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Group II

Development Document for Interim Final Effluent Limitations Guidelines and Proposed New Source Performance Standards for the

Photographic Processing

Subcategory of the Photographic Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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DEVELOPMENT DOCUMENT for INTERIM FINAL EFFLUENT LIMITATIONS, GUIDELINES AND PROPOSED NEW SOURCE PERFORMANCE STANDARDS

for the

PHOTOGRAPHIC PROCESSING SUBCATEGORY of the PHOTOGRAPHIC POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of a study of the photographic processing subcategory of the photographic point source category for the purpose of developing effluent limitations and guidelines for existing point sources and standards of performance and pretreatment standards for existing sources and for new sources, to implement Sections 301(b), 301(c), 304(b), 304(c), 306(b), 307(b), and 307(c) of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251, 1311, 1314(b) and (c), 1316(b) and 1317(b) and (c), 86 Stat. 816 et. seq.) (the "Act").

Effluent limitations and guidelines contained herein set forth the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available (BPT) and the degree of effluent reduction attainable through the application of the Best Available Technology Economically Achievable (BAT) which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The standards of performance and pretreatment standards for existing and new sources contained herein set forth the degree of effluent reduction which is achievable through the application of the Best Available Demonstrated Control Technology (NSPS), processes, operating methods, or other alternatives.

The development of data and recommendations in this document relate to the photographic processing point source category which is one of eight industrial segments of the miscellaneous chemicals point source category. Effluent limitations were developed for a single subcategory covering the photographic processing industry on the basis of the level of raw waste load as well as on the degree of treatment achievable by suggested model systems. These systems include biological and physical/chemical treatment and systems for reduction in pollutant loads. Various combinations of in-plant and end-of-pipe technologies are considered for photographic processing laboratories (plants).

Supporting data and rationale for development of the proposed effluent limitations, guidelines and standards of performance for the photographic processing subcategory of the photographic point source category are contained in this report.

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SECTION I

CONCLUSIONS

General

The miscellaneous chemicals manufacturing point source category encompasses eight segments, grouped together for administrative purposes. This document provides background information for the photographic processing subcategory of the photographic point source category and represents a revision of a portion of the initial contractor's draft document issued in February, 1975.

In that document it was pointed out that each segment differs from the others in raw materials, manufacturing processes, and final products. Water usage and subsequent wastewater discharges also were found to vary considerably. Consequently, for the purpose of the development of the effluent limitations and guidelines for corresponding BPT (Best Practicable Control Technology Currently Available), NSPS (Best Available Demonstrated Control Technology) for new sources, and BAT (Best Available Technology Economically Achievable) requirements, each segment is treated independently.

The diversity of products and manufacturing operations to be covered indicates the need for separate effluent limitations for (segments of the industry) industries, and these are presented in separate development documents for each segment of the miscellaneous chemicals point source category. This development document deals only with the photographic processing industry.

The photographic processing subcategory of the photographic point source category is defined to include commodities listed under Standard Industrial Classifications (SIC) 7221, 7333, 7395 and 7819.

It should be emphasized that the proposed treatment model technology is used only as a guideline and to establish a cost basis. The model may not be the most appropriate in every case. The cost models for BPT, BAT, and NSPS were developed to facilitate the economic analysis and should not be construed as the only technology capable of meeting the effluent limitations, guidelines and standards of performance presented in this development document. There are many alternative systems which, taken either singly or in combination, are capable of attaining the effluent limitations, guidelines and standards of performance recommended in this development document. These alternative choices include:

1. Various types of end-of-pipe wastewater treatment.
2. Various in-plant modifications and installation of at-source pollution control equipment.
3. Various combinations of end-of-pipe and in-plant technologies.

It is the intent of this study to allow the individual plant to make the choice of what specific combination of pollution control measures is best suited to its situation in complying with the limitations and standards of performance presented. To avoid substantial economic injury to small business concerns, a size exemption for photographic processing plants handling 150 square meters per day (1,600 square feet per day) of film and paper will be established by the Agency.

Photographic Processing

The photographic processing subcategory of the photographic point source category was not further subcategorized for the purpose of effluent limitations, guidelines and new source performance standards. Additional subcategorization was deemed unnecessary because the pollutants in the wastewaters were the same and the pollutant loadings per unit of production were in a relatively narrow range in the plants surveyed. This document represents the photographic processing portion of the photographic point source category. As time and resources permit, the additional segments of this category such as the manufacture of photographic film, photographic plates and photographic paper will be promulgated.

The major sources of wastewater in the photographic processing subcategory are photoprocessing solution overflows and wash waters. Wastewaters generated by this segment of the industry can be characterized as containing high concentrations of BOD_5, COD, TOC, silver and cyanides in various forms.

Existing control and treatment technology, as practiced in the category, includes primarily in-plant pollutant reductions for silver and cyanides through recovery of bleaches and silver which is widely practiced for economic reasons. An estimate of 95% of all photographic processing plants discharge their wastewaters to municipal sewer systems; only one plant visited had any end-of-pipe treatment facility, a 20,000-gpd capacity pilot biological treatment system to investigate the treatability of its wastewaters.

Effluent limitations and guidelines have been established for silver and total cyanides. The choice of these parameters was based on economic considerations. Furthermore, these pollutants may exert a toxic effect on a biological treatment process and are the major contaminants in the photographic processing wastewaters.

The treatment models recommended to attain each of the three levels of treatment technology are:

Technology Level	End-of-pipe Treatment Model
BPT	In-plant modifications
NSPS	BPT plus cyanide destruction, dual-media filtration and ion exchange for silver removal
BAT	BPT plus cyanide destruction, dual-media filtration and ion exchange for silver removal

It is emphasized that in-plant measures to reduce silver and ferrocyanide concentrations as well as end-of-pipe treatment methods are included as part of the recommended treatment technologies as these are currently in wide use in the industry.

In conclusion, effluent limitations guidelines were derived on the basis of the maximum for any one day (maximum day limitation) and the average of daily values for any period of thirty consecutive days (maximum thirty day limitation). Since no long-term data for exemplary treatment were uncovered in the photographic processing industry during this study, the factors used in deriving these time-based limitations were derived from generally accepted and achievable variability factors for the physical/chemical treatment systems evaluated in the electroplating point source category. The paucity of end-of-pipe wastewater treatment systems in the photographic processing industry led to the decision to use performance factors from a category that had similar wastewater treatment systems. Hence, the performance factors used from the electroplating point source category were applied to both the in-plant BPT

Table I -1

Summary Table
Photographic Processing Industry

Subcategory	Contaminants of Interest	Flow L/1,000 sq. m (gal/1,000 sq.ft.)	RWL Parameter	RWL kg/1,000 sq. m (lbs./1,000 sq.ft.)	RWL mg/L	BPCTCA (1977) (BPT) Treatment Technology	BPCTCA (1977) (BPT) Long-Term Daily Effluent Parameter	BPCTCA (1977) (BPT) Long-Term Daily Effluent kg/1,000 sq. m (lbs./1,000 sq.ft.)
Entire Industry	BOD_5, COD, TOC, TSS, TKN, TDS, Silver, Ferrocyanide	163,000 (4,000)	BOD_5	36.7 (7.5)	225	Regeneration of Bleach and Silver Recovery	Ag (Silver)	0.07 (0.015)
			COD	123.0 (25.1)	752		CN (Total)	0.09 (0.019)
			Ag (Silver)	0.07 (0.015)	0.45			
			CN (Total)	0.09 (0.019)	0.57			

Subcategory	BAT (1983) Treatment Technology	BAT (1983) Long-Term Daily Effluen Parameter	BAT (1983) Long-Term Daily Effluen kg/1,000 sq. m (lbs./1,000 sq. ft.	New Source Performance Standards (NSPS) Treatment Technology	New Source Performance Standards (NSPS) Long-Term Daily Effluent Parameter	New Source Performance Standards (NSPS) Long-Term Daily Effluent kg/1,000 sq. m (lbs./1,000 sq. ft.)
Entire Industry	Oxidation, Filtration, and Ion Exchange	Ag (Silver)	.0016 .00034)	Oxidation, Filtration, and Ion Exchange	Ag (Silver)	.0016 .00034)
		CN (Total)	0.008 (0.0017)		CN (Total)	.008 .0017)

treatment, which utilizes bleach regeneration and electrolytic silver recovery, and to BAT/NSPS physical/chemical treatment steps consisting of cyanide destruction, dual-media filtration and ion exchange for silver removal.

Table I-1 summarizes the contaminants of interest, raw waste loads, and recommended treatment technologies for BPT, BAT, and NSPS for the photographic processing subcategory of the photographic point source category.

SECTION II

RECOMMENDATIONS

General

The recommendations for effluent limitations and guidelines commensurate with the BPT, BAT and NSPS are presented in the following text. A discussion of in-plant and end-of-pipe controls technology required to achieve the recommended effluent limitations, guidelines and new source performance standards are included. The NSPS for new sources includes the most exemplary process controls.

Photographic Processing

The BPT, BAT, and NSPS effluent limitations proposed for the photographic processing industry are presented in Tables II-1 and II-2. These effluent limitations guidelines are based on the maximum day limitation and the maximum thirty day limitation. These effluent limitation values are developed using the performance factors for the treatment plant operation as discussed in Section XIII of this development document.

Wastewaters subject to these limitations include all process wastewaters, but do not include sanitary wastewaters.

Implicit in the recommended guidelines for the photographic processing subcategory of the photographic point source category is the use of in-plant control measures to reduce silver and cyanide. In-plant modifications will lead to reductions in wastewater flow, increased quantity of water used for recycle, and improvement in raw wastewater quality.

In-plant treatment technologies described in Section VIII should be utilized by the photographic processing subcategory to achieve BPT effluent limitations and guidelines.

To meet BAT and NSPS effluent limitations and new source performance standards treatment technologies equivalent to in-plant BPT treatment followed by cyanide destruction, dual-media filtration and ion exchange for silver removal are recommended.

After varying degrees of in-plant pollution abatement measures which serve as a pretreatment step most photographic processing plants discharge their effluents to

Table II-1

BPT Effluent Limitations Guidelines

Photographic Processing Industry

		Effluent Limitations	
Subcategory	Effluent Characteristic	Average of Daily Values for 30 Consecutive Days Shall not exceed kg/1,000 m^2 (lb/1,000 ft^2)	Maximum for Any one day kg/1,000 m^2 (lb/1,000 ft^2)
Entire Industry	Ag (Silver)	0.07 (0.015)	0.14 (0.030)
	CN (Total)	0.09 (0.019)	0.18 (0.038)

Table II -2

BAT and NSPS Effluent Limitations Guidelines

Photographic Processing Industry

Subcategory	Effluent Characteristic	Effluent Limitations: Average of Daily Values for 30 Consecutive Days Shall not Exceed kg/1,000 m^2 (lb 1,000 ft^2)	Effluent Limitations: Maximum for Any One Day kg/1,000 m^2 (lb/1,000 ft^2)
Entire Industry	Ag (Silver)	0.0016 (0.00034)	0.0032 (0.00067)
	CN (Total)	0.008 (0.0017)	0.016 (0.0034)

municipal sewer systems. Certain constituents (i.e., silver and cyanide) which could exert toxic effects on a biological system and various non-biodegradable material may also be present. Therefore, in-plant measures or pretreatment to reduce the concentrations of such contaminants to levels acceptable to local authorities must be utilized.

SECTION III

INTRODUCTION

Purpose and Authority

The Federal Water Pollution Control Act Amendments of 1972 (the Act) made a number of fundamental changes in the approach to achieving clean water. One of the most significant changes was to shift from a reliance on effluent limitations related to water quality to a direct control of effluents through the establishment of technology-based effluent limitations to form an additional basis, as a minimum, for issuance of discharge permits.

The Act requires EPA to establish guidelines for technology-based effluent limitations which must be achieved by point sources of discharges into the navigable waters of the United States. Section 301(b) of the Act requires the achievement by not later than July 1, 1977 of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the BPT as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983 of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the BAT, resulting in progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of federal standards of performance providing for the control of the discharge of pollutants, which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the NSPS process, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish regulations based on the degree of effluent reduction attainable through the application of the BPT and the best control measures and practices achievable, including treatment techniques, process and procedure innovations, operation methods, and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the photographic processing subcategory of the photographic point source category. Section 304(c) of the Act requires the Administrator to issue information on the processes, procedures, or operating methods which result in the elimination or reduction in the discharge of pollutants to implement standards of performance under Section 306 of the Act. Such information is to include technical and other data, including costs, as are available on alternative methods of elimination or reduction of the discharge of pollutants.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing federal standards of performance for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624) a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources.

Furthermore, Section 307(b) provides that:

1. The Administrator shall, from time to time, publish proposed regulations establishing pretreatment standards for introduction of pollutants into treatment works (as defined in Section 212 of this Act) which are publicly owned, for those pollutants which are determined not to be susceptible to treatment by such treatment works or which would interfere with the operation of such treatment works. Not later than ninety days after such publication, and after opportunity for public hearing, the Administrator shall promulgate such pretreatment standards. Pretreatment standards under this subsection shall specify a time for compliance not to exceed three years from the date of promulgation and shall be established to prevent the discharge of any pollutant through treatment works (as defined in Section 212 of this Act) which are publicly owned, which pollutant interferes with, passes through, or otherwise is incompatible with such works.

2. The Administrator shall, from time to time, as control technology, processes, operating methods, or other alternatives change, revise such standards, following the procedure established by this subsection for promulgation of such standards.

3. When proposing or promulgating any pretreatment standard under this section, the Administrator shall designate the category or categories of sources to which such standard shall apply.

4. Nothing in this subsection shall affect any pretreatment requirement established by any State or local law not in conflict with any pretreatment standard established under this subsection.

In order to insure that any source introducing pollutants into a publicly owned treatment works, which would be a new source subject to Section 306 if it were to discharge pollutants, will not cause a violation of the effluent limitations established for any such treatment works, the Administrator is required to promulgate pretreatment standards for the category of such sources simultaneously with the promulgation of standards of performance under Section 306 for the equivalent category of new sources. Such pretreatment standards shall prevent the discharge into such treatment works of any pollutant which may interfere with, pass through, or otherwise be incompatible with such works.

The Act defines a new source to mean any source the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance. Construction means any placement, assembly, or installation of facilities or equipment (including contractual obligations to purchase such facilities or equipment) at the premises where such equipment will be used, including preparation work at such premises.

Methods Used for Development of the Effluent Limitations and Standards for Performance

The effluent limitations, guidelines and standards of performance proposed in this document were developed in the following manner. The miscellaneous chemicals manufacturing point source category was first divided into industrial segments, based on type of manufacturing and products manufactured. Determination was then made as to whether further subcategorization would aid in description of the category. Such determinations were made on the basis of raw materials required, products manufactured, processes employed, and other factors.

The raw waste characteristics for each category and/or subcategory were then identified. This included an analysis of: 1) the source and volume of water used in the process employed and the sources of wastes and wastewaters in the plant; and 2) the constituents of all wastewaters (including toxic constituents) which result in taste, odor, and color in water. The constituents of wastewaters which should be subject to effluent limitations, guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within each category and/or subcategory was identified. This included an identification of each distinct control and treatment technology, including both in-plant and end- of-pipe technologies, which are existent or capable of being designed for each subcategory or category. It also included an identification of the effluent level resulting from the application of each of the treatment and control technologies, in terms of the amount of constituents and of the chemical, physical, and biological characteristics of pollutants. The problems, limitations, and reliability of each treatment and control technology and the required implementation time were also identified. In addition, the non-water quality environmental impacts (such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, radiation, and noise) were also identified. The energy requirements of each of the control and treatment technologies were identified, as well as the cost of the application of such technologies.

The information, as outlined above, was evaluated in order to determine what levels of technology constituted the BPT, BAT, and NSPS. In identifying such technologies, factors considered included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impact (including energy requirements), and other factors.

During the initial phases of the study, an assessment was made of the availability, adequacy, and usefulness of all existing data sources. Data on the identity and performance of wastewater treatment systems were known to be included in:

1. NPDES permit applications.
2. Self-reporting plant discharge data from various states.

3. Surveys conducted by trade associations or by agencies under research and development grants.

A preliminary analysis of these data indicated an obvious need for additional information.

Additional data in the following areas were required: 1) process raw waste load (RWL) related to production; 2) currently practiced or potential in-process waste control techniques; and 3) the identity and effectiveness of end-of-pipe treatment systems. The best source of information was the manufacturers themselves. Additional information was obtained from direct interviews and sampling visits to production facilities.

Collection of the data necessary for development of RWL and effluent treatment capabilities within dependable confidence limits required analysis of both production and treatment operations. In a few cases, the plant visits were planned so that the production operations of a single plant could be studied in association with an end-of-pipe treatment system which receive only the wastes from that production. The RWL for this plant and associated treatment technology would fall within a single subcategory. However, the wide variety of products manufactured by most of the industrial plants made this situation rare.

In the majority of cases, it was necessary to visit facilities where the products manufactured fell into several subcategories. The end-of-pipe treatment facilities received combined wastewaters associated with several subcategories (several products, processes, or even unrelated manufacturing operations). It was necessary to analyze separately the production (waste-generating) facilities and the effluent (waste treatment) facilities. This approach required establishment of a common basis, the raw waste load (RWL), for common levels of treatment technology for the products within a subcategory and for the translation of treatment technology between categories and/or subcategories.

The selection of wastewater treatment plants was developed from information available in the NPDES permit applications, state self-reporting discharge data, and contacts within the segment. Every effort was made to choose facilities where meaningful information on both treatment facilities and manufacturing processes could be obtained. Plants were selected for visits as being representative of the category.

Survey teams composed of project engineers and scientists conducted the actual plant visits. Information on the identity and performance of wastewater treatment systems was obtained through:

1. Interviews with plant water pollution control personnel or engineering personnel.
2. Examination of treatment plant design and historical operating data (flow rates and analyses of influent and effluent).
3. Treatment plant influent and effluent sampling.

Information on process plant operations and the associated RWL was obtained through:

1. Interviews with plant operating personnel.
2. Examination of plant design and operating data (design specification, flow sheets, day-to-day material balances around individual process modules or unit operations where possible).
3. Individual process wastewater sampling and analysis.
4. Historical production and treatment data.

The data base obtained in this manner was then utilized by the methodology previously described to develop recommended effluent limitations, guidelines and standards of performance for the photographic processing subcategory of the photographic point source category. All of the references utilized are included in Section XV of this report. The data obtained during the field data collection program are included in Supplement B. Cost information are available in Supplement A. These documents are available for examination by interested parties at the EPA Public Information Reference Unit, Room 2922, (EPA Library), Waterside Mall, 401 M St., S.W., Washington, D.C. 20460.

Photographic Processing Industry

Scope of the Study

For the purposes of this study, the photographic processing subcategory of the photographic point source category was defined to include all film processing activities listed under SIC 7221 (Photographic Studios, Portrait), SIC 7333

(Commercial Photography, Art, and Graphics), SIC 7395 (Photofinishing Laboratories), and SIC 7819 (Developing and Printing of Commercial Motion Picture Film). Lists of the specific services covered by these Standard Industrial Classifications are presented in Tables III-1, III-2, III-3, and III-4.

The photographic processing subcategory of the photographic point source category is made up of industrial and commercial laboratories serving both the photographic trade and the general public in film developing, photoprinting, and enlarging. Photographic processing plants vary greatly in size and are subject to seasonal variations in production, nevertheless the waste loads are similar in quality and quantity per unit of production.

Technical Approach to the Development of Effluent Limitations Guidelines

The effluent limitations, guidelines and standards of performance recommended in this document for photographic processing were developed as described above. The technical approach specific to photographic processing is described below:

1. Plants were selected for visits as being representative of the subcategory. The purpose of the plant visits were threefold. First, the individual processes for black and white and color film and paper within the plants were investigated for familiarization with process concepts. At this time, valuable information, otherwise unavailable, was obtained on the various processes. Secondly, the purpose was to investigate treatment technology, if any existed. Lastly, and most importantly, the purpose was to verify existing plant data on wastewater discharges with analytical data measured on the site visits.

2. The raw waste loads (RWL) were determined from field measurements taken on three photographic processing plants visited and data received on Eastman Kodak plant located on the west coast. Data supplied by the Eastman Kodak Company was also used to substantiate the field survey data. There was very strong similarity in the RWL's determined for the three plants.

3. Effluent limitations, guidelines and new source performance standards were developed by applying an end-of-pipe treatment model to the raw wastewater and were developed for the subcategory as a whole. Studies indicated there was no need to impose different levels of treatment

Table III -1

Photographic Studios, Portrait - SIC 7221

Home Photographers
Passport Photographers
Portrait Photographers
School Photographers
Transient Photographers

Table III -2

Commercial Photography, Art, and Graphics - SIC 7333

Commercial Photography
Photographic Studios, Commercial

Table III -3

Photofinishing Laboratories - SIC 7395

Developing and printing of film, except commercial motion picture film

Developing and processing of home movies

Film processing, except for the motion picture industry

Photograph developing and retouching

Photographic laboratories (not manufacturing)

Table III -4

Services Allied to Motion Picture Production - SIC 7819

Developing and printing of commercial motion picture film within the photographic processing subcategory. Effluent limitations have been developed for silver and cyanide based on the removal rate attained by widely used and generally available in-plant treatment systems. For BAT/NSPS the wastewater treatment technology and systems utilized in the electroplating point source category are transferred to this industry. Cyanide destruction by alkaline chlorination and silver removal by ion exchange are the particular waste treatment models used. Refer to Section VIII for detailed design consideration.

Scope of Coverage for Data Base

Although there are an estimated 12,500 photographic processing plants in the United States, only 650 of these facilities are considered major laboratories with significant wastewater discharges. In order to obtain the information required to establish realistic effluent limitations, sampling surveys were conducted at three photoprocessing plants by the EPA contractor. Since limited information was available on the treatment of photoprocessing wastes, a fourth plant was visited which had a pilot biological treatment plant in operation at the time of the survey. A special field survey of 30 non-Kodak photographic processing plants was conducted by NAPM in the spring of 1976 utilizing Kodak field teams. Data for flow, BOD_5 and COD resulting from this effort plus data from 6 Kodak plants collected in the past three years were merged with the 4 plants sampled by the EPA contractor. The weighted averages for these three parameters were used to build the RWL's reported in Table V-1. In addition to the field surveys, supplemental historical data compiled by the Eastman Kodak Company for approximately 200 photoprocessing plants was acquired and used as back up data but was not employed in the calculation of the raw waste load. This data was too random and had not been validated by on-site sampling. However, the 200 plant survey summary was useful in identifying current methods of in-plant treatment such as silver recovery, bleach regeneration, bleach-fixer regeneration, squeegees, and wash water controls which are in-plant controls widely used in the industry. Further information on these in-plant control measures was provided by the EROS Data Center in Sioux Falls, South Dakota. In addition, a field visit to the Naval Photographic Center in Washington, D.C. was made to develop an overview of photographic processing technology in the military sector.

SECTION IV

INDUSTRIAL CATEGORIZATION

General

The purpose of the total study is the development of effluent limitations, guidelines and new source performance standards for the photographic processing point source category that will be commensurate with different levels of in-process waste reduction and end-of-pipe pollution control technology. These effluent limitations and guidelines specify the quantity of pollutants which will be discharged from a specific facility and will be related to a common yardstick for the manufacturing segment, such as quantity of production.

Photographic Processing

Discussion of the Rationale of Categorization

The photographic processing subcategory serves the photographic trade, the military establishment, the scientific community, the medical profession, the dental profession, and general public in the developing of films and in photoprinting and enlarging. The following factors were considered to determine whether further subdivision of the subcategory and the establishment of separate effluent limitations and guidelines for different point sources of the subcategory were justified.

Plant Type

Photographic processing laboratories differ in the services they provide. Among the estimated 12,500 processing plants in the United States, approximately 3,000 are amateur operations, 3,000 are "captive" laboratories in business and industrial firms, 650 are major labs specializing in work for professional and industrial photographers, and the remaining plants are portrait and commercial studios. Table IV-3 presents the RWL data summary for 30 non-Kodak plants and 6 Kodak plants according to NAPM's classification by source of business. Based on this inspection, further subdivision based on plant type was not justified.

Plant Size

Photoprocessing laboratories range in size from the small amateur operations to the major professional laboratory which may process as much as 100,000 square feet of film and paper daily. According to the NAPM many photographic processing plants process between 25,000 and 50,000 square feet per day. A profile of estimated plant sizes derived from the 200 plant survey is given in Table IV-1. A separate economic study was performed to determine the economic impact of the recommended effluent limitations reported in this text. This review indicated that the Agency should incorporate a size cut-off and exempt photographic processing plants which process less than 150 square meters per day (equivalent to 1,600 square feet per day).

Plant Location

Plants are located mostly in urban areas throughout the country. The three plants for which RWL data were analyzed were located in Michigan, Massachusetts, and Texas. In addition a pilot biological treatment system was visited at a plant in New York. Supplemental data (questionnaire) compiled by Eastman Kodak Company for approximately 200 photographic processing plants was reviewed. During the spring of 1976 NAPM took field samples from thirty plants located in four U.S. metropolitan areas (New York, Washington, D.C., Chicago and Detroit). In addition data from six Eastman Kodak plants have been reviewed. Because all plants operate within buildings and because the processes require strict ambient processing conditions plant location is not a basis for subcategorization.

Products

The products produced by the industry are finished color and black and white films and prints of both. Most large plants process both color and black and white materials; however, one plant visited processed only color films and no significant differences in the raw waste loadings were observed. Difference in photographic products were therefore, deemed not to be a basis for subcategorization.

Plant Processes

There are a wide variety of photoprocessing machines used to finish a specific film or paper. These may be either the continuous or "rack and tank" or "dip and dunk" operations. The nature, basic principles and waste characteristics of photograhic processing are the same in all facilities regardless of size and age. Only the quantity of waste per unit of production (lbs per 1,000 square feet or kg per 1,000 square meters) showed a consistent relationship.

TABLE IV -1

Plant Size From "200" Plant Survey Summary Data

*Wastewater gpd	Number of Plants	**Est. Production sq. ft./day
less than 1,000	27	below 250
1,000 to 10,000	92	250 to 2,500
10,000 to 50,000	64	2,500 to 12,500
over 50,000	28	over 12,500
unknown	26	--
Total	237	

*Wastewater flow profile from Table VII G-1
**Based on 4,000 gal/1,000 sq. ft. from Table VG-1

Hence, process was eliminated as a basis for subcategorization.

Wastewater Characteristics

As a result of the production of both color and black and white products, large volumes of wastewater are discharged during the process. These process wastewaters include both photoprocessing solution overflows and wash waters. Together, these spent waters are high in BOD, COD, TOC, TDS, silver, and complex cyanide ion. Generally, the pollutants of significance are the same for both color and black and white photofinishing operations with the exception of ferrocyanide, which is generated during the bleaching step in color development. Therefore wastewater characteristics are not a basis for subcategorization.

Summary of Considerations

Data was collected on both color and black and white processes at three different plants identified as plants 32, 33, and 34. These plants varied in size by production, flow rate, and geographic location, as shown in the following tabulation:

Plant No. (Location)	Average Daily Production sq ft	Flow Rate gpd	Average Flow gal/1000 sq.ft.
32 (Mich.)	19,300	62,600	3,244
33 (Mass.)	22,400	67,900	3,031
34 (Texas)	13,300	42,000	3,158

Based on the total quantity of production, measured in square feet of product, pollutant loadings from the color and black and white processes compare well in order-of-magnitude. The arithmetic mean flow for the three plants of 3,144 gallons per 1,000 square feet of production covers all three plants within a range of plus or minus 4 percent. When the NAPM field survey for 30 non-Kodak plants is combined with historical data for 6 Kodak plants, a weighted flow of 4,050 gallons per 1000 square feet results. This is reported in Table V-1 as plant number 00. The overall industry RWL flow is computed by merging the 4 EPA contractor data points together with the data points from the 36 plants in the NAPM survey. The final overall RWL flow rate is 4,000 gallons per 1000 per square feet. The raw waste loads are fairly uniform throughout the industry in color and black and white operations because of the standardization of processes within the subcategory.

Because of this uniformity, further division of the subcategory for the development of effluent limitations, guidelines and new source performance standards could not be justified on the basis of size, location, type of processing or wastewater characteristics. The photographic processing subcategory is treated as a whole for the purposes of this document, and any analyses and regulations which are developed will be applicable to the whole point source category. Separate discussions of process types have, however, been presented for a more thorough understanding of the industry.

Process Descriptions

Most commercial photoprocessors handle many square feet of film and paper with automatic processing machines. The basic machines are called the "dip and dunk" or "rack and tank" types, which consist of a series of tanks with each tank containing photoprocessing solutions. These solutions impart the desired effect on the film or paper in each progressive step of development. Continuous length processors are used by most large firms, and roller transports are used in graphic arts and for hospital x-ray films.

During photoprocessing, many changes occur within the processing solutions. Because of these changes, the chemicals used in photoprocessing need to be replaced, strengthened, or replenished. Developing agents become oxidized and exhausted; developer activators and preservatives wear out; anti-foggants become used up; bromides or other halides resulting from the reduction of the silver by the developer become more concentrated; acid short stops become neutralized; and the removal of silver from the emulsion causes increased concentrations of silver in the fixers or hypo baths. Chemicals are added to maintain the correct chemical strength and photographic properties. When a replenisher is added, its volume must be sufficient to cause enough overflow of the unwanted by-products. Overflows from the processing tanks caused by the addition of replenishers and wash water overflows are two sources of wastewater from photoprocessing. Additional process wastewater results from "leader running" for quality control tests, from machines in "stand by" mode where machine is "certified" for quality control but not running film, and from start-up or shut-down operations. Miscellaneous factors including spills, quick dumps, mix tank washdown, machine room washdown, etc., contribute the total flow.

Leader to Film Relationship

By definition, a continuous processing machine cannot be run without a leader. This leader is used to keep the machine continuously threaded and is run while film is still in other parts of the machine. Since film is still being processed while this leader is run, wash water is still required. Typical situations requiring leader are:

1. Leader is required for every film run:
    - (a) While a photographic check and scratch test is run to certify the machine and process as satisfactory for customers' work
    - (b) To fill the machine when customers' work is finished.
2. Leader is required for dual purpose machines:
    - (a) If a machine runs two widths of film, such as 110 and 35 mm, leader is required to change sizes, and to change back again.
    - (b) If a machine runs two separate processes, such as Super 8 Ektachrome or ECO/ME-4, leader is run to clear the machine before it is rearranged.
3. Leader is required for special situations:
    - (a) If the web is damaged, either through machine malfunction or web defects, leader must be run to clear customers' film from the machine. In the case of real, or suspected, machine malfunctions, good practice requires running scratch test and photographic certification before processing any more customers' product.
    - (b) Occasionally, chemical errors or contaminations occur. These require leader for similar reasons as mechanical problems.

The amount of leader that must be run in connection with a square foot of film is highly variable. For example, it depends on:

1. The total process ("dry-to-dry") time.

2. The amount of customers' film run. Since each run takes a fixed amount of leader, the leader/film ratio varies with the length of the film run. Length of film run in turn depends on the time of year, overall size of the plant, pattern of incoming work, and committments to dealers for service time.

3. The type of process and/or machine as detailed in Item 2 above.

4. The capacity of the specific machine in square feet/minute in relation to square feet processed.

All of the above are considered as part of the overall raw wastewater loads in the field survey.

Black and White Film

General

Black and white film consists of a foundation layer, which is coated with a light-sensitive emulsion, and an outer protective layer. Silver salts, made up of positively-charged silver ions and negatively-charged bromide ions are among the chemicals contained in the emulsion. When radiant energy from light strikes the crystal, a dislodged electron from the bromide ion is captured by a silver ion to form metallic silver. The metallic silver clusters together on the film surface and a latent image is formed. This image is made visible by a step in photoprocessing called development. Two development processes are used in industry: the two-step negative-positive process and the one-step reversal process.

Negative-positive Process

The silver bromide crystals in the gelatin emulsion are bathed in a chemical solution called a developer, which causes the visible image to form. The developer solution contains developing agents, activators, preservatives, restrainers, anti-foggants, and water conditioners. In general, the developing agents for black and white photography are aromatic compounds (for example, hydroquinone).

After the photographic material has been developed the desired amount, the developing process must be stopped. This is normally done by treatment in an acidic solution called a short stop, which neutralizes the basic activators of the developer and conditions the emulsion for future processing steps. Sometimes plain water is sufficient for a stop bath. After stopping the action of the developer, the unexposed and undeveloped silver must be removed from the emulsion. This is done not only to make the image more visible and the film more transparent, but to prevent the remaining unused silver from eventually being reduced to metallic silver by the action of light. There are a number of solvent fixers, including sodium thiosulfate, ammonium thiosulfate, and sodium thiocyanate. Following fixation, photographic materials are washed and dried. The process flow diagram for black and white film is shown in Figure IV-1.

The quality of wastewaters from black and white film development is relatively uniform throughout the industry and is characterized by the presence of hydroquinone in the developer waste; sulfites in the stop bath waste; and acetates, sulfites, and a silver thiosulfate complex in the fixer waste. Inorganic oxygen-demanding chemicals such as thiosulfate and sulfite are major components of all processing effluents and may contribute more than 50% of the oxygen demand for some processing wastewaters. Other wastes are generated during the processing. These pollutants, however, vary in type and concentration depending upon which photoprocessing operation is employed.

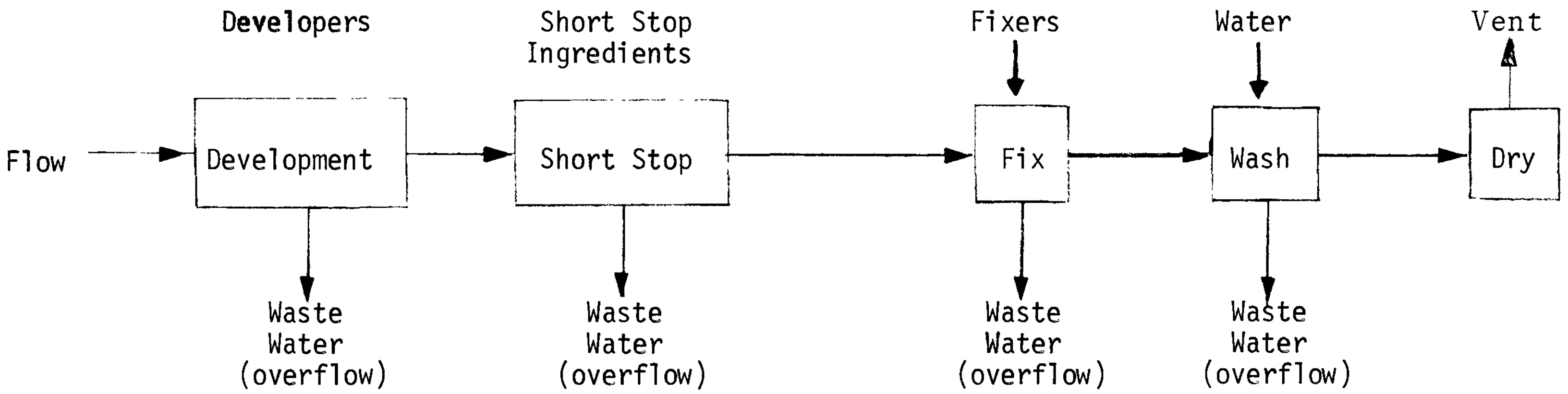
Once the black and white negative has been fully processed and is allowed to dry, the negative is transferred to a positive paper print by the black and white paper process. The process begins by directing a controlled exposure of light onto the negative, thereby creating a positive image on the paper, which has an emulsion layer similar to black and white film. The latent image formed is then developed, using different chemicals from those used in the film development process. Wastewaters from the paper processing are similar in type to the wastewaters in the film development process, although the concentrations are usually higher.

Reversal Development

This is a method for obtaining a positive image on the same film used for the original exposure. The exposed film is first fully developed to a negative. The film is then washed and the silver image removed by bathing in an acidic permanganate or dichromate bleach bath. A clearing bath (for example, bisulfite) is used to remove the bleaching agent and reaction products. The film is then given a

Figure IV -1

Black and White Film Processing



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uniform controlled exposure of light, and is developed a second time. As an alternative to the second exposure, a highly fogging developer or nonselective reducer may be used for the second development. The process continues as in other black and white processes with a wash, fix, final wash, and dry. Reversal development is often used in processing amateur and 16-mm motion picture film. Wastewaters in reversal processing are similar to other black and white film processing wastes. The process flow diagram for black and white reversal film is shown in Figure IV-2. Negative removal is accomplished by the addition of dichromate bleach. Chemicals very similar to those used in the development of color products are used in the black and white development.

Color Film

General

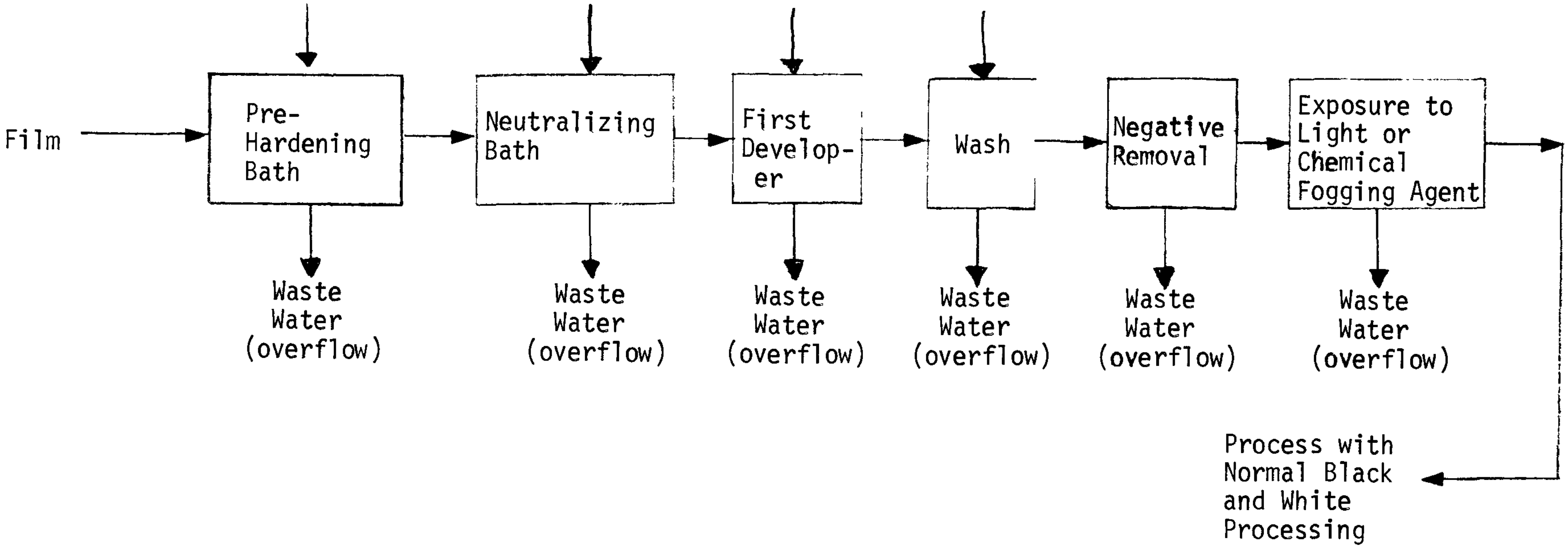
In black and white photographic materials, the emulsion is sensitive to wavelengths of light up to visible blue light. However, certain organic compounds can be included in the emulsion to extend the wavelength sensitivity of the silver grains. The silver grains then become latent images when exposed to green or red light. Color film has three separate light-sensitive layers which record an image of the blue light components on one layer, the green light components on another and the red light components on a third layer.

Negative-Positive Development

Color developer agents are generally N, N-dialkyl-p-phenylene-diamines whose reaction products react with a group of organic molecules called couplers to form dyes. The oxidized components of this special category of developers form colored dyes in the film emulsion layers with the incorporated color couplers. Frequently a stop bath follows the color developer step. As in black and white film processing, metallic silver is formed in color film upon exposure to light. However, in color film processing the silver image which is formed with the dye is converted back to silver halide by reactions with one of several complex iron compounds and a halide. Either ferricyanide with sodium bromide or ferric ammonium ethylenediamine tetracetic acid (ferric EDTA) with ammonium bromide is commonly used. Continuing the procedure of removing the unwanted silver image after the bleaching step, the film is treated in a fixer or hypo-bath. The film is then washed to remove residual processing chemicals and

Figure IV -2

Reversal Black and White Film Processing



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dried. Films of this type include Kodacolor and Agfa CNS. The process flow diagram for color film development is shown in Figure IV-3.

Effluent wastewaters from color film development are also relatively uniform in quality and are characterized by the presence of benzyl alcohol, developing agents, sulfates, sulfites, borate, and phosphate in the developer wastes; acetates in the short stop bath waste; ferrocyanide or ferric EDTA in the bleach waste; and acetates, sulfites, and silver thiosulfate complex in the fixing bath waste. The major pollutants which contribute to BOD are benzyl alcohol, sulfites, acetates, and thiosulfate.

Many variations of this basic process exist. Some color processes combine the bleach and fixing steps to give a "blix," which performs both operations simultaneously.

After the film is dried, positive paper prints are made by exposing light through the film onto color photographic paper with three color-sensitive layers containing couplers. Processing of the print is similar to that used in the negative development.

Color Reversal Development

There are two different types of color reversal films and their processings are slightly different. In one, the compounds which form the color image are incorporated into the emulsion layers at the time of manufacture. Most color reversal films are of this type. The second type of color reversal film has three black and white color-sensitive layers. In this type of film the color couplers are included in the color developer solutions.

In processing the first kind of color reversal film, after the negative image is formed, the emulsion is washed and may be treated in a hardening bath. The silver not used to form the negative image in the three layers is made developable either by light or chemical action, and a positive silver image is formed by the action of a color developer. The oxidized developer combines with the couplers in the three layers to form the three dye images. This part of the process is very similar to the processing of color negative material, except that the image on the film is positive. The remaining steps are much the same. Films of this type include Ektachrome, Ansochrome, Agfachrome, and Fugichrome. The process flow diagram for color reversal development with incorporated couplers is shown in Figure IV-4.

Figure IV -3

Color Negative Film Processing

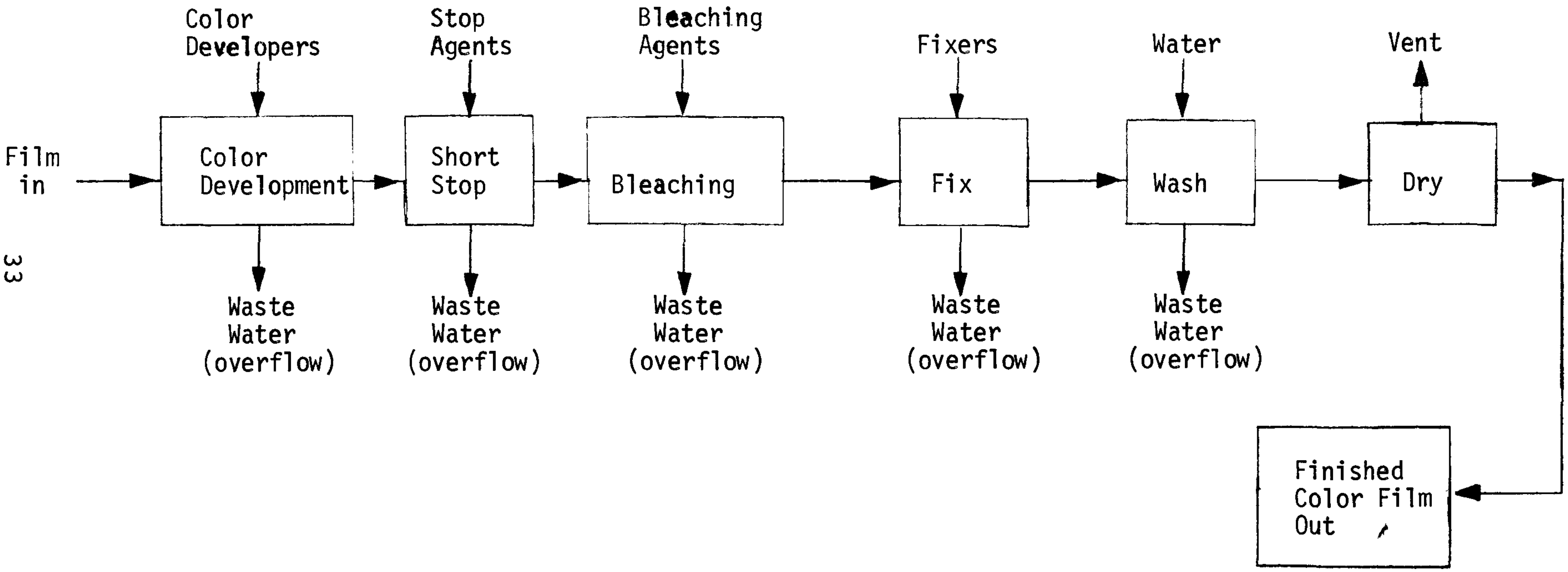

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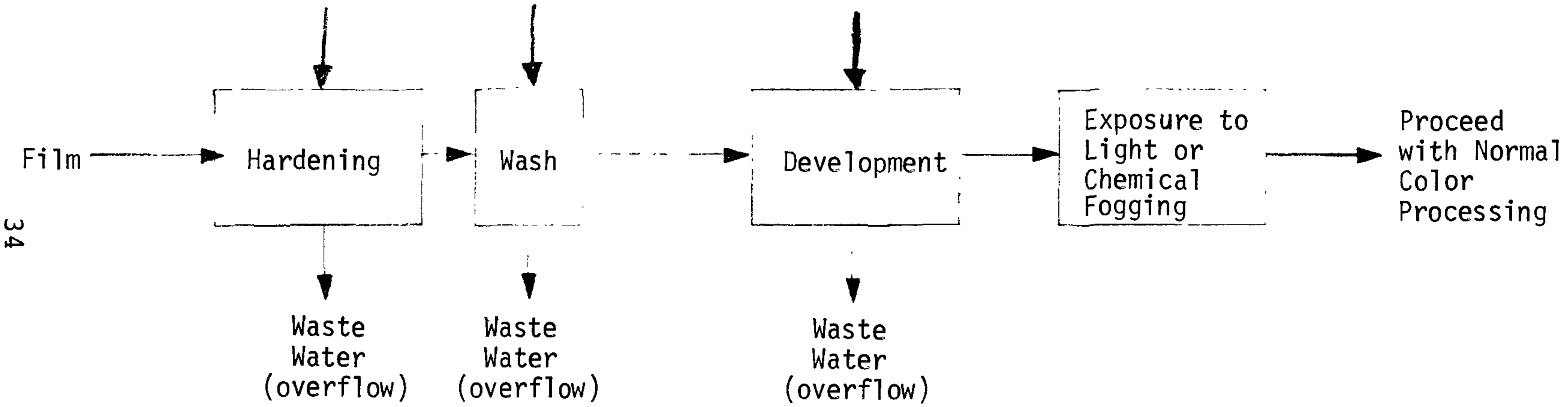
Figure IV -4

Color Reversal Processing
(Incorporated Couplers)



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The wastes in the reversal process are similar to the color process wastes except for the addition of sulfate from the reversal bleach process and acetate and sulfate from the hardening bath. Sulfamic acid is used in some reversal black and white processes but is not used in color reversal processes.

Color reversal film without the incorporated couplers is processed in a manner similar to those just described up to the formation of the negative image in all three layers. After this, all three layers in the emulsion are treated separately. First, the red-sensitive layer is made developable by exposure to red light through the base of the film. The other two layers, which are not sensitive to red light, are unaffected. The film is then treated with a color developer that contains, among many other ingredients, a soluble cyan dye coupler. As the color developer agent reduces the silver and forms an image, the oxidized color developer in the vicinity of the developed silver grains forms a positive cyan dye (red) image.

After washing, the film is exposed from the top with blue light forming a latent image in the top blue-sensitive layer. A yellow filter layer protects the middle green-sensitive layer. A second color developer, containing a soluble yellow coupler, produces both a silver and yellow positive dye image in the top layer.

After a wash, the film is either exposed to white light or chemically fogged and a third color developer, containing a magenta coupler, forms the final positive silver and magenta colored dye image (green). In the film or paper, there are three negative silver images, three positive silver images and three colored dye images. The silver images are removed as in the negative color process by bleaching and fixing, washing and drying. Films of this type include Kodachrome and GAF Moviechrome. The process flow diagram for color reversal development with couplers in the developer is shown in Figure IV-5.

Ferricyanide in Photographic Processing Wastes

Ferricyanide bleaches are found in color photographic processing applications, where it has been used as a standard bleaching agent for years. The function of the bleach in the photographic process is to oxidize the metallic silver in the photographic emulsion to a silver halide. During that oxidation, the ferricyanide and halide ion concentrations of the bath decrease, while the ferrocyanide concentration increases. Bromide ion is the

FIGURE IV -5

COLOR REVERSAL PROCESSING (COUPLERS IN DEVELOPER)

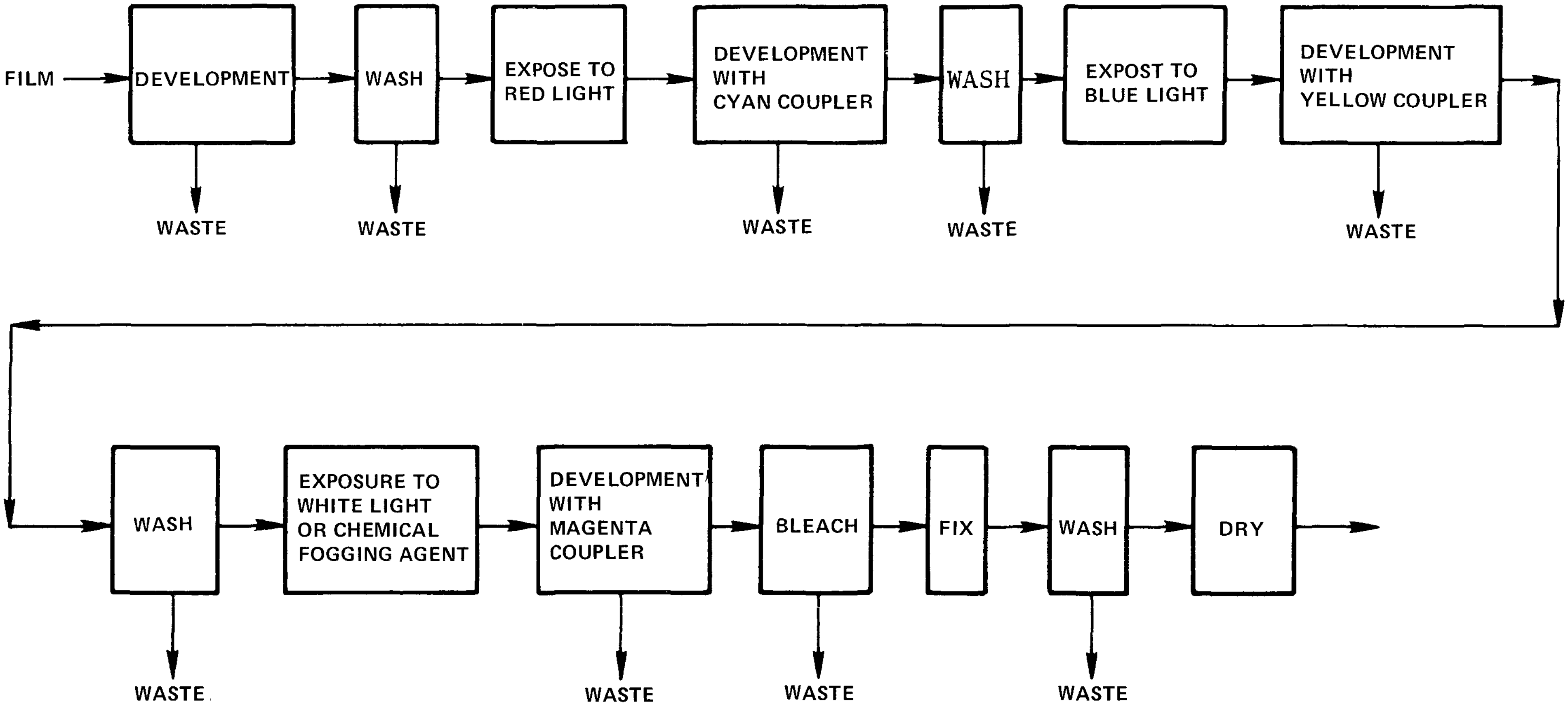

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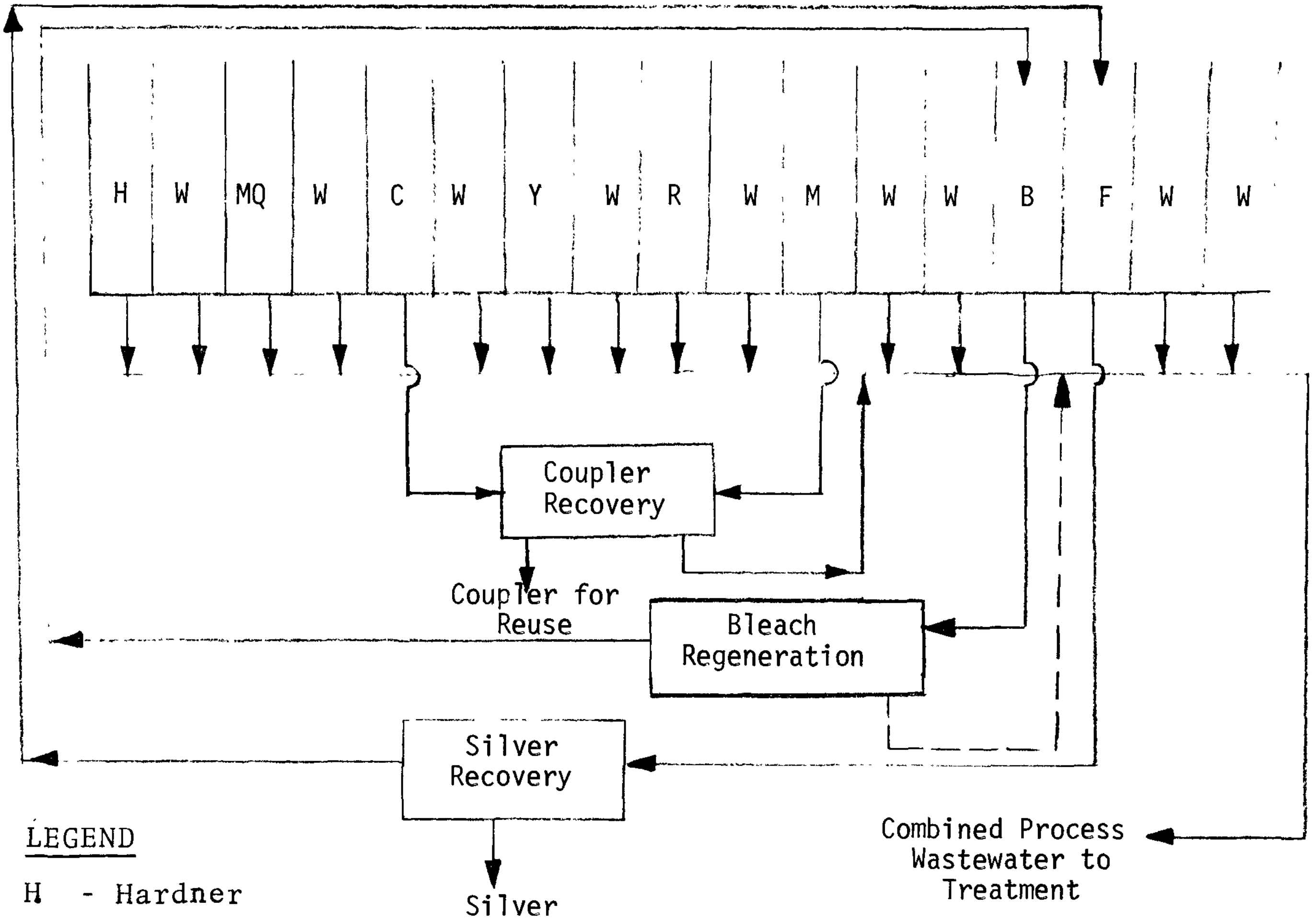
Figure IV -6

Typical Photographic Processing

Flow Diagram



LEGEND

H - Hardner
MQ - 1st Developer
C - Cyan
Y - Yellow
R - Reversal
M - Magenta
B - Bleach
F - Hypo Fix
W - Wash

most common halide ion. The reaction for photographic bleaching is:

$$\begin{array}{ccccccccc} Ag^{0} & + & Fe(CN)_{6}^{-3} & + & Br^{-} & = & AgBr & + & Fe(CN)_{6}^{-4} \\ \text{metallic} & & \text{ferri-} & & \text{Bromine} & & \text{Silver} & & \text{ferro-} \\ \text{silver} & & \text{cyanide} & & \text{ion} & & \text{Bromide} & & \text{cyanide} \\ & & & & & & \text{precipitate} & & \end{array}$$

To maintain the proper concentration of solution constituents, the solution is constantly replenished with fresh material. That distinguishes the two primary solutions for all processing formulations, the replenisher and working tank solutions. Table IV-2 shows some typical chemical concentrations for a working tank and a replenisher tank from three different color photographic processes.

The overflow bleach from the working tank is one source of ferrocyanide loss from the photographic process. In addition, as film passes through the processing solutions, it carries a certain volume of tank solution to the next tank. That carryover is the total of the surface liquid and the solution absorbed into the film emulsion. The carryover rate depends upon many factors, including the speed of the process and the photo products being processed. The carryover loss of solution bleach into the next bath in the process is a second source of bleach loss. The bath following the bleach is either a photographic fixing bath or a wash water.

All photographic processing laboratories are in a position to estimate the average concentration of ferricyanide discharged from the photographic laboratory over a specified period of time. That can be done by calculating the pounds of ferro- or ferricyanide purchased and dividing by the total volume of water used by the laboratory during the same period.

TABLE IV -2

Bleach Bath Composition

EXAMPLE A - From a Typical Color Reversal Process

	Working Tank (g/1)	Replenisher (g/1)
Sodium Ferrocyanide ($Na_4Fe\ (CN)_6 \cdot 10\ H_2O$)	45.0	5.0
Sodium Ferricyanide ($Na_3Fe(CN)_6$)	120.0	140.0
Sodium Bromide (NaBr)	25.0	55.0

EXAMPLE B - From A typical Color Negative Film Processor

	Working Tank (g/1)	Replenisher (g/1)
Sodium Ferrocyanide Decahydrate	6.0	2.0
Sodium Ferricyanide	23.0	26.0
Sodium Bromide	15.0	17.0

EXAMPLE C - From a Typical Color Positive Paper Processor

	Working Tank (g/1)	Replenisher (g/1)
Sodium Ferrocyanide Decahydrate	13.0	2.0
Sodium Ferricyanide	17.0	25.0
Sodium Bromide	7.0	8.0

TABLE IV-3

STATISTICAL ANALYSIS OF NAPM/FIELD SURVEY - SPRING 1976

Type of Operation	Statistical Parameter	BOD (lbs/1000 ft^2)	COD (lbs/1000 ft^2)	Flow (gal/1000 ft^2)
I (Kodak Historical Data)	Mean	12.09	34.16	6,279
	Standard Deviation	9.40	27.89	3,070
I*	Mean	4.84	13.31	2,857
	Standard Deviation	2.51	5.47	2,209
II	Mean	4.41	10.99	3,365
	Standard Deviation	2.02	5.18	1,417
III	Mean	4.64	15.18	4,428
	Standard Deviation	2.68	7.44	2,720
IV	Mean	11.58	33.23	3,584
	Standard Deviation	12.59	57.02	3,327
Total Survey Data	Mean	7.5**	25	4,050*
	Standard Deviation	7.9	34	2,800

*Samples from plants number 12 and 16 were not included.
**Samples from plant number 16 was not included.

KEY:
I = Amateur Photofinishers
II = Professional and Commercial Finishers
III = Does both I and II
IV = Motion Picture

SECTION V

WASTE CHARACTERIZATION

The raw waste loadings (RWL) for the photoprocessing industry presented in Table V-1 were determined from analyses of samples collected during plant visits by the EPA contractor and by NAPM. These data formed the data base and generally were consistent with existing plant data. The EPA contractor RWL in each case represents an average of four values: one each from two black and white film and paper operations and two color film and paper operations. The pollutant loadings from these four operations compared well in order-of-magnitude, and this formed the basis of categorization. Final overall RWL's overflow, BOD_5 and COD are based on a weighted composite of data points from the 4 plants surveyed by the EPA contractor, from 30 non-Kodak plants sampled by NAPM and from historical data from 6 Kodak plants. The overall industry RWL flow is 4,000 gallons per 1000 square feet; the overall industry RWL, BOD_5 is 7.50 lbs per 1000 square feet and the overall industry RWL, COD is 25.1 lbs per 1000 square feet. Supplemental information in the form of calculated RWLs for typical photographic processes is shown in Table V-2. The field survey revealed no full scale secondary treatment plant installations for stand alone photographic processing plants. The west coast plant was used to confirm historical and field survey data. The TSS data gathered from the field visits appeared to be low in relation to the west coast plant and was considered non-representative. The TSS RWL was, therefore, developed from the west coast plant data.

Concentrations of the various parameters were determined from grab samples collected from the combined wastewater overflows and wash waters from each process (C-22, C-41, C-42, Ektaprint 3, etc.). The concentration values for a specific pollutant were found to vary among seemingly identical machines. Because of this variation direct comparison of the concentrations was not possible.

The constituents of the wastewater for which RWL were determined were those parameters which are frequently present in the wastewater and may have significant ecological consequences once discharged. Other parameters which may be potentially toxic to municipal treatment plants, such as cadmium and chromium were generally found in trace quantities.

Table V -1
Raw Waste Loads

Photographic Processing Industry

Plant No.	Type of Operation	Raw Waste Load - kg/1,000 sq. m. (lbs./1,000 sq. ft.)												
		BOD_5	COD	TOC	TDS	Silver	TSS	Phenol	Iron	Boron	T-P	Surfactants	TKN	Total Cyanide[8]
32	Black & White	18.4	86.6	11.1	319.8	0.10		1.48×10^{-4}	0.10	7.03	0.13		4.9	
		(3.77)	(17.7)	(2.27)	(65.2)	(0.02)		(3.03×10^{-5})	(0.021)	(1.44)	(0.027)		(1.005)	
33	Black & White	41.6	167.7	48.9	307.1	0.08		0.0097	10.4	0.01	0.36	0.33	46.0	
		(8.5)	(34.3)	(10.0)	(62.8)	(0.016)		(0.0020)	(2.14)	(0.0021)	(0.074)	(0.0679)	(9.42)	
32	Color	45.7	152.6	34.2	158.9	0.06		0.0078	0.85	0.75	0.18	0.07	13.4	
		(9.34)	(31.2)	(7.0)	(32.5)	(0.013)		(0.0016)	(0.174)	(0.154)	(0.036)	(0.0144)	(2.75)	
33	Color	1.46	3.42	1.12	31.5	0.05		0.029	0.25	0.07	0.69		1.19	
		(0.30)	(0.7)	(0.23)	(6.46)	(0.011)		(0.0059)	(0.0509)	(0.0142)	(0.141)		(0.243)	
34	Color	40.3	120.3	44.1	219.0	0.08		0.011	0.69	0.73	1.17	0.011	3.98	
		8.25	(24.6)	(9.01)	(44.8)	(0.016)		(0.0023)	(0.142)	(0.15)	(0.24)	(0.0215)	(0.814)	
00[6]		36.7 (7.5)	122 (25)	N/A[7]	N/A[7]	N/A[7]		N/A[7]	N/A[7]	N/A[7]	N/A[7]	N/A[7]	N/A[7]	
Raw Waste Load		36.7	123.0	34.6	251.0	0.07	3.03	0.014	2.47	2.15	0.507	0.17	13.9	0.09
		(7.5)[1]	(25.1)[1]	(7.07)[1]	(51.3)[1]	(0.015)[2]	(0.622)[5]	(0.003)[2]	(0.506)	(0.44)[3]	(0.104)	(0.035)	(2.85)	(0.019)
RWL Concentration, mg/L[4]		225	752	212	1,538	0.45	19	0.09	15.2	13.2	3.1	1.1	85	0.57[8]

[1] Plant 33 - Color not included in RWL average

[2] Plant 32 - Black and White not included in RWL average

[3] Plant 33 - Black and White not included in RWL average

[4] Values based on average wastewater flow from the three plants (4,000 gallons per 1,000 sq. ft.) except for TSS, total cyanide, and ferrocyanide

[5] Values based on data obtained from Eastman Kodak's Palo Alto Plant

[6] Values from 73 additional data points from 36 plants.

[7] N/A = not available.

[8] Value based on average from 55 parameter analysis results and used with 4,000 gal./1,000 sq. ft. flow rate to back calculate Raw Waste Load mass loadings per area immediately above.

TABLE V -2

Calculated RWL for Typical Photographic Processes

	Flow gal/1000 sq. ft.	BOD5 lb/1000sq. ft.	COD lb/1000sq. ft.
RWL	2960	7.36	26.4
Ektaprint 3[1] - 4C - 2K Processor 15' /min 2-3-1/2" strands	542	5.42	9.8
Kodachrome K-14[2,3] - at 50 '/min	3015	6.1	21
Ektachrome EA-5 - 9-1/2" at 3.2 '/min 1411-M	2660	62.	95
Ektachrome E-4 35mm at 26 '/min	4420	43.5	67.5
Ektaprint R-5 - 3-1/2" at 3 '/min 4R Processor	12000	26.7	44.8
Eastman Color Print - 35 mm at 125 '/min	1280	23.2	30
Eastman Color Negative - 35 mm at 50 '/min	1470	26.4	37.3
B&W Paper - 5" at 6.66 '/min Himatic Chemicals	1460	4.5	5.4
B&W Aerial Film - 5" at 14 '/min Versamat 641 Dev. & Fix	195	6	8
DuPont Graphic Arts Process	---	35	51
DuPont Medical X-Ray Processing	---	17	21
Cronaflex^{R} Engineering Reproduction	---	11.5	14

[1] Bl-Fix Regeneration
[2] Bl-Regeneration
[3] Fixer Regeneration

Data Supplied by NAPM

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

General

From review of NPDES permit applications for direct discharge of wastewaters from the photographic processing subcategory of the photographic point source category and examination of related published data, twenty parameters (listed in Table VI-1) were selected and examined during the field data collection program. All field sampling data are summarized in Supplement B. Supplement B includes laboratory analytical results, data from plants visited, RWL calculations, historical data, analysis of historical data, computer print-outs (showing flows, production, and pollutants, performance data on treatment technologies and effluent limitations calculations). Supplement B is available for examination at the EPA Public Information Reference Unit, Room 2922, (EPA Library), Waterside Mall, 401 M. St., S.W., Washington, D.C. 20460.

The degree of impact on the overall environment has been used as a basis for dividing the pollutants into groups as follows:

Pollutants of significance.
Rationale for the selection of pollutant parameters.
Pollutants of specific significance.

The rationale and justification for pollutant categorization within the foregoing groupings, as discussed herein, will indicate the basis for selection of the parameters upon which the actual effluent limitations and guidelines were postulated. In addition, particular parameters have been discussed in terms of their validity as measures of environmental impact.

Pollutants observed from photographic processing field data that were present in sufficient concentrations so as to interfere with, be incompatible with, or pass with inadequate treatment through publicly owned treatment works are discussed in Section XII of this document.

Pollutants of Significance

Parameters of major concern are BOD$_5$, COD, silver and cyanides in various forms including complexes (ferrocyanide and ferric cyanide).

BOD$_5$ and COD have been selected as pollutants of significance because they are the primary measurements of organic pollution. In the survey of the industrial categories, most of the effluent data collected from wastewater treatment facilities were based upon BOD$_5$, because most of the end-of-pipe treatment facilities and municipal treatment systems were biological processes. Where other processes (such as evaporation, incineration, activated carbon or physical/chemical) are utilized, either COD or TOC may be a more appropriate measure of pollution.

Table VI-1

List of Parameters to be Examined

- Acidity and Alkalinity-pH
- Dissolved Oxygen
- Biochemical Oxygen Demand
- Chemical Oxygen Demand
- Total Organic Carbon
- Total Suspended Solids
- Phenol
- Phosphorus
- Dissolved Solids
- Nitrogen Compounds
- Sulfates
- Temperature
- Boron
- Cadmium
- Chromium
- Cyanide
- Ferrocyanide
- Silver
- Thiosulfate
- Dye Couplers

RATIONALE FOR THE SELECTION OF POLLUTANT PARAMETERS

I. Pollutant Properties

Acidity and Alkalinity - pH

Although not a specific pollutant, pH is related to the acidity or alkalinity of a waste water stream. It is not a linear or direct measure of either, however, it may properly be used as a surrogate to control both excess acidity and excess alkalinity in water. The term pH is used to describe the hydrogen ion - hydroxyl ion balance in water. Technically, pH is the hydrogen ion concentration or activity present in a given solution. pH numbers are the negative logarithm of the hydrogen ion concentration. A pH of 7 generally indicates neutrality or a balance between free hydrogen and free hydroxyl ions. Solutions with a pH above 7 indicate that the solution is alkaline, while a pH below 7 indicates that the solution is acid.

Knowledge of the pH of water or waste water is useful in determining necessary measures for corrosion control, pollution control, and disinfection. Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and such corrosion can add constituents to drinking water such as iron, copper, zinc, cadmium, and lead. Low pH waters not only tend to dissolve metals from structures and fixtures but also tend to redissolve or leach metals from sludges and bottom sediments. The hydrogen ion concentration can affect the "taste" of the water and at a low pH, water tastes "sour".

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity* to aquatic life of many materials is increased by changes in the water pH. For example, metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. Similarly, the toxicity of ammonia is a function of pH. The bactericidal effect of chlorine in most cases is less as the pH increases, and it is economically advantageous to keep the pH close to 7.

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*The term toxic or toxicity is used herein in the normal scientific sense of the word and not as a specialized term referring to section 307(a) of the Act.

Acidity is defined as the quantitative ability of a water to neutralize hydroxyl ions. It is usually expressed as the calcium carbonate equivalent of the hydroxyl ions neutralized. Acidity should not be confused with pH value. Acidity is the quantity of hydrogen ions which may be released to react with or neutralize hydroxyl ions while pH is a measure of the free hydrogen ions in a solution at the instant the pH measurement is made. A property of many chemicals, called buffering, may hold hydrogen ions in a solution from being in the free state and being measured as pH. The bond of most buffers is rather weak and hydrogen ions tend to be released from the buffer as needed to maintain a fixed pH value.

Highly acid waters are corrosive to metals, concrete and living organisms, exhibiting the pollutional characteristics outlined above for low pH waters. Depending on buffering capacity, water may have a higher total acidity at pH values of 6.0 than other waters with a pH value of 4.0.

Alkalinity: Alkalinity is defined as the ability of a water to neutralize hydrogen ions. It is usually expressed as the calcium carbonate equivalent of the hydrogen ions neutralized.

Alkalinity is commonly caused by the presence of carbonates, bicarbonates, hydroxides and to a lesser extent by borates, silicates, phophates and organic substances. Because of the nature of the chemicals causing alkalinity, and the buffering capacity of carbon dioxide in water, very high pH values are seldom found in natural waters.

Excess alkalinity as exhibited in a high pH value may make water corrosive to certain metals, detrimental to most natural organic materials and toxic to living organisms.

Ammonia is more lethal with a higher pH. The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Oxygen Demand (BOD, COD, TOC and DO)

Organic and some inorganic compounds can cause an oxygen demand to be exerted in a receiving body of water. Indigenous microorganisms utilize the organic wastes as an energy source and oxidize the organic matter. In doing so their natural respiratory activity will utilize the dissolved oxygen.

Dissolved oxygen (DO) in water is a quality that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and less able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food utilization efficiency, growth rate, and maximum sustained swimming speed. Other organisms are likewise affected adversely during conditions of decreased DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total depletion of dissolved oxygen due to a high oxygen demand can kill all the inhabitants of the affected aquatic area.

It has been shown that fish may, under some natural conditions, become acclimatized to low oxygen concentrations. Within certain limits, fish can adjust their rate of respiration to compensate for changes in the concentration of dissolved oxygen. It is generally agreed, moreover, that those species which are sluggish in movement (e.g.,carp, pike, eel) can withstand lower oxygen concentrations than fish which are more lively in habit (such as trout or salmon).

The lethal affect of low concentrations of dissolved oxygen in water appears to be increased by the presence of toxic substances, such as ammonia, cyanides, zinc, lead, copper, or cresols. With so many factors influencing the effect of oxygen deficiency, it is difficult to estimate the minimum safe concentrations at which fish will be unharmed under natural conditions. Many investigations seem to indicate that a DO level of 5.0 mg/l is desirable for a good aquatic environment and higher DO levels are required for selected types of aquatic environments.

Biochemical oxygen demand (BOD) is the quantity of oxygen required for the biological and chemical oxidation of waterborn substances under ambient or test conditions. Materials which may contribute to the BOD include: carbonaceous organic materials usable as a food source by aerobic organisms; oxidizable nitrogen derived from nitrites, ammonia and organic nitrogen compounds which serve as food for specific bacteria; and certain chemically oxidizable materials such as ferrous iron, sulfides, sulfite, etc. which will react with dissolved oxygen or are metabolized by bacteria. In most industrial and municipal waste waters, the BOD derives principally from organic materials and from ammonia (which is itself derived from animal or vegetable matter).

The BOD of a waste exerts an adverse effect upon the dissolved oxygen resources of a body of water by reducing the oxygen available to fish, plant life, and other aquatic species. Conditions can be reached where all of the dissolved oxygen in the water is utilized resulting in anaerobic conditions and the production of undesirable gases such as hydrogen sulfide and methane. The reduction of dissolved oxygen can be detrimental to fish populations, fish growth rate, and organisms used as fish food. A total lack of oxygen due to the exertion of an excessive BOD can result in the death of all aerobic aquatic inhabitants in the affected area.

Water with a high BOD indicates the presence of decomposing organic matter and associated increased bacterial concentrations that degrade its quality and potential uses. A by-product of high BOD concentrations can be increased algal concentrations and blooms which result from decomposition of the organic matter and which form the basis of algal populations.

The BOD_5 (5-day BOD) test is used widely to estimate the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into receiving streams. The test is an important one in water pollution control activities. It is used for pollution control regulatory activities, to evaluate the design and efficiencies of waste water treatment works, and to indicate the state of purification or pollution of receiving bodies of water.

Complete biochemical oxidation of a given waste may require a period of incubation too long for practical analytical test purposes. For this reason, the 5-day period has been accepted as standard, and the test results have been designated as BOD_5. Specific chemical test methods are not readily available for measuring the quantity of many degradable substances and their reaction products. Reliance in such cases is placed on the collective parameter, BOD_5, which measures the weight of dissolved oxygen utilized by microorganisms as they oxidize or transform the gross mixture of chemical compounds in the waste water. The biochemical reactions involved in the oxidation of carbon compounds are related to the period of incubation. The five-day BOD normally measures only 60 to 80% of the carbonaceous biochemical oxygen demand of the sample, and for many purposes this is a reasonable parameter. Additionally, it can be used to estimate the gross quantity of oxidizable organic matter.

The BOD_5 test is essentially a bioassay procedure which provides an estimate of the oxygen consumed by microorganisms utilizing the degradable matter present in a waste under conditions that are representative of those that are likely to occur in nature. Standard conditions of time, temperature, suggested microbial seed, and dilution water for the wastes have been defined and are incorporated in the standard analytical procedure. Through the use of this procedure, the oxygen demand of diverse wastes can be compared and evaluated for pollution potential and to some extent for treatability by biological treatment processes.

Because the BOD test is a bioassay procedure, it is important that the environmental conditions of the test be suitable for the microorganisms to function in an uninhibited manner at all times. This means that toxic substances must be absent and that the necessary nutrients, such as nitrogen, phosphorous, and trace elements, must be present.

Chemical oxygen demand (COD) is a purely chemical oxidation test devised as an alternate method of estimating the total oxygen demand of a waste water. Since the method relies on the oxidation-reduction system of chemical analyses rather than on biological factors, it is more precise, accurate, and rapid than the BOD test. The COD test is widely used to estimate the total oxygen demand (ultimate rather than 5-day BOD) to oxidize the compounds in a waste water. It is based on the fact that organic compounds, with a few exceptions, can be oxidized by strong chemical oxidizing agents under acid conditions with the assistance of certain inorganic catalysts.

The COD test measures the oxygen demand of compounds that are biologically degradable and of many that are not. Pollutants which are measured by the BOD_5 test will be measured by the COD test. In addition, pollutants which are more resistant to biological oxidation will also be measured as COD. COD is a more inclusive measure of oxygen demand than is BOD_5 and will result in higher oxygen demand values than will the BOD_5 test.

The compounds which are more resistant to biological oxidation are becoming of greater and greater concern not only because of their slow but continuing oxygen demand on the resources of the receiving water, but also because of their potential health effects on aquatic life and humans. Many of these compounds result from industrial discharges and some have been found to have carcinogenic, mutagenic and similar adverse effects, either singly or in combination. Concern about these compounds has increased as a result of demonstrations that their long life in receiving waters - the result of a slow biochemical oxidation rate - allows them to contaminate downstream water intakes. The commonly used systems of water purification are not effective in removing these types of materials and disinfection such as chlorination may convert them into even more hazardous materials.

Thus the COD test measures organic matter which exerts an oxygen demand and which may affect the health of the people. It is a useful analytical tool for pollution control activities. It provides a more rapid measurement of the oxygen demand and an estimate of organic compounds which are not measured in the BOD_5 test.

Total organic carbon (TOC) is measured by the catalytic conversion of organic carbon in a waste water to carbon dioxide. Most organic chemicals have been found to be measured quantitatively by the equipment now in use. The time of analyses is short, from 5 to 10 minutes, permitting a rapid and accurate estimate of the organic carbon content of the waste waters to be made by relatively unskilled personnel.

A TOC value does not indicate the rate at which the carbon compounds are oxidized in the natural environment. The TOC test will measure compounds that are readily biodegradable and measured by the BOD_5 test as well as those that are not. TOC analyses will include those biologically resistant organic compounds that are of concern in the environment.

BOD and COD methods of analyses are based on oxygen utilization of the waste water. The TOC analyses estimates the total carbon content of a waste water. There is as yet no fundamental correlation of TOC to either BOD or COD. However, where organic laden waste waters are fairly uniform, there will be a fairly constant correlation among TOC, BOD and COD. Once such a correlation is established, TOC can be used as an inexpensive test for routine process monitoring.

Total Suspended Solids (TSS)

Suspended solids include both organic and inorganic materials. The inorganic compounds include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, and animal and vegetable waste products. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Suspended solids in water interfere with many industrial processes, cause foaming in boilers and incrustations on equipment exposed to such water, especially as the temperature rises. They are undesirable in process water used in the manufacture of steel, in the textile industry, in laundries, in dyeing, and in cooling systems.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often damaging to the life in water. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a food source for sludgeworms and associated organisms.

Disregarding any toxic effect attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages of various aquatic fauna. Indirectly, suspended solids are inimical to aquatic life because they screen out light, and they promote and maintain the development of noxious conditions through oxygen depletion. This results in the killing of fish and fish food organisms. Suspended solids also reduce the recreational value of the water.

Turbidity: Turbidity of water is related to the amount of suspended and colloidal matter contained in the water. It affects the clearness and penetration of light. The degree of turbidity is only an expression of one effect of suspended solids upon the character of the water. Turbidity can reduce the effectiveness of chlorination and can result in difficulties in meeting BOD and suspended solids limitations. Turbidity is an indirect measure of suspended solids.

Phenols

Phenols, defined as hydroxy derivatives of benzene and its condensed nuclei, may occur in domestic and industrial waste water and in drinking water supplies. Chlorination of such waters can produce odoriferous and objectionable tasting chlorophenols which may include o-chlorophenol, p-chlorophenol, and 2, 4-dichlorophenol.

Although described in the technical literature simply as phenols, the phenol waste category can include a wide range of similar chemical compounds. In terms of pollution control, reported concentrations of phenols are the result of a standard methodology which measures a general group of similar compounds rather than being based upon specific identification of the single compound, phenol (hydroxybenzene).

Phenols are used in some cutting oils and in the molding of plastics. Cutting fluids can contain phenolic compounds since these materials are normal constituents of hydrocarbon mixtures. In addition, phenolic compounds are added to oils as preservatives or for odor control. They also are found in the waste waters from the petroleum industry and from certain products of the organic chemical industry.

Phenolic compounds may adversely affect fish in two ways: first, by a direct toxic action, and second, by imparting a taste to the fish flesh. The toxicity of phenol towards fish increases as the dissolved oxygen level is diminished, as the temperature is raised, and as the hardness is lessened. Phenol appears to act as a nerve poison causing too much blood to get to the gills and to the heart cavity and is reported to have a toxic threshold of 0.1 - 1.5 mg/l.

Mixed phenolic substances appear to be especially troublesome in imparting taste to fish flesh. Chlorophenol produces a bad taste in fish far below lethal or toxic doses. Threshold concentrations for taste or odor in chlorinated water supplies have been reported as low as 0.00001-0.001 mg/l. Phenols in concentrations of only one part per billion have been known to affect water supplies.

The ingestion of concentrated solutions of phenol by humans results in severe pain, renal irritation, shock, and possibly death. A total dose of 1.5 grams may be fatal. Phenols can be metabolized and oxidized in waste treatment facilities containing organisms acclimated to the phenol concentration in the wastes.

Phosphorus

Phosphorus occurs in natural waters and in waste waters in the form of various types of phosphate. These forms are commonly classified into orthophosphates, condensed phosphates (pyro-, meta-, and polyphosphorus), and organically bound phosphates. These may occur in the soluble form, in particles of detritus or in the bodies of aquatic organisms.

The various forms of phosphates find their way into waste waters from a variety of industrial, residential, and commercial sources. Small amounts of certain condensed phosphates are added to some water supplies in the course of potable water treatment. Large quantities of the same compounds may be added when the water is used for laundering or other cleaning since these materials are major constituents of many commercial cleaning preparations. Phosphate coating of metals is another major source of phosphates in certain industrial effluents.

The increasing problem of the growth of algae in streams and lakes appears to be associated with the increasing presence of certain dissolved nutrients, chief among which is phosphorus. Phosphorus is an element which is essential to the growth of organisms and it can often be the nutrient that limits the aquatic growth that a body of water can support. In instances where phosphorous is a growth limiting nutrient, the discharge of sewage, agricultural drainage or certain industrial wastes to a receiving water may stimulate the growth, in nuisance quantities, of photosynthetic aquatic microorganisms and macroorganisms.

The increase in organic matter production by algae and plants in a lake undergoing eutrophication has ramifications throughout the aquatic ecosystem. Greater demand is placed on the dissolved oxygen in the water as the organic matter decomposes at the termination of the life cycles. Because of this process, the deeper waters of the lake may become entirely depleted of oxygen, thereby, destroying fish habitats and leading to the elimination of desirable species. The settling of particulate matter from the productive upper layers changes the character of the bottom mud, also leading to the replacement of certain species by less desirable organisms. Of great importance is the fact that nutrients inadvertently introduced to a lake are, for the most part, trapped there and recycled in accelerated biological processes. Consequently, the damage done to a lake in a relatively short time requires a many fold increase in time for recovery of the lake.

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as a physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

Dissolved Solids

In natural waters, the dissolved solids are mainly carbonates, chlorides, sulfates, phosphates, and, to a lesser extent, nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances.

Many communities in the United States and in other countries use water supplies containing 2,000 to 4,000 mg/l of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4,000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated. Waters containing 5,000 mg/l or more are reported to be bitter and act as a bladder and intestinal irritant. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/l, depending on species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids (TDS) concentrations higher than 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l, water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and can cause interference with cleanliness, color, or taste of many finished products. High concentrations of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in water and to the water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

Nitrogen Compounds

Ammonia nitrogen (NH_3-N) and total Kjeldahl nitrogen (TKN) are two parameters which have received a substantial amount of interest in the last decade. TKN is the sum of the NH_3-N and organic nitrogen present in the sample. Both NH_3 and TKN are expressed in terms of equivalent nitrogen values in mg/l to facilitate mathematical manipulations of the values.

Organic nitrogen may be converted in the environment to ammonia by saprophytic bacteria under either aerobic or anaerobic conditions. The ammonia nitrogen then becomes the nitrogen and energy source for autotrophic organisms (nitrifiers). The oxidation of ammonia to nitrite and then to nitrate has a stoichiometric oxygen requirement of approximately 4.6 times the concentration of NH_3-N. The nitrification reaction is much slower than the carbonaceous reactions, and, therefore, the dissolved oxygen utilization is observed over a much longer period.

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations, including ammonium chloride and other salts.

Infant methemoglobinemia, a disease characterized by specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants.

Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions (NH_4^+) predominate.

In streams polluted with sewage, up to one-half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l non-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and may cause fish to suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly, are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

Sulfates

Sulfates occur naturally in waters, particulary in the western Unites States, as a result of leachings from gypsum and other common materials. They also occur as the final oxidized state of sulfides, sulfites and thiosulfates. Sulfates may also be present as the oxidized state of organic matter in the sulfur cycle, but they in turn, may serve as sources of energy for sulfate splitting bacteria. Sulfates may also be discharged in numerous industrial wastes, such as those from tanneries, sulfate-pulp mills, textile mills, and other plants that use sulfates or sulfuric acid.

In moderate concentrations, sulfates are not harmful and it has been reported that concentrations up to 1000 mg/l are harmless. Irrigation concentrations less than 336 mg/l are considered to be good to excellent.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines what species may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances, and the decay rate increases as the temperature of the water increases, reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges.

Spawning may not occur at all when temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change; primary production is decreased; and bottom-associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperature may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers deplete oxygen in water more rapidly at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms, to green algae, then, at high temperatures, to blue-green algae because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperature increases above 90°F, which is close to the tolerance limit for the water's population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish mortalities resulting from their returning to cooler water after being attracted to heated waters in winter may be considerable.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the aesthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of fresh waters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Boron

Never found in nature in its elemental form, boron occurs as sodium borate (borax) or as calcium borate (colemanite) in mineral deposits and natural waters of Southern California and Italy. Elemental boron is used in nuclear installations as a shielding material (neutron absorber). It is also used in metallurgy to harden other metals.

Boric acid and boron salts are used extensively in industry for such purposes as weatherproofing wood, fireproofing fabrics, manufacturing glass and porcelain and producing leather, carpets, cosmetics and artificial gems. Boric acid is used as a bactericide and fungicide and boron, in the form of boron hydrides or borates, is used in high energy fuels.

Boron is present in the ordinary human diet at about 10 to 20 mg/day, with fruits and vegetables being the largest contributors. In food or in water, it is rapidly and completely absorbed by the human system, but it is also promptly excreted in urine. Boron in drinking water is not generally regarded as a hazard to humans. It has been reported that boron concentrations up to 30 mg/l are not harmful.

Cadmium (Cd)

Cadmium is a relatively rare element that is seldom found in sufficient quantities in a pure state to warrant mining or extraction from the earth's surface. It is found in trace amounts of about 1 ppm throughout the earth's crust. Cadmium is, however, a valuable by-product of zinc production.

Cadmium is used primarily as a metal plating material and can be found as an impurity in the secondary refining of zinc, lead, and copper. Cadmium is also used in the manufacture of primary cells of batteries and as a neutron adsorber in nuclear reactors. Other uses of cadmium are in the production of pigments, phosphors, semi-conductors, electrical contactors, and special purpose low temperature alloys.

Cadmium is an extremely dangerous cumulative toxicant, causing insidious progressive chronic poisoning in mammals, fish, and probably other animals because the metal is not excreted. Cadmium could form organic compounds which might lead to mutagenic or teratogenic effects. Cadmium is known to have marked acute and chronic effects on aquatic organisms also.

Toxic effects of cadmium on man have been reported from throughout the world. Cadmium is normally ingested by humans through food and water and also by breathing air contaminated by cadmium. Cadmium in drinking water supplies is extremely hazardous to humans, and conventional treatment, as practiced in the United States, does not remove it. Cadmium is cumulative in the liver, kidney, pancreas, and thyroid of humans and other animals. A severe bone and kidney syndrome in Japan has been associated with the ingestion of as little as 600 ug/day of cadmium. The allowable cadmium concentration in drinking water is set as low as 0.01 mg/l in the U. S. and as high as 0.10 mg/l in Russia.

Cadmium acts synergistically with other metals. Copper and zinc substantially increase its toxicity. Cadmium is concentrated by marine organisms, particularly molluscs, which accumulate cadmium in calcareous tissues and in the viscera. A concentration factor of 1000 for cadmium in fish muscle has been reported, as have concentration factors of 3000 in marine plants, and up to 29,600 in certain marine animals. The eggs and larvae of fish are apparently more sensitive than adult fish to poisoning by cadmium, and crustaceans appear to be more sensitive than fish eggs and larvae.

Chromium (Cr)

Chromium is an elemental metal usually found as a chromite ($FeCr_2O_4$). The metal is normally produced by reducing the oxide with aluminum.

Chromium and its compounds are used extensively throughout industry. It is used to harden steel and as an ingredient in other useful alloys. Chromium is also used in the electroplating industry as an ornamental and corrosion resistant plating on steel and can be used in pigments and as a pickling acid (chromic acid).

The two most prevalent chromium forms found in industry waste waters are hexavalent and trivalent chromium. Chromic acid used in industry is a hexavalent chromium compound which is partially reduced to the trivalent form during use. Chromium can exist as either trivalent or hexavalent compounds in raw waste streams. Hexavalent chromium treatment involves reduction to the trivalent form prior to removal of chromium from the waste stream as a hydroxide precipitate.

Chromium, in its various valence states, is hazardous to man. It can produce lung tumors when inhaled and induces skin sensitizations. Large doses of chromates have corrosive effects on the intestinal tract and can cause inflammation of the kidneys. Levels of chromate ions that have no effect on man appear to be so low as to prohibit determination to date. The recommendation for public water supplies is that such supplies contain no more than 0.05 mg/l total chromium.

The toxicity of chromium salts to fish and other aquatic life varies widely with the species, temperature, pH, valence of the chromium and synergistic or antagonistic effects, especially those of hard water. Studies have shown that trivalent chromium is more toxic to fish of some types than hexavalent chromium. Other studies have shown opposite effects. Fish food organisms and other lower forms of aquatic life are extremely sensitive to chromium and it also inhibits the growth of algae. Therefore, both hexavalent and trivalent chromium must be considered harmful to particular fish or organisms.

Cyanide (CN)

Cyanide is a compound that is widely used in industry primarily as sodium cyanide (NaCN) or hydrocyanic acid (HCN). The major use of cyanides is in the electroplating industry where cyanide baths are used to hold ions such as zinc and cadmium in solution. Cyanides in various compounds are also used in steel plants, chemical plants, photographic processing, textile dying, and ore processing.

Of all the cyanides, hydrogen cyanide (HCN) is probably the most acutely lethal compound. HCN dissociates in water to hydrogen ions and cyanide ions in a pH dependent reaction. The cyanide ion is less acutely lethal than HCN. The relationship of pH to HCN shows that as the pH is lowered to below 7 there is less than 1% of the cyanide molecules in the form of the CN ion and the rest is present as HCN. When the pH is increased to 8, 9, and 10, the percentage of cyanide present as CN ion is 6.7, 42, and 87%, respectively. The toxicity of cyanides is also increased by increases in temperature and reductions in oxygen tensions. A temperature rise of 10°C produced a two- to threefold increase in the rate of the lethal action of cyanide.

In the body, the CN ion, except for a small portion exhaled, is rapidly changed into a relatively non-toxic complex (thiocyanate) in the liver and eliminated in the urine. There is no evidence that the CN ion is stored in the body. The safe ingested limit of cyanide has been estimated at something less than 18 mg/day, part of which comes from normal environment and industrial exposure. The average fatal dose of HCN by ingestion by man is 50 to 60 mg. It has been recommended that a limit of 0.2 mg/l cyanide not be exceeded in public water supply sources.

The harmful effects of the cyanides on aquatic life is affected by the pH, temperature, dissolved oxygen content, and the concentration of minerals in the water. The biochemical degradation of cyanide is not affected by temperature in the range of 10 degrees C to 35 degrees C while the toxicity of HCN is increased at higher temperatures.

On lower forms of life and organisms, cyanide does not seem to be as toxic as it is toward fish. The organisms that digest BOD were found to be inhibited at 1.0 mg/l and at 60 mg/l although the effect is more one of delay in exertion of BOD than total reduction.

Certain metals such as nickel may complex with cyanide to reduce lethality, especially at higher pH values. On the other hand, zinc and cadmium cyanide complexes may be exceedingly toxic.

Pollutants of Specific Significance

Review of analytical data indicate that the pollutants of special significance in the photographic processing industry are cyanide and silver in various forms.

Ferrocyanide

Ferrocyanide concentrations were determined through a visual determination method developed by the American National Standards Institute. This analysis is not a standard method, but the results serve as a reasonable guide for differentiating between the various forms of cyanide when used in conjunction with the results from the total cyanide determination.

The ferrocyanide ion, $Fe(CN)_6^{-4}$, comes from the bleach used in some color processes, i.e., ferricyanide bleach. Ferrocyanide is one of the most objectionable pollutants resulting from photographic processing. Primarily, the complexed ion is potentially harmful because it is converted to free, highly toxic cyanide in the presence of sunlight. Ferrocyanide concentration was 4.7 mg/l in the wastewater discharge from plant 34.

Complex cyanides (ferro- and ferricyanide) in industrial wastewaters impose a direct threat upon the environment. However, methods to recover or destroy these compounds are currently employed in the photographic processing industry. This compound represents a potential hazard in the form of toxic cyanide ion, and since it is not easily biodegraded in municipal secondary treatment plants, it must be treated at its source.

Lur'e and Panova have shown that ferrocyanide first oxidizes to ferricyanide with air in water and then photochemically oxidizes to iron hydroxide, hydrocyanic acid and simple soluble cyanides. The proposed mechanism is:

$$4\ Fe(CN)_6^{-4} + O_2 + 2\ H_2O = 4\ Fe(CN)_6^{-3} + 4\ OH^-$$

$$4\ Fe(CN)_6^{-3} + 12\ H_2O = 4\ Fe(OH)_3 + 12\ HCN + 12\ CN^-$$

Overall Reaction:

$$4\ Fe(CN)_6^{-4} + O_2 + 14\ H_2O + hv\ 4\ Fe(OH)_3 + 12\ HCN + 4\ OH^- + 12\ CN^-$$

They report that the rate of oxidation of ferrocyanide in the presence of sunlight leaves about 25% of the original concentration in five days.....the ferrocyanide disappearing completely in 10-12 days.

A recent government report has confirmed the increased toxicity of complex cyanides from photographic wastes in the presence of sunlight. The results of various tests show that the conversion of complex cyanide to volatile cyanide (HCN) is probably reversible and product limited. The testing was carried out using an Ektachrome photographic waste similar to all commercial film processing ferricyanide bleaches.

Ferrocyanide can be oxidized to ferricyanide in overflow photographic color process bleaches using ozone and the waste bleach recirculated for reuse in the process. Dilute concentrations of ferricyanide can be destroyed using ozone or chlorine under proper conditions of temperature, pH, and catalyst addition (for chlorination only). Since there are obvious economic advantages for reducing the discharge of ferrocyanides, no plant should be allowed to continue to dump waste waters containing harmful concentrations of this compound.

Silver (Ag)

Silver is by far the most prevalent among the heavy metals in photographic processing wastewaters. Most of the silver enters the wastewater stream from either the fix or bleach-fix bath overflow. At this point, silver is usually in a soluble complex form as silver thiosulfate, and is somewhat less toxic than ionic silver, but it can and often exists in other forms. As reported in one study, essentially no free silver ion results from photographic processing operations. Silver measured in the effluent from plant 34 was 0.26 mg/l.

Silver is a soft lustrous white metal that is insoluble in water and alkali. It is readily ionized by electrolysis and has a particular affinity for sulfur and halogen elements. In nature, silver is found in the elemental state and combined in ores such as argentite (Ag_2S), cerargyrite ($AgCl$), proustite (Ag_3AsS_3), and pyrargyrite (Ag_3SbS_3).

From these ores, silver ions may be leached into ground waters and surface waters, but since many silver salts such as the chloride, sulfide, phosphate, and arsenate are insoluble, silver ions do not generally occur in significant concentration in natural waters.

While silver itself is not considered to be toxic, most of its salts are poisonous due to anions present. Silver compounds can be absorbed in the circulatory system and reduced silver deposited in the various tissues of the body. A condition known as argyria, a permanent greyish pigmentation of the skin and mucous membranes, can result. Concentrations in the range of 0.4-1 mg/l have caused pathological changes in the kidneys, liver and spleen of rats.

According to Kodak researchers, silver is usually solubilized as the tightly formed thiosulfate complex during processing of photographic paper and film. The predominant complex formed in the fixing bath after development is $Ag(S_2O_3)_2^{-3}$.

A second method of removing silver from film which does not utilize the thiosulfate fixing processes is found in certain black-and-white reversal processes. This method involves the use of silver solvent bleaches containing potassium dichromate and sulfuric acid (or sulfamic acid). The silver metal is oxidized by the dichromate and is solubilized as silver sulfate or silver sulfamate. Silver is precipitated from these bleaches by halides, or complexed by thiosulfate. Silver will exist as insoluble silver bromide (AgBr), silver sulfide (Ag_2S) or soluble, silver thiosulfate complex.

A third type of process is the wash-off process, in which non-image silver is removed by washing off the emulsion containing either silver halides or metallic silver. Since there is no silver complexing agent in these processes, the concentration of dissolved silver would be limited by the solubility of the most soluble silver halide present. Silver bromide is commonly used in this type of emulsion and has a solubility product of 4.8×10^{-13} at 25 C. The 1962 U.S. Public Health Service drinking water standards limit the concentration of silver to 0.05 mg/l (ppm).

Eastman Kodak Company respirometric studies (Warburg) indicate no toxicity to unacclimated activated sludge by silver thiosulfate at silver levels of 100 mg/l. In fact, there is a 17% stimulation of oxygen uptake due to the presence of thiosulfate. On the other hand, 10 mg/l of freely dissociable silver nitrate ($AgNO_3$) results in about an 84% inhibition. Extremely insoluble silver sulfide has no effect at 100 mg/l. It is evident that the toxicity of silver to biological treatment plants is dependent upon the free silver ion concentration.

Silver Analyses from Influent and Effluent of Eastman Kodak Company's King's Landing Water Purification Plant

Data from the Kodak King's Landing Water Purification Plant, a 36 mgd (136,260 Cu m/day) activated sludge plant, indicate that silver is removed by the plant with an efficiency in the range of 70 to 80 percent. The influent silver to this plant comes not only from photoprocess waste, but also from manufacturing operations. Analyses of 7-day composites for the entire year of 1973 showed an average influent concentration of about 0.28 mg/l and an average effluent concentration of about 0.07 mg/l. These data are shown on Table V-3. Several peak influent concentrations to the plant ranged from 0.5 to 1.0 mg/l, but the respective effluent concentrations ranged from 0.04 to 0.06 mg/l. The BOD_5 reduction obtained at these peak loads ranged from 95 to 98%.

Table VI-2

Summary Data for Kodak King's Landing Plant

	Influent mg Ag/l	Effluent mg Ag/l	% Ag Removal	% BOD Removal
1973 Avg.	0.28	0.07	78	95.5
Extremes	0.06-1.04	<0.02-0.30	40-93	80-99

< = less than

The biological system operated at King's Landing is very similar to those of municipal secondary facilities except that it has a higher MLSS concentration than that of most municipal facilities. However, it receives influent concentrations of silver much higher than would be expected in a municipal treatment plant and yet operates with an efficiency of about 95% in regard to BOD_5 removal. Recent analyses of silver concentration in the return sludge indicate a range of 1000-3400 mg/kg dry weight (or approximately 30-100 troy ounces per ton of dry solids).

Dye Couplers

If a coupler is to be removed from solution by use of carbon dioxide and reclaimed for reuse, a centrifuge should be used since it is easily cleaned and produces recovered couplers of high purity. However, if the coupler was going to be removed only for pollution-abatement purposes, to prevent unwanted coupler from going into the sewer, the filter press with filter aid would be preferred, according to a study by Eastman Kodak in 1972.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGIES

General

The entire spectrum of wastewater control and treatment technology is at the disposal of the photographic processing subcategory. The selection of technology options depends on the economics of that technology and the magnitude of the final effluent concentration. Control and treatment technology may be divided into two major groupings: in-plant pollution abatement and end-of-pipe treatment.

After discussing the available performance data, conclusions will be made relative to the reduction of various pollutants commensurate with the following distinct technology levels:

I. Best Practicable Control Technology Currently Available (BPT)

II. Best Available Technology Economically Achievable (BAT)

III. Best Available Demonstrated Control Technology (NSPS)

To assess the economic impact of these proposed effluent limitations and guidelines, model treatment systems have been proposed which are considered capable of attaining the recommended RWL reduction. It should be noted and understood that the particular systems were chosen for use in the economic analysis only, and are not the only systems capable of attaining the specified pollutant reductions.

There are many possible combinations of in-plant and end-of-pipe systems capable of attaining the effluent limitations guidelines and standards of performance suggested in this report.

It is the intent of this study to allow the individual plant to make the final decision about what specific combination of pollution control measures is best suited to its situation in complying with the limitations and standards presented in this report.

TABLE VII -1

WASTE DISPOSAL METHODS IN THE PHOTOGRAPHIC PROCESSING INDUSTRY

	TOTAL (237)*	1000 gal/ day (27)	1000-10000 gal/day(92)	10000-50000 gal/day(64)	50000 gal/day(28)	Unknown gal/day(26)
METHOD OF WASTE DISPOSAL	(212)*	(25)	(83)	(60)	(28)	(15)
Direct Discharge	6.1%	4 %	6 %	10 %	3.5%	0 %
Municipal Sewer	83.5%	88 %	89 %	73.5%	96.5%	80 %
Pretreatment Prior to Municipal Sewer	8 %	0 %	7.2%	6.7%	25 %	0 %
On-Site Treatment	9 %	8 %	7.2%	21.7%	3.5%	20 %
SILVER RECOVERY	(191)	(22)	(78)	(55)	(27)	(9)
Metallic Replacement	66 %	50 %	75.7%	65.5%	66.7%	22 %
Electrolytic	36 %	9.1%	23.1%	49.1%	74 %	22 %
Other	5.2%	4.5%	3.4%	7.3%	3.7%	11 %
None	5.8%	41 %	7.7%	0 %	0 %	45 %
BLEACH REGENERATION	(179)	(5)	(79)	(54)	(27)	(7)
Persulfate	55.8%	20 %	49.3%	74.2%	70 %	14.3%
Ozone	1.7%	0 %	0 %	0 %	7.5%	14.3%
Aeration	4.5%	40 %	2.6%	5.4%	0 %	14.3%
None	42.5%	40 %	50.7%	25.8%	22.5%	71.4%
BLEACH-FIXER	(72)	(4)	(35)	(22)	(9)	(2)
Regeneration	85 %	50 %	80 %	95.5%	100 %	50 %
No Regeneration	15 %	50 %	20 %	4.5%	0 %	50 %

*Number of Photographic Processing Plants is Indicated in Parentheses

TABLE VII -1 (CONTINUED)

	TOTAL (237)*	1000 gal/ day (27)	1000-10000 gal/day(92)	10000-50000 gal/day(64)	50000 gal/day(28)	Unknown gal/day(26)
REUSE OF OTHER SOLUTIONS	(192)	(20)	(78)	(54)	(28)	(12)
Yes	16.7%	0 %	5.1%	18.5%	64 %	0 %
No	83.3%	100 %	94.9%	81.5%	36 %	100 %
REUSE OF WASH WATERS	(176)	(22)	(79)	(46)	(23)	(6)
Yes	5.7%	5 %	2.5%	13 %	13 %	0 %
No	94.3%	95 %	97.5%	87 %	87 %	100 %
USE OF SQUEEGEES	(84)	(8)	(37)	(28)	(14)	(1)
Yes	63.2%	37.5%	65 %	64.3%	86 %	0 %
No	36.8%	62.5%	35 %	35.7%	14 %	100 %
WASH WATER CONTROLS	(107)	(15)	(49)	(27)	(13)	(3)
Yes	41 %	40 %	27 %	44.5%	61.5%	0 %
No	59 %	60 %	63 %	55.5%	38.5%	100 %
BOD_5 LOADING (lbs/day)	(227)	(26)	(90)	(62)	(27)	(22)
10	22.5%	88.5%	16.6%	1.6%	0 %	54.6%
10-100	48.9%	11.5%	79 %	45.2%	3.7%	36.4%
100-500	21.1%	0 %	4.4%	43.5%	59.3%	4.5%
500	7.5%	0 %	0 %	9.7%	37 %	4.5%

*Number of Photographic Processing Plants is Indicated in Parentheses

Photographic Processing

In-plant Pollution Abatement

Regeneration and Reuse

Present state-of-the-art techniques can effectively reduce most of the photoprocessing effluent loads. The most advantageous system, both environmentally and economically, is the regeneration and reuse of solutions.

Eastman Kodak Company has reported that silver and sodium ferrocyanide are removed from all fixers before they are sewered at their Dallas and Palo Alto processing laboratories. Both plants discharge into municipal systems. In addition, couplers are removed from Kodachrome solutions before they are sewered. Coupling agents precipitated from K-12 cyan and magenta solutions as well as from K-14 cyan, yellow and magenta solutions are reused. Both locations regenerate 100% of the ferricyanide bleach using the persulfate method.

At the U.S. Naval Photographic Center in Washington, D.C., cost reduction procedures have resulted in significant pollution abatement. Procedures implemented include: the reconstitution and reuse of motion picture black and white developers, the recovery of silver from fixing baths, and the rejuvenation and reuse of fixing bath solutions. The reconstitution of the processing solutions consists of diverting chemical wastewaters from the various processing machines to two large sump tanks prior to discharge to the sanitary sewer. The wastewaters are pumped to the chemical mix area as needed for chemical analyses and reconstituted for use. Silver is recovered electrolytically from the fixing baths. The electrolytic units recover over 90% of the spent silver. This major military photoprocessing installation uses eighteen processing machines and has a wastewater flow of 150,000 gpd. Wastewater sources consist of developer solutions, bleach solutions, fix solutions and rinse water.

A review of in-plant pollution abatement practices tabulated from 200 plant survey data from Kodak (Table VII-1) reflects that over 85% of the plants recover silver, over 56% regenerate bleach, over 30% regenerate bleach-fixer, and over 15% reuse their solutions. In addition, this tabulation shows that 25% of the photographic processing plants use squeegees and 20% use wash water controls. It is apparent that these in-plant pollution abatement practices are well demonstrated and are found in photographic processing plants ranging in size from less than 1,000 gpd to over 50,000 gpd operations.

EROS has designed a "Chemical Management System" to handle the chemicals used at their Sioux Falls, S.D. location. The system involves reuse of fixers, bleach/fixers, and bleaches, and a waste destruct system which detoxifies the chemicals before they are discharged. The system is controlled by a mini-digital computer with a panel display of actual working condition.

The "Chemical Management System" is divided into eleven separate systems which are discussed below. Four fix regeneration systems are used to desilver the fix with thiosulfate and recycle the regenerated fix back to the process. One bleach/fix recovery system is used to desilver this formulation electrolytically. The bleach/fix is then aerated to oxidize the ferrous ion, and then regenerated with fresh chemicals for reuse. One bleach reuse system is used to ozonate the used bleach. The ozone converts the ferrocyanide to ferricyanide. The regenerated bleach is mixed with fresh chemicals and reused.

Two waste systems are used to desilver (electrolytically) the used fix and bleach/fix which will not be reused. The wastewater is then pumped to the "General Waste System". The waste bleach also has a separate treatment system. It is treated chemically by either precipitation with ferrous sulfate or with sodium hydroxide/sodium hypochlorite reaction. The treated wastewater is then discharged to the waste treatment ponds.

The tenth step of the system is the "General Waste System" which consists of a series of tanks with ozonation in each. This system reduces the COD from an average of 25,000 mg/l to less than 5,000 mg/l. The ozonated water is then discharged to the treatment ponds.

The final step of the system is a "Quick Dump System" which holds any process dumps until the "General Waste System" can handle the extra flow.

The waste treatment system at EROS Data Center consists of a series of five ponds, one aerated, one settling, two polishing, and a final lake. The system receives the ozonated wastewater and the used chemicals which undergo easy biodegradation (stops, stabilizers, prehardeners, and neutralizers). On a yearly average, the treatment system has achieved a COD of 30 mg/l, ferrocyanide of 0.05 mg/l and a total silver of 0.006 mg/l.

A. Silver Recovery

Basically there are four methods of recovering silver from photographic processing solutions: metallic replacement, electrolytic plating, ion exchange and chemical precipitation. These methods can be used singly or in combination, depending on which is most suitable for the particular needs of the user. These four methods are examined in detail.

Metallic Replacement

Metallic replacement occurs when a metal, such as iron, comes in contact with a solution containing dissolved ions of a less active metal, such as silver. The dissolved silver, which is present in the form of a thiosulfate complex, reacts with solid metal (iron); the more active metal (iron) goes into solution as an ion, and an ion of the less active metal becomes solid metal (silver).

Silver ions will displace ions of many of the common metals from their solid state. Zinc or iron can be used to recover silver from fixes. Because of its economy and convenience, steel wool is the form of metal used most often. Furthermore, the zinc that would be carried into the drain is potentially a pollutant. Its use, therefore, is not generally considered acceptable from an environmental standpoint.

The acidity of the fix is an important factor when using steel wool in the recovery of silver. Below a pH of 4, the dissolution of the steel wool is too rapid. Above a pH of 6.5, the replacement reaction may be so slow that an excessive amount of silver may be lost because of the long reaction time required to recover the silver. Silver loss in this case will depend on the flow rate through the reaction cartridge.

Silver recovery by metallic replacement is most often carried out using commercially available cartridges consisting of a sealed plastic bucket containing steel wool. The fixer that comes out of a steel wool cartridge will usually contain less than 50 mg/l silver. Common practice is to replace the cartridge when the silver reaches 1,000 mg/l, as shown on a silver test paper. With careful maintenance, 90% or more of the silver in the fixer can be recovered by this method.

Electrolytic Recovery

In the electrolytic method of recovery, silver is removed from fixing baths by passing a controlled, direct electrical current between two electrodes (cathode and anode) suspended in the fixer solution. Silver is deposited on the cathode in the form of nearly pure silver plate. The cathodes are removed periodically, and the silver is stripped off.

Electrolytic systems can be installed in two basic ways. One is to de-silver the fixer overflow from a processing machine as it flows to the sewer. The system can be operated for either a batch or a continuous flow cell. Another method is to remove silver from the fixer in a continuously recirculating in-line system at approximately the rate at which silver is being added by processing. The latter procedure has the advantage of maintaining a low silver concentration in the processing bath so that the amount of silver carried out with the fixer into the wash tanks is minimal. A modification of the circulating system can collect fixer overflowing from several processing machines, deliver it in a separate electrolytic system, and then reconstitute the de-silvered fixer to supply the processing equipment again where recommended by the manufacturer.

In-line electrolytic silver recovery can maintain the silver concentration in a recirculated fixer system between 500 mg/l and 1,000 mg/l. When used as a tailing or terminal treatment, a silver concentration of 20 mg/l to 50 mg/l can be achieved.

Ion Exchange

Ion exchange is a unit process in which ions held by electrostatic forces to charged functional groups on the interior of a polymer bead are exchanged for ions in a solution.

Ion exchange is a method of removing certain dissolved solids from water. During the removal process, wastewater is percolated through a column or bed of ion-exchange material. Ion exchangers are very similar in construction to pressure-type sand filters, except that an ion-exchange material such as zeolite replaces the sand. The ion-exchange material has the capacity to replace mineral ions in the water with ions from inside the zeolite. No chemicals are added during the exchange process. Eventually the ion-exchange capacity of the zeolite is exhausted and it is then necessary to regenerate it by addition of a chemical.

A number of synthetic ion-exchange resins have been developed making it now possible to remove either or both anions and cations from the solution. The most common set up is to run the ion-exchange columns in series but any combination can be set up depending on the requirements of the specific situation.

When resins are exhausted they must be regenerated; an acid is used to supply hydrogen ion to a cation resin, and a base is used to supply hydroxyl ions to an anion resin. Where water reuse is mandatory, it can be used to keep down the buildup of certain undesirable dissolved solids. The water that is put through the ion exchange process should first have had as much of the dissolved organics removed as possible in order to minimize the danger of fouling the resin. Ion-exchange units can remove silver to virtually nondetectable limits from a waste stream if operated properly.

Sulfide Precipitation

Silver may be precipitated from fixers and their washes with sodium sulfide. The precipitation is quantitative in an alkaline solution, and the resultant silver sulfide is one of the most insoluble substances known. It has a solubility product of about 10^{-50}. The physical characteristics are not as favorable as the chemical characteristics. Silver sulfide tends to form colloidal suspensions. Its very small particle size makes filtration difficult, and the filter cake produced is extremely dense. Diatomaceous earth filter aid can be used to improve filtration. About three grams of filter aid are required for each gram of silver if a conventional filter press is used.

With sulfide precipitation it is possible to remove virtually all the silver from both the fixer and the wash following the fixer. Tests on experimental equipment have given results of less than 0.5 mg/l. The actual concentration usually depends on the efficiency of the filtering or settling step. Any silver lost is in the form of insoluble silver sulfide particles.

B. Regeneration of Ferricyanide Bleach

The basis for all the regeneration methods is the use of a sufficiently strong oxidizing agent that has reaction products compatible with or used in the process. Since bromide is required in the bleach formula, bromate, bromite, and elemental bromine have been used. Persulfate can be used because some sulfate can be tolerated. Ozone, hydrogen peroxide, and electrolytic oxidation have also been used because they leave no chemical by-products.

Persulfate Regeneration

In actual practice, persulfate is most widely used. This technique has the advantages of being simple to use, involving no significant capital expenditure, and requiring only comparatively safe and stable chemicals. However, regeneration of a bleach with persulfate results in a build-up of the sulfate ion that slows the rate of bleaching. The build-up of sulfate is higher in bleaches for reversal products because of the comparatively large amounts of persulfate used in the regeneration process. In some processes, especially if squeegees are used to minimize water carry-in, the sulfate build-up may require the sewering of up to 10 percent of the bleach for each regeneration cycle in order to maintain adequate bleaching.

Ozone Regeneration

This process is characterized by the following stoichiometric reaction:

$$\begin{array}{ccccccccccc} 2[Fe(CN)_6]^{-4} & + & H_2O & + & O_3 & = & 2[Fe(CN)_6]^{-3} & + & 2(OH)^{-1} & + & O_2 \\ \text{ferrocyanide} & & \text{water} & & \text{ozone} & & \text{ferricyanide} & & \text{hydroxyl} & & \text{oxygen} \\ \text{ion} & & & & & & \text{ion} & & \text{ion} & & \end{array}$$

The pH of the bleach increases as the reaction proceeds; consequently, it is necessary to add acid. Bromide is required in the bleaching process; the use of hydrobromic acid, therefore, furnishes both the bromide and the hydrogen ion. Theoretically, one bromide ion is required for each ferrocyanide ion that is oxidized to ferricyanide. The hydrobromic acid avoids all build-up of sulfate and other unwanted products. If in practice there is a slight build-up of bromide ion, a small amount of sulfuric acid could be added without danger of high sulfate build-up. Likewise, slight pH adjustments could be made with sulfuric acid.

C. Developer Recovery

Developers become exhausted both by loss of active developing agents and by increase of reaction products. The limiting factor is usually the increased bromide concentration. Two approaches may be taken to reuse developers: 1) the reaction products can be removed so that the bulk of the solution may be reused; or 2) specific chemicals can be separated from the bulk of the solution and reused with or without further purification.

Ion Exchange

Ion exchange generally can give a greater reduction in chemical usage. As an example, bromide and developer decomposition products can be removed by ion exchange from Eastman Color Developers; other constituents are not affected. After passing through an ion exchange column, the developer is reconstituted to replenisher strength and is reused.

Precipitation and Extraction

The recovery of specific chemicals may not have as great an effect on reduced chemical usage as the removal of bromide by ion exchange, but significant cost savings can be realized and certain non-biodegradable organics can be removed. The most widely practiced application is the recovery of couplers from the various color developers in the process for Kodachrome film. The couplers are soluble in an alkaline solution but precipitate at a neutral or acid pH.

It is common practice to use CO_2 to adjust the solution to pH 7 and then remove the precipitated coupler by centrifuging. The coupler is dried, assayed, and sometimes repurified.

Developing agents can be extracted with organic solvents using conventional liquid-liquid-extraction techniques. One problem is that unwanted substances are also extracted, often making the chemical analysis of the extract difficult. This technique is not in use at the present time and is being considered only for possible use in the event of shortages of certain chemicals.

D. Use of Squeegees

Effluent loads can also be minimized in the photographic process by the correct use of mechanical aids such as squeegees, which generally inhibit the carry-over from one tank to the next.

There are four general locations for squeegee action in the photographic process:

1. After the photographic solution but prior to a wash

2. After a wash but prior to a photographic solution
3. Between two photographic solutions
4. After a wash but prior to drying

Generally, a squeegee following a photographic solution will have relatively little effect on the replenishment rate of that solution. An exception to this would be the first solution in the sequence, such as a developer or prehardener. The first solution is usually alkaline and causes a considerable swelling of the gelatin; consequently, large amounts of chemicals are included in the swollen emulsion. Solution removed in this manner is not replaced by carry-over from any previous solution. The squeegee action here will retain most of the solution on the surfaces of the film, thus possibly reducing the replenishment rate. The advantage of the squeegee in this situation, however, is not only to reduce the replenishment rate, but to increase chemical recovery. The squeegee prevents the processing solution from being transported by the film to the wash water which is generally discarded. Instead it allows more of the solution to overflow where it is collected and ultimately reused or treated to remove unwanted materials.

The squeegee following a wash, like the processing solution discussed, will have little effect on the wash itself. Again, the water must go somewhere and if the squeegee removes it from the film, the resulting build-up of water will simply go out the overflow if the wash rates are not reduced accordingly. The important effect of the squeegee in this instance is evident by a reduction in replenishment in the next bath caused by the reduction in dilution water. The reduction of dilution water results in higher concentration in the bath, which generally means both a cost savings to the processor and fewer chemical pollutants going to the sewer.

Careful study is required when considering a squeegee between two photographic solutions. There may be some interdependence between the two chemical baths that were designed into the process. By placing a squeegee between them, the equilibrium could be upset, thus reducing the effectiveness of the process. A detailed list of advantages and disadvantages of squeegees is shown in Table VII-2.

E. Use of Holding Tanks

Large-scale processors operate on a continuously replenished system, not in batches. Normal operations require no

TABLE VII -2

Squeegee Summary

Squeegee Type	Advantages	Disadvantages
Vacuum	1. Power requirement less than air squeegee 2. Moisture carried away fromffilm	1. High maintenance required 2. Film damage possible 3. Requires a vacuum source
Air	1. No physical contact with film 2. Good squeegee action 3. Simplicity	1. Supply of oil free air 2. High noise level 3. Solution moisture - - causing possible contamination 4. High maintenance required
Rubber	1. Inexpensive 2. Simplicity	1. High blade wear 2. Film damage possible
Offset Polyurethane	1. Good squeegee	1. Film damage possible 2. Maintenance required 3. Lower efficiency at high film speeds
Spring Loaded Polyurethane	1. Constant tension 2. Low Blade pressure 3. Self-aligning 4. High efficiency at high film speeds 5. Size not limited	1. Film damage possible 2. Eventual blade wear
Rotary Buffers	1. Simplicity 2. Good squeegee action 3. Low power consumption 4. Size not limited	1. Separate power drive required 2. Maintenance for nap wear
Wringer Sling	1. No external power supply 2. Good crossover squeegee 3. Relatively simple	1. Film damage possible 2. Operation limited to high film speeds 3. Fair squeegee action

dumping of solutions. However, because of an emergency, periodic shutdown, contamination, or exhaustion of solutions, occasional disposal of a processing solution may be necessary. If this is suddenly "dumped" untreated, it may shock load or overload wastewater treatment facilities. This situation can be avoided by a controlled discharge of the solution. A holding tank large enough to hold the total volume of solution that might be reasonably expected to be dumped at any one time is used, and the solution in the holding tank should be treated to remove silver and cyanides before being bled slowly to the wastewater sewer.

End-of-pipe Treatment

A. Biological Treatment

Activated Sludge

An activated sludge pilot unit is being operated on photographic processing wastes. BOD reductions of over 80% have been obtained with this system while the silver influent concentration was as high as 5 mg/l. In addition, the sludge in the aeration tank had a silver content greater than 250 mg/l of silver. This silver is predominantly in the form of insoluble silver sulfide with a smaller amount of elemental silver. The extended aeration unit has a capacity of 20,000 gpd and was chosen for its high potential for BOD_5 reduction and its low solids production. The processing wastes fed to the extended-aeration plant were collected from nine processing machines. These wastes, which varied over a period of years, included effluents from Ektaprint R, Ektaprint C, and Ektaprint 3 chemicals and from the E-4, C-22, CRI-I, and K-12 processes. The effluents from the machine flows were collected and pumped to two 1,000-gallon fiberglass holding tanks. These were used to smooth out surges and to provide a constant source of feed for the treatment plant and insure a constant flow to the system.

During the first year of operation BOD_5 reductions were low, because of a combination of hydraulic overloading and poor sludge settling characteristics, which caused high suspended solids in the effluent. As a result, the MLSS content in the aeration tank was low. This was remedied by the installation of sand filters to increase MLSS by recycling the backwash wastewater into the aeration tank. After the sand filters were put into operation, BOD reduction immediately improved. For example, before implementation of the sand filters, overall BOD_5 reductions of 85% were obtained only 12% of the time. After the installation of the filters, 85% BOD5 reductions were obtained 64% of the time. Simultaneously, the food to microorganisms ratio decreased because of the MLSS increase. The pH of the influent and effluent was monitored daily. The pH of the influent was always alkaline, varying from 7.2 to 10.3. More than 98% of the time, the effluent pH was between 6.5 and 8.5.

Lagoons

Lagooning and ponding are popular methods for treating industrial and municipal wastes. However, a significant amount of acreage is required for satisfactory treatment. The use of surface mechanical aeration equipment or of diffused aeration has helped lagoons become an economical alternative in biological waste treatment of industrial wastes.

Several processing laboratories have used lagoons for treating their photographic processing effluent. The overall BOD5 reductions ranged from 30% to 90% depending upon the loading and the use of supplemental aeration.

According to the literature a photographic processing laboratory (plant) in suburban Detroit has been treating its wash waters in a lagoon prior to discharge to a small receiving stream. A second example of a successful biological system treating photographic processing effluent is a facility in Webster, New York. This wastewater treatment plant utilized a two-stage aerated lagoon. Oxygen-demand reductions were in excess of 90% and the silver content in the lagoon systems was generally in the 1 to 5 mg/l range. Another example is the previously mentioned system at the EROS Data Center in Sioux Falls, South Dakota.

B. Physical/Chemical Treatment

Ozonation

Biological treatment experiments have shown that the photographic chemicals used in the largest quantity (such as thiosulfate, acetate, sulfite, hydroquinone, and benzyl alcohol) respond well to biological treatment. However, a small percentage of chemicals (such as color-developing agents and EDTA) appear to be biodegraded only slowly or not at all. Consequently, ozonation, a non-biological waste treatment system, has been tested to evaluate the treatability of such chemicals.

The results of these experiments are summarized in Table VII-3. Only acetate and glycine were found to be untreatable, and ethylene glycol, methanol, ferricyanide, and ethylene diamine were marginally treatable;. The other chemicals are considered treatable. However, the degree of degradation by ozonation is subject to variation and is not fully substantiated.

Several factors may influence the rate of ozonation of photoprocessing wastes. These include the contact time between gas and solution, gas bubble size and flow rate, concentration of ozone, nature and concentration of chemical, temperature, pressure, pH, and the presence of catalysts.

The suggested uses of ozone are: 1) as a preliminary treatment for overflow color developer solution; 2) as a preliminary treatment for solutions that may contain substantial amounts of thiocyanate, formate, EDTA, or black and white developing agents (other than hydroquinone); and 3) as a means of tertiary treatment and disinfection for an overall mixed waste, after that waste has first been treated biologically.

Ozone Decomposition of Ferrocyanide

The decomposition of the ferrocyanide ion has been found to be a very complex mechanism, involving a number of competing reactions.

$$2\ Fe(CN)_6^{-4} + O_3 + H_2O = 2\ Fe(CN)_6^{-3} + 2\ OH^- + O_2$$

$$Fe(CN)_6^{-3} = Fe^{+3} + 6\ CN^-$$

Destruction of free cyanide ion

$$CN^- + O_3 = OCN^- + O_2$$

Destruction of cyanate ion

$$OCN^- + 2H^+ + H_2O = CO_2 + NH_4^+$$

$$OCN^- + NH_4^+ = NH_2^-\ CONH_2^+$$

$$2\ OCN^- + H_2O + 3O_3 = 2\ HCO_3^- + N_2 + 3\ O_2$$

Free cyanide breaks down readily in the presense of ozone to the cyanate ion, which is generally considered to be less toxic than cyanide. The cyanate ion is not stable under oxidation conditions, but its oxidation reaction is not well

Table VII -3

Summation of Ozonation Results

Treatable Chemicals

HAS
Benzyl Alcohol
Color Developing Agent
Thiosulfate
Sulfate
Hydroquinone
Kodak Elon Developing Agent
Phenidone
EDTA
Ferric EDTA
Formate Ion
Formalin
Maleic Acid
Eastman Color Print Effluent
Ektaprint 3 Effluent
Flexicolor Effluent
Synthetic Effluent from Combined Process

Non-treatable Chemicals

Glycine
Acetate ion

Marginally Treatable Chemicals

Ethylene Glycol
Methanol
Ferricyanide
Ethylene Diamine
Ektachrome ME-4 Effluent

understood. Apparently, the breakdown consists of a combination of reactions, including both hydrolysis and oxidation.

Activated Carbon Adsorption

The feasibility of treating various photographic processing chemicals and solutions by activated carbon is summarized in Table VII-4.

As with ozonation, more of the photographic processing chemicals are treatable than are untreatable.

Chemical Precipitation

Precipitation can be used effectively for the removal of ferrocyanide and ferricyanide from photoprocessing wastewaters. These complex ions can be precipitated by using iron salts; ferrous sulfate has proved to be an economical and effective precipitant.

When employing precipitation for removal of ferri-ferrocyanide, four items must be considered: equalization, chemical feed system, clarification, and solids handling and disposal. The purpose of equalization is to minimize the peaks in flow and concentration so that the treatment system can be designed to provide reliable and consistent results. The chemical feed system adds the precipitation chemicals in the proper quantity at the proper point. Ferrous sulfate dosage in the range of 250-500 mg/l with pH of about 8.5 or greater has been reported to give good results. The precipitated materials may be removed in a clarifier.

The advantages of the precipitation technique for ferri-ferrocyanide over other forms of destruction or removal are: 1) precipitation occurs instantaneously, and the system thus requires less reaction tank capacity per unit volume of wastes; 2) precipitation removes virtually all of the ferri-ferrocyanide; 3) hour-to-hour fluctuations in concentration of the waste do not significantly change the operating characteristics; and 4) the process works equally well with a variable influent since only the ferri-ferrocyanide in the system reacts with iron. Disposal of the ferrocyanide sludges presents some problems.

Reverse Osmosis

The major chemicals used in photoprocessing have been tested to find the degree to which they are stopped by a cellulose acetate membrane under reverse osmosis conditions. Water,

Table VII -4

Feasibility of Treating Photographic Processing Chemicals with Activated Carbon

Treatable Solutions

- Ektaprint 3 Mixed Effluent
- Ektaprint R Color Developer
- Color Developers
  - CD-1, CD-2, CD-3, CD-4
- Anti-Calcium No. 3
- Elon
- Phenidone
- Citric Acid
- Benzyl Alcohol
- Hydroquinone
- $Na_4EDTA \cdot 2H_2O$
- $NH_4FeEDTA$

Non-Treatable Solutions

- Citrizinic Acid
- HAS
- $Na_2S_2O_3 \cdot 5H_2O$
- Ethylene Glycol
- Potassium Oxalate
- Ferricyanide

Marginally-Treatable Solutions

- Ethylene Diamine
- Formic Acid
- Acetic Acid
- Overall Photographic Effluent

hydroquinone, and alcohol passed through the membrane easily, but halides and the complex inorganic ions found in fixing baths and bleaches were easily stopped. Recent studies have confirmed that fixer wash water is easily separated into two streams, one containing the concentrated salts and the other stream containing nearly pure water. Thus, it is possible to return the fixer concentrate or the bleach concentrate to the mix area for reuse in building a new replenisher. The fixer concentrate contains virtually all of the silver complex that was in the wash water, and it is now practical to remove it electrolytically.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

General

Quantative cost information for the suggested end-of-pipe treatment models is presented in the following discussion for the purpose of assessing the economic impact of the proposed effluent limitations and guidelines. An economic analysis of treatment cost impact will be available in a separate document.

In order to evaluate the economic impact of treatment on a uniform basis, end-of-pipe treatment models which will provide the desired level of treatment were proposed. In-plant control measures have not been evaluated separately. Although there are general cost and energy requirements for equipment items, these correlations are usually expressed in terms of specific design parameters. Such parameters are related to the production rate and other specific considerations at a particular production site.

In this point source category, there is a wide variety of process plant sizes and unit operations. Many detailed designs might be required to develop a meaningful understanding of the economic impact of process modifications. Such a development is really not necessary, however, because the end-of-pipe models are capable of attaining the recommended effluent limitations. An optional biological design for an end-of-pipe treatment model has been provided. In addition, in-plant modification costs for a 20,000 gpd flow system which incorporates electrolytic silver recovery, squeegees on photoprocessing machines and bleach regeneration are presented. Costs for these in-plant changes for this size system is approximately $67,000 on an installed basis. These in-plant controls constitute the BPT treatment model. These models can be related directly to the range of influent hydraulic and organic loading within each plant. Costs associated with these systems can be divided by the production rate to show the economic impact of the system in terms of dollars per 1,000 square feet of product or dollars per 1,000 square meters of product. The combination of in-plant controls and end-of-pipe treatment used to attain the effluent limitations, guidelines and new source performance standards presented in this document should be a decision made by the individual plant based generally upon economic considerations.

The major non-water quality consideration associated with in-process control measures is the means of ultimate disposal of wastes. As the volume of the process RWL is reduced, alternative disposal techniques such as incineration, pyrolysis, evaporation, ocean discharge, and deep-well injection become more feasible. Recent regulations tend to limit the use of ocean discharge and deep-well injection because of the potential long-term detrimental effects associated with these disposal procedures. Incineration and evaporation are viable alternatives for concentrated waste streams. Considerations involving air pollution and auxiliary fuel requirements, depending on the heating value of the waste, must be evaluated individually for each situation.

Other non-water quality aspects such as noise levels will not be perceptibly affected by the proposed wastewater treatment systems. Equipment associated with in-process and end-of-pipe control systems would not add significantly to current noise levels.

Extensive annual and capital cost estimates have been prepared for the end-of-pipe treatment models to evaluate the economic impact of the proposed effluent limitations and guidelines. The capital costs were generated on a unit process basis (e.g., equalization, neutralization, etc.) and are reported in the form of cost curves in Supplement A for the proposed treatment systems. The particular cost curves used in the treatment models for photographic processing are shown later in this section under the paragraphs titled BPT Cost Model and BAT Cost Model. The following percentage figures were added on to the total unit process costs to develop the total capital cost requirements:

Item	Percent of Unit Process Capital Cost
Electrical	14
Piping	20
Instrumentation	8
Site Work	6
Engineering Design and Construction Surveillance Fees	15
Construction Contingency	15

Land costs were computed independently and added directly to the total capital costs.

Annual costs were computed using the following cost basis:

Item	Cost Allocation
Capital Recovery plus Return	10 yrs at 10 percent
Operations and Maintenance	Includes labor and supervision, chemicals, sludge hauling and disposal, insurance and taxes (computed at 2 percent of the capital cost), and maintenance (computed at 4 percent of the capital cost).
Energy and Power	Based on $0.02/kw hr for electrical power and 17¢/gal for grade 11 furnace oil.

The 10-year period used for capital recovery is acceptable under current Internal Revenue Service regulations pertaining to industrial pollution control equipment.

The following is a qualitative as well as a quantitative discussion of the possible effects that variations in treatment technology or design criteria could have on the total capital costs and annual costs.

Technology or Design Criteria	Capital Cost Differential
1. Use aerated lagoons and sludge dewatering lagoons in place of the proposed treatment system.	1. The cost reduction could be 20 to 40 percent of the proposed figures.
2. Use earthen basins with a plastic liner in place of reinforced concrete construction, and floating aerators with permanent-access walkways.	2. Cost reduction could be 20 to 30 percent of the total cost.
3. Place all treatment tankage above grade to minimize excavation, especially if a pumping station is required in any case. Use all-steel tankage to minimize capital cost.	3. Cost savings would depend on the individual situation.
4. Minimize flows and maximize	4. Cost differential would

concentrations through extensive in-plant recovery and water conservation, so that other treatment technologies, e.g., incineration, may be economically competitive.	depend on a number of items, e.g., age of plant, accessibility to process piping, local air pollution standards, etc.

All cost data were computed in terms of August 1972 dollars, which corresponds to an Engineering News Records index (ENR) value of 1780.

This section provides quantitative cost information relative to assessing the economic impact of the proposed effluent limitations on the photographic processing point source category. In order to evaluate the economic impact on a uniform treatment basis, end-of-pipe treatment models are proposed which will provide the desired level of treatment:

Technology Level	End-of-Pipe Treatment Model
BPT	In-plant modifications
NSPS	BPT plus cyanide destruction, dual-media filtration and ion exchange
BAT	BPT plus cyanide destruction, dual-media, filtration and ion exchange

The combination of in-plant controls and end-of-pipe treatment used to attain effluent limitations and guidelines is left up to the individual manufacturer to choose on the basis of cost-effectiveness.

BPT Cost Model/In-Plant Modification Costs

Cost estimates obtained from an industry source for a 20,000 gallons per day system is as follows:

Electrolytic silver recovery	$22,000
Squeeges on machines	5,460
Bleach regenerators	40,000
Total Installed Cost	$67,570

Biological Cost Model

Activated sludge treatment process has been selected as an alternate treatment system. The 20,000 gpd activated sludge facility was not chosen as the model for BPT treatment for economic reasons. The BPT cost model is based on in-plant modifications only. Performance data on other end-of-pipe treatment systems presently on line were insufficient. Furthermore, a survey of the photographic processing subcategory indicated that there are no full plant scale end-of-pipe wastewater treatment systems.

The application of the activated sludge treatment scheme in the photographic processing subcategory was made because of the success encountered by the system in reducing BOD_5. Average BOD_5 removals from this process were 70%. Higher BOD_5 removals (perhaps as much as 85%) are possible by increasing the size of the equalization tank used in the biological model plant. This slight design change will allow the treatment process to accomodate variable incoming flows without adversely affecting performance. Also, allowances were made in the proposed biological system to handle any excessive sludge produced by the upgraded treatment process. Figure VIII-1 illustrates the unit processes included in the treatment system. A summary of the general design basis for this system is presented in Table VIII-1. Cost curves used to compute capital costs for biological model are:

Figure	Cost Curve	Description
VIII-3	No. 1	Equalization Basin
VIII-4	No. 5	Aeration Basin
VIII-5	No. 5B	Fixed Mounted Aerators
VIII-6	No. 2,6	Primary & Secondary Clarifier
VIII-7	No. 7	Sludge Thickeners

Specific in-plant modifications aimed to reduce both the silver and ferrocyanide concentrations in the wastewater flow should be incorporated into end-of-pipe treatment. These in-plant changes are considered part of good housekeeping practice; modifications include electrolytic silver recovery from the fix or bleach-fix baths, regeneration of the ferricyanide bleach by ozone, using ferric EDTA bleach in some processes after evaluating the respective effectiveness, using squeegees, and collecting the spent concentrated solutions in a holding tank for controlled bleed-off to a dilute wastewater stream.

BAT Cost Model

FIGURE VIII -1

Biological COST MODEL

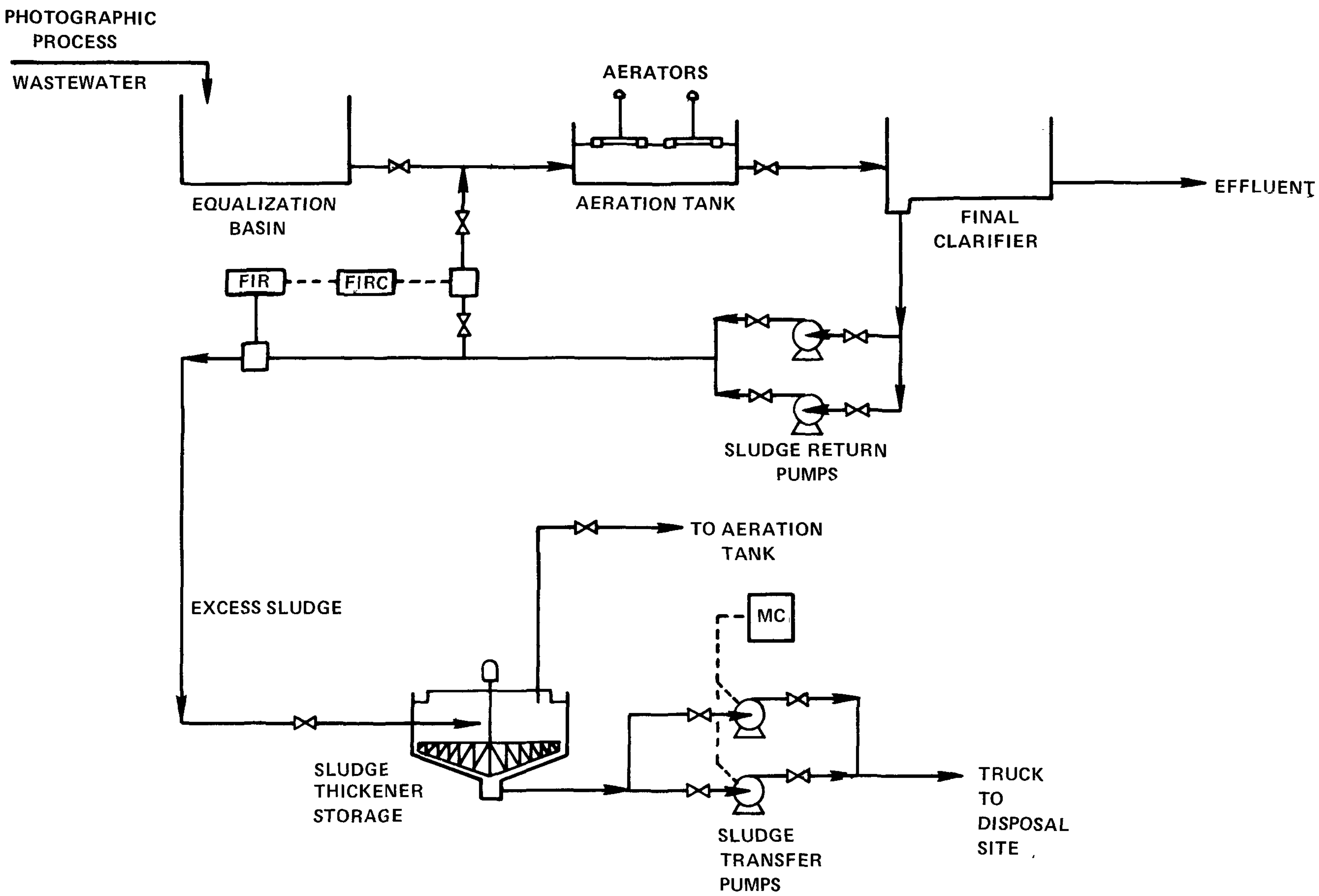


Table VIII -1

Biological Treatment System Design Summary

Treatment System Hydraulic Loading: 20,000 gpd

Equalization

For plants with less than 24-hour/day and 7 day/week production (as is the case for most photoprocessors), a minimum holding time of 1.5 days is provided, with continuous discharge from the equalization basin over 24 hours. Given the design flow of 20,000 gpd, the basin size becomes 30,000 gallons.

Aeration Basin

Aeration Basins are sized on the basis of historic treatability data collected during the survey. The aeration tank has a volume of 20,000 gallons. Mechanical turbine blowers will be provided to supply the air. There are sufficient phosphates and nitrates in the wastewaters to satisfy the nutrient requirement of the system.

Secondary Flocculator Clarifiers

Secondary flocculator-clarifiers are designed for an overflow rate of 300 gpd/sq ft. The required surface area of the clarifier is then 70 square feet.

Sludge Thickener

The thickener was designed on the basis of a solids loading of 6 lbs/sq ft/day.

Final Sludge Disposal

Excess biological sludge is disposed of to a sanitary landfill by a contract hauler.

The filtration of the effluent from the alternate biological system, using dual-media filters, was selected as the BAT treatment system. In order to protect the ion exchange beds for BAT removal of silver, dual-media filtration also applies. Filtration of the effluent from the biological treatment process would provide incremental BOD_5 reduction of 33 percent. Silver measured in the effluent from the model plant was 1 mg/l, which represents an 80 percent reduction from the influent to the biological system. Figures VIII-2a, VIII-2b and VIII-2c illustrate the unit processes involved in the treatment system. A summary of the general design basis for the system is presented in Table VIII-2. Unit process cost curve(s) employed to determine incremental capital costs for BAT cost filtration model is Figure VIII-8 cost curve No. 10, Multi-Media Filters Including Feed Well, Pumps and Sump.

Table VIII-2

BAT Treatment System Design Summary Photographic Processing Industry

Cyanide Destruction

The ferricyanide complex may be chemically destroyed by chlorination under alkaline conditions at pH 10 or higher. This alkaline chlorination will completely oxidize cyanide to carbon dioxide and nitrogen. Additional chlorine and contact time are required to oxidize the ferricyanide complex. A neutralization step was included after the contact tank to bring the pH back to a normal range. The cyanide destruct system was sized for the 5,000 ft^2 and the 50,000 ft^2 production plant sizes. The costs for the systems were developed from similar systems for the electroplating industry.

Dual-Media Filter

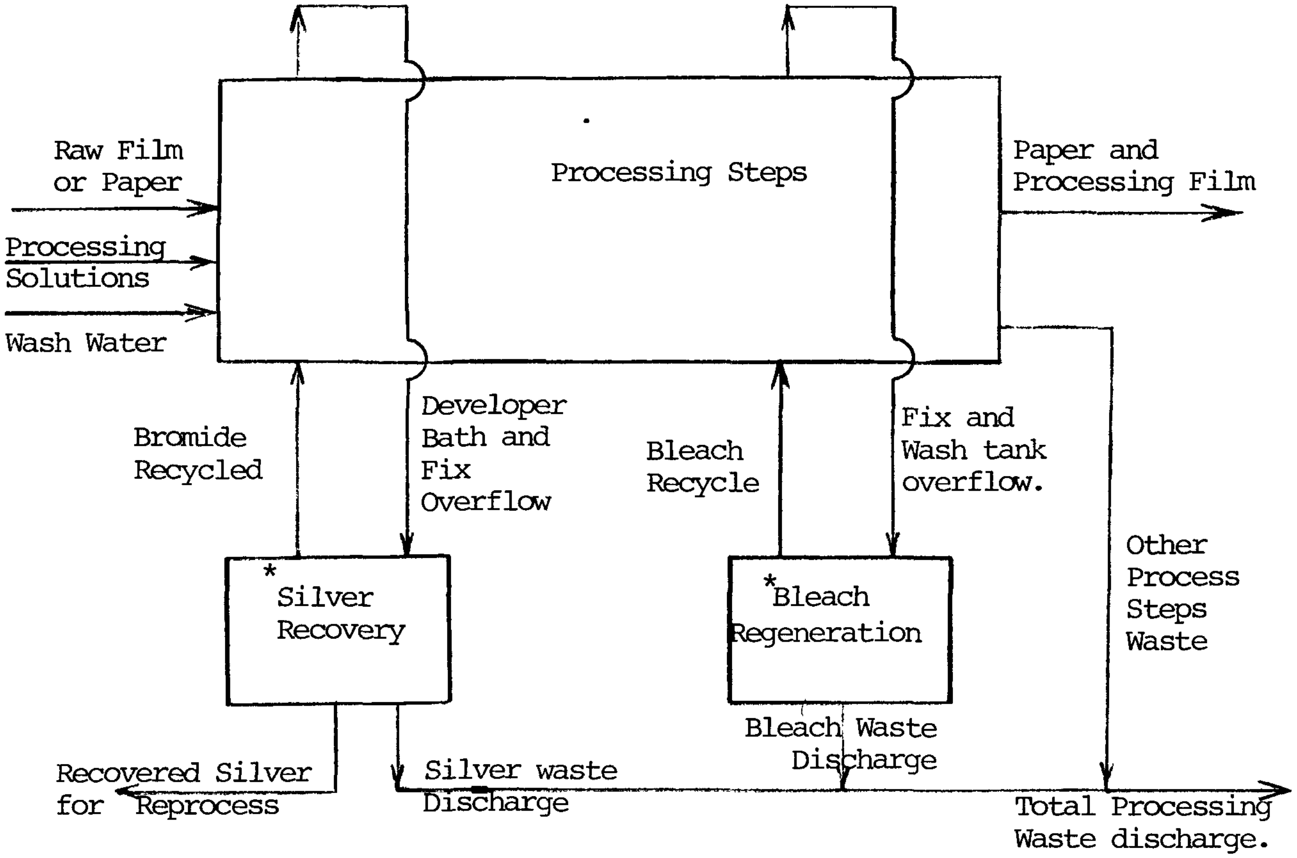
The filters are sized on the basis of an average hydraulic loading of 3 gpm/sq ft. Backwash facilities are sized to provide rates up to 20 gpm/sq ft and for a total backwash cycle of up to 10 min. in duration. The filter media are 18" of anthracite (0.45m), 6" of sand (0.15m), and a drainage bed of 12" (0.3m) of graded gravel.

Ion Exchange

Ion exchange is a unit process in which ions held by electrostatic forces to charged functional groups on the interior of a polymer bead are exchanged for ions in a

Figure VIII-1(a)

BPT Wastewater Treatment
Cost Model Flow Sheet



* In-Plant cost model, including squeegees.

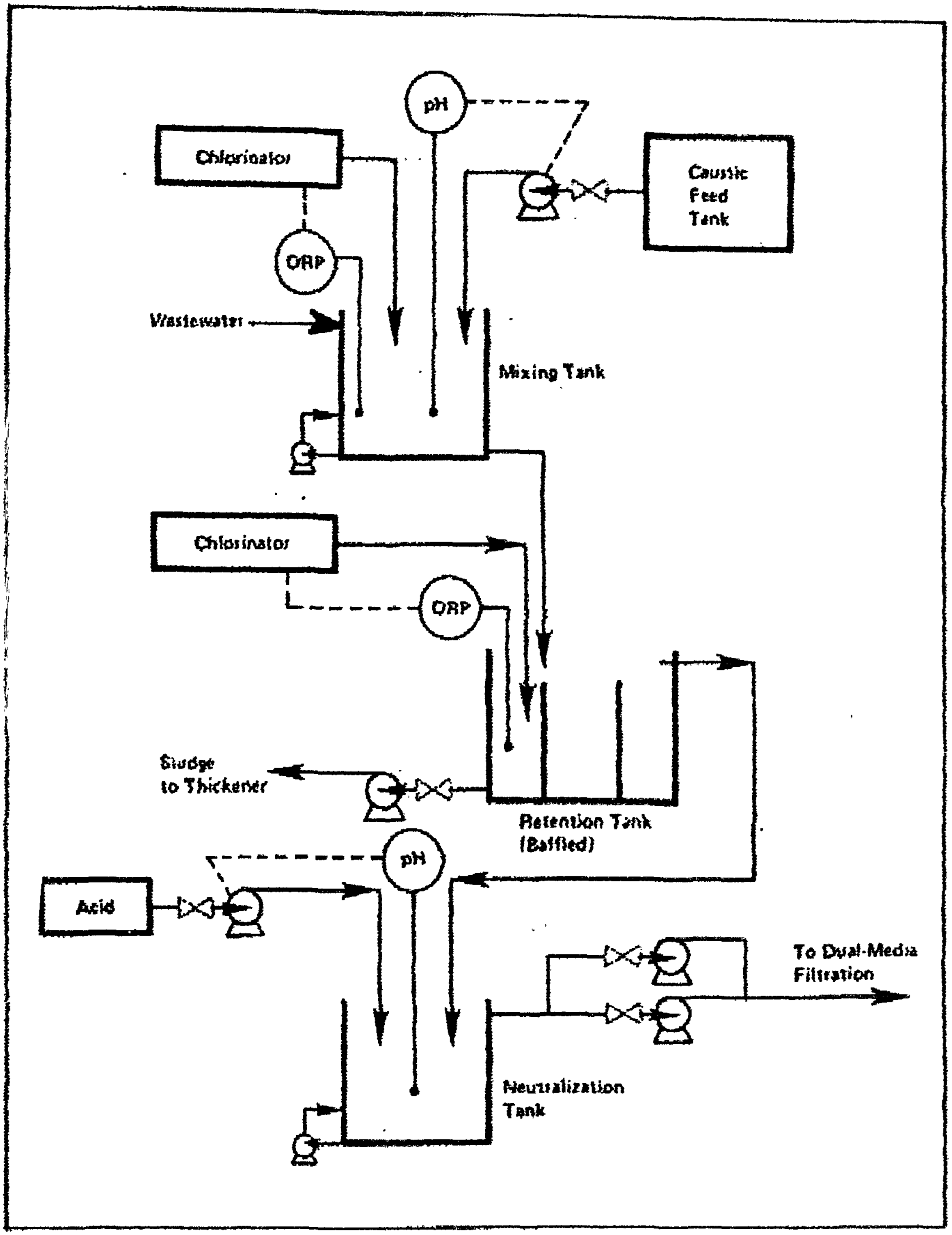


FIGURE VIII-2A BAT/NSPS WASTEWATER TREATMENT COST MODEL CYANIDE DESTRUCT FLOW SHEET

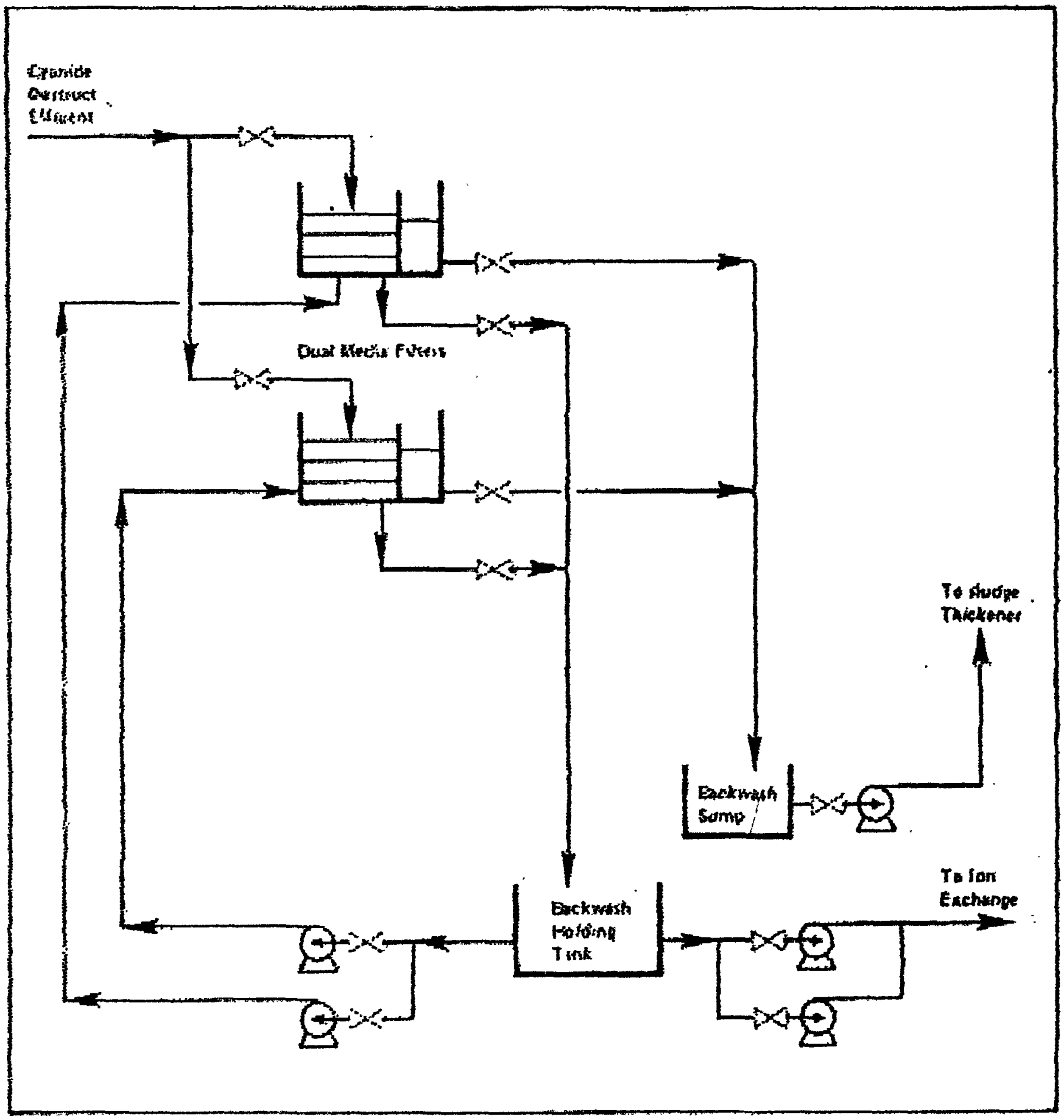


FIGURE VIII-2B BAT/NSPS WASTEWATER TREATMENT COST MODEL
FILTRATION FLOW SHEET

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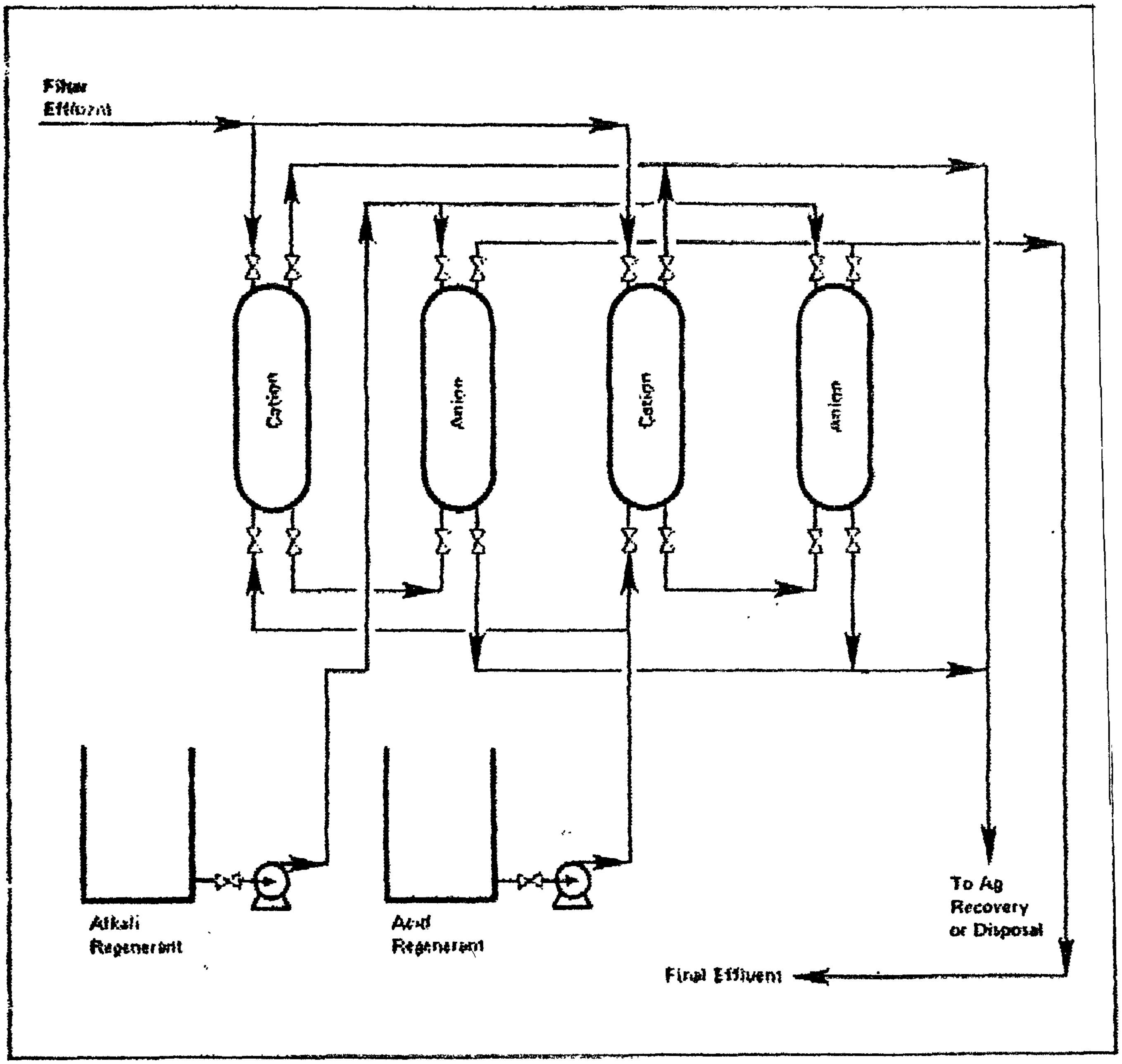

FIGURE VIII-2C BAT/NSPS WASTEWATER TREATMENT COST MODEL ION EXCHANGE FLOW SHEET solution. Both cationic and anionic resin columns were designed because the silver may exist in the wastewater with either a positive or negative charge. The ion exchange columns follow the filtration step to prevent the resins from becoming fouled due to particulate matter. The system design includes two columns for each type of resin in order to have flexibility of operation. The system cost was derived by adjusting the cost from a similar system on the basis of flow differences. The capital costs were also adjusted from the article to the 1780 ENR Index used throughout this document.

NSPS Cost Model

For new plant sources, the in-plant modifications available for reducing the raw waste loads should be applied wherever possible. In addition, a minimum of end-of-pipe treatment as described in the BAT treatment system subsection should be applied; this consists of the BPT in-plant control system plus cyanide destruction, dual-media filtration and ion exchange for residual silver removal.

Cost

Capital and annual cost estimates were prepared for the treatment models described above. Average process water consumption (4,000 gal/1,000 sq ft) for the industry was based on the average of the three plants visited and 36 plants from the NAPM field survey. Costs were developed for an average flow rate of 20,000 gpd, as explained earlier in Section VII under "Size of Facility." In addition, a model was prepared for an average flow rate of 200,000 gpd. This additional model represents the costs for a plant with an average production of 4,650 square meters per day as compared to the 465 square meters per day production in the original model. The costs presented for BAT and NSPS in these tables are incremental costs over the cost for BPT. For example, in Table VIII-3 the total capital cost for the average size photoprocessing plant to attain BPT effluent limitation is $67,000. The incremental capital costs for achieving the recommended NSPS in Table VIII-3 would be $127,400. This cost would be in addition to the capital investment made to achieve the BPT effluent limitation.

Tables VIII-3 and VIII-4 also illustrate RWL and effluent limitations based on the production for an alternate biological model plant. Percent removals for BOD_5 and COD are based on past operating experience of the large-scale activated sludge treatment process.

TABLE VIII -3

Wastewater Treatment Costs for BPT, NSPS and BAT Effluent Limitations (ENR 1780 - August, 1972 Costs)

Photographic Processing Industry (5,000 sq ft/day Production Rate)

	RWL	Technology Level Biological Plus In-Plant	NSPS[2]	BAT[2]	BPT[4]
Average Production 465 sq m/day (5000 sq ft/day)					
Production Days 276					
Wastewater Flow - kL/day	75.7				
(gpd)	(20,000)				
kL/1,000 sq m	163				
(gal/1,000 sq ft)	(4000)				
BOD Effluent Limitation[3] - kg BOD/1,000 sq m product (lbs/1000 sq. ft.)	36.7 (7.50)	5.5 (1.13)	3.7 (.76)	3.7 (0.76)	-
COD Effluent Limitation[3] - kg COD/1,000 sq m product (lbs/1000 sq. ft.)	123 (25.1)	61.6 (12.6)	49.4 (10.1)	49.4 (10.1)	-
TOTAL CAPITAL COSTS		$ 247,000	$127,400	$127,400	$67,570
ANNUAL COSTS					
Capital Recovery plus return at 10% at 10 years		$ 40,300	$ 20,770	$ 20,770	$11,000
Operating + Maintenance		34,300	$ 5,600	$ 5,600	$ 5,660
Energy + Power		700	$ 600	$ 600	$ 940
Total Annual Cost		$ 75.300	$ 26,970	$ 26,970	$17,600
Cost[1] /1,000 sq m Product		$ 587	$ 210	$ 210	$ 137

[1] Cost based on total annual cost

[2] Incremental cost over BPCTCA cost

[3] Long term average

[4] Based on in-plant alone

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TABLE VIII -4

Wastewater Treatment Costs for
BPT, NSPS and BAT Effluent Limitations
(ENR 1780 - August, 1972 Costs)

Photographic Processing Industry
(50,000 sq ft/day Production Rate)

	RWL	Technology Level			
		Biological Plus In-Plant	NSPS [2]	BAT [2]	BPT[4]
Average Production 4650 sq m/day (50,000 sq ft/day)					
Production Days 276					
Wastewater Flow - kL/day	757				
(gpd)	(200,000)				
kL/1,000 sq m	163				
(gal/1,000 sq ft)	(400)				
BOD_5 Effluent Limitation[3] - kg BOD_5/1,000 sq m Product (lbs/1000 sq.ft.)	36.7 (7.50)	5.5 (1.13)	3.7 (0.76)	3.7 (0.76)	-
COD Effluent Limitation[3] - kg COD/1,000 sq m Product (lbs/1000 sq.ft.)	123 (25.1)	61.6 (12.6)	49.4 (10.1)	49.4 (10.1)	-
TOTAL CAPITAL COSTS		$ 783,000	$364,200	$364,200	$120,000
ANNUAL COSTS					
Capital Recovery plus return at 10%		$ 128,000	$ 59,400	$ 59,400	$ 19,500
Operating + Maintenance		$ 117,000	$ 33,500	$ 33,500	$ 9,900
Energy + Power		$ 6,000	$ 3,900	$ 3,900	$ 1,700
Total Annual Cost		$ 251,000	$ 96,800	$ 96,800	$ 31,100
Cost[1] /1,000 sq m Product		196	$ 75.40	$ 75.40	$ 24.23

[1] Cost Based on total annual cost

[2] Incremental cost over BPCTCA cost

[3] Long term average

[4] Based on in-plant alone.

Tables VIII-5 and VIII-6 present a breakdown of the BPT capital costs for the wastewater treatment systems which apply to in-plant modifications for both production rates.

Tables VIII-7 and VIII-8 show the BAT/NSPS capital costs for the wastewater treatment modules which include cyanide destruction, dual-media filtration and ion exchange.

These cost estimates were prepared based on the recommended design basis. Variations in the design basis or selection of alternative treatment processes can have appreciable effects on the reported capital costs, as discussed in the General section.

Energy

The size ranges of the BPT and BAT treatment models preclude the application of high-energy-using units such as sludge incinerators. Therefore, the overall impact on energy should be minimal. Table VIII-3 presents the cost for energy and power for the treatment models for BPT, BAT, and NSPS. The details for energy and power requirements are included in the Supplement A.

Non-water Quality Aspects

The major non-water quality aspects of the proposed effluent limitations encompass sludge disposal for the alternate biological model and noise and air pollution.

The biological treatment model proposes landfilling of biological sludge. If practiced correctly, this disposal method will not create health hazards or nuisance conditions. However, there is a widespread diversity of opinion over the effects of silver leaching into ground water supplies. Carefully controlled sludge application should minimize these problems.

Solid waste control must be considered. Pollution control technologies generate many different amounts and types of solid wastes and liquid concentrates through the removal of pollutants. These substances vary greatly in their chemical and physical composition and may be either hazardous or non-hazardous. A variety of techniques may be employed to dispose of these substances depending on the degree of hazard.

If thermal processing (incineration) is the choice for disposal of sludge to concentrate silver in the resulting ash for recovery purposes, provisions must be made to ensure

TABLE VIII -5

SUMMARY OF CAPITAL COSTS
FOR WASTEWATER TREATMENT

Biological Plus
In-Plant Model

Category Photographic

Model Size 5,000 sq ft/day

Unit Processes		Capital Cost (ENR 1780 August 1972 Costs)	
Low Lift Pump Station			
Equalization Basin (concrete)		$21,000	
Equalization Basin Mixers			
Neutralization Tanks			
Lime Additions Facilities			
Sulphuric Acid Additions Facilities			
Rapid Mix Tanks			
Primary Flocculator Clarifier			
Sludge Pumps			
Aeration Basins (concrete)		$22,800	
Aeration Basin Aerators		$11,200	
Secondary Flocculator Clarifier		$16,150	
Recycle Pumps			
Nutrient Additions Facilities			
Polymer Additions Facilities			
Sludge Thickeners		$22,300	
Aerobic Digesters			
Digester Aerators			
Sluge Pumps			
Vacuum Filters			
Flow Measurement & Sampling			
Subtotal A			$ 93,450
Piping	20% of (A)	$18,690	
Electrical	14% of (A)	$13,083	
Instrumentation	8% of (A)	$ 7,476	
Sitework	6% of (A)	$ 5,607	
Land			
Subtotal B			$ 44,856
Total A & B			$138,306
Engineering	15% of (A) & (B)	$20,746	
Contingency	15% of (A) & (B)	$20,746	
Subtotal C			$ 41,492
In-Plant Modifications		$67,570	
GRAND TOTAL (A + B + C + In-Plant)			$247,368
		(rounded)	$247,000

TABLE VIII-5(a)

Summary of Capital Cost For Wastewater Treatment

In-Plant (BPT) Model

Category: Photographics

Model Size: 5,000 sq ft/day

Unit Processes	Capital Cost (ENR 1780 August, 1972 costs)
Electrolytic Silver Recovery[1]	$22,000
Squeegees on Machines[1]	$ 5,570
Bleach Regeneration[1]	$40,000
Total Capital Cost	$67,570

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[1] Installation Cost Excluded

TABLE VIII-6

SUMMARY OF CAPITAL COSTS FOR WASTEWATER TREATMENT

Biological Plus In-Plant Model

Category Photographic

Model Size 50,000 ft^2/d

Unit Processes		Capital Cost (ENR 1780 August 1972 Costs)	
Low Lift Pump Station			
Equalization Basin (Earthen w/liner concrete)		35,000	
Equalization Basin Mixers		16,000	
Neutralization Tanks			
Lime Additions Facilities			
Sulphuric Acid Additions Facilities			
Rapid Mix Tanks			
Primary Flocculator Clarifier			
Sludge Pumps			
Aeration Basins (concrete)		125,000	
Aeration Basin Aerators		20,000	
Secondary Flocculator Clarifier		95,000	
Recycle Pumps		10,000	
Nutrient Additions Facilities			
Polymer Additions Facilities			
Sludge Thickeners		22,000	
Aerobic Digesters			
Digester Aerators			
Sludge Pumps			
Vacuum Filters			
Flow Measurement & Sampling		15,000	
Subtotal A			338,000
Piping	20% of (A)	67,600	
Electrical	14% of (A)	47,300	
Instrumentation	8% of (A)	27,000	
Sitework	6% of (A)	20,300	
Land		10,000	
Subtotal B			172,200
Total A & B			510,200
Engineering	15% of (A) & (B)	76,500	
Contingency	15% of (A) & (B)	76,500	
Subcategory C			153,000
In-plant modification		120,000	
Grand Total (A + B + C + In-Plant)			783,000

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TABLE VIII-6(a)

Summary of Capital Costs
For Wastewater Treatment

In-Plant (BPT) Model

Category: Photographics
Model Size: 50,000 sq ft/day

Unit Processes	Capital Cost (ENR 1780 August, 1972 costs)
Electrolytic Silver Recovery	$40,000
Squeegees on Machines	$ 6,000
Bleach Regeneration	$46,000
Installation	$28,000
Total Capital Cost	$120,000

TABLE VIII-7

SUMMARY OF CAPITAL COSTS
FOR WASTEWATER TREATMENT
BAT and NSPS Model
5,000 sq. ft./ day

Category Photographic Processing

Subcategory 5,000 sq. ft./day

Unit Processes		Capital Cost (ENR 1780 August 1972 Costs)	
Cyanide Destruction		32,400	
Multi Media Filter		22,800	
Ion Exchange		11,000	
Neutralization Tanks			
Lime Additions Facilities			
Sulphuric Acid Additions Facilities			
Rapid Mix Tanks			
Primary Flocculator Clarifier			
Sludge Pumps			
Aeration Basins			
Aeration Basin Aerators			
Secondary Flocculator Clarifier			
Recycle Pumps			
Nutrient Additions Facilities			
Polymer Additions Facilities			
Sludge Thickeners			
Aerobic Digesters			
Digester Aerators			
Sludge Pumps			
Vacuum Filters			
Flow Measurement & Sampling			
Subtotal A			66,200
Piping	20% of (A)	13,240	
Electrical	14% of (A)	9,270	
Instrumentation	8% of (A)	5,350	
Sitework	6% of (A)	3,970	
Land		–	
Subtotal B		31,800	
Total A & B		98,000	
Engineering	15% of (A) & (B)	14,700	
Contingency	15% of (A) & (B)	14,700	
Subtotal C		29,400	
Grand Total (BAT)		$127,400	

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TABLE VIII-8
SUMMARY OF CAPITAL COSTS FOR WASTEWATER TREATMENT
BAT and NSPS MODEL
50,000 sq. ft./day

Category Photographic Processing

Subcategory 50,000 sq.ft./day

Unit Processes		Capital Cost (ENR 1780 August 1972 Costs)	
Cyanide Destruction		37,300	
Multi Media Filter		88,000	
Ion Exchange		64,000	
Neutralization Tanks			
Lime Additions Facilities			
Sulphuric Acid Additions Facilities			
Rapid Mix Tanks			
Primary Flocculator Clarifier			
Sludge Pumps			
Aeration Basins			
Aeration Basin Aerators			
Secondary Flocculator Clarifier			
Recycle Pumps			
Nutrient Additions Facilities			
Polymer Additions Facilities			
Sludge Thickeners			
Aerobic Digesters			
Digester Aerators			
Sludge Pumps			
Vacuum Filters			
Flow Measurement & Sampling			
Subtotal A			189,300
Piping	20% of (A)	37,860	
Electrical	14% of (A)	26,500	
Instrumentation	8% of (A)	15,140	
Sitework	6% of (A)	11,360	
Land		—	
Subtotal B			90,860
Total A & B			280,200
Engineering	15% of (A) & (B)	42,000	
Contingency	15% of (A) & (B)	42,000	
Subtotal C			84,000
Grand Total (BAT/NSPS)			$364,200

FIGURE VIII-3

EQUALIZATION BASIN

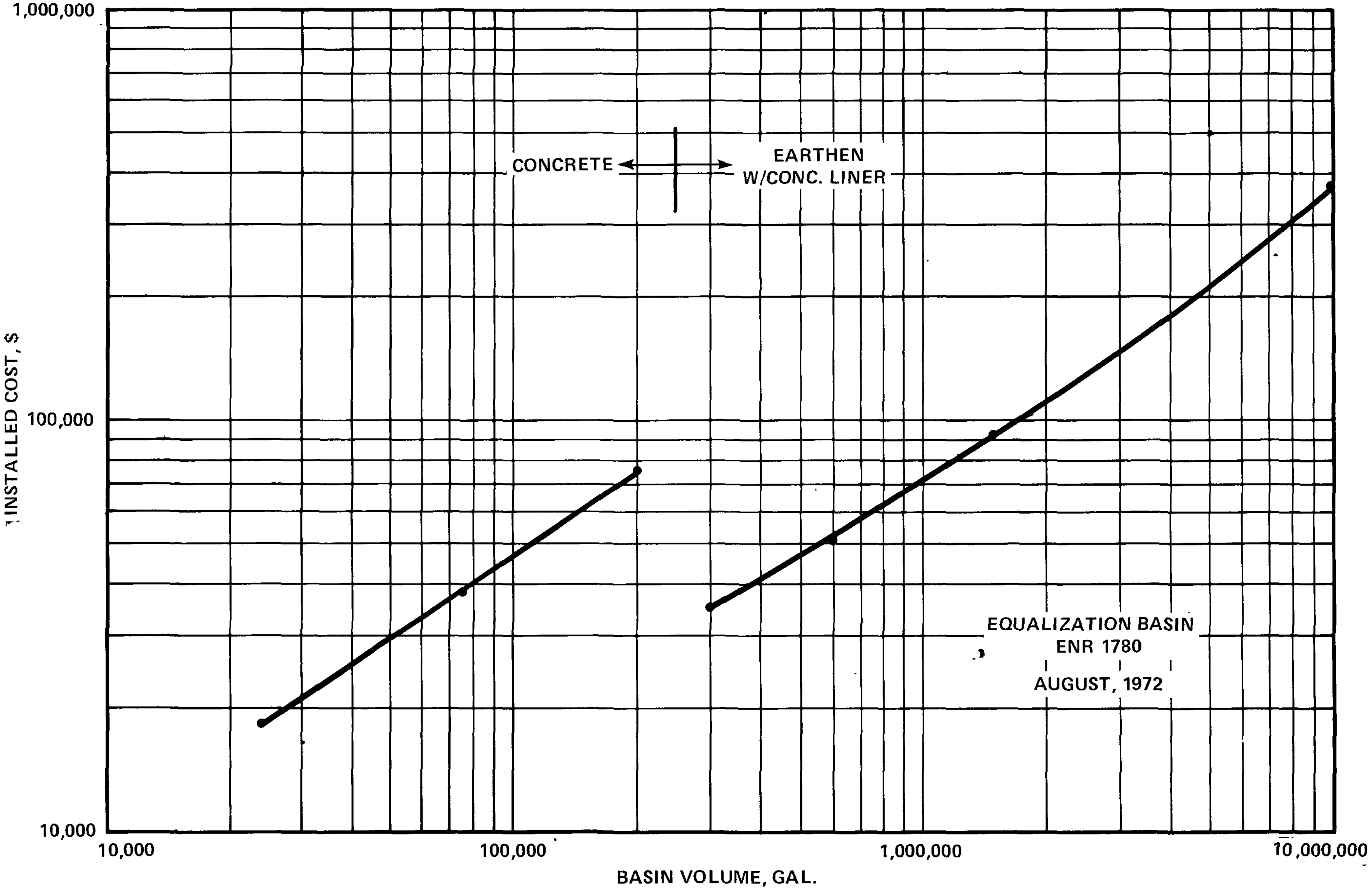

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FIGURE VIII-4

AERATION BASIN

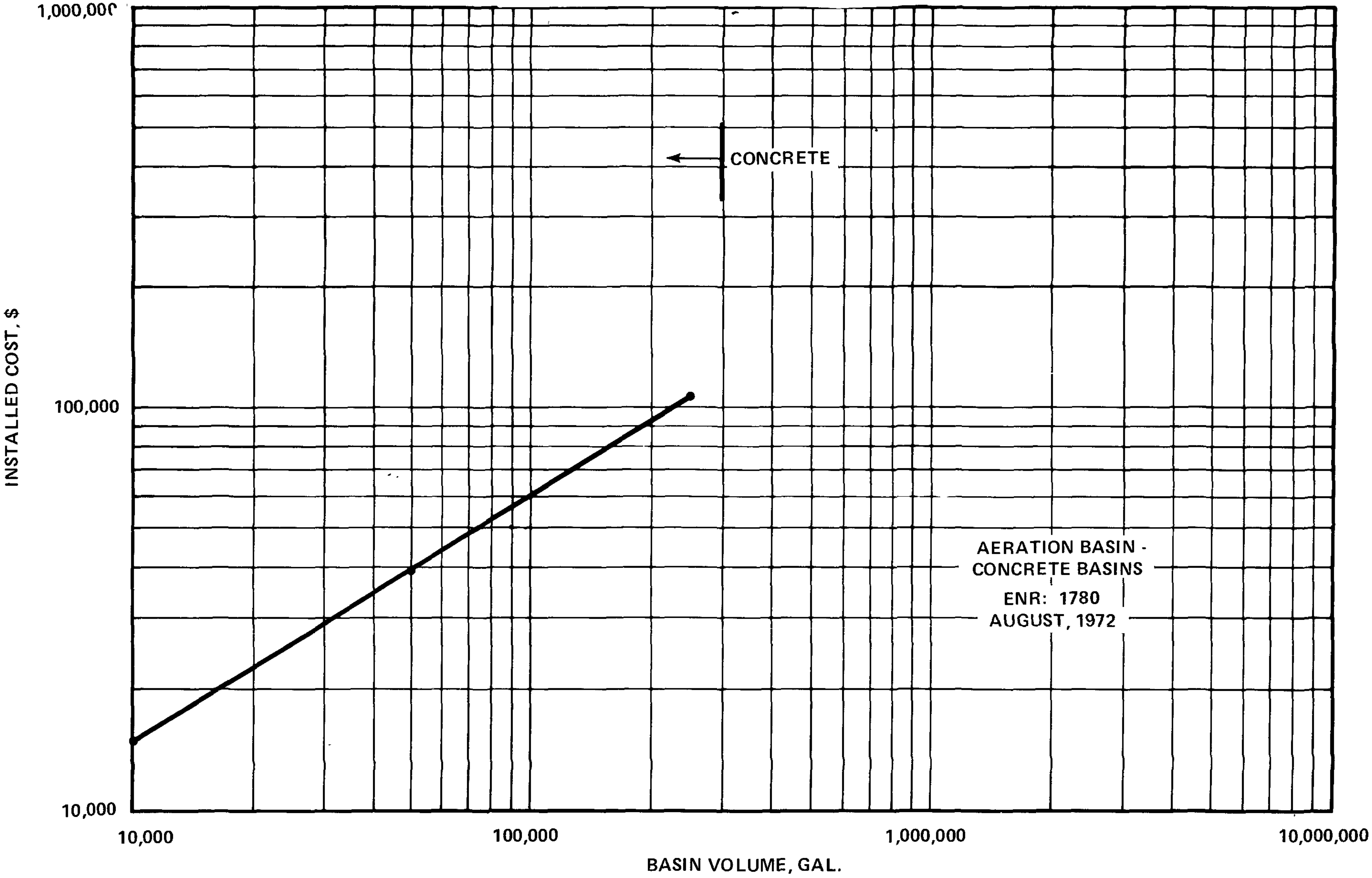

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FIGURE VIII-5

FIXED-MOUNTED AERATORS

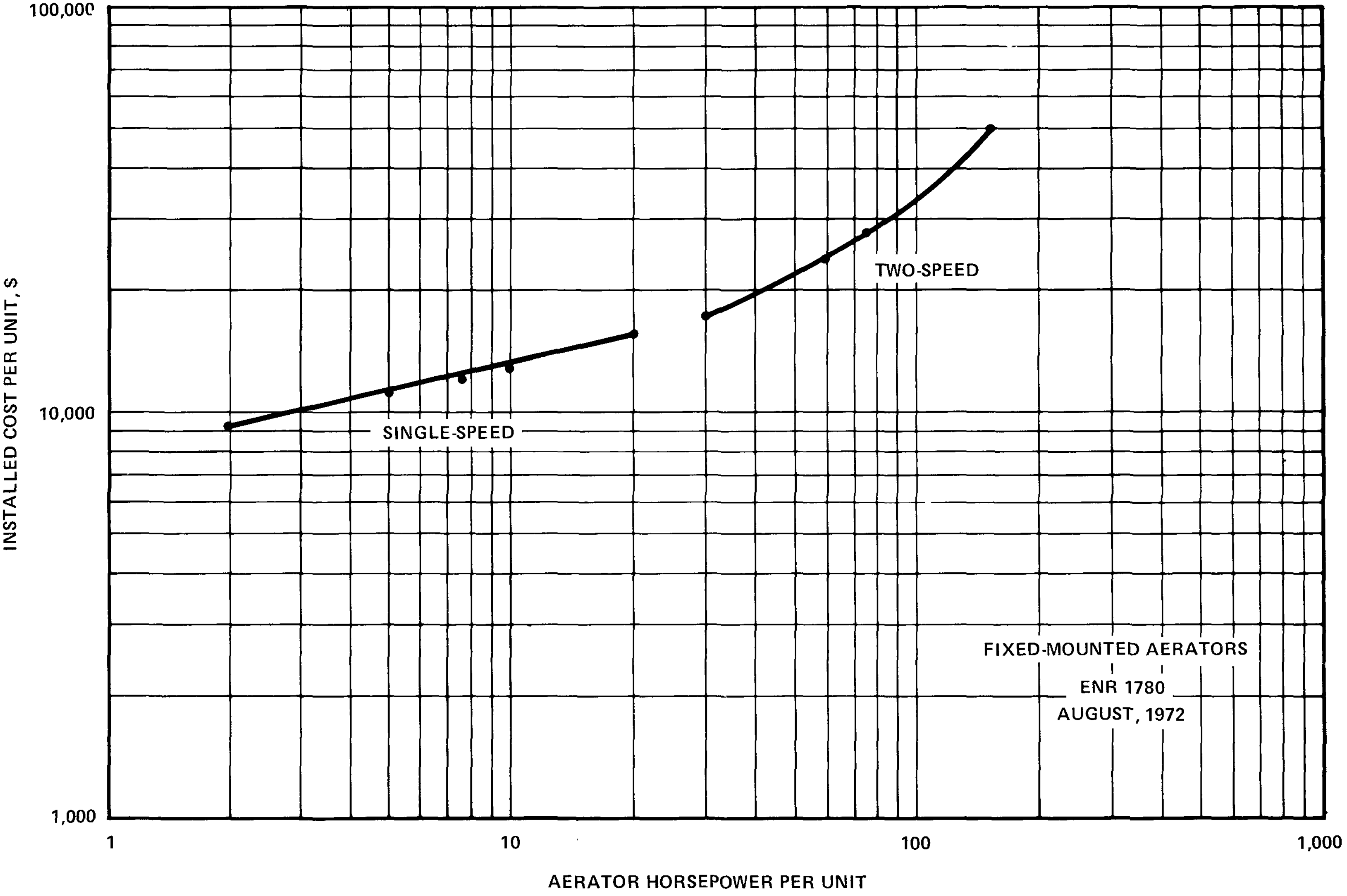

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FIGURE VIII-6

PRIMARY & SECONDARY CLARIFIER

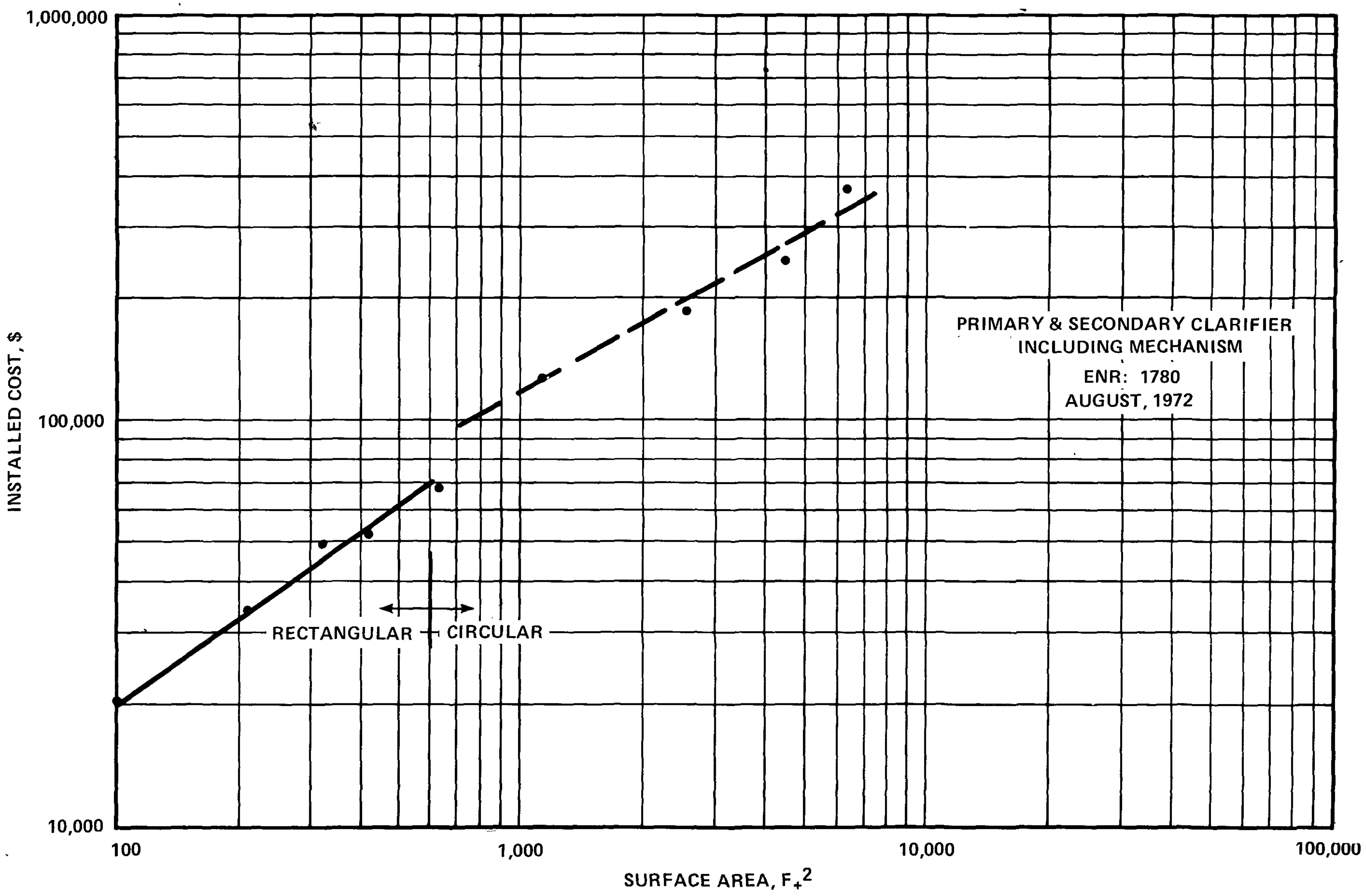

FIGURE VIII-7

SLUDGE THICKENERS INCLUDING MECHANISM

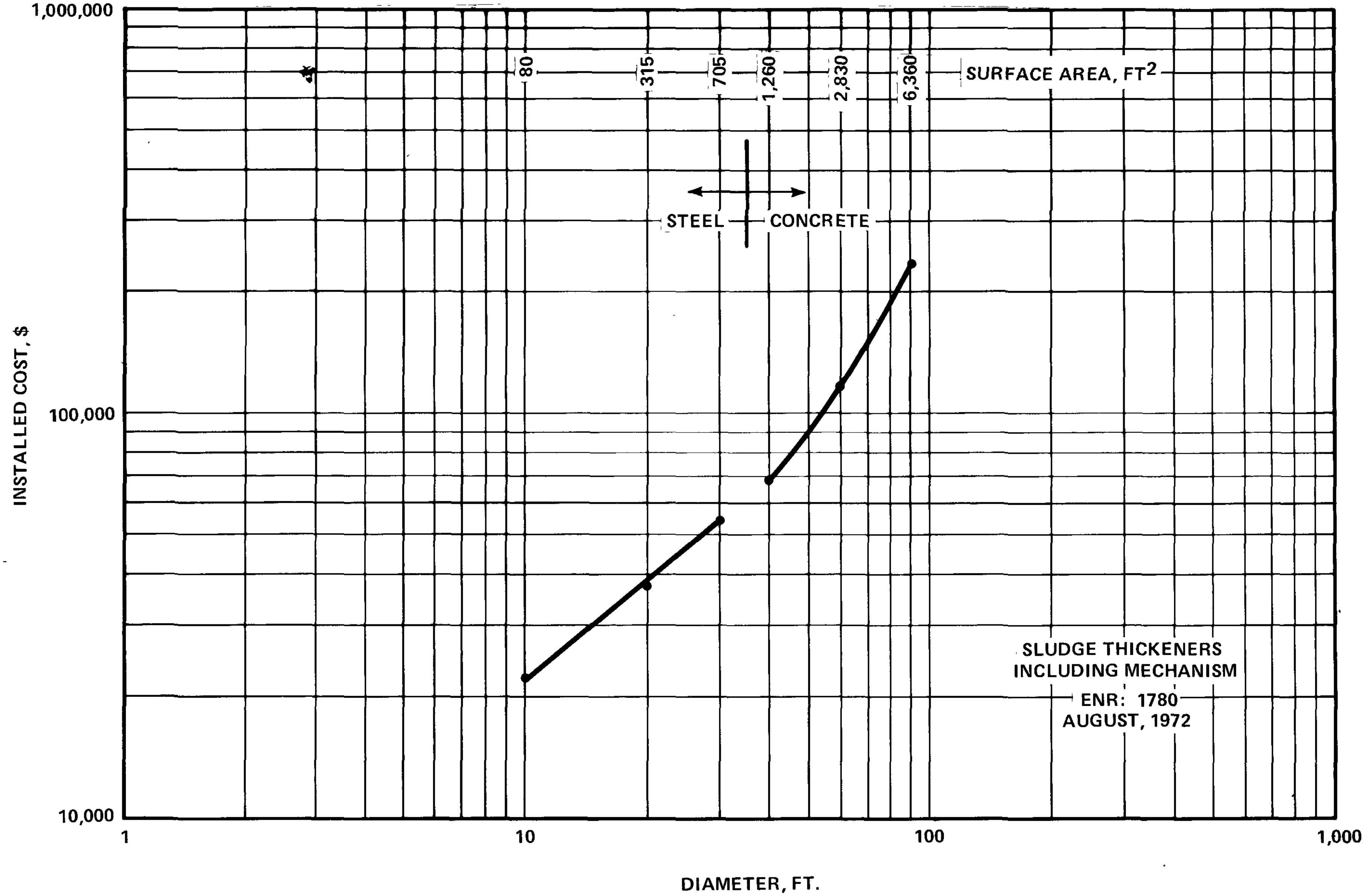

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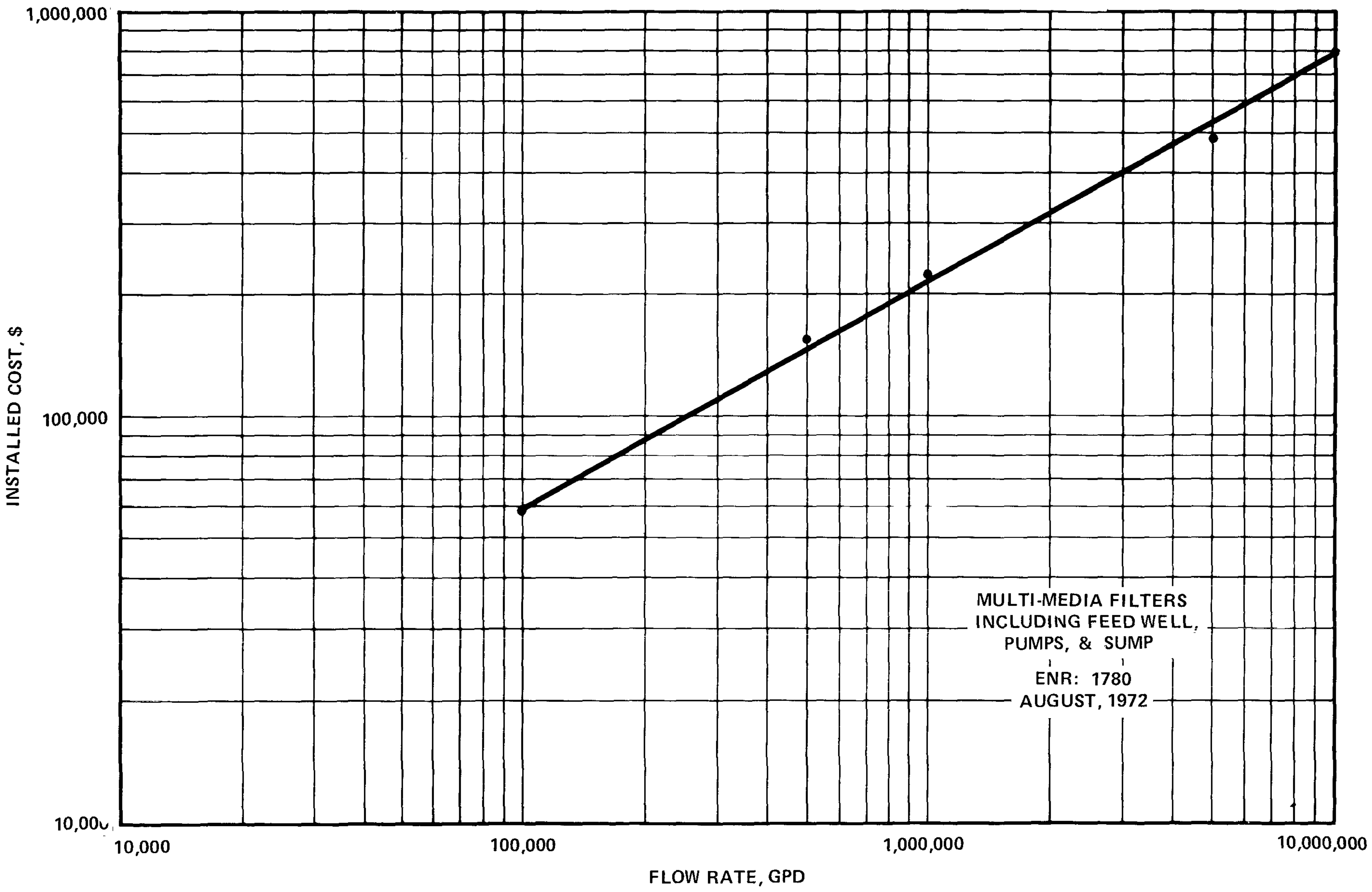
FIGURE VIII-8

MULTI-MEDIA FILTERS INCLUDING FEEDWELL, PUMPS AND SUMP



against entry of hazardous pollutants into the atmosphere. Consideration should also be given to recovery of materials of value in the wastes.

For those waste materials considered to be non-hazardous where land disposal is the choice for disposal, practices similar to proper sanitary landfill technology may be followed. The principles set forth in the EPA's Land Disposal of Solid Wastes Guidelines 40 CFR Part 241 may be used as guidance for acceptable land disposal techniques.

Best practicable control technology as known today requires disposal of the pollutants removed from waste waters in this industry in the form of solid wastes and liquid concentrates. In most cases these are nonhazardous substances requiring only minimal custodial care. However, some constituents may be hazardous and may require special consideration. In order to ensure long-term protection of the environment from these hazardous or harmful constituents, special consideration of disposal sites must be made. All landfill sites where such hazardous wastes are disposed should be selected so as to prevent horizontal and vertical migration of these contaminants to ground or surface waters. In cases where geologic conditions may not reasonably ensure this, adequate legal and mechanical precautions (e.g., impervious liners) should be taken to ensure long-term protection to the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of legal jurisdiction.

Noise levels will not be appreciably affected with the implementation of the proposed treatment models. Air pollution should only be a consideration if sludge incineration is selected as the waste disposal alternative.

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE (BPT)

General

The effluent limitations that must be achieved by all plants by 1 July, 1977 through the application of the Best Practicable Control Technology Currently Available (BPT) are based upon an average of the best performance achievements of existing exemplary plants. In those industrial categories where an exemplary treatment plant does not exist, the effluent limitations have been based upon levels of technology which are currently practiced in other industries with similar wastewater characteristics and which can be practicably implemented by 1 July, 1977.

The development of the BPT has been based on both in-plant and alternate end-of-pipe technology. The effluent limitations and guidelines commensurate with the BPT have been established on the basis of information in Sections III through VIII of this report, and are presented in the following sections. It has been shown that these limitations can be attained through the application of BPT pollution control technology.

Photographic Processing

Effluent limitations and guidelines for the photographic processing subcategory of the photographic point source category were developed by applying the in-plant treatment model presented in Sections VII and VIII. The in-plant measures include silver recovery, bleach regeneration, and squeegee installation. These in-plant pollution abatement techniques, except for squeegees, are in common use within the photographic processing subcategory. Squeegees, on the other hand, require special operational attention and careful maintenance. The variability in this system is discussed in Section XIII.

The design data from the activated sludge unit was the basis of the BOD_5, COD, and silver reduction presented in Table IX-1 under biological model. Although the effluent limitations and guidelines for BPT may be attained by a number of combinations of in-process and end-of-process means, the numerical values for these guidelines were calculated by the application of waste reduction factors from the electroplating point source category and applied to

Table IX -1

BPT Effluent Limitations Guidelines Photographic Processing Industry

Subcategory	Flow	Raw Waste Load (RW)			BPT Long-Term Average Daily Effluent	BPT Effluent Limitations	
						Average of Daily Values for 30 Consecutive Days Shall Not Exceed	Maximum for Any One Day
	L/1,000 sq m (gal/1,000 sq ft)	Parameter	kg/1,000 sq m (lb/1,000 sq ft)	mg/L	kg/1,000 (lb/1,000 sq ft)	kg/1,000 (lb/1,000 sq ft)	kg/1,000 (lb/1,000 sq ft)
Entire Industry	163,000 (4,000)	Ag (Silver)	0.07 (0.015)	0.45	0.07 (0.015)	0.07 (0.015)	0.14 (0.03)
		CN (Total)	0.09 (0.019)	0.57	0.09 (0.019)	0.09 (0.019)	0.18 (0.038)

the BPT in-plant treatment model for cyanide and silver parameters.

SECTION X

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

General

The effluent limitations and guidelines to be achieved by all plants by July 1, 1983 through the application of the Best Available Technology Economically Achievable (BAT) are based upon the very best control and treatment technology employed by the existing exemplary plants in each industrial subcategory. Where this level of control and treatment technology was found inadequate for the purpose of defining BAT, control and treatment technologies were transferred from other point source categories or technology demonstrated in pilot plant studies were employed for the photographic processing subcategory.

Photographic Processing

Treatment commensurate with BAT for the photographic processing subcategory requires the application of cyanide destruction by alkaline chlorination, dual-media filtration and ion exchange (to remove the silver) added to the BPT in-plant treatment. The performance of these systems has been discussed in Section VII.

Effluent limitations and guidelines for BAT were calculated by applying the above reduction factors to the BPT effluent limitations and guidelines as shown in Table IX-1. Performance factors from Table XIII-1 were applied for maximum day limitations and maximum thirty day limitations.

The BAT effluent limitations for silver (Ag) and for cyanide (CN) were determined by using achievable concentration limits from the electroplating industry for the same treatment technology. Concentratons were converted to a mass basis using a RWL flow of 4000 gallons per 1000 square feet of film and/or paper processed. Concentrations used in this technology transfer as as follows:

Parameter	Maximum Day Concentration	Maximum 30 day Concentration
Ag	0.02 mg/l	0.01 mg/l
CN	0.10 mg/l	0.05 mg/l

The effluent limitations and guidelines for BAT are presented in Table X-1.

Table X -1

BAT Effluent Limitations Guidelines
Photographic Processing Industry

Subcategory	Flow	Parameter	BPCTCA Long-Term Average Daily Effluent	BAT and BADCT Effluent Limitations		
				Long-Term Average Daily	Average of Daily Values for 30 Consecutive Days shall not exceed	Maximum Value for Any One Day
	L/1,000 sq m (gal/1,000 sq ft)		kg/1,000 sq m (lbs/1,000 sq ft)	kg/1,000 sq m (lbs/1,000 sq ft)	kg/1,000 sq m (lbs/1,000 sq ft)	kg/1,000 sq m (lbs/1,000 sq ft)
Entire Industry	163,000 (4,000)	Ag (Silver)	0.07 (0.015)	0.07 (0.015)	0.0016 (0.00034)	0.0032 (0.00067)
		CN (Total)	0.09 (0.019)	0.09 (0.019)	0.008 (0.0017)	0.016 (0.0034)

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

General

The term "new source" is defined in the "Federal Water Pollution Control Act Amendments of 1972" to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance". Technology applicable to new sources shall be the Best Available Demonstrated Control Technology (NSPS), defined by a determination of what higher levels of pollution control can be attained through the use of improved production process and/or wastewater treatment techniques. Thus, in addition to considering the best in-plant and end-of-pipe control technology, NSPS technology are to be based upon an analysis of how the level of effluent may be reduced by changing the production process itself.

Photographic Processing

Best Available Demonstrated Control Technology (NSPS) for the photographic processing point source category is based upon the utilization of both in-process controls and end-of-pipe process treatment technologies as proposed for BAT. Performance standards for silver and cyanide parameters are identical with the BAT effluent limitations, guidelines and new source performance standards. Table XI-1 presents NSPS performance standards for the photographic processing subcategory of the photographic point source category.

TABLE XI-1

New Source Performance Standards
Photographic Processing Industry

Subcategory	Flow L/1,000 sq m (gal/1,000 sq ft)	Parameter	BPT Long-Term Average Daily Effluent kg/1,000 sq m (lbs/1,000 sq ft)	BAT and NSPS Effluent Limitations		
				Long-Term Average Daily kg/1,000 sq m (lbs/1,000 sq ft)	Average of Daily Values for 30 Consecutive Days shall not exceed kg/1,000 sq m (lbs/1,000 sq ft)	Maximum Value for Any One Day kg/1,000 sq m (lbs/1,000 sq ft)
Entire Industry	163,000 (4,000)	Ag (Silver)	0.07 (0.015)	0.07 (0.015)	0.0016 (0.00034)	0.0032 (0.00067)
		CN (Total)	0.09 (0.019)	0.09 (0.019)	0.008 (0.0017)	0.016 (0.0034)

SECTION XII

PRETREATMENT GUIDELINES

General

Pollutants from specific processes within this subcategory may interfere with, pass through, or otherwise be incompatible with publicly owned treatment works (POTWs). The following sections examine the general wastewater characteristics of the various industries and the pretreatment unit operations which may be applicable to the photographic processing industry.

Approximately 5 percent of all major photoprocessing plants are classified as existing point sources and, therefore, are subject to the effluent limitations contained herein. The remaining 95 percent of the plants discharge their wastewater to municipal treatment systems and are regulated by the pretreatment guidelines for those systems. These guidelines are designed to prevent plants from discharging industrial wastewaters which would upset the treatment processes used by the municipal system and industrial wastewaters which would pass through the works without adequate treatment.

The incompatible pollutants in the photographic processing wastewater are silver and ferrocyanide. The developing solutions, couplers and fixers may become a problem if dumped in a slug to a treatment plant. Although most processing plants operate on a continuous basis, dumping of solutions occur during emergencies, periodic shutdowns, contamination, or exhaustion of solutions. To prevent a shock to the wastewater treatment plant, a holding tank should be installed to permit equalization of the flow to the treatment plant.

The most practical pretreatment of incompatible pollutants involves regeneration and reuse of processing solutions. Various in-process modifications are currently in use by a majority of the Photographic Processing Industry as indicated by the Eastman-Kodak survey (Table VII-1). In addition to being economical for the plant, the reuse procedures substantially reduce the pollutant loading in the wastewater. Both silver and ferrocyanide may be recovered and reused.

The following in-plant controls have been discussed in Sections VII and VIII and are recommended as pretreatment control procedures:

1. Silver may be recovered from the solutions by any of four methods: metallic replacement, electrolytic plating, ion exchange, chemical precipitation.

2. The regeneration of ferrocyanide bleach may be done by oxidation with persulfate or ozone. The Kodak plants in Dallas and Palo Alto are regenerating 100% of the bleach.

3. Developing solutions may be cleaned for reuse by ion exchange or precipitation and extraction.

4. The use of squeegees is a mechanical means of reducing the quantity of wastewater by preventing solution carry-over between process steps and decreasing dilution water usage.

In addition to in-plant control measures, pretreatment for new sources would include cyanide destruction, dual-media filtration and ion exchange.

The pretreatment standards for new sources within the photographic processing subcategory of the photographic point source category are as follows:

Pollutant or Pollutant Property	Pretreatment Standards	
	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
(Metric units)	kg/1000 m² of product	
Ag(Silver)	0.0032	0.0016
CN(Total Cyanide)	0.016	0.008
pH	Within the range 6.0 to 9.0.	
(English units)	lb/1000 sq ft of product	
Ag(Silver)	0.00067	0.00034
CN(Total Cyanide)	0.0034	0.0017
pH	Within the range 6.0 to 9.0.	

Table XII -1

Pretreatment Unit Operations

Suspended Biological System	Fixed Biological System	Independent Physical Chemical System
Physical methods and chemical precipitation + solids separation + equalization	Physical methods and chemical precipitation + solids separation + equalization	Physical methods and chemical precipitation + solids separation + equalization

Cost to implement these abatement measures are estimated to be equivalent to the incremental costs shown in Tables VIII-3 and VIII-4 for 5000 square foot per day and 50,000 square foot per day NSPS treatment models respectively. The 150 square meter per day and below facilities would be given an exemption based on economic impact except for cyanide destruction, equalization of flow and neutralization as is done in the electroplating industry.

New York is the only state specifically limiting the discharge of complex cyanides into receiving waters. The limit is 0.4 mg/l $Fe(CN)_6$.

Due to the conversion of complex cyanides to toxic simple cyanides, the complex should be converted to the equivalent amount of cyanide (CN) and treated prior to discharge to a receiving stream. The range of sewer codes for cyanide is 0.0 to 10.0 mg/l while the range in stream standards is 0.0 to 1.0 mg/l. These values depend upon the specific city, stream, point of entry, etc., but represent a reasonable range of concentrations that cyanide treatment equipment should be capable of meeting.

The yearly discharge of cyanide salts from photographic sources has been estimated at over 5,000,000 pounds.

SECTION XIII

PERFORMANCE FACTORS FOR TREATMENT PLANT OPERATIONS

General

Variations in the performance of wastewater treatment plants are usually attributable to one or more of the following:

1. Severe ambient air temperature changes. Although ambient temperature changes may not be controlled, design features such as injection of steam or hot water can be incorporated that will minimize these effects.

2. Variations in sampling techniques and analytical methods do not affect the performance of a waste treatment system but may result in false or incorrect evaluation of such systems performance. Establishment and use of standard methods can eliminate apparent variations.

3. Variations in one or more operational parameters, e.g., the organic removal rate by the biological mass, settling rate changes of biological sludge. These are usually the result of changing flow or waste loadings and the addition of an equalization tank normally takes care of this problem.

5. Controllable changes in the treatability characteristics of the process wastewaters even after adequate equalization. Good tight operating practices and training skilled operators and personnel will aid in reducing this type of variation in treatment performance.

Variability in Biological Waste Treatment Systems

In the past, effluent requirements for wastewater treatment plants have been related to the achievement of a desired treatment efficiency based on long term performance.

The effluent limitations promulgated by EPA and developed in this document include values that limit both long term and short term waste discharges. These restrictions are necessary to assure that deterioration of the nation's waters does not occur on a short term basis due to heavy intermittent discharges, even though an annual average may be attained.

Some of the controllable causes of variability and techniques that can be used to minimize their effect include:

A. Storm Runoff

Storm water holding or diversion facilities should be designed on the basis of rainfall history and area being drained. The collected storm runoff can be drawn off at a constant rate to the treatment system. The volume of this contaminated storm runoff should be minimized through segregation and the prevention of contamination. Storm runoff from outside the plant area, as well as uncontaminated runoff, should be diverted around the plant or contaminated area.

B. Flow Variations

Raw waste load variations can be reduced by properly sized equalization units. Equalization is a retention of the wastes in a suitably designed and operated holding system to average out the influent before allowing it into the treatment system.

C. Spills

Spills of certain materials in the plant can cause a heavy loading on the treatment system for a short period of time. A spill may not only cause higher effluent levels as it goes through the system, but may inhibit a biological treatment system and therefore have longer term effects. Equalization helps to lessen the effects of spills. However, long term reliable control can only be attained by an aggressive spill prevention and maintenance program including training of operating personnel. Industrial associations such as the Manufacturing Chemists Association have developed guidelines for prevention, control and reporting of spills. These note how to assess the potential of spill occurrence and how to prevent spills. If every plant were to use such guidelines as part of plant waste management control programs, its raw waste load and effluent variations would be decreased.

D. Climatic Effects

The design and choice of type of a treatment system should be based on the climate at the plant location so that this effect can be minimized. Where there are severe seasonal climatic conditions, the treatment system should be designed and sufficient operational flexibility should be available so that the system can function effectively under all ambient conditions.

E. Treatment Process Inhibition

Chemicals likely to inhibit the treatment processes should be identified and prudent measures taken to see that they do not enter the wastewater in concentrations that may result in treatment process inhibition. The common indicator of the pollution characteristics of the discharge from a plant historically has been the long-term average of the effluent load. However, the long-term (yearly) average is not the only parameter on which to have an effluent limitation. Shorter term averages also are needed, both as an indication of performance and for enforcement purposes.

Wherever possible, the best approach to develop the annual and shorter term limitations is to use historical data from the industry in question. If enough data is available from a well designed and well operated plant, the shorter term limitations can be developed from a detailed analysis of the hourly, daily, weekly or monthly data. Rarely, however, is there an adequate amount of short term data. However, using data which show the variability in the effluent load, statistical analyses can be used to compute short term limits (30 day average or daily) which should be attained, provided that the plant is adequately designed and operated in the proper way to achieve the desired results. These analyses can be used to establish variability factors for effluent limitations or to check those factors that have been developed.

Photographic Processing

It is apparent from the performance data collected on the activated sludge unit during the field study that BOD_5 and COD reductions were variable during the first two years of performance. Following the installation of the sand filters in the second year, BOD_5 reduction in percent brought about by the combined installation varied from 78 percent to 91 percent; during a different period, COD reduction varied from 45 percent to 70 percent. It is apparent that either the system was improperly designed or improperly operated or both.

The photographic processing subcategory is characterized by batch-type operations, a very diverse product mix, and seasonal production variation. As these process variations are similar to those in the pharmaceutical point source category, the organic load variability on end-of-pipe treatment plants for the photographic processing subcategory and the pharmaceutical point source category are, therefore, anticipated to be closely related. For the same reason, the performance of end-of-pipe treatment plants in these two categories should be similar. Consequently, the performance factors of treatment plant operations as developed for the pharmaceutical point source category from the long-term performance of biological treatment plant operations could be applied to the alternate biological systems considered for the photographic processing subcategory also. These performance factors are as follows:

TABLE XIII-1

Performance Factor Summary

Parameter	Performance Factor for Maximum Monthly Effluent Value	Performance Factor for Maximum Daily Effluent Value
BOD5	2.1	2.9
COD	2.1	2.9
CN	1.0	2.0
Ag	1.0	2.0
TSS	2.1	2.9

As additional treatment plant performance data in this subcategory becomes available, the above performance factors will be reevaluated and modified, if necessary.

Sufficient historical data were not available from this industry to perform a statistical analysis to determine variability factors for silver and cyanide in treatment plant effluent. The draft development document for effluent limitations guidelines for the metal finishing industry establishes a variability factor of 2.0 between the maximum for any single day average and the thirty-day average. Silver and cyanide numerical values for the maximum average of daily values for any period of thirty consecutive days (maximum thirty day limitation) and maximum value for any one day (maximum day limitation) shown in Tables II-1 and II-2 are developed using performance factors of 1.0 and 2.0 respectively.

The performance factors presented in this section were applied to the long-term average daily effluent limitations to develop the effluent limitations, guidelines and new source performance standards for the maximum thirty day limitation and the maximum day limitation, as presented in Sections II, IX, X, and XI of this document.

SECTION XIV

ACKNOWLEDGEMENTS

This report was prepared by the Environmental Protection Agency on the basis of a comprehensive study of this industry performed by Roy F. Weston, Inc., under contract No. 68-01-2932. The original study was conducted and prepared for the Environmental Protection Agency under the direction of Project Director James H. Dougherty, P.E., and Technical Project Manager Jitendra R. Ghia, P.E. Update of the original study was done by W.D. Sitman and Dr. K.M. Peil of RFW, Inc.

The original RFW study and this EPA revision were conducted under the supervision and guidance of Mr. Joseph S. Vitalis, Project Officer, assisted by Mr. George Jett, Assistant Project Officer.

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SECTION XV

BIBLIOGRAPHY

G. Photographic Processing Industry

G-1. "Information Form For Requesting Assistance In Pollution Abatement," Photographic Technology Division, Eastman Kodak Company, Rochester, N.Y.

G-2. "Wolfman Report on the Photographic Industry in the United States," Modern Photography Magazine, 1973-1974.

G-3. Bard, C.E., et al, "Silver in Photoprocessing Effluents," Eastman Kodak Company, Rochester, N.Y.

G-4. Dagon, T.J., "Biological Treatment Of Photoprocessing Effluents," JWPCF, Vol. 15, No. 10, October 1973.

G-5. "Pretreatment of Pollutants Introduced Into Publicly Owned Treatment Works," EPA, October 1973.

G-6. Fulweiler, S.B., "The Nature of Photographic Processing," Presented at Photoprocessing and the Environment Seminar, June 1974.

G-7. "American National Standard on Photographic Processing Effluents," Drafts, ANSI, November 1974.

G-8. Terhaar, C.J., et al, "Toxicity of Photographic Processing Chemicals to Fish," Photographic Science and Engineering, Vol. 16, No. 5, September - October 1972.

G-9. Cooley, A.C., "Reuse and Recovery of Processing Chemicals," Presented at Photoprocessing and the Environment Seminar, June 1974.

G-10. Ayers, G.L., "How Processor Waste Loads Can Be Minimized," Presented at Photoprocessing and the Environment Seminar, June 1974.

G-11. Dagon, T.J., "Specific Applications Of Photographic Processing Effluent Treatment," Presented at Photoprocessing and the Environment Seminar, June 1974.

G-12. Dufficy, T.J., "The Federal Water Pollution Control Act of 1972. Its Effect on Photographic Processing Operations," Photoprocessing and the Environment Seminar, June 1974.

G-13. "Effluent Limitations Guidelines and Standards of Performance - Metal Finishing Industry," Draft Development Document, January 1974.

G-14. Lamp, G.E., Jr., "Package Treatment Plant Prices," *Water Pollution Control Federation Journal*, Vol. 46, No. 11; 1974; pp. 2604 - 2610.

G-15. Hammer, M.J., "Determination of Design Capacity of a Wastewater Treatment Plant," *Water and Sewage Works*; 1973; pp. R110 - R115.

G-16. National Association of Photographic Manufacturers; *American National Standard on Photographic Processing Effluent*, American National Standards Institute, pub.; 1975.

G-17. Bober, T.W., and Dagon, T.J., "Ozonation of Photographic Processing Wastes," *Journal WPCF*; Vol. 47, No. 8; August 1975; pp. 2114-2129.

G-18. National Association of Photographic Manufacturers; *Environmental Effect of Photoprocessing Chemicals*, Vol. 1; NAPM, 600 Mamaroneck Ave., Harrison, N.Y. 10528; June 1974.

G-19. National Association of Photographic Manufacturers; *Environmental Effect of Photoprocessing Chemicals*, Vol. II; NAPM, 600 Mamaroneck Ave., Harrison, N.Y., 10528; June 1974.

G-20. U.S. EPA; *Treatment of Complex Cyanide Compounds for Reuse or Disposal*; EPA-R2-73-269; Prepared by Thomas N. Hendrickson and Dr. Louis G. Daignault for EPA Office of Research and Monitoring, Washington, D.C. 20460; June, 1973.

G-21. Lur'e, Yu. Yu. and Panova, V. A., "Behavior of Cyano Compounds in Water Ponds", *Hydrochemical Materials*, Vol. 37, p. 133-43, Moscow, Russia, 1964.

G-22. Alletag, Gerald C., "Truth in Pollution Abatement", Paper presented at Pure Meeting, Washington, D.C., April 6, 1971.

G-23. Bober, T.M., and Cooley, A.C., "The Filter Press for the Filtration of Insoluble Photographic Processing Wastes," Photographic Science and Engineering; Vol. 16, Number 2, March-April, 1972.

G-24 Neblette, C.B.; Photography lts Materials and Processes, 6th Edition; Van Nostrand Reinhold Company, New York, 1961.

G-25. Dufficy, T. J., "Effluent Limitations, Guidelines and Standards of Performance - Miscellaneous Chemicals Industry (Photographic Processing)," NAPM memorandum to W. J. Hunt; May 1976.

G-26. Kennedy, D.C., et.al.; "Prediction of Ion-Exchange Sorption of Metal Ions from Complex-Ion Formation Data," a paper presented at the 171st National ACS Meeting, New York City, New York; April 7, 1976.

G-27. Luther, P.A., et.al.; "Treatability and Functional Design of a Physical-Chemcial Wastewater Treatment System for a Printing and Photodeveloping Plant," a paper presented at the 31st Annual Purdue University, West Lafayette, Indiana; May 6, 1976.

G-28. Kreye, W.C., et.al.; "Kinetic Parameters and Operation Problems in the Biological Oxidation of High Thiosulfate Industrial Wastewaters," Proceedings of the 30th Purdue Industrial Waste Conference, Purdue University; 1975; pp. 410 - 419.

G-29. Netzer, A. and Wilkinson, P.; "Removal of Heavy Metals from Wastewater by Adsorption on Sand," Proceedings of the 30th Purdue Industrial Waste Conference, Purdue University; 1975; pp. 841 - 845.

G-30. Raef, S.F., et.al.; "Fate of Cyanide and Related Compounds in Industrial Waste Treatment," Proceedings of the 30th Purdue Industrial Waste Conference. Purude University; 1975; pp. 832 - 840.

G-31. Supplement A&B - Detailed Record of Data Base for "Development Document for Interim Final Effluent Limitations, Guidelines and Proposed New Source Performance Standards for the Photographic Processing Point Source Category," U.S. EPA, Washington, D.C. 20460, June, 1976.

G-32. Cooley, A.C.; "Regeneration and Disposal of Photographic Processing Solutions Containing

Hexacyanoferrate," Journal of Applied Photographic Engineering, Vol. 2, No. 2, Spring 1976.

G-33. The Impact of Snow Enhancement - Technology Assessment of Winter Orographic Snowpack Augmentation in the Upper Colorado River Basin. Compiled by Leo W. Weisbecker, Stanford Research Institute, University of Oklahoma Press.

References

GR-1 AICHE Environmental Division; "Industrial Process Design for Pollution Control," Volume 4; October, 1971.

GR-2 Allen, E.E.; "How to Combat Control Valve Noise," Chemical Engineering Progress, Vol. 71, No. 8; August, 1975; pp. 43-55.

GR-3 American Public Health Association; Standard Methods for Examination of Water and Waste Water, 13th Edition; APHA, Washington, D.C. 20036; 1971.

GR-4 Barnard, J.L.; "Treatment Cost Relationships for Industrial Waste Treatment," Ph.D. Dissertation, Vanderbilt University; 1971.

GR-5 Bennett, H., editor; Concise Chemical and Technical Dictionary; F.A.I.C. Chemical Publishing Company, Inc., New York, New York; 1962.

GR-6 Blecker, H.G., and Cadman, T.W.; Capital and Operating Costs of Pollution Control Equipment Modules, Volume I - User Guide; EPA-R5-73-023a; EPA Office of Research and Development, Washington, D.C. 20460; July 1973.

GR-7 Blecker, H.G., and Nichols, T.M.; Capital and Operating Costs of Pollution Control Equipment Modules, Volume II - Data Manual; EPA-R5-73-023b; EPA Office of Research and Development, Washington, D.C. 20460; July, 1973.

GR-8 Bruce, R.D., and Werchan, R.E.; "Noise Control in the Petroleum and Chemical Industries," Chemical Engineering Progress, Vol. 71, No. 8; August, 1975; pp. 56-59.

GR-9 Chaffin, C.M.; "Wastewater Stabilization Ponds at Texas Eastman Company."

GR-10 Chemical Coagulation/Mixed Media Filtration of Aerated Lagoon Effluent, EPA-660/2-75-025; Environmental Protection Technology Series, National Environmental Research Center, Office of Research and Development, U.S. EPA, Corvallis, Oregon 97330.

GR-11 Chemical Engineering, August 6, 1973; "Pollution Control at the Source."

GR-12 Chemical Engineering, 68 (2), 1961; "Activated-Sludge Process Solvents Waste Problem."

GR-13 Chemical Week, May 9, 1973; "Making Hard-to-treat Chemical Wastes Evaporate."

GR-14 Cheremisinoff, P.N., and Feller, S.M.; "Wastewater Solids Separation," Pollution Engineering.

GR-15 Control of Hazardous Material Spills, Proceedings of the 1972 National Conference on Control of Hazardous Material Spills, Sponsored by the U.S. Environmental Protection Agency at the University of Texas, March 1972.

GR-16 Cook, C.; "Variability in BOD Concentration from Biological Treatment Plants," EPA internal memorandum; March, 1974.

GR-17 Davis, K.E., and Funk, R.J.; "Deep Well Disposal of Industrial Waste," Industrial Waste; January-February, 1975.

GR-18 Dean, J.A., editor; Lange's Handbook of Chemistry, 11th Edition; McGraw-Hill Book Company, New York, New York; 1973.

GR-19 Eckenfelder, W.W., Jr.; Water Quality Engineering for Practicing Engineers; Barnes and Noble, Inc., New York, New York; 1970.

GR-20 Eckenfelder, W.W., Jr.; "Development of Operator Training Materials," Environmental Science Services Corp., Stamford, Conn.; August, 1968.

GR-21 Environmental Science and Technology, Vol. 8, No. 10, October, 1974; "Currents-Technology."

GR-22 Fassell, W.M.; Sludge Disposal at a Profit?, a report presented at the National Conference on

Municipal Sludge Management, Pittsburgh, Pennsylvania; June, 1974.

GR-23 *Guidelines for Chemical Plants in the Prevention Control and Reporting of Spills*; Manufacturing Chemists Association, Inc., Washington, D.C. 1972.

GR-24 Hauser, E.A., *Colloidal Phenomena*, 1st Edition, McGraw-Hill Book Company, New York, New York; 1939.

GR-25 Iowa State University Department of Industrial Engineering and Engineering Research Institute, "Estimating Staff and Cost Factors for Small Wastewater Treatment Plants Less Than 1 MGD," Parts I and II; EPA Grant No. 5P2-WP-195-0452; June, 1973.

GR-26 Iowa State University Department of Industrial Engineering and Engineering Research Institute, "Staffing Guidelines for Conventional Wastewater Treatment Plants Less Than 1 MGD," EPA Grant No. 5P2-WP-195-0452; June, 1973.

GR-27 Judd, S.H.; "Noise Abatement in Existing Refineries," *Chemical Engineering Progress*, Vol. 71, No. 8; August, 1975; pp. 31-42.

GR-28 Kent, J.A., editor; *Reigel's Industrial Chemistry*, 7th Edition; Reinhold Publishing Corporation, New York; 1974.

GR-29 Kirk-Othmer; Encyclopedia of Chemical Technology, 2nd Edition; Interscience Publishers Division, John Wiley and Sons, Inc.

GR-30 Kozlorowski, B., and Kucharski, J.; *Industrial Waste Disposal*; Pergamon Press, New York; 1972.

GR-31 Lindner, G. and K. Nyberg; *Environmental Engineering, A Chemical Engineering Discipline*; D. Reidel Publishing Company, Boston, Massachusetts 02116, 1973.

GR-32 Liptak, B.G., editor; *Environmental Engineers' Handbook, Volume I, Water Pollution*; Chilton Book Company, Radnor, Pa.; 1974.

GR-33 Marshall, G.R. and E.J. Middlebrook; *Intermittent Sand Filtration to Upgrade Existing Wastewater Treatment Facilities*, PR JEW 115-2; Utah Water

Research Laboratory, College of Engineering, Utah State University, Logan, Utah 84322; February, 1974.

GR-34 Martin, J.D., Dutcher, V.D., Frieze, T.R., Tapp, M., and Davis, E.M.; "Waste Stabilization Experiences at Union Carbide, Seadrift, Texas Plant."

GR-35 McDermott, G.N.; Industrial Spill Control and Pollution Incident Prevention, J. Water Pollution Control Federation, 43 (8) 1629 (1971).

GR-36 Minear, R.A., and Patterson, J.W.; Wastewater Treatment Technology, 2nd Edition; State of Illinois Institute for Environmental Quality; January, 1973.

GR-37 National Environmental Research Center; "Evaluation of Hazardous Waste Emplacement in Mined Openings;" NERC Contract No. 68-03-0470; September, 1974.

GR-38 Nemerow, N.L.; Liquid Waste of Industry - Theories, Practices and Treatment; Addision-Wesley Pulbishing Company, Reading, Massachusetts; 1971.

GR-39 Novak, S.M.; "Biological Waste Stabilization Ponds at Exxon Company, U.S.A. Baytown Refinery and Exxon Chemical Company, U.S.A. Chemical Plant (Divisions of Exxon Corporation) Baytown, Texas."

GR-40 Oswald, W.J., and Ramani, R.; "The Fate of Algae in Receiving Waters," a paper submitted to the Conference on Ponds as a Wastewater Treatment Alternative, University of Texas, Austin; July, 1975.

GR-41 Otakie, G.F.; A Guide to the Selection of Cost-effective Wastewater Treatment Systems; EPA-430/9-75-002, Technical Report, U.S. EPA, Office of Water Program Operations, Washington, D.C. 20460.

GR-42 Parker, C.L.; Estimating the Cost of Wastewater Treatment Ponds; Pollution Engineering, November, 1975.

GR-43 Parker, W.P.; Wastewater Systems Engineering, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1975.

GR-44 Parker, D.S.; "Performance of Alternative Algae Removal Systems," a report submitted to the Conference on Ponds as a Wastewater Treatment Alternative, University of Texas, Austin; July, 1975.

GR-45 Perry, J.H., et. al.; Chemical Engineers' Handbook, 5th Edition; McGraw-Hill Book Company, New York, New York; 1973.

GR-46 Public Law 92-500, 92nd Congress, S.2770; October 18, 1972.

GR-47 Quirk, T.P.; "Application of Computerized Analysis to Comparative Costs of Sludge Dewatering by Vacuum Filtration and Centrifugation," Proc., 23rd Industrial Waste Conference, Purdue University; 1968; pp. 69-709.

GR-48 Riley, B.T., Jr.; The Relationship Between Temperature and the Design and Operation of Biological Waste Treatment Plants, submitted to the Effluent Guidelines Division, EPA; April, 1975.

GR-49 Rose, A., and Rose, E.; The Condensed Chemical Dictionary, 6th Edition; Reinhold Publishing Corporation, New York; 1961.

GR-50 Rudolfs, W.; Industrial Wastes, Their Disposal and Treatment; Reinhold Publishing Corporation, New York; 1953.

GR-51 Sax, N.I.; Dangerous Properties of Industrial Material, 4th Edition; Van Nostrand Reinhold Company, New York; 1975.

GR-52 Seabrook, B.L.; Cost of Wastewater Treatment by Land Application; EPA-430/9-75-003, Technical Report; U.S. EPA, Office of Water Program Operations, Washington, D.C. 20460.

GR-53 Shreve, R.N.; Chemical Process Industries, Third Edition; McGraw-Hill, New York; 1967.

GR-54 Spill Prevention Techniques for Hazardous Polluting Substances, OHM 7102001; U.S. Environmental Protection Agency, Washington, D.C. 20460; February 1971.

GR-55 Stecher, P.G., editor; The Merck Index, An Encyclopedia of Chemicals and Drugs, 8th Edition; Merck and Company, Inc., Rahway, New Jersey; 1968.

GR-56 Stevens, J.I., "The Roles of Spillage, Leakage and Venting in Industrial Pollution Control", Presented at Second Annual Environmental Engineering and Science Conference, University of Louisville, April 1972.

GR-57 Supplement A & B - Detailed Record of Data Base for "Draft Development Document for Interim Final Effluent Limitations, Guidelines and Standards of Performance for the Miscellaneous Chemicals Manufacturing Point Source Category", U.S. EPA, Washington, D.C. 20460, February 1975.

GR-58 Swanson, C.L.; "Unit Process Operating and Maintenance Costs for Conventional Waste Treatment Plants;" FWQA, Cincinnati, Ohio; June, 1968.

GR-59 U.S. Department of Health, Education, and Welfare; "Interaction of Heavy Metals and Biological Sewage Treatment Processes," Environmental Health Series; HEW Office of Water Supply and Pollution Control, Washington, D.C.; May, 1965.

GR-60 U.S. Department of the Interior; "Cost of Clean Water," Industrial Waste Profile No. 3; Dept. of Int. GWQA, Washington, D.C.; November, 1967.

GR-61 U.S. EPA; Process Design Manual for Upgrading Existing Waste Water Treatment Plants, U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; October, 1974.

GR-62 U.S. EPA; Monitoring Industrial Waste Water, U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; August, 1973.

GR-63 U.S. EPA; Methods for Chemical Analysis of Water and Wastes, U.S. EPA Technology Transfer; EPA 625/6-74-003; Washington, D.C. 20460; 1974.

GR-64 U.S. EPA; Handbook for Analytical Quality Control in Water and Waste Water Laboratories, U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; June, 1972.

GR-65 U.S. EPA; Process Design Manual for Phosphorus Removal, U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; October, 1971.

GR-66 U.S. EPA; Process Design Manual for Suspended Solids Removal, U.S. EPA Technology Transfer; EPA 625/1-75-003a, Washington, D.C. 20460; January, 1975.

GR-67 U.S. EPA; Process Design Manual for Sulfide Control in Sanitary Sewerage Systems, U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; October, 1974.

GR-68 U.S. EPA; Process Design Manual for Carbon Adsorption, U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; October, 1973.

GR-69 U.S. EPA; Process Design Manual for Sludge Treatment and Disposal, U.S. EPA Technology Transfer; EPA 625/1-74-006, Washington, D.C. 20460; October, 1974.

GR-70 U.S. EPA; Effluent Limitations Guidelines and Standards of Performance, Metal Finishing Industry, Draft Development Document; EPA 440/1-75/040 and EPA 440/1-75/040a; EPA Office of Air and Water Programs, Effluent Guidelines Division, Washington, D.C. 20460; April, 1975.

GR-71 U.S. EPA; Development Document for Effluent Limitations Guidelines and Standards of Performance - Organic Chemicals Industry; EPA 440/1-74/009a; EPA Office of Air and Water Programs, Effluent Guidelines Division, Washington, D.C. 20460; April, 1974.

GR-72 U.S. EPA; Draft Development Document for Effluent Limitations Guidelines and Standards of Performance - Steam Supply and Noncontact Cooling Water Industries; EPA Office of Air and Water Programs, Effluent Guidelines Division, Washington, D.C. 20460; October, 1974.

GR-73 U.S. EPA; Draft Development Document for Effluent Limitations Guidelines and Standards of Performance - Organic Chemicals Industry, Phase II Prepared by Roy F. Weston, Inc. under EPA Contract No. 68-01-1509; EPA Office of Air and Water Programs, Effluent Guidelines Division, Washington, D.C. 20460; February, 1974.

GR-74 U.S. EPA; Evaluation of Land Application Systems, Technical Bulletin; EPA 430/9-75-001; EPA, Washington, D.C. 20460; March, 1975.

GR-75 U.S. EPA; "Projects in the Industrial Pollution Control Division," Environmental Protection Technology Series; EPA 600/2-75-001; EPA, Washington, D.C. 20460; December, 1974.

GR-76 U.S. EPA; Wastewater Sampling Methodologies and Flow Measurement Techniques; EPA 907/9-74-005; EPA Surveillance and Analysis, Region VII, Technical Support Branch; June, 1974.

GR-77 U.S. EPA; A Primer on Waste Water Treatment; EPA Water Quality Office; 1971.

GR-78 U.S. EPA; Compilation of Municipal and Industrial Injection Wells in the United States; EPA 520/9-74-020; Vol. I and II; EPA, Washington, D.C. 20460; 1974.

GR-79 U.S. EPA; "Upgrading Lagoons," U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; August, 1973.

GR-80 U.S. EPA; "Nitrification and Denitrification Facilities," U.S. EPA Technology Transfer; August, 1973.

GR-81 U.S. EPA; "Physical-Chemical Nitrogen Removal," U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; July, 1974.

GR-82 U.S. EPA; "Physical-Chemical Wastewater Treatment Plant Design," U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; August, 1973.

GR-83 U.S. EPA; "Oxygen Activated Sludge Wastewater Treatment Systems, Design Criteria and Operating Experience," U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; August, 1973.

GR-84 U.S. EPA; Wastewater Filtration Design Considerations; U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460; July, 1974.

GR-85 U.S. EPA; "Flow Equalization," *U.S. EPA Technology Transfer*; EPA, Washington, D.C. 20460; May, 1974.

GR-86 U.S. EPA; "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants," U.S. EPA Technology Transfer; EPA, Washington, D.C. 20460.

GR-87 U.S. EPA; Supplement to Development Document for Effluent Limitations, Guidelines and New Source Performance Standards for the Corn Milling Subcategory, Grain Processing, EPA, Office of Air and Water Programs, Effluent Guidelines Division, Washington, D.C. 20460, August 1975.

GR-88 U.S. EPA; *Pretreatment of Pollutants Introduced Into Publicly Owned Treatment Works*; EPA Office of Water Program Operations, Washington, D.C. 20460; October, 1973.

GR-89 U.S. Government Printing Office; *Standard Industrial Classification Manual*; Government Printing Office, Washington, D.C. 20492; 1972.

GR-90 U.S. EPA; Tertiary Treatment of Combined Domestic and Industrial Wastes, EPA-R2-73-236, EPA, Washington, D.C. 20460; May, 1973.

GR-91 Wang, Lawrence K.; *Environmental Engineering Glossary* (Draft) Calspan Corporation, Environmental Systems Division, Buffalo, New York 14221, 1974.

GR-92 *Water Quality Criteria* 1972, EPA-R-73-033, National Academy of Sciences and National Academy of Engineering; U.S. Government Printing Office, No. 5501-00520, March, 1973.

GR-93 Weast, R., editor; *CRC Handbook of Chemistry and Physics*, 54th Edition; CRC Press, Cleveland, Ohio 44128; 1973-1974.

GR-94 Weber, C.I., editor; Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents," *Environmental Monitoring Series*; EPA 670/4-73-001; EPA, Cincinnati, Ohio 45268; July, 1973.

GR-95 APHA, ASCE, AWWA, and WPCF, *Glossary of Water and Wastewater Control Engineering*, American Society of Civil Engineers, New York, 1969.

GR-96 Kennedy, D.C., et.al.; "Functional Design of a Zero Discharge WasteWater Treatment System for the National Center for Toxicological Research," a paper presented at the 31st Annual Purdue Industrial Wastewater Conference, Purdue University, West Lafayette, Indiana; May 6, 1976.

GR-97 Sittig, M.; *Pollutant Removal Handbook*, Noyes Data Corporation, Park Ridge, New Jersey and London, England; 1973.

GR=98 U.S. EPA; *Development Document for Interim Final Effluent Limitations Guidelines and Proposed New Source Performance Standards for the Common and Precious Metals Segment of the Electroplating Point Source Category*; EPA 440/1-75/040, Group I, Phase II, EPA Office of Water and Hazardous Materials, Effluent Guidelines Division, Washington, D.C. 20460; April, 1975.

GR-99 U.S. EPA; *Revised BATEA Supplement to Development Document for Interim Final Effluent Limitations Guidelines for the Common and Precious Metals and Metal Finishing Segments of the Electroplating Point Source Category*, Draft Document; EPA Office of Water and Hazardous Materials, Effluent Guidelines Division, Washington, D.C. 20460; December, 1975.

SECTION XVI

GLOSSARY

G. Photographic Processing Industry

Black and White Film. This film consists of a support, usually a plastic film which is coated with a light sensitive emulsion and an outer protective layer. The emulsion is adhered to the supporting base with a special layer called a sub. The emulsion is made of: gelatin; silver salts of bromide, iodide, and chloride; sensitizers; hardeners; couplers; and emulsion plasticizers.

Bleaching. A step in color film processing whereby the silver image which is formed with the dye image is converted back to silver halide by reactions with ferricyanide and sodium bromide or ferric EDTA.

Blix. A solution that contains both bleaching and fixing chemicals used in some color processing to simultaneously fix and bleach the processed material.

Complex Cyanide. This term refers to ferrocyanide $[Fe(CN)_6^{-4}]$ and/or ferricyanide $[Fe(CN)_6^{-3}]$.

Couplers. A group of organic chemicals which react with the oxidized components of the developers to form color dyes. They are either incorporated in the film emulsion at the time of manufacture (e.g., Ektachrome film) or they are included in the color developing solution (e.g., Kodachrome film).

Developing Agents. These photographic materials usually are aromatic compounds with phenolic or amino electron-donor groups arranged ortho or para with respect to each other, such as: hydroquinone, methyl p-amino-phenol (metol), or 1-phenol-3 pyrazolidone (phenidone).

Development. A step in photoprocessing whereby the latent image is made visible in a developer solution.

Developer Solution. This solution contains: (1) activators like sodium or potassium carbonate, sodium hydroxide, borax, phosphate; (2) preservatives like sodium sulfite, hydroxylamine; (3) restrainers like sodium or potassium bromide, sodium chloride, potassium iodide; (4) anti foggants like benzotrizole; and (5) water conditioners like phosphates, EDTA, or NCA.

"Dip and Dunk". An automatic processing machine whereby strips of film are "dipped" into successive photoprocessing tanks and held for development.

Dye Image. A color image formed when the oxidized developer combines with the color couplers.

EDTA. The disodium salt of ethylenediamine tetraacetic acid. EDTA is oxidized well by ozonation.

Fix. A step in photoprocessing whereby the unexposed and undeveloped silver must be removed from the emulsion. Common among the solvent fixers are sodium thiosulfate.

Formalin. A 37.5 percent aqueous solution of formaldehyde containing about 5 to 15 percent methanol. Dilute solutions of formalin are readily biodegradable.

Glycine. Aminoacetic acid. Glycine does not oxidize with ozonation. Glycine is not to be confused with para-hydroxyphenyl glycine, commonly known as photographic-grade glycine.

Hypo. The common name for the chemical compound sodium thiosulfate which is a fixing agent.

Incorporated Couplers. Couplers that are included in film at the time of manufacture, common to reversal film.

Negative Film Development. A two-step process whereby, following the negative development, a controlled exposure of light is directed onto paper through the negative creating a negative of a negative, or a positive image on paper.

Photochemical Reaction. A chemical reaction catalyzed by light.

"Rack and Tank". See "Dip and Dunk".

Regeneration. The oxidation of ferrocyanide to ferricyanide.

Reversal Development. A method of obtaining a positive image on the same film used for the original exposure.

Short Stop. A step in photoprocessing which follows development whereby the basic activators in the developer are neutralized to prevent further development.

Silver Halide. Usually silver bromide, which, upon exposure to light converts to metallic silver, forming a latent image.

Three Layers. Color film that has three separate chemical layers that are sensitive to red, blue, and green light, respectively.

Toxicity. The quality of being poisonous. The term toxic or toxicity is used herein in the normal scientific sense of the word and not as a specialized term referring to section 307(a) of the Act.

General Definitions

Abatement. The measures taken to reduce or eliminate pollution.

Absorption. A process in which one material (the absorbent) takes up and retains another (the absorbate) with the formation of a homogeneous mixture having the attributes of a solution. Chemical reaction may accompany or follow absorption.

Acclimation. The ability of an organism to adapt to changes in its immediate environment.

Acid. A substance which dissolves in water with the formation of hydrogen ions.

Acid Solution. A solution with a pH of less than 7.00 in which the activity of the hydrogen ion is greater than the activity of the hydroxyl ion.

Acidity. The capacity of a wastewater for neutralizing a base. It is normally associated with the presence of carbon dioxide, mineral and organic acids and salts of strong acids or weak bases. It is reported as equivalent of $CaCO_3$ because many times it is not known just what acids are present.

Acidulate. To make somewhat acidic.

Act. The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500.

Activated Carbon. Carbon which is treated by high-temperature heating with steam or carbon dioxide producing an internal porous particle structure.

Activated Sludge Process. A process which removes the organic matter from sewage by saturating it with air and biologically active sludge. The recycle "activated" microooganisms are able to remove both the soluble and colloidal organic material from the wastewater.

Adsorption. An advanced method of treating wastes in which a material removes organic matter not necessarily responsive to clarification or biological treatment by adherence on the surface of solid bodies.

Adsorption Isotherm. A plot used in evaluating the effectiveness of activated carbon treatment by showing the amount of impurity adsorbed versus the amount remaining. They are determined at a constant temperature by varying the amount of carbon used or the concentration of the impurity in contact with the carbon.

Advance Waste Treatment. Any treatment method or process employed following biological treatment to increase the removal of pollution load, to remove substances that may be deleterious to receiving waters or the environment or to produce a high-quality effluent suitable for reuse in any specific manner or for discharge under critical conditions. The term tertiary treatment is commonly used to denote advanced waste treatment methods.

Aeration. (1) The bringing about of intimate contact between air and a liquid by one of the following methods: spraying the liquid in the air, bubbling air through the liquid, or agitation of the liquid to promote surface absorption of air. (2) The process or state of being supplied or impregnated with air; in waste treatment, a process in which liquid from the primary clarifier is mixed with compressed air and with biologically active sludge.

Aeration Period. (1) The theoretical time, usually expressed in hours, that the mixed liquor is subjected to aeration in an aeration tank undergoing activated-sludge treatment. It is equal to the volume of the tank divided by the volumetric rate of flow of wastes and return sludge. (2) The theoretical time that liquids are subjected to aeration.

Aeration Tank. A vessel for injecting air into the water.

Aerobic. Ability to live, grow, or take place only where free oxygen is present.

Aerobic Biological Oxidation. Any waste treatment or process utilizing aerobic organisms, in the presence of air or oxygen, as agents for reducing the pollution load or oxygen demand of organic substances in waste.

Aerobic Digestion. A process in which microorganisms obtain energy by endogenous or auto-oxidation of their cellular protoplasm. The biologically degradable constituents of cellular material are slowly oxidized to carbon dioxide, water and ammonia, with the ammonia being further converted into nitrates during the process.

Algae. One-celled or many-celled plants which grow in sunlit waters and which are capable of photosynthesis. They are a food for fish and small aquatic animals and, like all plants, put oxygen in the water.

Algicide. Chemical agent used to destroy or control algae.

Alkali. A water-soluble metallic hydroxide that ionizes strongly.

Alkalinity. The presence of salts of alkali metals. The hydroxides, carbonates and bicarbonates of calcium, sodium and magnesium are common impurities that cause alkalinity. A quantitative measure of the capacity of liquids or suspensions to neutralize strong acids or to resist the establishment of acidic conditions. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, volatile acids, salts and occasionally borates and is usually expressed in terms of the concentration of calcium carbonate that would have an equivalent capacity to neutralize strong acids.

Alum. A hydrated aluminum sulfate or potassium aluminum sulfate or ammonium aluminum sulfate which is used as a settling agent. A coagulant.

Ammonia Nitrogen. A gas released by the microbiological decay of plant and animal proteins. When ammonia nitrogen is found in waters, it is indicative of incomplete treatment.

Ammonification. The process in which ammonia is liberated from organic compounds by microoganisms.

Anaerobic. Ability to live, grow, or take place where there is no air or free oxygen present.

Anaerobic Biological Treatment. Any treatment method or process utilizing anaerobic or facultative organisms, in the absence of air, for the purpose of reducing the organic matter in wastes or organic solids settled out from wastes.

Anaerobic Digestion. Biodegradable materials in primary and excess activated sludge are stabilized by being oxidized to carbon dioxide, methane and other inert products. The primary digester serves mainly to reduce VSS, while the secondary digester is mainly for solids-liquid separation, sludge thickening and storage.

Anion. Ion with a negative charge.

Antagonistic Effect. The simultaneous action of separate agents mutually opposing each other.

Aqueous Solution. One containing water or watery in nature.

Arithmetic Mean. The arithmetic mean of a number of items is obtained by adding all the items together and dividing the total by the number of items. It is frequently called the average. It is greatly affected by extreme values.

Backwashing. The process of cleaning a rapid sand or mechanical filter by reversing the flow of water.

Bacteria. Unicellular, plant-like microorganisms, lacking chlorophyll. Any water supply contaminated by sewage is certain to contain a bacterial group called "coliform".

Bateria, Coliform Group. A group of bacteria, predominantly inhabitants of the intestine of man but also found on vegetation, including all aerobic and facultative anaerobic gram-negative, non-sporeforming bacilli that ferment lactose with gas formation. This group includes five tribes of which the very great majority are Eschericheae. The Eschericheae tribe comprises three genera and ten species, of which Escherichia Coli and Aerobacter Aerogenes are dominant. The Escherichia Coli are normal inhabitants of the intestine of man and all vertbrates whereas Aerobacter Aerogenes normally are found on grain and plants, and only to a varying degree in the intestine of man and animals. Formerly referred to as B. Coli, B. Coli group, and Coli-Aerogenes Group.

Bacterial Growth. All bacteria require food for their continued life and growth and all are affected by the conditions of their environment. Like human beings, they consume food, they respire, they need moisture, they require heat, and they give off waste products. Their food requirements are very definite and have been, in general, already outlined. Without an adequate food supply of the type the specific organism requires, bacteria will not grow and multiply at their maximum rate and they will therefore, not perform their full and complete functions.

NSPS Effluent Limitations. Limitations for new sources which are based on the application of the Best Available Demonstrated Control Technology.

Base. A substance that in aqueous solution turns red litmus blue, furnishes hydroxyl ions and reacts with an acid to form a salt and water only.

Batch Process. A process which has an intermittent flow of raw materials into the process and a resultant intermittent flow of product from the process.

BAT Effluent Limitations. Limitations for point sources, other than publicly owned treatment works, which are based on the application of the Best Available Technology Economically Achievable. These limitations must be achieved by July 1, 1983.

Benthic. Attached to the bottom of a body of water.

Benthos. Organisms (fauna and flora) that live on the bottoms of bodies of water.

Bioassay. An assessment which is made by using living organisms as the sensors.

Biochemical Oxygen Demand (BOD). A measure of the oxygen required to oxidize the organic material in a sample of wastewater by natural biological process under standard conditions. This test is presently universally accepted as the yardstick of pollution and is utilized as a means to determine the degree of treatment in a waste treatment process. Usually given in mg/l (or ppm units), meaning milligrams of oxygen required per liter of wastewater, it can also be expressed in pounds of total oxygen required per wastewater or sludge batch. The standard BOD is five days at 20 degrees C.

Biota. The flora and fauna (plant and animal life) of a stream or other water body.

Biological Treatment System. A system that uses microorganisms to remove organic pollutant material from a wastewater.

Blowdown. Water intentionally discharged from a cooling or heating system to maintain the dissolved solids concentration of the circulating water below a specific critical level. The removal of a portion of any process flow to maintain the constituents of the flow within desired levels. Process may be intermittent or continuous. 2) The water discharged from a boiler or cooling tower to dispose of accumulated salts.

BOD5. Biochemical Oxygen Demand (BOD) is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The BOD test has been developed on the basis of a 5-day incubation period (i.e. BOD5).

BPT Effluent Limitations. Limitations for point sources, other than publicly owned treatment works, which are based on the application of the Best Practicable Control Technology Currently Available. These limitations must be achieved by July 1, 1977.

Break Point. The point at which impurities first appear in the effluent of a granular carbon adsorption bed.

Break Point Chlorination. The addition of sufficient chlorine to destroy or oxidize all substances that creates a chlorine demand with an excess amount remaining in the free residual state.

Brine. Water saturated with a salt.

Buffer. A solution containing either a weak acid and its salt or a weak base and its salt which thereby resists changes in acidity or basicity, and resists changes in pH.

Carbonaceous. Containing or composed of carbon.

Catalyst. A substance which changes the rate of a chemical reaction but undergoes no permanent chemical change itself.

Cation. The ion in an electrolyte which carries the positive charge and which migrates toward the cathode under the influence of a potential difference.

Caustic Soda. In its hydrated form it is called sodium hydroxide. Soda ash is sodium carbonate.

Centrate. The liquid fraction that is separated from the solids fraction of a slurry through centrifugation.

Centrifugation. The process of separating heavier materials from lighter ones through the employment of centrifugal force.

Centrifuge. An apparatus that rotates at high speed and by centrifugal force separates substances of different densities.

Chemical Oxygen Demand (COD). A measure of oxygen-consuming capacity of organic and inorganic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test. It does not differentiate between stable and unstable organic matter and thus does not correlate with biochemical oxygen demand.

Chemical Synthesis. The processes of chemically combining two or more constituent substances into a single substance.

Chlorination. The application of chlorine to water, sewage or industrial wastes, generally for the purpose of disinfection but frequently for accomplishing other biological or chemical results.

Clarification. Process of removing turbidity and suspended solids by settling. Chemicals can be added to improve and speed up the settling process through coagulation.

Clarifier. A basin or tank in which a portion of the material suspended in a wastewater is settled.

Clays. Aluminum silicates less than 0.002mm (2.0 um) in size. Therefore, most clay types can go into colloidal suspension.

Coagulation. The clumping together of solids to make them settle out of the sewage faster. Coagulation of solids is brought about with the use of certain chemicals, such as lime, alum or polyelectrolytes.

Coagulation and Flocculation. Processes which follow sequentially.

Coagulation Chemicals. Hydrolyzable divalent and trivalent metallic ions of aluminum, magnesium, and iron salts. They include alum (aluminum sulfate), quicklime (calcium oxide), hydrated lime (calcium hydroxide), sulfuric acid, anhydrous ferric chloride. Lime and acid affect only the solution pH which in turn causes coagulant precipitation, such as that of magnesium.

Coliform. Those bacteria which are most abundant in sewage and in streams containing feces and other bodily waste discharges. See bacteria, coliform group.

Colloid. A finely divided dispersion of one material (0.01-10 micron-sized particles), called the "dispersed phase" (solid), in another material, called the "dispersion medium" (liquid).

Color Bodies. Those complex molecules which impart color to a solution.

Color Units. A solution with the color of unity contains a mg/l of metallic platinum (added as potassium chloroplatinate to distilled water). Color units are defined against a platinum-cobalt standard and are based, as are all the other water quality criteria, upon those analytical methods described in Standard Methods for the Examination of Water and Wastewater, 12 ed., Amer. Public Health Assoc., N.Y., 1967.

Combined Sewer. One which carries both sewage and storm water run-off.

Composite Sample. A combination of individual samples of wastes taken at selected intervals, generally hourly for 24 hours, to minimize the effect of the variations in individual samples. Individual samples making up the composite may be of equal volume or be roughly apportioned to the volume of flow of liquid at the time of sampling.

Composting. The biochemical stabilization of solid wastes into a humus-like substance by producing and controlling an optimum environment for the process.

Concentration. The total mass of the suspended or dissolved particles contained in a unit volume at a given temperature and pressure.

Conductivity. A reliable measurement of electrolyte concentration in a water sample. The conductivity measurement can be related to the concentration of dissolved solids and is almost directly proportional to the ionic concentration of the total electrolytes.

Contact Stabilization. Aerobic digestion.

Contact Process Wastewaters. These are process-generated wastewaters which have come in direct or indirect contact with the reactants used in the process. These include such streams as contact cooling water, filtrates, centrates, wash waters, etc.

Continuous Process. A process which has a constant flow of raw materials into the process and resultant constant flow of product from the process.

Contract Disposal. Disposal of waste products through an outside party for a fee.

Crustaceae. These are small animals ranging in size from 0.2 to 0.3 milimeters long which move very rapidly through the water in search of food. They have recognizable head and posterior sections. They form a principal source of food for small fish and are found largely in relatively fresh natural water.

Crystallization. The formation of solid particles within a homogeneous phase. Formation of crystals separates a solute from a solution and generally leaves impurities behind in the mother liquid.

Culture. A mass of microorganisms growing in a media.

Cyanide. Total cyanide as determined by the test procedure specified in 40 CFR Part 136 (Federal Register, Vol. 38, no. 199, October 16, 1973).

Cyanide A. Cyanides amendable to chlorination as described in "1972 Annual Book of ASTM Standards" 1972: Standard D 2036-72, Method B, p. 553.

Demineralization. The total removal of all ions.

Denitrification. Bacterial mediated reduction of nitrate to nitrite. Other bacteria may act on the nitrite reducing it to ammonia and finally N_2 gas. This reduction of nitrate occurs under anaerobic conditions. The nitrate replaces oxygen as an electron acceptor during the metabolism of carbon compounds under anaerobic conditions. A biological process in which gaseous nitrogen is produced from nitrite and nitrate. The heterotrophic microoganisms which participate in this process include pseudomonades, achromobacters and bacilli.

Derivative. A substance extracted from another body or substance.

Desorption. The opposite of adsorption. A phenomenon where an adsorbed molecule leaves the surface of the adsorbent.

Diluent. A diluting agent.

Disinfection. The process of killing the larger portion (but not necessarily all) of the harmful and objectionable microorganisms in or on a medium.

Dissolved Air Flotation. The term "flotation" indicates something floated on or at the surface of a liquid. Dissolved air flotation thickening is a process that adds energy in the form of air bubbles, which become attached to suspended sludge particles, increasing the buoyancy of the particles and producing more positive flotation.

Dissolved Oxygen (DO). The oxygen dissolved in sewage, water or other liquids, usually expressed either in milligrams per liter or percent of saturation. It is the test used in BOD determination.

Distillation. The separation, by vaporization, of a liquid mixture of miscible and volatile substance into individual components, or, in some cases, into a group of components. The process of raising the temperature of a liquid to the boiling point and condensing the resultant vapor to liquid form by cooling. It is used to remove substances from a liquid or to obtain a pure liquid from one which contains impurities or which is a mixture of several liquids having different boiling temperatures. Used in the treatment of fermentation products, yeast, etc., and other wastes to remove recoverable products.

DO Units. The units of measurement used are milligrams per liter (mg/l) and parts per million (ppm), where mg/l is defined as the actual weight of oxygen per liter of water and ppm is defined as the parts actual weight of oxygen dissolved in a million parts weight of water, i.e., a pound of oxygen in a million pounds of water is 1 ppm. For practical purposes in pollution control work, these two are used interchangeably; the density of water is so close to 1 g/cm^3 that the error is negligible. Similarly, the changes in volume of oxygen with changes in temperature are insignificant. This, however, is not true if sensors are calibrated in percent saturation rather than in mg/l or ppm. In that case, both temperature and barometric pressure must be taken into consideration.

Dual Media. A deep-bed filtration system utilizing two separate and discrete layers of dissimilar media (e.g., anthracite and sand) placed one on top of the other to perform the filtration function.

Ecology. The science of the interrelations between living organisms and their environment.

Effluent. A liquid which leaves a unit operation or process. Sewage, water or other liquids, partially or completely treated or in their natural states, flowing out of a reservoir basin, treatment plant or any other unit operation. An influent is the incoming stream.

Elution. (1) *The process of washing out, or removing* with the use of a solvent. (2) In an ion exchange process it is defined as the stripping of adsorbed ions from an ion exchange resin by passing through the resin solutions containing other ions in relatively high concentrations.

Elutriation. A process of sludge conditioning whereby the sludge is washed, either with fresh water or plant effluent, to reduce the sludge alkalinity and fine particles, thus decreasing the amount of required coagulant in further treatment steps, or in sludge dewatering.

Emulsion. Emulsion is a suspension of fine droplets of one liquid in another.

Environment. The sum of all external influences and conditions affecting the life and the development of an organism.

Equalization Basin. A holding basin in which variations in flow and composition of a liquid are averaged. Such basins are used to provide a flow of reasonably uniform volume and composition to a treatment unit.

Eutrophication. The process in which the life-sustaining quality of a body of water is lost or diminished (e.g., aging or filling in of lakes). A eutrophic condition is one in which the water is rich in nutrients but has a seasonal oxygen deficiency.

Evapotranspiration. The loss of water from the soil both by evaporation and by transpiration from the plants growing thereon.

Facultative. Having the power to live under different conditons (either with or without oxygen).

Facultative Lagoon. A combination of the aerobic and anaerobic lagoons. It is divided by loading and thermal stratifications into an aerobic surface and an anaerobic bottom, therefore the principles of both the aerobic and anaerobic processes apply.

Fauna. The animal life adapted for living in a specified environment.

Fermentation. Oxidative decomposition of complex substances through the action of enzymes or ferments produced by microorganisms.

Filter, Trickling. A filter consisting of an artificial bed of coarse material, such as broken stone, clinkers, slate, slats or brush, over which sewage is distributed and applied in drops, films or spray, from troughs, drippers, moving distributors or fixed nozzles. The sewage trickles through to the underdrains and has the opportunity to form zoogleal slimes which clarify and oxidize the sewage.

Filter, Vacuum. A filter consisting of a cylindrical drum mounted on a horizontal axis and covered with a filter cloth. The filter revolves with a partial submergence in the liquid, and a vacuum is maintained under the cloth for the larger part of each revolution to extract moisture. The cake is scraped off continuously.

Filtrate. The liquid fraction that is separated from the solids fraction of a slurry through filtration.

Filtration, Biological. The process of passing a liquid through a biological filter containing media on the surfaces of which zoogleal films develop that absorb and adsorb fine suspended, colloidal and dissolved solids and that release various biochemical end products.

Flocculants. Those water-soluble organic polyelectrolytes that are used alone or in conjunction with inorganic coagulants such as lime, alum or ferric chloride or coagulant aids to agglomerate solids suspended in aqueous systems or both, The large dense flocs resulting from this process permit more rapid and more efficient solids-liquid separations.

Flocculation. The formation of flocs. The process step following the coagulation-precipitation reactions which consists of bringing together the colloidal particles. It is the agglomeration by organic polyelectroytes of the small, slowly settling flocs formed during coagulation into large flocs which settle rapidly.

Flora. The plant life characteristic of a region.

Flotation. A method of raising suspended matter to the surface of the liquid in a tank as scum-by aeration, vacuum, evolution of gas, chemicals, electrolysis, heat or bacterial decomposition and the subsequent removal of the scum by skimming.

Fungus. A vegetable cellular organism that subsists on organic material, such as bacteria.

Gland. A device utilizing a soft wear-resistant material used to minimize leakage between a rotating shaft and the stationary portion of a vessel such as a pump.

Gland Water. Water used to lubricate a gland. Sometimes called "packing water."

Grab Sample. (1) Instantaneous sampling. (2) A sample taken at a random place in space and time.

Grease. In sewage, grease includes fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oils and other nonfatty materials. The type of solvent to be used for its extraction should be stated.

Grit Chamber. A small detention chamber or an enlargement of a sewer designed to reduce the velocity of flow of the liquid and permit the separation of mineral from organic solids by differential sedimentation.

Groundwater. The body of water that is retained in the saturated zone which tends to move by hydraulic gradient to lower levels.

Hardness. A measure of the capacity of water for precipitating soap. It is reported as the hardness that would be produced if a certain amount of $CaCO_3$ were dissolved in water. More than one ion contributes to water hardness. The "Glossary of Water and Wastewater Control Engineering" defines hardness as: A characteristic of water, imparted by salts of calcium, magnesium, and ions, such as bicarbonates, carbonates, sulfates, chlorides, and nitrates, that cause curdling of soap, deposition of scale in boilers, damage in some industrial process, and sometimes objectionable taste. Calcium and magnesium are the most significant constituents.

Heavy Metals. A general name given for the ions of metallic elements, such as copper, zinc, iron, chromium, and aluminum. They are normally removed from a wastewater by the formation of an insoluble precipitate (usually a metallic hydroxide).

Hydrocarbon. A compound containing only carbon and hydrogen.

Hydrolysis. A chemical reaction in which water reacts with another substance to form one or more new substances.

Incineration. The combustion (by burning) of organic matter in wastewater sludge.

Incubate. To maintain cultures, bacteria, or other microorganisms at the most favorable temperature for development.

Influent. Any sewage, water or other liquid, either raw or partly treated, flowing into a reservoir, basin, treatment plant, or any part thereof. The influent is the stream entering a unit operation; the effluent is the stream leaving it.

In-Plant Measures. Technology applied within the manufacturing process to reduce or eliminate pollutants in the raw waste water. Sometimes called "internal measures" or "internal controls".

Ion. An atom or group of atoms possessing an electrical charge.

Ion Exchange. A reversible interchange of ions between a liquid and a solid involving no radical change in the structure of the solid. The solid can be a natural zeolite or a synthetic resin, also called polyelectrolyte. Cation exchange resins exchange their hydrogen ions for metal cations in the liquid. Anion exchange resins exchange their hydroxyl ions for anions such as nitrates in the liquid. When the ion-retaining capacity of the resin is exhausted, it must be regenerated. Cation resins are regenerated with acids and anion resins with bases.

Lacrimal. Tear forming fluid.

Lagoons. An oxidation pond that receives sewage which is not settled or biologically treated.

LC 50. A lethal concentration for 50% of test animals. Numerically the same as TLm. A statistical estimate of the toxicant, such as pesticide concentration, in water necessary to kill 50% of the test organisms within a specified time under standardized conditions (usually 24,48 or 96 hr).

Leach. To dissolve out by the action of a percolating liquid, such as water, seeping through a sanitary landfill.

Lime. Limestone is an accumulation of organic remains consisting mostly of calcium carbonate. When burned, it yields lime which is a solid. The hydrated form of a chemical lime is calcium hydroxide.

Liquid-liquid-extraction. The process by which the constituents of a solution are separated by causing their unequal distribution between two insoluble liquids.

Maximum Day Limitation. The effluent limitation value equal to the maximum for any one day and is the value to be published by EPA in the Federal Register.

Maximum Thirty Day Limitation. The effluent limitation value for which the average of daily values for thirty consecutive days shall not exceed and is the value to be published by EPA in the Federal Register.

Mean. The arithmetic average of the individual sample values.

Median. In a statistical array, the value having as many cases larger in value as cases smaller in value.

Median Lethal Dose (LD50). The dose lethal to 50 percent of a group of test organisms for a specified period. The dose material may be ingested or injected.

Median Tolerance Limit (TLm). In toxicological studies, the concentration of pollutants at which 50 percent of the test animals can survive for a specified period of exposure.

Microbial. Of or pertaining to a pathogenic bacterium.

Mixed Liquor. The mixture of recirculated activated sludge and primary clarifier overflow which enters the aeration tank.

Mixed Liquor Suspended Solids (MLSS). This is a vital design factor for conventional activated sludge systems and is used to define sludge retention time (SRT). SRT equals pounds of MLSS under aeration divided by the pounds of suspended solids wasted and pounds of suspended solids lost in final effluent per day.

Molecular Weight. The relative weight of a molecule compared to the weight of an atom of carbon taken as exactly 12.00; the sum of the atomic weights of the atoms in a molecule.

Mollusk (mollusca). A large animal group including those forms popularly called shellfish (but not including crustaceans). All have a soft unsegmented body protected in most instances by a calcareous shell. Examples are snails, mussels, clams, and oysters.

Mycelium. The mass of filaments which constitutes the vegetative body of fungi.

Navigable Waters. Includes all navigable waters of the United States; tributaries of navigable waters; interstate waters; intrastate lakes, rivers and streams which are utilized by interstate travellers for recreational or other purposes; intrastate lakes, rivers and streams from which fish or shellfish are taken and sold in interstate commerce; and intrastate lakes, rivers and streams which are utilized for industrial purposes by industries in interstate commerce.

Neutralization. The restoration of the hydrogen or hydroxyl ion balance in a solution so that the ionic concentration of each are equal. Conventionally, the notation "pH" (puissance d'hydrogen) is used to describe the hydrogen ion concentration or activity present in a given solution. For dilute solutions of strong acids, i.e., acids which are considered to be completely dissociated (ionized in solution), activity equals concentration.

New Source. Any facility from which there is or may be a discharge of pollutants, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance under section 306 of the Act.

Nitrate Nitrogen. The final decomposition product of the organic nitrogen compounds. Determination of this parameter indicates the degree of waste treatment.

Nitrification. Bacterial mediated oxidation of ammonia to nitrite. Nitrite can be further oxidized to nitrate. These reactions are brought about by only a few specialized bacterial species. Nitrosomonias sp. and Nitrococcus sp. oxidize ammonia to nitrite which is oxidized to nitrate by Nitrobacter sp.

Nitrifiers. Bacteria which causes the oxidation of ammonia to nitrites and nitrates.

Nitrite Nitrogen. An intermediate stage in the decomposition of organic nitrogen to the nitrate form. Tests for nitrite nitrogen can determine whether the applied treatment is sufficient.

Nitrobacteria. Those bacteria (an autotrophic genus) that oxidize nitrite nitrogen to nitrate nitrogen.

Nitrogen Cycle. Organic nitrogen in waste is oxidized by bacteria into ammonia. If oxygen is present, ammonia is bacterially oxidized first into nitrite and then into nitrate. If oxygen is not present, nitrite and nitrate are bacterially reduced to nitrogen gas. The second step is called "denitrification."

Nitrogen Fixation. Biological nitrogen fixation is carried on by a selected group of bacteria which take up atmospheric nitrogen and convert it to amine groups or for amino acid synthesis.

Nitrosomonas. Bacteria which oxidize ammonia nitrogen into nitrite nitrogen; an aerobic autotrophic life form.

Non-contact Cooling Water. Water used for cooling that does not come into direct contact with any raw material, intermediate product, waste product or finished product.

Non-contact Process Wastewaters. Wastewaters generated by a manufacturing process which have not come in direct contact with the reactants used in the process. These include such streams as non-contact cooling water, cooling tower blowdown, boiler blowdown, etc.

Nonputrescible. Incapable of organic decomposition or decay.

Normal Solution. A solution that contains 1 gm molecular weight of the dissolved substance divided by the hydrogen equivalent of the substance (that is, one gram equivalent) per liter of solution. Thus, a one normal solution of sulfuric acid (H_2SO_4, mol. wt. 98) contains (98/2) 49gms of H_2SO_4 per liter.

NPDES. National Pollution Discharge Elimination System. A federal program requiring industry to obtain permits to discharge plant effluents to the nation's water courses.

Nutrient. Any substance assimilated by an organism which promotes growth and replacement of cellular constituents.

Operations and Maintenance. Costs required to operate and maintain pollution abatement equipment including labor, material, insurance, taxes, solid waste disposal, etc.

Organic Loading. In the activated sludge process, the food to micoorganisms (F/M) ratio defined as the amount of biodegradable material available to a given amount of microorganisms per unit of time.

Osmosis. The diffusion of a solvent through a semipermeable membrane into a more concentrated solution.

Oxidation. A process in which an atom or group of atoms loses electrons; the combination of a substance with oxygen, accompanied with the release of energy. The oxidized atom usually becomes a positive ion while the oxidizing agent becomes a negative ion in (chlorination for example).

Oxidation Pond. A man-made lake or body of water in which wastes are consumed by bacteria. It receives an influent which has gone through primary treatment while a lagoon receives raw untreated sewage.

Oxidation Reduction (OR). A class of chemical reactions in which one of the reacting species gives up electrons (oxidation) while another species in the reaction accepts electrons (reduction). At one time, the term oxidation was restricted to reactions involving hydrogen. Current chemical technology has broadened the scope of these terms to include all reactions where electrons are given up and taken on by reacting species; in fact, the donating and accepting of electrons must take place simultaneously.

Oxygen, Available. The quantity of atmospheric oxygen dissolved in the water of a stream; the quantity of dissolved oxygen available for the oxidation of organic matter in sewage.

Oxygen, Dissolved. The oxygen (usually designated as DO) dissolved in sewage, water or another liquid and usually expressed in parts per million or percent of saturation.

Ozonation. A water or wastewater treatment process involving the use of ozone as an oxidation agent.

Ozone. That molecular oxygen with three atoms of oxygen forming each molecule. The third atom of oxygen in each molecule of ozone is loosely bound and easily released. Ozone is used sometimes for the disinfection of water but more frequently for the oxidation of taste-producing substances, such as phenol, in water and for the neutralization of odors in gases or air.

Parameter. A variable whose measurement aids in characterizing the sample.

Parts Per Million (ppm). Parts by weight in sewage analysis; ppm by weight is equal to milligrams per liter divided by the specific gravity. It should be noted that in water analysis ppm is always understood to imply a weight/weight ratio, even though in practice a volume may be measured instead of a weight.

Pathogenic. Disease producing.

Percolation. The movement of water beneath the ground surface both vertically and horizontally, but above the groundwater table.

Permeability. The ability of a substance (soil) to allow appreciable movement of water through it when saturated and actuated by a hydrostatic pressure.

pH. The negative logarithm of the hydrogen ion concentration or activity in a solution. The number 7 indicates neutrality, numbers less than 7 indicate increasing acidity, and numbers greater than 7 indicate increasing alkalinity.

Phenol. Class of cyclic organic derivatives with the basic chemical formula C_6H_5OH.

Phosphate. Phosphate ions exist as an ester or salt of phosphoric acid, such as calcium phosphate rock. In municipal wastewater, it is most frequently present as orthophosphate.

Phosphorus Precipitation. The addition of the multivalent metallic ions of calcium, iron and aluminum to wastewater to form insoluble precipitates with phosphorus.

Photosynthesis. The mechanism by which chlorophyll-bearing plants utilize light energy to produce carbohydrate and oxygen from carbon dioxide and water (the reverse of respiration).

Physical/Chemical Treatment System. A system that utilizes physical (i.e., sedimentation, filtration, centrifugation, activated carbon, reverse osmosis, etc.) and/or chemical means (i.e., coagulation, oxidation, precipitation, etc.) to treat wastewaters.

Phytoplankton. (1) Collective term for the plants and plant like organisms present in plankton; contrasts with zooplankton.

Plankton. Collective term for the passively floating or drifting flora and fauna of a body of water; consists largely of microscopic organisms.

Point Source. Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

Pollutional Load. A measure of the strength of a wastewater in terms of its solids or oxygen-demanding characteristics or other objectionable physical and chemical characteristics or both or in terms of harm done to receiving waters. The pollutional load imposed on sewage treatment works is expressed as population equivalent.

Polyelectrolytes. Synthetic chemicals (polymers) used to speed up the removal of solids from sewage. These chemicals cause solids to coagulate or clump together more rapidly than do chemicals such as alum or lime. They can be anionic (-charge), nonionic (+ and -charge) or cationic (+charge--the most popular). They are linear or branched organic polymers. They have high molecular weights and are water-soluble. Compounds similar to the polyelectrolyte flocculants include surface-active agents and ion exchange resins. The former are low molecular weight, water soluble compounds used to disperse solids in aqueous systems. The latter are high molecular weight, water-insoluble compounds used to selectively replace certain ions already present in water with more desirable or less noxious ions.

Population Equivalent (PE). An expression of the relative strength of a waste (usually industrial) in terms of its equivalent in domestic waste, expressed as the population that would produce the equivalent domestic waste. A population equivalent of 160 million persons means the pollutional effect equivalent to raw sewage from 160 million persons; 0.17 pounds BOD (the oxygen demand of untreated wastes from one person) = 1 PE.

Potable Water. Drinking water sufficiently pure for human use.

Potash. Potassium compounds used in agriculture and industry. Potassium carbonate can be obtained from wood ashes. The mineral potash is usually a muriate. Caustic potash is its hydrated form.

Preaeration . A preparatory treatment of sewage consisting of aeration to remove gases and add oxygen or to promote the flotation of grease and aid coagulation.

Precipitation. The phenomenon which occurs when a substance held in solution passes out of that solution into solid form. The adjustment of pH can reduce solubility and cause precipitation. Alum and lime are frequently used chemicals in such operations as water softening or alkalinity reduction.

Pretreatment. Any wastewater treatment process used to partially reduce the pollution load before the wastewater is introduced into a main sewer system or delivered to a treatment plant for substantial reduction of the pollution load.

Primary Clarifier. The settling tank into which the wastewater (sewage) first enters and from which the solids are removed as raw sludge.

Primary Sludge. Sludge from primary clarifiers.

Primary Treatment. The removal of material that floats or will settle in sewage by using screens to catch the floating objects and tanks for the heavy matter to settle in. The first major treatment and sometimes the only treatment in a waste-treatment works, usually sedimentation and/or flocculation and digestion. The removal of a moderate percentage of suspended matter but little or no colloidal or dissolved matter. It may effect the removal of 30 to 35 percent or more BOD.

Process Waste Water. Any water which, during manufacturing or processing, comes into direct contact with or results from the production or use of any raw material, intermediate product, finished product, by-product, or waste product.

Process Water. Any water (solid, liquid or vapor) which, during the manufacturing process, comes into direct contact with any raw material, intermediate product, by-product, waste product, or finished product.

Putrefaction. Biological decomposition of organic matter accompanied by the production of foul-smelling products associated with anaerobic conditions.

Pyrolysis. The high temperature decomposition of complex molecules that occurs in the presence of an inert atmosphere (no oxygen present to support combustion).

Raw Waste Load (RWL). The quantity (kg) of pollutant being discharged in a plant's wastewater. measured in terms of some common denominator (i.e., kkg of production or m^2 of floor area).

Receiving Waters. Rivers, lakes, oceans or other courses that receive treated or untreated wastewaters.

Recirculation. The refiltration of either all or a portion of the effluent in a high-rate trickling filter for the purpose of maintaining a uniform high rate through the filter. (2) The return of effluent to the incoming flow to reduce its strength.

Reduction. A process in which an atom (or group of atoms) gain electrons. Such a process always requires the input of energy.

Refractory Organics. Organic materials that are only partially degraded or entirely nonbiodegradable in biological waste treatment processes. Refractory organics include detergents, pesticides, color- and odor-causing agents, tannins, lignins, ethers, olefins, alcohols, amines, aldehydes, ketones, etc.

Residual Chlorine. The amount of chlorine left in the treated water that is available to oxidize contaminants if they enter the stream. It is usually in the form of hypochlorous acid of hypochlorite ion or of one of the chloramines. Hypochlorite concentration alone is called "free chlorine residual" while together with the chloramine concentration their sum is called "combined chlorine residual."

Respiration. Biological oxidation within a life form; the most likely energy source for animals (the reverse of photosynthesis).

Retention Time. Volume of the vessel divided by the flow rate through the vessel.

Reverse Osmosis. The process in which a solution is pressurized to a degree greater than the osmotic pressure of the solvent, causing it to pass through a membrane.

Salt. A compound made up of the positive ion of a base and the negative ion of an acid.

Sanitary Landfill. A sanitary landfill is a land disposal site employing an engineered method of disposing of solid wastes on land in a manner that minimizes environmental hazards by spreading the wastes in thin layers, compacting the solid wastes to the smallest practical volume, and applying cover material at the end of each operating day. There are two basic sanitary landfill methods; trench fill and area or ramp fill. The method chosen is dependent on many factors such as drainage and type of soil at the proposed landfill site.

Sanitary Sewers. In a separate system, pipes in a city that carry only domestic wastewater. The storm water runoff is handled by a separate system of pipes.

Screening. The removal of relatively coarse, floating and suspended solids by straining through racks or screens.

Secondary Treatment. The second step in most waste treatment systems in which bacteria consume the organic part of the wastes. This is accomplished by bringing the sewage and bacteria together either in trickling filters or in the activated sludge process.

Sedimentation, Final. The settling of partly settled, flocculated or oxidized sewage in a final tank. (The term settling is preferred).

Sedimentation, Plain. The sedimentation of suspended matter in a liquid unaided by chemicals or other special means and without any provision for the decomposition of the deposited solids in contact with the sewage. (The term plain settling is preferred).

Seed. To introduce microorganisms into a culture medium.

Settleable Solids. Suspended solids which will settle out of a liquid waste in a given period of time.

Settling Velocity. The terminal rate of fall of a particle through a fluid as induced by gravity or other external forces.

Sewage, Raw. Untreated sewage.

Sewage, Storm. The liquid flowing in sewers during or following a period of heavy rainfall and resulting therefrom.

Sewerage. A comprehensive term which includes facilities for collecting, pumping, treating, and disposing of sewage; the sewerage system and the sewage treatment works.

Silt. Particles with a size distribution of 0.05mm-0.002mm (2.0um). Silt is high in quartz and feldspar.

Skimming. Removing floating solids (scum).

Sludge, Activated. Sludge floc produced in raw or settled sewage by the growth of zoogleal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning the floc previously formed.

Sludge, Age. The ratio of the weight of volatile solids in the digester to the weight of volatile solids added per day. There is a maximum sludge age beyond which no significant reduction in the concentration of volatile solids will occur.

Sludge, Digested. Sludge digested under anaerobic conditions until the volatile content has been reduced, usually by approximately 50 percent or more.

Solution. A homogeneous mixture of two or more substances of dissimilar molecular structure. In a solution, there is a dissolving medium-solvent and a dissolved substance-solute.

Solvent. A liquid which reacts with a material, bringing it into solution.

Solvent Extraction. A mixture of two components is treated by a solvent that preferentially dissolves one or more of the components in the mixture. The solvent in the extract leaving the extractor is usually recovered and reused.

Sparger. An air diffuser designed to give large bubbles, used singly or in combination with mechanical aeration devices.

Standard Deviation. The square root of the variance which describes the variability within the sampling data on the basis of the deviation of individual sample values from the mean.

Standard Raw Waste Load (SRWL). The raw waste load which characterizes a specific subcategory. This is generally computed by averaging the plant raw waste loads within a subcategory.

Sterilization. The complete destuction of all living organisms in or on a medium; heat to 121°C at 5 psig for 15 minutes.

Stillwell. A pipe, chamber, or compartment with comparatively small inlet or inlets communicating with a main body of water. Its purpose is to dampen waves or surges while permitting the water level within the well to rise and fall with the major fluctuations of the main body of water. It is used with water-measuring devices to improve accuracy of measurement.

Stoichiometric. Characterized by being a proportion of substances exactly right for a specific chemical reaction with no excess of any reactant or product.

Substrate. (1) Reactant portion of any biochemical reaction, material transformed into a product. (2) Any substance used as a nutrient by a microorganism. (3) The liquor in which activated sludge or other material is kept in suspension.

Sulfate. The final decomposition product of organic sulfur compounds.

Supernatant. Floating above or on the surface.

Surge tank. A tank for absorbing and dampening the wavelike motion of a volume of liquid; an in-process storage tank that acts as a flow buffer between process tanks.

Suspended Solids. The wastes that will not sink or settle in sewage. The quantity of material deposited on a filter when a liquid is drawn through a Gooch crucible.

Synergistic. An effect which is more than the sum of the individual contributors.

Synergistic Effect. The simultaneous action of separate agents which, together, have greater total effect than the sum of their individual effects.

Tertiary Treatment. A process to remove practically all solids and organic matter from wastewater. Granular activated carbon filtration is a tertiary treatment process. Phosphate removal by chemical coagulation is also regarded as a step in tertiary treatment.

Thermal Oxidation. The wet combustion of organic materials through the application of heat in the presence of oxygen.

TKN (Total Kjeldahl Nitrogen). Includes ammonia and organic nitrogen but does not include nitrite and nitrate nitrogen. The sum of free nitrogen and organic nitrogen in a sample.

TLm. The concentration that kills 50% of the test organisms within a specified time span, usually in 96 hours or less. Most of the available toxicity data are reported as the median tolerance limit (TLm). This system of reporting has been misapplied by some who have erroneously inferred that a TLm value is a safe value, whereas it is merely the level at which half of the test organisms are killed. In many cases, the differences are great between TLm concentrations and concentrations that are low enough to permit reproduction and growth. LC50 has the same numerical value as TLm.

Total Organic Carbon (TOC). A measure of the amount of carbon in a sample originating from organic matter only. The test is run by burning the sample and measuring the carbon dioxide produced.

Total Solids. The total amount of solids in a wastewater both in solution and suspension.

Total Volatile Solids (TVS). The quantity of residue lost after the ignition of total solids.

Transport Water. Water used to carry insoluble solids.

Trickling Filter. A bed of rocks or stones. The sewage is trickled over the bed so that bacteria can break down the organic wastes. The bacteria collect on the stones through repeated use of the filter.

Turbidity. A measure of the amount of solids in suspension. The units of measurement are parts per million (ppm) of suspended solids or Jackson Candle Units. The Jackson Candle Unit (JCU) is defined as the turbidity resulting from 1 ppm of fuller's earth (and inert mineral) suspended in water. The relationship between ppm and JCU depends on particle size, color, index of refraction; the correlation between the two is generally not possible. Turbidity instruments utilize a light beam projected into the sample fluid to effect a measurement. The light beam is scattered by solids in suspension, and the degree of light attenuation or the amount of scattered light can be related to turbidity. The light scattering is called the Tyndall effect and the scattered light the Tyndall light. An expression of the optical property of a sample which causes light to be scattered and absorbed rather than transmitted in straight lines through the sample.

Volatile Suspended Solids (VSS). The quantity of suspended solids lost after the ignition of total suspended solids.

Waste Treatment Plant. A series of tanks, screens, filters, pumps and other equipment by which pollutants are removed from water.

Water Quality Criteria. Those specific values of water quality associated with an identified beneficial use of the water under consideration.

Weir. A flow measuring device consisting of a barrier across an open channel, causing the liquid to flow over its crest. The height of the liquid above the crest varies with the volume of liquid flow.

Wet Air Pollution Control. The technique of air pollution abatement utilizing water as an absorptive media.

Wet Oxidation. The direct oxidation of organic matter in wastewater liquids in the presence of air under heat and pressure; generally applied to organic matter oxidation in sludge.

Zeolite. Various natural or synthesized silicates used in water softening and as absorbents.

Zooplankton. (1) The animal portion of the plankton. (2) Collective term for the nonphotosynthetic organisms present in plankton; contrasts with phytoplantkton.

SECTION XVII

ABBREVIATIONS AND SYMBOLS

A.C.	activated
ac ft	acre-foot
Ag.	silver
atm	atmosphere
ave	average
B.	boron
Ba.	barium
bbl	barrel
BOD$_5$	biochemical oxygen demand, five day
Btu	British thermal unit
C	centigrade degrees
C.A.	carbon adsorption
cal	calorie
cc	cubic centimeter
cfm	cubic foot per minute
cfs	cubic foot per second
Cl.	chloride
cm	centimeter
CN	cyanide
COD	chemical oxygen demand
conc.	concentration
cu	cubic
db	decibels
deg	degree
DO	dissolved oxygen
E. Coli.	Escherichia coliform bacteria
Eq.	equation
F	Fahrenheit degrees
Fig.	figure
F/M	BOD$_5$ (Wastewater flow)/ MLSS (contractor volume)
fpm	foot per minute
fps	foot per second
ft	foot
g	gram
gal	gallon
gpd	gallon per day
gpm	gallon per minute
Hg.	mercury
hp	horsepower
hp-hr	horsepower-hour
hr	hour
in.	inch
kg	kilogram
kw	kilowatt
kwhr	kilowatt-hour

L(l)	liter
L/kkg	liters per 1000 kilograms
lb	pound
m	meter
M	thousand
me	milliequivalent
mg	milligram
mgd	million gallons daily
min	minute
ml	milliliter
MLSS	mixed-liquor suspended solids
MLVSS	mixed-liquor volatile suspended solids
MM	million
mole	gram-molecular weight
mph	mile per hour
MPN	most probable number
mu	millimicron
NO_3	nitrate
NH_3-N	ammonium nitrogen
O_2	oxygen
PO_4	phosphate
p.	page
pH	potential hydrogen or hydrogen-ion index (negative logarithm of the hydrogen-ion concentration)
pp.	pages
ppb	parts per billion
ppm	parts per million
psf	pound per square foot
psi	pound per square inch
psig	pounds per square inch gauge
R.O.	reverse osmosis
rpm	revolution per minute
RWL	raw waste load
sec	second
Sec.	Section
S.I.C.	Standard Industrial Classification
SO_x	sulfates
sq	square
sq ft	square foot
SS	suspended solids
stp	standard temperature and pressure
SRWL	standard raw waste load
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TLm	median tolerance limit
TOC	total organic carbon
TOD	total oxygen demand
TSS	total suspended solids
u	micron
ug	microgram
vol	volume
wt	weight
yd	yard

TABLE XVIII

METRIC TABLE

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS)		by		TO OBTAIN (METRIC UNITS)
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre-feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram-calories
British Thermal Unit/Pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	1	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555 (°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	1	liters
gallon/minute	gpm	0.0631	1/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
ton (short)	ton	0.907	kkg	metric ton (1000 kilograms)
yard	yd	0.9144	m	meter

*Actual conversion, not a multiplier