulsion Remover: *circle one:* Low, Moderate, High. *Describe:*

	Haze Remover: *circle one:* Low, Moderate, High. *Describe:*
If wipes were used for ink removal, specify the type, size and quantity used.	
Was a pressure washer used? *(check one for each step)*	For Ink Removal: No ______ Yes ______ (specify length of time used _________ mins.) For Emulsion Removal: No ______ Yes ______ (specify length of time used _________ mins.) For Haze Removal: No ______ Yes ______ (specify length of time used _________ mins.)
Was tap water (NOT pressure wash) used in any part of screen cleaning/reclamation?	Was (non-pressurized) water used in *(check all that apply)*: Ink Removal... or Emulsion Removal... or Haze Removal... Flowrate: ______________________ (gallons/minute) Length of time used: _______________________ (specify seconds or minutes)
Examine screen after ink removal.	Did the product effectively and easily remove the ink? Also note any side effects of the product on the mesh):
Examine screen after emulsion removal.	Is there any ink haze or stencil stain on the mesh? If so, describe in detail: If any emulsion is still present, describe the residue left on the screen in detail:

	Note any side effects on the screen *(e.g., mesh damage, corrosion, etc.)*
Examine screen after reclamation is complete.	Can the screen be reused for all jobs? *(check one)* Yes _______ No_______ If "No", describe why the screen cannot be reused or what limitations apply: *(e.g., Is there is a ghost image? Can the screen be used for reverse printing? for close tolerance work? Can transparent inks be used with it?)*
Remeasure the screen tension *of both major axes and record (specify units)*	major axis: ___________________ N/cm minor axis: ___________________ N/cm
Examine the substrate image after the screen is reused. Comment on the print image quality.	
Comments or suggestions - Use the back of this sheet to note anything unusual about this demonstration. (e.g., did you have to reapply any of the products? was this screen more difficult to clean than others?)	

5. Experience with Alternative Screen Reclamation Products

a. Have you tried any alternative chemical products to replace your current screen reclamation products?

- If yes, please list the product trade name(s) and the generic product type(s):

____

____

____

- Why were the alternative product(s) better, the same, or worse than your old product?

____

____

____

- If you have not tried a different chemical product, please check the box that best describes your reason for not trying alternatives:

Lack of adequate information to evaluate environmental performance:
Operators do not believe alternatives will work:
Not impressed with product descriptions:
Cost is prohibitive:
Other: (please explain):

b. Besides alternative chemical products, have you implemented any changes in equipment, procedures or work practices that reduced your use of screen reclamation chemicals, or reduce the time, effort or water required to use those products? Yes..... No.....

- If yes, please describe:

c. Does this facility have a pollution prevention, waste minimization, or source reduction program?

- If yes, please describe:

Appendix I
Ink Remover Evaluation Sheet for Printers

This Appendix provides a reproduction of the blank evaluation sheet used by printers to assess the effectiveness of ink removal products during the on-site performance demonstration.

INK REMOVER EVALUATION SHEET

Evaluation #____

Facility name and location:

____

Date: ___________ Time: _________ Ink Remover employee's name: _______________

	Fill in the blank or circle the appropriate characteristic. Make any notes or comments in the space to the right.
Screen Condition	
Screen identification and history	*Enter the identification marking (tracking) code for the screen:* *Estimate how much ink was left on the screen?*
Screen size	_________ inches x _________ inches
Screen condition and threads per inch	*Note screen condition including any rips, holes, corrosion:* *Record the screen mesh size:* __________________ threads/inch
Mesh *(Record mesh material type and type of mesh treatment, (e.g., abraded, calendared, etc.) if any)*	*Mesh type:* *Mesh treatment:*
Number of impressions of the screen's last run	
Ink type	*Circle one:* Solvent-based, UV, Water-based *Specify manufacturer and series #:*

INK REMOVER EVALUATION SHEET

Ink color	Blue, Black, Other (specify):
Emulsion type	*Circle one:* Capillary film, Direct photo, Dual cure, *Specify manufacturer and series #:*
	Check one: 25 - 50%… 50 - 75%… 100%…
	Time between end of press run and start of ink removal with ______ ____________ *(hours or*
Performance	
Ink Remover Dilution	*(enter ratio)* or
Quantity of Ink Remover Used	______________ oz.
(enter time from application of ink remover *the next step)*	Note: Do not include screen positioning or clean up time. mins.
Physical effort required	Low, Moderate, High

INK REMOVER EVALUATION SHEET *Evaluation #_____*

How many wipes did you use?	
Was a pressure washer used?	*(check one)* Yes _______ No_______
Examine screen after ink removal.	*Did the ink remover effectively and easily remove the ink? (Also note any side effects of the product on the screen)*
Comments or suggestions - Record any comments and note anything unusual about the reclamation on a separate sheet of paper. (e.g., did you have to reapply the product? why was the screen hard to clean?)	

Appendix J

Emulsion Remover and Haze Remover Evaluation Sheet

This Appendix provides a reproduction of the blank evaluation sheet used by printers to assess the effectiveness of emulsion removal products during the on-site performance.

EMULSION REMOVER AND HAZE REMOVER EVALUATION SHEET

Evalulation # ____

Facility name and location: ____

Date: _________ Time: _______ Screen Reclamation employee's name: ___________

	Fill in the blank or circle the appropriate characteristic. Make any notes or comments in the space to the right.
Screen Tracking	
Screen identification	*Enter the identification marking (tracking) code for the screen:*
Performance	
Drying Time *(Specify units; hours or mins.)*	Time from ink removal completed to start of emulsion removal: Time from emulsion removal completed to start of haze removal:
Dilution	Emulsion Remover _______________ *(ratio)* or *none* Haze Remover _______________ *(ratio)* or *none*
Quantity of Product Used	*Enter # of ounces used:* Emulsion Remover ____________________________ ounces *Enter # of ounces used:* Haze Remover _____________________________ ounces

EMULSION REMOVER AND HAZE REMOVER EVALUATION SHEET

Evaluation # ____

Product Use Time *(enter time from application of product until screen is ready for the next step)*	Emulsion Remover ________________ mins. Haze Remover ________________ mins.
Was a pressure washer used?	For emulsion removal? *(check one)* Yes _______ No_______ For haze removal? *(check one)* Yes _______ No_______
Physical effort required *(circle one for each step and describe the level of effort)*	**Emulsion Remover:** *circle one:* Low, Med., High; *Describe if the stencil dissolved easily or slowly, and if a great deal or very little scrubbing took place:*
	Haze Remover: *circle one:* Low, Med., High; *Describe the effort reqired for haze removal:*
Examine screen after emulsion removal.	Is there any ink haze or stencil stain on the mesh? If so, describe: If any emulsion is still present, describe the residue left on the screen in detail:

EMULSION REMOVER AND HAZE REMOVER EVALUATION SHEET

Evalulation # ____

Examine screen after reclamation is complete.	Can the screen be reused for all jobs? *check one:* Yes ______ No______ If "No", describe why the screen cannot be reused: *(e.g., Is there is a ghost image? Can the screen be used for reverse printing? Can it be used for close tolerance work? Can transparent inks be used with it?)*
Examine the substrate image after the screen is reused. Comment on the print image quality.	
Comments - Record any comments and note anything unusual about the reclamation on a separate sheet. (e.g., did you have to reapply the product? why was this screen more difficult to clean?)	

Appendix K
Weekly Follow-up Call Guidance

This Appendix provides a reproduction of the blank form used by observers to record their weekly calls to the printers participating in the on-site performance demonstration.

Weekly Follow-up Call to Screen Printers

in the DfE Performance Demonstration Project

Once a week, the observer will contact the facility by phone. This form is to guide the conversation, but let the printer discuss any problems, changes or concerns. ***Remind them to send in the envelope with this week's forms.***

1. In your opinion, is the performance of the alternative products better, worse or about the same as the products you used before this demonstration? Why?

____

____

____

2. Have you found any conditions where the products did not work? (e.g., is there any ink type or emulsion type where the product did not work?) If so, describe the condition(s).

____

____

____

3. Have you found any conditions (ink type, emulsion type, etc.) where the products work particularly well? If so, please describe the condition(s).

____

____

____

4. Have you changed the application procedure in any way to improve product performance? If so, please describe. For example,

do you apply the product to the screen sooner?
do you let the product sit/soak on the screen longer?
have you used a different type of brush? or scrubber? or wipe?

____

____

____

5. Have you tried any different application techniques that did <u>not</u> improve performance?

What did you change?
Why did you make the change?
Was product performance worse after the change? How?

____

---

6. Have you changed the quantity of product you use? Why?

7. How are you timing how long you use each product? (i.e., are you *estimating* the time or are you actually timing it?)

8. What measurement method are you using? Are you still using the same spray bottle and the same scoop provided?

9. Do you think the screen failure rate has increased, decreased or remained the same as a result of using the new product? What signs have you seen that suggest the failure rate may differ?

10. Do you have any other comments, concerns or problems regarding the alternative products?

Appendix L
Screen Printing Performance Demonstration Methodology

Note: This methodology incorporates comments from discussions with the Screen Printing Technical Foundation, the Screen Printing Association International, screen printers, and manufacturers and suppliers of screen reclamation products and equipment.

Performance Demonstration Overview

Goal

The objective of this performance demonstration is twofold: (1) to obtain specific information from printing facilities concerning the performance of commercial chemical and mechanical screen reclamation systems; (2) to encourage printers to experiment with new products and work practices that reduce human health and environmental risk. This data will be incorporated into the Cleaner Technologies Substitutes Assessment.

General Plan

The majority of printers participating in the performance demonstration will evaluate the effectiveness of one manufacturer product line/system for screen reclamation, using a method that includes the use of ink remover, emulsion remover and haze remover products in screen reclamation. Each facility will be responsible for reclaiming screens over a thirty-day period, utilizing the specified product system. The performance of one or two substitution processes relying on specially equipped mechanical and/or chemical reclamation cleaning systems will be demonstrated, including: (1) high-pressure water blaster; (2) sodium bicarbonate reclaim system.

Desired Characteristics to be Reported from Performance Demonstrations

Actual cost of chemical product or reclamation equipment

Definition: Cost per volume used per area of screen cleaned (ft^2).

We will ask that product manufacturers include the average purchase price of their individual products (haze remover, stencil remover, ink remover, reclamation equipment) when the product/equipment is submitted for the performance demonstration. The adjusted or actual cost of screen reclamation products will be determined through incorporation of product purchase price, product application cost, labor costs, and safety and disposal costs.

Product constraints

Example: Whether the product category (e.g. ink remover) is incompatible with certain types of inks

This information should be submitted by the manufacturers and may also be discovered as a result of the performance testing. If the manufacturer does not provide any information regarding product incompatibilities, we will assume that there are no incompatibility concerns.

Special storage, safety and disposal requirements

Examples: Flammability or volatility of the product

This information will be requested on the manufacturer questionnaire and will vary according to the chemicals comprising the products/equipment to be submitted. We will ask that manufacturers provide recommendations on disposal or treatment of wastes associated with the use of their products. The storage costs will be a factor in determining the adjusted cost of the product.

Ease of use

Definition: The physical effort required to effectively clean the screen using the test product

This is a subjective standard based on the judgment of the screen cleaner and printer. As a frame of reference, the screen reclamation employee or facility point-of-contact will be asked to describe their current work practices for screen reclamation and the physical effort required with their current system. When the performance information is tabulated for each manufacturer system demonstrated at a facility, the data regarding the products currently used at the facility will also be noted.

Duration of the Cleaning Cycle

Definition: The measured time of the screen cleaning process (e.g. beginning with the application of ink removal product to the screen until the final water wash is completed)

This will attempt to measure the labor costs associated with the use of the products. Labor costs will be based on the time required for the screen reclamation with the specific products and a standard screen cleaning wage.

Physical/Chemical properties of the screen reclamation system

Definition: Characteristics associated with use of the individual system, such as chemical components or pressure at which chemicals are applied.

The chemical components of each product system must be submitted by each manufacturer participating in the demonstration project. The physical characteristics of each system as used, including such factors as water pressure as applied and type of specialized equipment used, will be documented.

Effectiveness of the screen reclamation system

This is a subjective criteria and depends on the judgment of the printer and the employee reclaiming screens at the facility. They will examine the screen after the reclamation process is complete and answer two questions: (1) Can this screen be reused for general screen printing purposes?; (2) Can this screen be used to print a reverse image? These questions will not be answered solely on the basis of the screen appearance. When the screen is reused for printing, any problems with ghost images or weak screens will be documented.

Screen, stencil and ink information

The majority of screens reclaimed in the demonstration project should have a monofilament polyester mesh with a nominal thread count in the range of 230-390 Mc/in. However, if the screen mesh thread count is outside of this range, the data will be documented. Data recorded for each screen reclaimed should include threads per inch, the age of the screen and the prior printing history of the screen. The length of time between the end of the press run and the actual screen reclamation should be estimated. The color and type of ink, and the type of emulsion will also be reported. If possible, the tension level (N/m) of the screen should be recorded. The condition of the screen (rips, tears) before and after the test will be reported. The printing performance of the screen after it has been reclaimed will also be documented. This descriptive information serves two purposes: (1) it provides data to determine the specific effectiveness of the methods and various product lines; (2) it may assist in discovering and reporting incompatibilities between the products and types of inks and emulsions.

Methodology For On-Site Performance Demonstration

Selection of Products for the Performance Demonstration

- ❍ Products will be submitted by manufacturers in two shipments. One shipment of screen reclamation products, in bucket containers with manufacturer labels, will be sent to SPTF/SPAI, along with a standard OSHA MSDS; the quantity shipped should be sufficient to clean 3 screens of 10 ft^2 each. The manufacturer will also ship to SPAI a quantity of product necessary to reclaim

50 screens at the volunteer printing facility. SPAI will determine the quantity required for each site and notify the manufacturer prior to shipment.

- SPTF will determine the effectiveness of all of the products submitted. This will include evaluating the standard manufacturer instructions for each product and ensuring that the application technique specified for that product will enable the product to work effectively. Any instructions for an individual product pertaining to dilution or mixing will be followed. If the application technique specified for a particular product is determined to limit the effectiveness of the product or in any other way negatively affect performance, a second application technique will be chosen and tested.

- The effectiveness of each product system will be tested with up to three different ink types (solvent-based, UV-cured, and water-based), depending on the recommendations of the manufacturer. The specific methodology for the SPTF testing is detailed in a separate document (see Appendix G). **Only products deemed effective by SPTF will be used in the field demonstration portion of the project.**

- The selection of printers will take into account the type of inks primarily used and any specialized application equipment. SPAI will match printers with appropriate screen reclamation products. The in-field demonstrations will only include screens on which solvent-based or UV inks have been used. However, if screens on which water-based inks have been used are reclaimed with the product system, the data will be documented.

- After SPTF has completed the initial screening of the effectiveness of products, SPAI will ship the screen reclamation products to the screen printers participating in the field demonstrations. Products will be packaged in generic containers (no screen product manufacturer markings). The printer will receive the masked product that has a masked OSHA MSDS and a generic label. For all other aspects of the demonstration project, products will be identified only by a letter code.

Documentation of Standard Work Practices at Facility

- The observer will visit the facility and explain the project thoroughly to both the facility point-of-contact, and employees involved in printing and screen reclamation. Prior to the observer's visit, the facility will have received a Facility Background Questionnaire. When on-site, the observer will verify that this questionnaire has been accurately completed. Information categories on the questionnaire include: 1) general facility operations (types of products, number of employees), 2) screen reclamation operations (equipment used, number of screens reclaimed), 3) current reclamation products (application procedures, trade names), 4) storage and disposal practices.

❍ The observer will verify the questionnaire and document any other relevant information on the **general facility operations**. Recorded information will include the types of products printed, the printing substrates, the typical run length, and the water, sewer, and electric rates for the facility.

❍ The observer will verify the questionnaire and document any other relevant information on the **screen reclamation operations**. The observer will document the size and general specifics of the screen reclamation area(s), including the type of ventilation. The observer will also briefly describe the experience of the employee(s) participating in the test, including past experiences with testing of screen reclamation products, and document any potential biases.

❍ The observer will verify the questionnaire and document any other relevant information on the facility's **current reclamation products**. The observer will record the trade name and purchase price of the current screen reclamation products. The observer will document the current work practices by observing screen reclamation utilizing the present method and products used by the facility. The specifics of the screen to be cleaned, such as threads per inch, ink type, color of ink, emulsion type, age, size, tension level and printing history (including estimated time between the end of the press run and reclamation), will be recorded. The physical condition of the screen (small rips, etc.) will be documented before and after the reclamation. The observer will note any pre-application dilution of the product. The observer will measure the quantity of each product applied to the screen and record the time required for each cleaning step, and the overall cleaning of the screen, from application of the ink remover product to the final water wash.

❍ The observer will verify the questionnaire and document any other relevant information on the facility's **storage and disposal practices**. The observer will note how the products are stored in bulk and in the screen reclamation area. The current waste and rag disposal practices and costs will be documented by the observer.

Phase I: Initial Demonstration and Evaluation at the Printing Facility

❍ The employee involved in the performance demonstration will prepare to clean one screen using the masked products supplied for the ink removal, emulsion removal and haze removal steps. The employee will use the application technique designated by SPTF for each product. Prior to the reclamation process, the observer will document any pre-application dilution of the products that is necessary. The observer will note all characteristics of the screen as outlined in B.4.

- The employee will begin screen reclamation. The observer will record the quantity of each product that is applied to the screen. The observer will record all actions taken by the employee in reclaiming the screen to ensure adherence to any specific instructions. The observer will time the entire process, from the application of the ink remover to the final water wash.

- The observer will record the effectiveness of the product system in reclaiming the screen, based on visible appearance and the judgment of the printer and the screen cleaning employee. The observer will ask if the screen can be used again for printing and if there are any printing limitations, such as whether it can be used to print a reverse. After the screen is used again for printing, any problems with the screen, such as ghost images or damaged mesh, will be documented by the printer.

- A second and third screen will then be cleaned using the same method. The observer will follow the process outlined in steps 1 - 3. The purpose of cleaning three screens is to ensure that the screen cleaning employee is familiar with the cleaning method and products, before beginning longer-term testing.

Phase II: Further Demonstration of System Effectiveness at the Printing Facility

- After completion of the above demonstration, the screen reclamation performance demonstration will continue to be performed by the facility through the next thirty days. The masked products supplied by the manufacturer will be used to reclaim these screens. The observer will not be present during this phase of testing. The employee responsible for screen reclamation will record the characteristics of each screen cleaned (see B.4.), the volume of product used for each step in the process, and the effectiveness of the manufacturer system in reclaiming the screen (taking into account future printing performance of each screen). To simplify this process, a short evaluation sheet will be used.

- During the thirty day demonstration period, the observer will interview the facility contact every week over the telephone to document facts or perceptions concerning the reclamation process that could be helpful in determining the effectiveness of the products used. The observer will determine if there has been any deviation from the initial reclamation procedures. If there has been a deviation, the observer shall record the reasons for the deviation. A work sheet will be developed that will guide the observer through the questions they should ask. The observer will document each conversation on the work sheet, which will subsequently become the telephone log for the facility.

- If at any time during the long-term phase of the demonstration there is a problem, the screen reclamation employee or facility point of contact will document the specific problem and call SPTF for guidance. Any corrective action will be documented by both the industry specialist and the facility employee.

Trouble-shooting

- If problems arise during the field demonstration of the screen reclamation methods and products, the following procedures will be followed. If the observer is present, the problem will be documented and the observer will call SPTF/SPAI for guidance. If the observer is not present, the facility employee will document the problem and contact SPTF/SPAI.

- SPTF will first review the procedures used by the facility employee to ensure they are in compliance with the instructions provided with the product. If the procedures are correct, then SPTF will contact the manufacturer for assistance. SPTF will relay and filter the recommendation of the manufacturer to the printer. SPTF/SPAI will ensure the confidentiality of the products is maintained during this period. The identity of the product in the field will remain masked. The observer will document all actions taken.

- If the recommendations provided by SPTF/SPAI are unsuccessful, the facility employee can attempt to solve the problem. The observer will document the actions taken by the employee responsible for screen reclamation and the success or failure of the actions.

- If a medical emergency arises, CHEMTREC, the emergency response center of the Chemical Manufacturers Association, has volunteered to respond to emergency phone calls to the manufacturer by identifying masked products with chemical components and providing medical information. The phone number for CHEMTREC will be the emergency phone number listed on the MSDS.

Appendix M
Ecological Hazard Profile Methodology

The environmental hazard assessment of chemicals consists of the identification of the effects that a chemical may have on organisms in the environment. And overview of this assessment process has been reported by Zeeman and Gilford (1993a). The effects are expressed in terms of the toxicity of a chemical on the organisms and are generally given as the effective concentration (EC) that describe the type and seriousness of the effect for a known concentration of a chemical. When the effective concentrations for a range of species for a chemical is tabulated, the tabulation is called a Hazard Profile or Toxicity Profile. A more detailed discussion of a comprehensive hazard profile has been presented by now blahs, 1991. The most frequently used hazard profile for the aquatic environment consists of six effective concentrations as reported by Nabholz, et al., (1993 a). These are:

- A Fish Acute Value (usually a fish and 96-hour LC_{50} value)
- An Aquatic Invertebrate acute value (usually a Daphnid 48-hour LC_{50} value)
- A Green Algal Toxicity value (usually an Algal 96-hour EC_{50} value)
- A Fish Chronic value (usually it fish 28-day chronic value (ChV))
- An Aquatic Invertebrate Chronic value (usually a Daphnid 21-day ChV value)
- An Algal Chronic value (usually an Algal 96-hour NEC value for biomass)

For the acute values, the LC_{50} (mortality) (EC_{50}) (effects) refers to the concentration that resulted in 50% of the test organism's affected at the end of the specified exposure period. the chronic values represent the concentration of the chemical that results in no statistically significant effects on the test organism following a chronic.

The hazard profile can be constructed using effective concentrations based on toxicity test data (measured) were estimated toxicity values based on structure activity relationships (SARs). The measured values are preferred, but in the absence of test data SAR estimates, if available for the chemical class, can be used. Thus the Hazard Profile may consist of only measured data, only projected values, or combination of both. Also, the amount of data in that has a profile may range from a minimum of one acute or chronic in value to the full complement of three acute values and three chronic the values.

In the absence of measured toxicity values, estimates of these values can be made using the Structure Activity Relationships (SAR). But SAR methods include Quantitative Structure Activity Relationships (QSARs), qualitative SARs or use of the best analogue. The use of SARs buying OPPT has been described (Clemens, 1988, et al., 1994 in Press). The use and application of the QSARs for the hazard assessment of new chemicals have been presented (Clemens, et al., 1993a). The development, validation and application of SARs in OPPT have been presented by OPPT staff (Zeeman, et al., 1993; Boethling, 1993; Clemens, et al., 1993b; Nabholz, et al., 1993b; Newsome, et al., 1993 and Lipnick, 1993).

The predicted equations (QSARs) are used in lieu of test data to estimate a toxicity value for aquatic organisms within a specific chemical class. Although the equations are derived from correlation and linear regression analysis based on measure data, the confidence interval associated with the equation are not used to provide a range of toxicity values. Even with measure test data the use of the confidence limits to determine the range of values is not used.

Determination of concern concentration

Upon completion of a hazard profile, it concern concentration is determined. Is concerned concentration is the concentration of the chemical in the aquatic and garment which, if exceeded, because is significant risk. Conversely, if the CC is not exceeded, the assumption is made that probability of a significant risks occurring is low and no regulatory action is required. The CC for each chemical is determined by applying assessment factors to the effect concentrations in the hazard profile.

Assessment factors incorporate the concept of the uncertainty associated with (1) toxicity data; laboratory tests versus field test and measured versus estimated that and (2) species sensitivity. For example, if only a single LC_{50} value for a single species, is available, but there several uncertainties to consider. First, how good is the value itself? If the test were to be done again by the same laboratory or a different laboratory, with the value defer? Second, there are differences and sensitivity, and between species that have been considered. Is the species tested the most or the least sensitive? In general, if only a single toxicity value is available, there is a large uncertainty about the applicability of is valued to other organisms in the firm in and large assessment factor, that is, 1000, is applied to cover the breath of sensitivity known to exist among and between organisms in the garment. The mercy, the more information than is available results in more certainty concerning the toxicity values and requires the use of a smaller assessment factor. For example, if toxicity values are derived from field tests, then an assessment factor on one is used.

Four AsFs are used by OPPT to set a CC for chronic rest: 1, 10, 100, and 1000. The AsFs rule use is dependent on the amount and type of toxicity data contained in the hazard profile and reflects the amount of uncertainty about the potential effects associated with a toxicity value. In general, the more complete the hazard profile and the greater the quality of the toxicity data, is smaller factor is used. Following discussion describes the use application of the assessment factors:

1. If the hazard profile only contains one or two acute toxicity values, the concern concentration is set at 1/1000 of the acute value.
2. If the hazard profile contains three acute values (base set), the concern concentration is set at 1/100 of the lowest acute value.
3. If that has a profile contains one chronic value, but concerned concentration is set at 1/10 of the cup chronic value of the value is for the most sensitive species. Otherwise, it is 1/100 of the acute value for the most sensitive species.
4. If the hazard profile contains three chronic values, the concern concentration is set at 1/10 of the lowest chronic value.
5. If the hazard profile contains a measure chronic value from the field study, then an assessment factor of 1 is used.

Hazard Ranking

Chemicals can also be ranked aCCording to hazard concern levels for the aquatic environment. This ranking can be based upon the acute toxicity values expressed in milligrams per liter (MG/L). The generally aCCepted scoring is as follows:

High concern (H)	□ 1
Moderate concern (M)	> 1 and < 100
Low concern (L)	> 100

The ranking can also be expressed in terms of chronic values as follows:

High concern (H)	□ 0.1
Moderate concern (M)	> 0.1 and < 10.0
Low concern (L)	□ 10.0

Chronic toxicity ranking takes precedence over the acute ranking.