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Acute Exposure Guideline Levels for Selected Airborne Chemicals

VOLUME 11

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Preface

Extremely hazardous substances (EHSs)[2] can be released accidentally as a result of chemical spills, industrial explosions, fires, or accidents involving railroad cars and trucks transporting EHSs. Workers and residents in communities surrounding industrial facilities where EHSs are manufactured, used, or stored and in communities along the nation's railways and highways are potentially at risk of being exposed to airborne EHSs during accidental releases or intentional releases by terrorists. Pursuant to the Superfund Amendments and Reauthorization Act of 1986, the U.S. Environmental Protection Agency (EPA) has identified approximately 400 EHSs on the basis of acute lethality data in rodents.

As part of its efforts to develop acute exposure guideline levels for EHSs, EPA and the Agency for Toxic Substances and Disease Registry (ATSDR) in 1991 requested that the National Research Council (NRC) develop guidelines for establishing such levels. In response to that request, the NRC published *Guidelines for Developing Community Emergency Exposure Levels for Hazardous Substances* in 1993. Subsequently, *Standard Operating Procedures for Developing Acute Exposure Guideline Levels for Hazardous Substances* was published in 2001, providing updated procedures, methodologies, and other guidelines used by the National Advisory Committee (NAC) on Acute Exposure Guideline Levels for Hazardous Substances and the Committee on Acute Exposure Guideline Levels (AEGLs) in developing the AEGL values.

Using the 1993 and 2001 NRC guidelines reports, the NAC—consisting of members from EPA, the Department of Defense (DOD), the Department of Energy (DOE), the Department of Transportation (DOT), other federal and state governments, the chemical industry, academia, and other organizations from the private sector—has developed AEGLs for more than 270 EHSs.

In 1998, EPA and DOD requested that the NRC independently review the AEGLs developed by NAC. In response to that request, the NRC organized within its Committee on Toxicology (COT) the Committee on Acute Exposure Guideline Levels, which prepared this report. This report is the eleventh volume in that series. AEGL documents for bis-chloromethyl ether, chloromethyl

[2]As defined pursuant to the Superfund Amendments and Reauthorization Act of 1986.

methyl ether, chlorosilanes, nitrogen oxides, and vinyl chloride are each published as an appendix in this report. The committee concludes that the AEGLs developed in these appendixes are scientifically valid conclusions based on the data reviewed by NAC and are consistent with the NRC guideline reports. AEGL reports for additional chemicals will be presented in subsequent volumes.

The committee's review of the AEGL documents involved both oral and written presentations to the committee by the authors of the documents. The committee examined the draft documents and provided comments and recommendations for how they could be improved in a series of interim reports. The authors revised the draft AEGL documents based on the advice in the interim reports and presented them for reexamination by the committee as many times as necessary until the committee was satisfied that the AEGLs were scientifically justified and consistent with the 1993 and 2001 NRC guideline reports. After these determinations have been made for an AEGL document, it is published as an appendix in a volume such as this one.

The five interim reports of the committee that led to this report were reviewed in draft form by individuals selected for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of the five committee interim reports, which summarize the committee's conclusions and recommendations for improving NAC's AEGL documents for bis-chloromethyl ether (interim reports 18 and 19a), chloromethyl methyl ether (interim reports 11, 18, and 19a), chlorosilanes (interim reports 18 and 19a), nitrogen oxides (interim reports 15, 18, and 19a), and vinyl chloride (interim reports 16, 18, and 19a): Deepak Bhalla (Wayne State University), Harvey Clewell (The Hamner Institutes for Health Sciences), Sidney Green, Jr. (Howard University), A. Wallace Hayes (Harvard School of Public Health), Rogene Henderson (Lovelace Respiratory Research Institute [retired]), Sam Kacew (University of Ottawa), James McDougal (Wright State University [retired]), Charles Reinhardt (DuPont Haskell Laboratory [retired]), Andrew Salmon (California Environmental Protection Agency), Joyce Tsuji (Exponent, Inc.), and Judith Zelikoff (New York University).

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of this volume before its release. The review of interim report 11 was overseen by Rakesh Dixit (MedImmune/AstraZeneca Biologics, Inc.), and interim reports 15, 16, 18, and 19a were overseen by Robert Goyer (University of Western Ontario [retired]). Appointed by the NRC, they were responsible for making certain that an independent examination of the interim reports was carried out in accordance with institutional

procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

The committee gratefully acknowledges the valuable assistance provided by the following persons: Ernest Falke and Iris A. Camacho (both from EPA) and George Rusch (Risk Assessment and Toxicology Services). The committee also acknowledges Susan Martel, the project director for her work this project. Other staff members who contributed to this effort are James J. Reisa (director of the Board on Environmental Studies and Toxicology), Radiah Rose (manager of editorial projects), Mirsada Karalic-Loncarevic (manager of the Technical Information Center), and Tamara Dawson (program associate). Finally, I would like to thank all members of the committee for their expertise and dedicated effort throughout the development of this report.

Donald E. Gardner, *Chair*
Committee on Acute Exposure
Guideline Levels

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Acute Exposure Guideline Levels for Selected Airborne Chemicals

VOLUME 11

National Research Council Committee Review of Acute Exposure Guideline Levels of Selected Airborne Chemicals

This report is the eleventh volume in the series *Acute Exposure Guideline Levels for Selected Airborne Chemicals*.

In the Bhopal disaster of 1984, approximately 2,000 residents living near a chemical plant were killed and 20,000 more suffered irreversible damage to their eyes and lungs following accidental release of methyl isocyanate. The toll was particularly high because the community had little idea what chemicals were being used at the plant, how dangerous they might be, or what steps to take in an emergency. This tragedy served to focus international attention on the need for governments to identify hazardous substances and to assist local communities in planning how to deal with emergency exposures.

In the United States, the Superfund Amendments and Reauthorization Act (SARA) of 1986 required that the U.S. Environmental Protection Agency (EPA) identify extremely hazardous substances (EHSs) and, in cooperation with the Federal Emergency Management Agency and the U.S. Department of Transportation, assist local emergency planning committees (LEPCs) by providing guidance for conducting health hazard assessments for the development of emergency response plans for sites where EHSs are produced, stored, transported, or used. SARA also required that the Agency for Toxic Substances and Disease Registry (ATSDR) determine whether chemical substances identified at hazardous waste sites or in the environment present a public health concern.

As a first step in assisting the LEPCs, EPA identified approximately 400 EHSs largely on the basis of their immediately dangerous to life and health values, developed by the National Institute for Occupational Safety or Health. Although several public and private groups, such as the Occupational Safety and Health Administration and the American Conference of Governmental Industrial

Hygienists, have established exposure limits for some substances and some exposures (e.g., workplace or ambient air quality), these limits are not easily or directly translated into emergency exposure limits for exposures at high levels but of short duration, usually less than 1 hour (h), and only once in a lifetime for the general population, which includes infants (from birth to 3 years of age), children, the elderly, and persons with diseases, such as asthma or heart disease.

The National Research Council (NRC) Committee on Toxicology (COT) has published many reports on emergency exposure guidance levels and spacecraft maximum allowable concentrations for chemicals used by the U.S. Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) (NRC 1968, 1972, 1984a,b,c,d, 1985a,b, 1986a, 1987, 1988, 1994, 1996a,b, 2000a, 2002a, 2007a, 2008a). COT has also published guidelines for developing emergency exposure guidance levels for military personnel and for astronauts (NRC 1986b, 1992, 2000b). Because of COT's experience in recommending emergency exposure levels for short-term exposures, in 1991 EPA and ATSDR requested that COT develop criteria and methods for developing emergency exposure levels for EHSs for the general population. In response to that request, the NRC assigned this project to the COT Subcommittee on Guidelines for Developing Community Emergency Exposure Levels for Hazardous Substances. The report of that subcommittee, *Guidelines for Developing Community Emergency Exposure Levels for Hazardous Substances* (NRC 1993), provides step-by-step guidance for setting emergency exposure levels for EHSs. Guidance is given on what data are needed, what data are available, how to evaluate the data, and how to present the results.

In November 1995, the National Advisory Committee (NAC)[1] for Acute Exposure Guideline Levels for Hazardous Substances was established to identify, review, and interpret relevant toxicologic and other scientific data and to develop acute exposure guideline levels (AEGLs) for high-priority, acutely toxic chemicals. The NRC's previous name for acute exposure levels—community emergency exposure levels (CEELs)—was replaced by the term AEGLs to reflect the broad application of these values to planning, response, and prevention in the community, the workplace, transportation, the military, and the remediation of Superfund sites.

AEGLs represent threshold exposure limits (exposure levels below which adverse health effects are not likely to occur) for the general public and are applicable to emergency exposures ranging from 10 minutes (min) to 8 h. Three levels—AEGL-1, AEGL-2, and AEGL-3—are developed for each of five expo-

[1]NAC completed its chemical reviews in October 2011. The committee was composed of members from EPA, DOD, many other federal and state agencies, industry, academia, and other organizations. From 1996 to 2011, the NAC discussed over 300 chemicals and developed AEGLs values for at least 272 of the 329 chemicals on the AEGLs priority chemicals lists. Although the work of the NAC has ended, the NAC-reviewed technical support documents are being submitted to the NRC for independent review and finalization.

sure periods (10 min, 30 min, 1 h, 4 h, and 8 h) and are distinguished by varying degrees of severity of toxic effects. The three AEGLs are defined as follows:

AEGL-1 is the airborne concentration (expressed as ppm [parts per million] or mg/m^3 [milligrams per cubic meter]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

Airborne concentrations below AEGL-1 represent exposure levels that can produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic nonsensory adverse effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, it is recognized that individuals, subject to idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL.

SUMMARY OF REPORT ON GUIDELINES FOR DEVELOPING AEGLS

As described in *Guidelines for Developing Community Emergency Exposure Levels for Hazardous Substances* (NRC 1993) and the NRC guidelines report *Standing Operating Procedures for Developing Acute Exposure Guideline Levels for Hazardous Chemicals* (NRC 2001a), the first step in establishing AEGLs for a chemical is to collect and review all relevant published and unpublished information. Various types of evidence are assessed in establishing AEGL values for a chemical. These include information from (1) chemical-physical characterizations, (2) structure-activity relationships, (3) in vitro toxicity studies, (4) animal toxicity studies, (5) controlled human studies, (6) observations of humans involved in chemical accidents, and (7) epidemiologic studies. Toxicity data from human studies are most applicable and are used when available in preference to data from animal studies and in vitro studies. Toxicity data from

inhalation exposures are most useful for setting AEGLs for airborne chemicals because inhalation is the most likely route of exposure and because extrapolation of data from other routes would lead to additional uncertainty in the AEGL estimate.

For most chemicals, actual human toxicity data are not available or critical information on exposure is lacking, so toxicity data from studies conducted in laboratory animals are extrapolated to estimate the potential toxicity in humans. Such extrapolation requires experienced scientific judgment. The toxicity data for animal species most representative of humans in terms of pharmacodynamic and pharmacokinetic properties are used for determining AEGLs. If data are not available on the species that best represents humans, data from the most sensitive animal species are used. Uncertainty factors are commonly used when animal data are used to estimate risk levels for humans. The magnitude of uncertainty factors depends on the quality of the animal data used to determine the no-observed-adverse-effect level (NOAEL) and the mode of action of the substance in question. When available, pharmacokinetic data on tissue doses are considered for interspecies extrapolation.

For substances that affect several organ systems or have multiple effects, all end points (including reproductive [in both genders], developmental, neurotoxic, respiratory, and other organ-related effects) are evaluated, the most important or most sensitive effect receiving the greatest attention. For carcinogenic chemicals, excess carcinogenic risk is estimated, and the AEGLs corresponding to carcinogenic risks of 1 in 10,000 (1×10^{-4}), 1 in 100,000 (1×10^{-5}), and 1 in 1,000,000 (1×10^{-6}) exposed persons are estimated.

REVIEW OF AEGL REPORTS

As NAC began developing chemical-specific AEGL reports, EPA and DOD asked the NRC to review independently the NAC reports for their scientific validity, completeness, and consistency with the NRC guideline reports (NRC 1993, 2001a). The NRC assigned this project to the COT Committee on Acute Exposure Guideline Levels. The committee has expertise in toxicology, epidemiology, occupational health, pharmacology, medicine, pharmacokinetics, industrial hygiene, and risk assessment.

The AEGL draft reports were initially prepared by ad hoc AEGL development teams consisting of a chemical manager, chemical reviewers, and a staff scientist of the NAC contractors—Oak Ridge National Laboratory and subsequently Syracuse Research Corporation. The draft documents were then reviewed by NAC and elevated from "draft" to "proposed" status. After the AEGL documents were approved by NAC, they were published in the *Federal Register* for public comment. The reports were then revised by NAC in response to the public comments, elevated from "proposed" to "interim" status, and sent to the NRC Committee on Acute Exposure Guideline Levels for final evaluation.

The NRC committee's review of the AEGL reports prepared by NAC and its contractors involves oral and written presentations to the committee by the authors of the reports. The NRC committee provides advice and recommendations for revisions to ensure scientific validity and consistency with the NRC guideline reports (NRC 1993, 2001a). The revised reports are presented at subsequent meetings until the committee is satisfied with the reviews.

Because of the enormous amount of data presented in AEGL reports, the NRC committee cannot verify all of the data used by NAC. The NRC committee relies on NAC for the accuracy and completeness of the toxicity data cited in the AEGL reports. Thus far, the committee has prepared ten reports in the series *Acute Exposure Guideline Levels for Selected Airborne Chemicals* (NRC 2001b, 2002b, 2003, 2004, 2007b, 2008b, 2009, 2010a,b, 2011). This report is the eleventh volume in that series. AEGL documents for bis-chloromethyl ether, chloromethyl methyl ether, chlorosilanes, nitrogen oxides, and vinyl chloride are each published as an appendix in this report. The committee concludes that the AEGLs developed in these appendixes are scientifically valid conclusions based on the data reviewed by NAC and are consistent with the NRC guideline reports. AEGL reports for additional chemicals will be presented in subsequent volumes.

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Appendixes

3

Selected Chlorosilanes[1]

Acute Exposure Guideline Levels

PREFACE

Under the authority of the Federal Advisory Committee Act (FACA) P.L. 92-463 of 1972, the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (NAC/AEGL Committee) has been established to identify, review, and interpret relevant toxicologic and other scientific data and develop AEGLs for high-priority, acutely toxic chemicals.

AEGLs represent threshold exposure limits for the general public and are applicable to emergency exposure periods ranging from 10 minutes (min) to 8 hours (h). Three levels—AEGL-1, AEGL-2, and AEGL-3—are developed for each of five exposure periods (10 and 30 min and 1, 4, and 8 h) and are distinguished by varying degrees of severity of toxic effects. The three AEGLs are defined as follows:

AEGL-1 is the airborne concentration (expressed as parts per million or milligrams per cubic meter [ppm or mg/m^3]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

[1]This document was prepared by the AEGL Development Team composed of Chery Bast (Oak Ridge National Laboratory), Julie M. Klotzbach (Syracuse Research Corporation), and Chemical Manager Ernest V. Falke (National Advisory Committee [NAC] on Acute Exposure Guideline Levels for Hazardous Substances). The NAC reviewed and revised the document and AEGLs as deemed necessary. Both the document and the AEGL values were then reviewed by the National Research Council (NRC) Committee on Acute Exposure Guideline Levels. The NRC committee has concluded that the AEGLs developed in this document are scientifically valid conclusions based on the data reviewed by the NRC and are consistent with the NRC guidelines reports (NRC 1993, 2001).

AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Airborne concentrations below the AEGL-1 represent exposure concentrations that could produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic, nonsensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, it is recognized that individuals, subject to idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL.

SUMMARY

Chlorosilanes contain one or more chlorine atoms covalently bonded to a silicon atom; the maximum chlorine-to-silicon ratio is four. Chlorosilanes are chemical intermediates used in the production of silicone and silicone-containing materials, and are often produced in bulk and transported to manufacturing sites for use. Chlorosilanes are corrosive, and inhalation exposure might cause nasal, throat, or lung irritation, coughing, wheezing, and shortness of breath. Chlorosilanes react rapidly with water, steam, or moisture; hydrolysis yields hydrogen chloride (HCl) gas along with silanols and other condensation products.

The 26 chlorosilanes considered in this chapter are:

Allyl trichlorosilane
Amyl trichlorosilane
Butyl trichlorosilane
Chloromethyl trichlorosilane
Dichlorosilane
Diethyl dichlorosilane
Dimethyl chlorosilane
Dimethyl dichlorosilane
Diphenyl dichlorosilane
Dodecyl trichlorosilane
Ethyl trichlorosilane
Hexyl trichlorosilane
Methyl chlorosilane
Methyl dichlorosilane
Methyl trichlorosilane
Methylvinyl dichlorosilane
Nonyl trichlorosilane
Octadecyl trichlorosilane
Octyl trichlorosilane
Propyl trichlorosilane
Tetrachlorosilane
Trichloro(dichlorophenyl)silane
Trichlorophenylsilane
Trichlorosilane
Trimethyl chlorosilane
Vinyl trichlorosilane

Although chemical-specific toxicity data are not available for many of these chlorosilanes, acute inhalation data from rat studies are available for structurally-similar chlorosilanes (propyl trichlorosilane, methyl trichlorosilane, vinyl trichlorosilane, ethyl trichlorosilane, methylvinyl dichlorosilane, methyl dichlorosilane, dimethyl dichlorosilane, dimethyl chlorosilane, trimethylchlorosilane, and tetrachlorosilane). These data suggest that the acute toxicity of chlorosilanes is largely explained by the HCl hydrolysis product; acute toxicity of these chlorosilanes is qualitatively (based on clinical signs) and quantitatively (based on molar equivalents of HCl) similar to that of HCl (Jean et al. 2006).

On the basis of these data, and in the absence of appropriate chemical-specific data for the chlorosilanes considered in this document, the AEGLs for HCl were used to derive AEGLs for the chlorosilanes. For each class of chlorosilanes (mono-, di-, tri-, and tetra-chlorosilanes), the molar ratio (moles of HCl released per mole of chlorosilane, assuming complete hydrolysis) was used to adjust the AEGL values for HCl to the equivalent concentration of chlorosilane. Detailed information on the derivation of AEGLs for HCl is available in NRC (2004). The calculated values are listed in the Table 3-1.

1. INTRODUCTION

Chlorosilanes contain one or more chlorine atoms covalently bonded to a silicon atom; the maximum chlorine-to-silicon ratio is four. Chlorosilanes are chemical intermediates used in the production of silicone and silicone-containing materials, and are often produced in bulk and transported to manufacturing sites for use.

Chlorosilanes react very rapidly with water, steam, or moisture, releasing HCl gas (AIHA 1998, 1999, 2001a,b,c, 2006). The primary vapor detected in air when chlorosilanes are released is HCl; much less of the parent chlorosilane is detectable (Nakashima et al. 1996; Jean et al. 2006). In an experiment using 11 different chlorosilanes, Jean et al. (2006) reported that the percentage of parent chlorosilane in the test atmosphere ranged from <10% to 58%; other constituents of the atmosphere (in addition to HCl) included silanols and other condensation products. When x-ray microanalysis was performed on air filtered from a dichlorosilane exposure chamber, small (<1 μM in diameter), unidentified particles containing silicon and chloride were detected (Nakashima et al. 1996).

Numerous reports of chlorosilane spills and releases have been received by the U.S. Coast Guard National Response Center. For example, between January 1990 and July 2007, there were 23 reports of dichlorosilane releases ranging from 6 to 2,596 pounds; 32 reports of trichlorosilane releases ranging from 2.6 to 343 pounds; and 14 reports of tetrachlorosilane releases ranging from 2 to 330 pounds (USCG 2007). Releases were from both fixed and mobile sources and were the result of equipment failure and operator error.

TABLE 3-1 Summary of AEGL Values for Selected Chlorosilanes[a]

Compound	Classification	10 min	30 min	1 h	4 h	8 h	End Point (Reference)
MONOCHLOROSILANES							
Dimethyl chlorosilane	AEGL-1	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm	AEGLs for HCl (NRC 2004)
Methyl chlorosilane	AEGL-2	100 ppm	43 ppm	22 ppm	11 ppm	11 ppm	
Trimethylchlorosilane	AEGL-3	620 ppm	210 ppm	100 ppm	26 ppm	26 ppm	
DICHLOROSILANES							
Dichlorosilane	AEGL-1	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm	AEGLs for HCl divided by a molar adjustment factor of 2 (NRC 2004)
Diethyl dichlorosilane	AEGL-2	50 ppm	22 ppm	11 ppm	5.5 ppm	5.5 ppm	
Dimethyl dichlorosilane	AEGL-3	310 ppm	110 ppm	50 ppm	13 ppm	13 ppm	
Diphenyl dichlorosilane							
Methyl dichlorosilane							
Methylvinyl dichlorosilane							
TRICHLOROSILANES							
Allyl trichlorosilane	AEGL-1	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm	AEGL values for HCl divided by a molar adjustment factor of 3 (NRC 2004)
Amyl trichlorosilane	AEGL-2	33 ppm	14 ppm	7.3 ppm	3.7 ppm	3.7 ppm	
Butyl trichlorosilane	AEGL-3	210 ppm	70 ppm	33 ppm	8.7 ppm	8.7 ppm	
Chloromethyl trichlorosilane							
Dodecyl trichlorosilane							
Ethyl trichlorosilane							
Hexyl trichlorosilane							
Methyl trichlorosilane							
Nonyl trichlorosilane							
Octadecyl trichlorosilane							
Octyl trichlorosilane							
Propyl trichlorosilane							

(Continued)

TABLE 3-1 Continued

Compound	Classification	10 min	30 min	1 h	4 h	8 h	End Point (Reference)
TRICHLOROSILANES (*continued*)							
Trichloro(dichlorophenyl)silane							
Trichlorophenylsilane							
Trichlorosilane							
Vinyl trichlorosilane							
TETRACHLOROSILANE							
	AEGL-1	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm	AEGL values for HCl divided by a molar adjustment factor of 4 (NRC 2004)
	AEGL-2	25 ppm	11 ppm	5.5 ppm	2.8 ppm	2.8 ppm	
	AEGL-3	160 ppm	53 ppm	25 ppm	6.5 ppm	6.5 ppm	

[a]Values given in ppm. To convert ppm to mg/m^3: (ppm × molecular weight) ÷ 24.5. See Appendix A for the appropriate molecular weight. For mono-, di-, and tri-chlorosilanes not listed, use of HCl equivalents may be considered for AEGL-value derivation.

The chlorosilanes have pungent irritating odors, are corrosive, and inhalation exposure might cause nasal, throat, or lung irritation, coughing, wheezing, and shortness of breath. Although chemical-specific toxicity data are not available for many of the chlorosilanes, acute inhalation data from rat studies are available for structurally-similar chlorosilanes (propyl trichlorosilane, methyl trichlorosilane, vinyl trichlorosilane, ethyl trichlorosilane, methylvinyl dichlorosilane, methyl dichlorosilane, dimethyl dichlorosilane, dimethyl chlorosilane, trimethylchlorosilane, and tetrachlorosilane). These data suggest that the acute toxicity of chlorosilanes is from the HCl hydrolysis product; acute toxicity of the chlorosilanes is qualitatively (based on clinical signs) and quantitatively (based on molar equivalents of HCl) similar to that of HCl (Jean et al. 2006) (see Section 4.3).

On the basis, and in the absence of adequate chemical-specific data for the chlorosilanes considered in this document, the AEGL values for HCl (NRC 2004) were used to obtain AEGL values for the chlorosilanes. The molar ratio (moles HCl released per mole of chlorosilane, assuming complete hydrolysis) was used to adjust the AEGL values for HCl to the equivalent concentration of chlorosilane. Available physicochemical data for the 26 chlorosilanes covered in this chapter are presented in Appendix A.

2. HUMAN TOXICITY DATA

An accidental release of tetrachlorosilane at a chemical plant in a south San Francisco industrial park provided some human exposure data (Kizer et al. 1984). A delivery truck taking a short-cut through a chemical plant hit the tank-coupling unit of a tetrachlorosilane storage tank. The pipeline ruptured and the tetrachlorosilane liquid spilled onto the moist ground; it hydrolyzed rapidly and formed a large gray-white cloud that quickly spread. Workers were unable to stop the leak because the valve was behind a wire enclosure, and approximately 1,200 gallons of tetrachlorosilane was released before the leak was stopped several hours later. By that time, the cloud had risen 500 feet and had spread more than a mile over the industrial park. Five- to ten-thousand employees from 600 businesses over 3 square miles were evacuated. Twenty-eight people reported to local hospitals for treatment of eye or airway irritation. Seven of the patients were employees at the chemical plant, and six of them were smokers. The remaining 21 patients were firemen, policemen, passersby, and employees of other companies in the area. There were no deaths, and no one was hospitalized. Six of the chemical plant employees were referred for further evaluation; these employees were all male, ranged in age from 25 to 56, and were all smokers. Their exposures ranged from 10 to 20 min in duration. Symptoms generally resolved within 24 h, and included lacrimation, rhinorrhea, burning of the mouth and throat, headache, coughing, and wheezing. Pulmonary function tests were normal except that mild obstructive airway disease was noted in four patients. However, it was unclear if the disease was from exposure to tetrachlorosilane or

related to smoking status. Two patients also complained of pedal dysesthesias after the accident. No air concentrations of tetrachlorosilane or HCl were reported.

Reactive airways dysfunction syndrome is an asthma-like condition that develops after a single exposure to high concentrations of a chemical irritant, and has been described after exposure to HCl. Symptoms occur within minutes to hours after the initial exposure and can persist as nonspecific bronchial hyperresponsiveness for months to years (Bernstein 1993). Promisloff et al. (1990) reported reactive airways dysfunction syndrome in three male police officers (36-45 years of age) who responded to a roadside chemical spill. The subjects were exposed to unquantified amounts of sodium hydroxide, tetrachlorosilane, and HCl as a byproduct of trichlorosilane hydrolysis. Because of the mixture of irritants involved in the release, it is probable that all of the compounds contributed to the syndrome observed after this accident.

3. ANIMAL TOXICITY DATA

3.1. Acute Toxicity

One-hour LC_{50} (lethal concentration, 50% lethality) studies were conducted for 10 chlorosilanes: tetrachlorosilane, propyl trichlorosilane, vinyl trichlorosilane, methyl trichlorosilane, ethyl trichlorosilane, methylvinyl dichlorosilane, dimethyl dichlorosilane, methyl dichlorosilane, trimethyl chlorosilane, and dimethyl chlorosilane (Jean et al. 2006). In each study, groups of five male and five female Fischer 344 rats were exposed to varying concentrations of a chlorosilane for 1 h and observed for up to 14 days. The studies appeared to conform to Good Laboratory Practices and were well-described. The authors used nominal concentrations to calculate LC_{50} values because chlorosilanes react rapidly with moisture to produce HCl and other hydrolysis products. Using actual chamber concentrations of chlorosilanes would only reflect toxicity of the parent compound, not the toxicity of the parent compound and hydrolysis products. There was agreement between the electrolytic conductivity detector and the nominal concentrations, indicating efficient vaporization of the test material.

Clinical signs were consistent with HCl exposure and included lacrimation, salivation, dried material around the eyes or nose, green staining around the nose and mouth, and perineal urine staining. Labored breathing, rales, hypoactivity, closed or partially closed eyes, prostration, corneal opacity or opaqueness, and swollen or necrotic paws also were observed. Hemorrhage, congestion, and consolidation of the lungs; ectasia of the lungs; gaseous distension of the gastrointestinal tract; absence of body fat; obstruction of nostrils; dried or firm nares; alopecia around the eyes; and discoloration of hair were observed at necropsy. Mortality data and LC_{50} values from 1-h exposure studies with rats are summarized in Table 3-2.

TABLE 3-2 Mortality Data and LC_{50} Values from 1-Hour Exposure Studies with Rats

Compound	Exposure Concentration (ppm)	Mortality			LC_{50}, ppm (95% confidence limits)
		Male	Female	Total	
Tetrachlorosilane	1,209	1/5	2/5	3/10	1,312 (1,006-1,529) [a]
	1,497	5/5	3/5	8/10	
	3,051	5/5	5/5	10/10	
Propyl trichlorosilane	1,123	0/5	0/5	0/10	1,352 (1,254-1,455) [a]
	1,317	2/5	2/5	4/10	
	1,414	3/5	4/5	7/10	
Vinyl trichlorosilane	1,186	0/5	0/5	0/10	1,611 (1,505-1,724) [b]
	1,605	4/5	2/5	6/10	
	1,681	2/5	1/5	3/10	
	1,989	5/5	5/5	10/10	
Methyl trichlorosilane	622	0/5	0/5	0/10	1,365 (1,174-2,104) [a]
	1,047	0/5	1/5	1/10	
	1,439	4/5	2/5	6/10	
	3,075	5/5	5/5	10/10	
Ethyl trichlorosilane	1,156	1/5	1/5	2/10	1,257 (1,175-1,320) [a]
	1,326	4/5	2/5	6/10	
	1,415	5/5	5/5	10/10	
Methylvinyl dichlorosilane	1,597	1/5	0/5	1/10	2,021 (1,806-2,257) [a]
	2,005	3/5	2/5	5/10	
	2,119	3/5	3/5	6/10	
	2,242	4/5	3/5	7/10	
Dimethyl dichlorosilane	1,309	0/5	0/5	0/10	2,092 (1,492-2,240) [a]
	2,077	4/5	1/5	5/10	
	2,353	5/5	3/5	8/10	
	2,762	5/5	5/5	10/10	
Methyl dichlorosilane	1,431	0/5	0/5	0/10	1,785 (1,671-1,963) [a]
	1,678	1/5	2/5	3/10	
	1,889	4/5	3/5	7/10	
Trimethyl chlorosilane	3,171	0/5	0/5	0/10	4,257 (4,039-4,488) [b]
	4,139	2/5	0/5	2/10	
	4,268	3/5	3/5	6/10	
	5,121	5/5	5/5	10/10	
Dimethyl chlorosilane	4,108	1/5	1/5	2/10	4,478 (4,281-6,327) [a]
	4,179	1/5	1/5	2/10	
	4,409	3/5	3/5	6/10	
	4,589	3/5	2/5	5/10	

[a]Probit analysis.
[b]Spearman-Karber analysis.
Source: Jean et al. 2006. Reprinted with permission; copyright 2006, *Inhalation Toxicology*.

In another study, groups of 10 male ICR mice were exposed for 4 h to nominal concentrations of dichlorosilane at 49-259 ppm, followed by a 14-day observation period (Nakashima et al. 1996). Mortality was 0/10, 0/10, 1/10, 6/10, 4/10, 10/10, 10/10, 9/10, and 10/10 for groups exposed at 0, 49, 100, 131, 141, 199, 216, 218, and 259 ppm, respectively. An LC_{50} of 144 ppm was calculated.

3.2. Developmental and Reproductive Toxicity

No data on developmental or reproductive toxicity were found.

3.3. Genotoxicity

The only genotoxicity data found were for tetrachlorosilane. Tetrachlorosilane was not mutagenic in *Salmonella typhimurium* strains TA98, TA100, TA 1535, TA1537, or TA1538; *Saccharomyces cerevisiae* strain D-4; or *Escherischia coli* strains W3110/polA$^+$ and P3478/polA$^-$ either with or without metabolic activation. It was also negative in a L5178Y mouse lymphoma assay (AIHA 1999).

3.4. Chronic Toxicity and Carcinogenicity

No data on chronic toxicity or carcinogenicity were found.

3.5. Summary

Although toxicity data are sparse for individual chlorosilanes, well-conducted 1-h inhalation toxicity studies in rats are available for a series of chlorosilanes (Jean et al. 2006). In general, LC_{50} values for monochlorosilanes were approximately twice the LC_{50} values for dichlorosilanes and three times the LC_{50} values for trichlorosilanes. Tetrachlorosilane had an LC_{50} value similar to the trichlorosilanes; however, there were experimental difficulties at the lowest concentration tested. Clinical signs were indicative of severe irritation or corrosion. The evidence suggests that the acute toxicity of chlorosilanes is largely attributable to the release of HCl; however, no information on the identity or potential toxicity of other decomposition products was found. No data concerning developmental or reproductive toxicity, genotoxicity, or carcinogenicity for exposure to the chlorosilanes were found in the literature.

4. SPECIAL CONSIDERATIONS

4.1. Metabolism and Disposition

No information was found concerning the metabolism and disposition of chlorosilanes.

4.2. Mechanism of Toxicity

Chlorosilanes react violently with water to produce HCl gas (AIHA 1998, 1999, 2001a,b,c, 2006). In an experiment using 11 different chlorosilanes, Jean et al. (2006) reported that the percentage of parent chlorosilane in the test atmosphere range from <10 to 58%; other constituents of the atmosphere (in addition to HCl) included silanols and other condensation products. Nakashima et al. (1996) reported that small particles containing silicon and chlorine were detected in an inhalation exposure chamber into which dichlorosilane was introduced; the identity and quantity of particles were not reported. IPCS (2002a) reported that, when heated, trimethylchlorosilane decomposition could release HCl and phosgene. No other information on potential decomposition products of chlorosilanes was found. Available data suggest that the acute toxicity of chlorosilanes is largely from the HCl hydrolysis product; acute toxicity of the chlorosilanes is qualitatively (based on clinical signs) and quantitatively (based on molar equivalents of HCl) similar to that of HCl.

4.3. Structure Activity Relationships

A 1-h LC_{50} study with HCl was performed in rats and used for comparison with the chlorosilane 1-h LC_{50} values (Jean et al. 2006). According to the authors, the study with HCl was unpublished, but was performed in the same laboratory and was conducted using the same protocol as that used in the chlorosilane study (1-h whole-body exposure with a 14-day recovery period). Five rats per sex were exposed to HCl at 0, 2,456, 3,236, or 4,210 ppm for 1 h and observed for up to 14 days. Chamber concentrations were determined by a Fourier transform infrared spectrophotometer analyzer. Clinical signs included labored breathing; gasping; emaciation; rough coat; lethargy; corneal opacity; crusting, necrotic, discolored, and blocked nares or nasal opening; paws with missing, necrotic, or swollen digits; and weight loss. Gross pathology of animals dying during the study included irritation and necrosis of most extremities, severe respiratory-tract injuries, and corneal opacity. A 1-h LC_{50} of 3,627 ppm was calculated for HCl.

The LC_{50} data obtained for the chlorosilanes showed a strong association with chlorine content for the mono-, di-, and tri-chlorosilanes. In general, LC_{50} values for monochlorosilanes were approximately twice the LC_{50} values for dichlorosilanes and three times the LC_{50} values for trichlorosilanes. Tetrachlorosilane exhibited an LC_{50} value similar to the trichlorosilanes.

The predicted 1-h LC_{50} values for the chlorosilanes, based on HCl equivalents, are presented in Table 3-3. The predicted values for the chlorosilanes are comparable to the experimentally-derived 1-h LC_{50} values (log * log regression analysis of chlorosilane LC_{50} values vs. the number of chlorine groups yielded an r^2 value of 0.97). The data suggest that the acute toxicity of the chlorosilanes is similar to or slightly less than what would be expected based on HCl molar

equivalents. The within-class LC_{50} values were not significantly influenced by the number or type of hydrocarbon R-group(s) present (methyl, ethyl, propyl, or vinyl). Cases where the predicted value is less might be attributed to incomplete hydrolysis in the test atmosphere; however, continued hydrolysis and generation of HCl would be expected for any remaining chlorosilane when in contact with moist tissues (mucous membranes, lung) (Jean et al. 2006). This information taken in conjunction with the observed clinical signs suggests that the acute toxicity of the chlorosilanes is quantitatively and qualitatively similar to HCl and that the HCl hydrolysis product is responsible for the acute toxicity of the chlorosilanes.

TABLE 3-3 Measured and Predicted 1-Hour LC_{50} Values for Selected Chlorosilanes

Compound	Measured LC_{50} (ppm) (95% confidence limits)	Predicted LC_{50} (ppm)	Predicted Ratio of LC_{50} Values	Measured Ratio of LC_{50} Values
Hydrogen chloride	3,627			
Tetrachlorosilane	1,312 (1,006-1,529)	3,627 ÷ 4 = 907	4:1	2.8:1
Propyl trichlorosilane	1,352 (1,254-1,455)	3,627 ÷ 3 = 1,209	3:1	2.7:1
Vinyl trichlorosilane	1,611 (1,505-1,724)	3,627 ÷ 3 = 1,209	3:1	2.3:1
Methyl trichlorosilane	1,365 (1,174-2,104)	3,627 ÷ 3 = 1,209	3:1	2.7:1
Ethyl trichlorosilane	1,257 (1,175-1,320)	3,627 ÷ 3 = 1,209	3:1	2.9:1
Methylvinyl dichlorosilane	2,021 (1,806-2,257)	3,627 ÷ 2 = 1,814	2:1	1.8:1
Dimethyl dichlorosilane	2,092 (1,492-2,240)	3,627 ÷ 2 = 1,814	2:1	1.7:1
Methyl dichlorosilane	1,785 (1,671-1,963)	3,627 ÷ 2 = 1,814	2:1	2:1
Trimethyl chlorosilane	4,257 (4,039-4,488)	3,627 ÷ 1 = 3,627	1:1	0.9:1
Dimethyl chlorosilane	4,478 (4,281-6,327)	3,627 ÷ 1 = 3,627	1:1	0.8:1

Source: Adapted from Jean et al. 2006.

The 4-h mouse LC_{50} of 144 ppm for dichlorosilane (Nakashima et al. 1996) also supports the conclusion that the acute inhalation toxicity of chlorosilanes is from the HCl hydrolysis product. The reported 1-h mouse LC_{50} for HCl is 1,108 ppm (NRC 2004). Scaling across time for HCl may be accomplished using the equation $C^n \times t = k$, where n = 1 based on regression analysis of combined rat and mouse LC_{50} data (1-100 min) (NRC 2004). Scaling the 1-h LC_{50} value for HCl of 1,108 ppm to a 4-h period yields an approximate 4-h LC_{50} value of 277 ppm. Dividing this 4-h LC_{50} by a molar adjustment factor of 2, yields a predicted LC_{50} of 139 ppm for dichlorosilane, which is similar to the experimentally-derived value of 144 ppm.

The 26 chlorosilanes addressed in this chapter include those with alkane, alkene, aromatic, and chlorinated substituents. Although the evidence from Jean et al. (2006) suggests that the acute toxicity is from HCl formed as a hydrolysis product, the data were generated using 11 of the 26 chlorosilanes, including primarily alkane-subsituted compounds and two of the three compounds with alkene substituent groups. Of the 26, two have aromatic substituents and two (including one of the aromatics) have chlorinated substituents; none of those was among the tested compounds.

4.4. Other Relevant Information

4.4.1. Species Variability

Data were not available regarding species variability in lethal and nonlethal toxicity from chlorosilane exposure. Differences in response to HCl have been observed between primates and rodents. Rodents exhibit sensory and respiratory irritation after exposure to high concentrations of HCl. Concentration-dependent decreases in respiratory frequency indicative of a protective mechanism are observed in rodents, whereas baboons exposed at 500, 5,000, or 10,000 ppm exhibited concentration-dependent increases in respiratory frequency indicative of a compensatory response to hypoxia and a possible increase in the total dose delivered to the lung (NRC 1991). Kaplan et al. (1988) found that five of six mice died when exposed to HCl at 2,550 ppm for 15 min, but no baboons died when exposed at 10,000 ppm for 15 min. The LC_{50} values reported by Darmer et al. (1974), Wohlslagel et al. (1976), and Higgins et al. (1972) indicate that mice are approximately three times more sensitive than rats to HCl. Guinea pigs also appear to be more sensitive than rats to HCl; however, the guinea pig studies have provided conflicting results. For respiratory irritants such as HCl, the mouse "may not be a good model for extrapolation to humans," because "mice appear to be much more susceptible to the lethal effects of HCl than other rodents or baboons. To some extent, this increased susceptibility may be due to less effective scrubbing of HCl in the upper respiratory tract" (NRC 1991).

Because most rodents are obligatory nose breathers whereas humans may be mouth breathers, especially during exercise, Stavert et al. (1991) studied the effects of inhaling HCl through the nose and mouth in rats. HCl was delivered directly to the trachea by cannulation. Higher mortality rates occurred with orally-cannulated rats compared with rats exposed by nose. Tracheal necrosis and inflammatory-cell accumulation were found in cannulated rats, whereas effects in nose-breathing rats were confined to the nasal passages. These results indicate that the site of injury and resultant toxicologic effects differ with oral or nasal breathing, with the former mode resulting in more severe responses under similar exposure situations.

4.4.2. Susceptible Populations

No information was available on populations that might be especially sensitive to chlorosilane or HCl. However, clinical signs of chlorosilane and HCl exposure are consistent with contact irritation. In general, contact-irritant effects are not expected to vary widely among individuals. However, as noted by NRC (2004), asthmatic persons and others with sensitive airways might be more susceptible to the effects of HCl inhalation.

On the basis of the study by Stavert et al. (1991), which showed more severe respiratory responses to HCl in orally-cannulated rats compared with nose-breathing rats, it is possible that persons who habitually breathe orally might experience more pronounced or different health effects than those who primarily breathe nasally. Likewise, physical exertion might intensify the respiratory effects of HCl or chlorosilane exposure as individuals shift from nasal to oral breathing during exertion.

5. DATA ANALYSIS FOR AEGL-1

5.1. Summary of Human Data Relevant to AEGL-1

No human data relevant to development of AEGL-1 values were found.

5.2. Summary of Animal Data Relevant to AEGL-1

No animal data relevant to development of AEGL-1 values were found.

5.3. Derivation of AEGL-1

AEGL-1 values for the chlorosilanes were determined by modifying the AEGL-1 values that were established for HCl. The use of HCl as a surrogate for chlorosilanes was deemed appropriate because adverse effects from exposure to chlorosilanes have been attributed to their hydrolysis product, HCl. The AEGL-1 values for HCl were based on a no-observed-adverse-effect level in exercising adult with asthma (NRC 2004). The same AEGL-1 value was applied across all

specified exposure periods, because mild irritation generally does not vary greatly over time and because prolonged exposure is not expected to result in an enhanced effect (NRC 2004). The key study and calculations used to determine the AEGL-1 values for HCl are summarized in Appendixes C and E (more detail is available in the technical support document for HCl published in NRC [2004]). The molar ratio (moles of HCl released per mole of chlorosilane, assuming complete hydrolysis) was used to adjust the AEGLs for HCl to the equivalent concentration of chlorosilane. Although the 1-h rat LC_{50} value for tetrachlorosilane suggests that only 3 moles of HCl were produced, the use of a molar adjustment factor of 4 is considered appropriate because of experimental difficulties that occurred at lower exposure concentrations in this study. The use of the molar adjustment factor of 4 will yield protective AEGL values and is consistent with the approach taken for the overall chlorosilane database. The AEGL-1 values for the chlorosilanes are presented in Table 3-4, and their calculations are presented in Appendix B.

TABLE 3-4 AEGL-1 Values for Selected Chlorosilanes[a]

Compound	10 min	30 min	1 h	4 h	8 h
MONOCHLOROSILANES					
Dimethyl chlorosilane	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm
Methyl chlorosilane					
Trimethyl chlorosilane					
DICHLOROSILANES					
Dichlorosilane	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm
Diethyl dichlorosilane					
Dimethyl dichlorosilane					
Diphenyl dichlorosilane					
Methyl dichlorosilane					
Methylvinyl dichlorosilane					
TRICHLOROSILANES					
Allyl trichlorosilane	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm
Amyl trichlorosilane					
Butyl trichlorosilane					
Chloromethyl trichlorosilane					
Dodecyl trichlorosilane					
Ethyl trichlorosilane					
Hexyl trichlorosilane					
Methyl trichlorosilane					
Nonyl trichlorosilane					
Octadecyl trichlorosilane					
Octyl trichlorosilane					
Propyl trichlorosilane					
Trichloro(dichlorophenyl)silane					
Trichlorophenylsilane					
Trichlorosilane					
Vinyl trichlorosilane					
TETRACHLOROSILANE	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm

[a]Values given in ppm. To convert ppm to mg/m^3: (ppm × molecular weight) ÷ 24.5. See Appendix A for the appropriate molecular weight.

6.3. Derivation of AEGL-2

AEGL-2 values for the chlorosilanes were determined by modifying the AEGL-2 values that were established for HCl. The use of HCl as a surrogate for chlorosilanes was deemed appropriate because adverse effects from exposure to chlorosilanes have been attributed to their hydrolysis product, HCl. AEGL-2 values for HCl were based on severe nasal or pulmonary histopathologic changes in rats (exposed for 30 min to 8 h) or a modification of the mouse 50% respiratory rate decrease (RD_{50}) (exposed for 10 min) (NRC 2004). The key study and calculations used to determine the AEGL-2 values for HCl are summarized in Appendixes C and E (more detail is available in the technical support document for HCl published in NRC [2004]). The molar ratio (moles of HCl released per mole of chlorosilane, assuming complete hydrolysis) was used to adjust the AEGLs for HCl to the equivalent concentration of chlorosilane. The AEGL-2 values for the chlorosilanes are presented in Table 3-5, and their calculations are presented in Appendix B.

7. DATA ANALYSIS FOR AEGL-3

7.1. Summary of Human Data Relevant to AEGL-3

No human data relevant to development of AEGL-3 values were found.

7.2. Summary of Animal Data Relevant to AEGL-3

One-hour rat LC_{50} values were reported by Jean et al. (2006) to be 4,478 ppm for dimethyl dichlorosilane and 2,021 ppm for methylvinyl dichlorosilane. One-hour rat LC_{50} values for trichlorsilanes were 1,257, 1,352, and 1,611 ppm for ethyl trichlorosilane, propyl trichlorosilane, and vinyl trichlorosilane, respectively (Jean et al. 2006). A 1-h rat LC_{50} value of 1,312 ppm was reported for tetrachlorosilane (Jean et al. 2006). A 4-h mouse LC_{50} value of 144 ppm was reported for dichlorosilane (Nakashima et al. 1996), but the mouse is considered to be an unreliable model for the acute toxicity of HCl in humans (NRC 1991, 2004). No animal data relevant to development of AEGL-3 values were found for the other chlorosilanes.

7.3. Derivation of AEGL-3

AEGL-3 values for the chlorosilanes were determined by modifying the AEGL-3 values that were established for HCl. The use of HCl as a surrogate for chlorosilanes was deemed appropriate because adverse effects from exposure to chlorosilanes have been attributed to their hydrolysis product, HCl. The AEGL-3 values for HCl were based on a 1-h rat LC_{50} value divided by 3 to estimate a lethality threshold (NRC 2004). The key study and calculations used to determine the AEGL-3 values for HCl are summarized in Appendixes C and E (more detail

is available in the technical support document for HCl published in NRC [2004]). The molar ratio (moles of HCl released per mole of chlorosilane, assuming complete hydrolysis) was used to adjust the AEGLs for HCl to the equivalent concentration of chlorosilane. The AEGL-2 values for the chlorosilanes are presented in Table 3-6, and their calculations are presented in Appendix B.

8. SUMMARY OF AEGLS

8.1. AEGL Values and Toxicity End Points

AEGL values for selected chlorosilanes are summarized in Table 3-7. Derivation summary tables appear in Appendix E, and category plots for the selected chlorosilanes are in Appendix F. AEGL values were based on molar adjustments of the AEGL values for HCl. For mono-, di-, and tri- chlorosilanes not listed, use of HCl equivalents may be considered for AEGL-value derivation.

TABLE 3-5 AEGL-2 Values for Selected Chlorosilanes[a]

Compound	10 min	30 min	1 h	4 h	8 h
MONOCHLOROSILANES					
Dimethyl chlorosilane	100 ppm	43 ppm	22 ppm	11 ppm	11 ppm
Methyl chlorosilane					
Trimethyl chlorosilane					
DICHLOROSILANES					
Dichlorosilane	50 ppm	22 ppm	11 ppm	5.5 pm	5.5 ppm
Diethyl dichlorosilane					
Dimethyl dichlorosilane					
Diphenyl dichlorosilane					
Methyl dichlorosilane					
Methylvinyl dichlorosilane					
TRICHLOROSILANES					
Allyl trichlorosilane	33 ppm	14 ppm	7.3 ppm	3.7 pm	3.7 ppm
Amyl trichlorosilane					
Butyl trichlorosilane					
Chloromethyl trichlorosilane					
Dodecyl trichlorosilane					
Ethyl trichlorosilane					
Hexyl trichlorosilane					
Methyl trichlorosilane					
Nonyl trichlorosilane					
Octadecyl trichlorosilane					
Octyl trichlorosilane					
Propyl trichlorosilane					
Trichloro(dichlorophenyl)silane					
Trichlorophenylsilane					
Trichlorosilane					
Vinyl trichlorosilane					
TETRACHLOROSILANE	25 ppm	11 ppm	5.5 ppm	2.8 ppm	2.8 ppm

[a]Values given in ppm. To convert ppm to mg/m^3: (ppm × molecular weight) ÷ 24.5. See Appendix A for the appropriate molecular weight.

TABLE 3-6 AEGL-3 Values for Selected Chlorosilanes

Compound	10 min	30 min	1 h	4 h	8 h
MONOCHLOROSILANES					
Dimethyl chlorosilane	620 ppm	210 ppm	100 ppm	26 ppm	26 ppm
Methyl chlorosilane					
Trimethyl chlorosilane					
DICHLOROSILANES					
Dichlorosilane	310 ppm	110 ppm	50 ppm	13 ppm	13 ppm
Diethyl dichlorosilane					
Dimethyl dichlorosilane					
Diphenyl dichlorosilane					
Methyl dichlorosilane					
Methylvinyl dichlorosilane					
TRICHLOROSILANES					
Allyl trichlorosilane	210 ppm	70 ppm	33 ppm	8.7 ppm	8.7 ppm
Amyl trichlorosilane					
Butyl trichlorosilane					
Chloromethyl trichlorosilane					
Dodecyl trichlorosilane					
Ethyl trichlorosilane					
Hexyl trichlorosilane					
Methyl trichlorosilane					
Nonyl trichlorosilane					
Octadecyl trichlorosilane					
Octyl trichlorosilane					
Propyl trichlorosilane					
Trichloro(dichlorophenyl)silane					
Trichlorophenylsilane					
Trichlorosilane					
Vinyl trichlorosilane					
TETRACHLOROSILANE	160 ppm	53 ppm	25 ppm	6.5 ppm	6.5 ppm

[a]Values given in ppm. To convert ppm to mg/m^3: (ppm × molecular weight) ÷ 24.5. See Appendix A for the appropriate molecular weight.

8.2. Comparison with Other Standards and Guidelines

There are no standards or guidelines for most of the chlorosilanes considered in this chapter. The few guidelines available are Emergency Response Planning Guidelines (ERPGs) and Workplace Environmental Exposure Level (WEEL) ceiling levels for trimethylchlorosilane, dimethyl dichlorosilane, trichlorosilane, methyl trichlorosilane, vinyl trichlorosilane, and tetrachlorosilane. Available standards and guidelines are presented in Tables 3-8. The available ERPG values are comparable to the AEGLs derived herein.

TABLE 3-7 Summary of AEGL Values for Selected Chlorosilanes[a]

Compound	Classification	10 min	30 min	1 h	4 h	8 h
MONOCHLOROSILANES						
Dimethyl chlorosilane	AEGL-1	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm
Methyl chlorosilane	AEGL-2	100 ppm	43 ppm	22 ppm	11 ppm	11 ppm
Trimethyl chlorosilane	AEGL-3	620 ppm	210 ppm	100 ppm	26 ppm	26 ppm
DICHLOROSILANES						
Dichlorosilane	AEGL-1	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm
Diethyl dichlorosilane	AEGL-2	50 ppm	22 ppm	11 ppm	5.5 pm	5.5 ppm
Dimethyl dichlorosilane	AEGL-3	310 ppm	110 ppm	50 ppm	13 ppm	13 ppm
Diphenyl dichlorosilane						
Methyl dichlorosilane						
Methylvinyl dichlorosilane						
TRICHLOROSILANES						
Allyl trichlorosilane	AEGL-1	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm
Amyl trichlorosilane	AEGL-2	33 ppm	14 ppm	7.3 ppm	3.7 pm	3.7 ppm
Butyl trichlorosilane	AEGL-3	210 ppm	70 ppm	33 ppm	8.7 ppm	8.7 ppm
Chloromethyl trichlorosilane						
Dodecyl trichlorosilane						
Ethyl trichlorosilane						
Hexyl trichlorosilane						
Methyl trichlorosilane						
Nonyl trichlor osilane						
Octadecyl trichlorosilane						
Octyl trichlorosilane						
Propyl trichlorosilane						
Trichloro(dichlorophenyl)silane						
Trichlorophenylsilane						
Trichlorosilane						
Vinyl trichlorosilane						

(Continued)

TABLE 3-7 Continued

Compound	Classification	10 min	30 min	1 h	4 h	8 h
TETRACHLOROSILANE						
	AEGL-1	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm
	AEGL-2	25 ppm	11 ppm	5.5 ppm	2.8 ppm	2.8 ppm
	AEGL-3	160 ppm	53 ppm	25 ppm	6.5 ppm	6.5 ppm

[a]Values given in ppm. To convert ppm to mg/m^3: (ppm × molecular weight) ÷ 24.5. See Appendix A for the appropriate molecular weight.

TABLE 3-8 Extant Standards and Guidelines for Selected Chlorosilanes

Guideline	Exposure Duration				
	10 min	30 min	1 h	4 h	8 h
MONOCHLOROSILANES					
AEGL-1	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm
AEGL-2	100 ppm	43 ppm	22 ppm	11 ppm	11 ppm
AEGL-3	620 ppm	210 ppm	100 ppm	26 ppm	26 ppm
Trimethylchlorosilane					
ERPG-1 (AIHA)[a]			3 ppm		
ERPG-2 (AIHA)[a]			20 ppm		
ERPG-3 (AIHA)[a]			150 ppm		
WEEL (AIHA)[b]			5 ppm (ceiling)		
DICHLOROSILANES					
AEGL-1	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm
AEGL-2	50 ppm	22 ppm	11 ppm	5.5 ppm	5.5 ppm
AEGL-3	310 ppm	110 ppm	50 ppm	13 ppm	13 ppm
Dimethyl dichlorosilane					
ERPG-1 (AIHA)[a]			2 ppm		
ERPG-2 (AIHA)[a]			10 ppm		
ERPG-3 (AIHA)[a]			75 ppm		
WEEL (AIHA)[b]			2 ppm (ceiling)		
TRICHLOROSILANES					
AEGL-1	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm
AEGL-2	33 ppm	14 ppm	7.3 ppm	3.7 ppm	3.7 ppm
AEGL-3	210 ppm	70 ppm	33 ppm	8.7 ppm	8.7 ppm
Trichlorosilane					
ERPG-1 (AIHA)[a]			1 ppm		
ERPG-2 (AIHA)[a]			3 ppm		
ERPG-3 (AIHA)[a]			25 ppm		
WEEL (AIHA)[b]			0.5 ppm (ceiling)		
Methyl trichlorosilane					
ERPG-1 (AIHA)[a]			0.5 ppm		
ERPG-2 (AIHA)[a]			3 ppm		
ERPG-3 (AIHA)[a]			15 ppm		
WEEL (AIHA)[b]			1 ppm (ceiling)		
Methyl trichlorosilane					
ERPG-1 (AIHA)[a]			0.5 ppm		
ERPG-2 (AIHA)[a]			5 ppm		

(Continued)

TABLE 3-8 Continued

Guideline	Exposure Duration				
	10 min	30 min	1 h	4 h	8 h
ERPG-3 (AIHA)[a]			50 ppm		
WEEL (AIHA)[b]			1 ppm (ceiling)		
TETRACHLOROSILANE					
AEGL-1	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm
AEGL-2	25 ppm	11 ppm	5.5 ppm	2.8 ppm	2.8 ppm
AEGL-3	160 ppm	53 ppm	25 ppm	6.5 ppm	6.5 ppm
ERPG-1 (AIHA)[a]			0.75 ppm		
ERPG-2 (AIHA)[a]			5 ppm		
ERPG-3 (AIHA)[a]			37 ppm		
WEEL (AIHA)[b]			1 ppm (ceiling)		

[a]ERPG (Emergency Response Planning Guidelines, American Industrial Hygiene Association) (AIHA 2010).
ERPG-1 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing effects other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor. An ERPG-1 was not derived because of insufficient data.
ERPG-2 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action. The ERPG-2 for BCME is based on animal data, and was intended to be below 0.21 ppm, which was calculated to have a 1×10^{-4} excess carcinogenicity risk, and 0.7 ppm, which caused serious respiratory lesions in animals.
ERPG-3 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing or developing life-threatening health effects. The ERPG-3 for BCME is based on animal lethality data.
[b]WEEL (Workplace Environmental Exposure Level, American Industrial Hygiene Association) (AIHA 2010).
WEELs are health-based values, expressed as either time-weighted average (TWA) concentrations or ceiling values believed to provide guidance for protection of most workers exposed as a result of their occupations. A WEEL ceiling value is the instantaneous concentration that should not be exceeded at any time during the workday to prevent acute adverse health effects or discomfort.

8.3. Data Adequacy and Research Needs

There are no human or animal data on chlorosilanes relevant to AEGL-1 health end points. Likewise, there are no appropriate human data and few animal data relevant to AEGL-2 end points. A single study (Jean et al. 2006) that estimated LC_{50} values for 11 of the 26 chlorosilanes considered in this chapter provided data on lethality (an AEGL-3 end point). This study also supports the inference that the hydrolysis product, HCl, is largely responsible for the acute

inhalation toxicity of the chlorosilanes. There is anecdotal information on other hydrolysis and decomposition products (Nakashima et al. 1996). However, no information on the chemical form, physiological disposition, or potential toxicity of these decomposition products was found. Additional research on the identity and potential toxicity of decomposition products would enhance confidence in the database.

The available data on chlorosilane toxicity is limited to 11 of the 26 compounds addressed herein, and there were no data on chlorosilanes with aromatic or chlorinated substituents. The lack of data on the contribution of aromatic or chlorinated substituents to the toxicity of the chlorosilanes introduces uncertainty with respect to the protection afforded by using the molar equivalent of AEGL values for HCl as a surrogate for the AEGLs estimated for diphenyl dichlorosilane, trichloro(dichlorophenyl)silane, and trichlorophenylsilane. Additional research would enhance confidence in the AEGLs for these compounds.

The database on HCl was described by NRC (2004, pp. 107-109) as follows:

> Human data are limited to one study showing no significant effects in asthmatic subjects and to dated anecdotal information. Furthermore, the involvement of [reactive airway dysfunction syndrome] in HCl toxicity is unclear. Many more data are available for animal exposures; however, many of those studies used compromised animals or very small experimental groups, resulting in limited data for many species but no in-depth database for a given species. Also, some studies involve very short exposures to high concentrations of HCl. Thus, confidence in the AEGL values is at best moderate.

One important area of uncertainty is the role of ambient humidity on the release of HCl and the toxicity of chlorosilanes. The LC_{50} values reported by Jean et al. (2006), and used as the basis for concluding that the toxicity of chlorosilanes is well-predicted by HCl content, were obtained at a relative humidity of 35%. Higher humidity would probably have increased the degree of hydrolysis, resulting in higher HCl concentrations and lower concentrations of parent compound; whether this would affect the lethal concentrations is unknown and merits additional research.

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APPENDIX A

PHYSICAL AND CHEMICAL PROPERTIES OF SELECTED CHLOROSILANES

TABLE A-1 Chemical and Physical Properties for Allyl Trichlorosilane

Parameter	Value	References
Synonyms	Propen-3-yltrichlorosilane; trichloroallylsilane; trichloro-2-propenyl-silane	HSDB 2007a
CAS registry no.	107-37-9	HSDB 2007a
Chemical formula	$C_3H_5Cl_3Si$	HSDB 2007a
Molecular weight	175.52	HSDB 2007a
Physical state	Colorless liquid	HSDB 2007a
Melting point	35°C	HSDB 2007a
Boiling point	117.5°C	HSDB 2007a
Vapor density (air = 1)	6.05	HSDB 2007a
Liquid density/specific gravity	1.20 g/cm^3 at 20°C	HSDB 2007a
Solubility in water	Hydrolyzes to form HCl	HSDB 2007a
Vapor pressure	53 mm Hg at 47.5°C	HSDB 2007a
Conversion factors	1 ppm = 7.2 mg/m^3 1 mg/m^3 = 0.14 ppm	

TABLE A-2 Chemical and Physical Properties for Amyl Trichlorosilane

Parameter	Value	References
Synonyms	Pentylsilicon trichloride; pentyltrichlorosilane; trichloropentylsilane; trichloroamylsilane; trichloropentylsilane	HSDB 2007b
CAS registry no.	107-72-2	HSDB 2007b
Chemical formula	$C_5H_{11}Cl_3Si$	HSDB 2007b
Molecular weight	205.59	HSDB 2007b
Physical state	Colorless to yellow liquid	HSDB 2007b
Boiling point	172°C	HSDB 2007b
Liquid density/specific gravity	1.1330 g/cm^3 at 20°C	HSDB 2007b
Solubility in water	Hydrolyzes to form HCl	HSDB 2007b
Conversion factors	1 ppm = 8.4 mg/m^3 1 mg/m^3 = 0.12 ppm	

TABLE A-3 Chemical and Physical Properties for Butyl Trichlorosilane

Parameter	Value	References
Synonyms	Trichlorobutyl silane; butylsilicon trichloride	HSDB 2007c
CAS registry no.	7521-80-4	HSDB 2007c
Chemical formula	$C_4H_9Cl_3Si$	HSDB 2007c
Molecular weight	191.56	HSDB 2007c
Physical state	Colorless liquid	HSDB 2007c
Boiling point	148.5°C	HSDB 2007c
Vapor density (air = 1)	6.4	HSDB 2007c
Liquid density/specific gravity	1.160 g/cm^3 at 20°C	HSDB 2007c
Solubility in water	Hydrolyzes to form HCl	HSDB 2007c
Conversion factors	1 ppm = 7.8 mg/m^3 1 mg/m^3 = 0.13 ppm	

TABLE A-4 Chemical and Physical Properties for Chloromethyl Trichlorosilane

Parameter	Value	References
Synonyms	Silane, trichloro(chloromethyl)-; Chloromethyl(trichloro)-silane	HSDB 2002a
CAS registry no.	1558-25-4	HSDB 2002a
Chemical formula	CH_2Cl_4Si	HSDB 2002a
Molecular weight	183.93	HSDB 2002a
Physical state	Liquid	HSDB 2002a
Boiling point	118°C	EPA 1987
Liquid density/specific gravity	1.476 g/cm^3	HSDB 2002a
Vapor pressure	30 mm Hg at 25°C	EPA 1987
Conversion factors	1 ppm = 7.5 mg/m^3 1 mg/m^3 = 0.13 ppm	

TABLE A-5 Chemical and Physical Properties for Dichlorosilane

Parameter	Value	References
Synonyms	Chlorosilane; silicon chloride hydride	IPCS 1997
CAS registry no.	4109-96-0	IPCS 1997
Chemical formula	H_2Cl_2Si	IPCS 1997
Molecular weight	101.01	IPCS 1997

(Continued)

TABLE A-5 Continued

Parameter	Value	References
Physical state	Colorless gas	IPCS 1997
Melting point	-122°C	IPCS 1997
Boiling point	8°C	IPCS 1997
Vapor density (air = 1)	3.48	IPCS 1997
Solubility in water	Hydrolyzes to form HCl	IPCS 1997
Vapor pressure	163.6 kPa at 20°C	IPCS 1997
Conversion factors	1 ppm = 4.1 mg/m^3 1 mg/m^3 = 0.24 ppm	

TABLE A-6 Chemical and Physical Properties for Diethyl Dichlorosilane

Parameter	Value	References
Synonyms	Dichloroethylsilane	HSDB 2007d
CAS registry no.	1719-53-5	HSDB 2007d
Chemical formula	$C_4H_{10}Cl_2Si$	HSDB 2007d
Molecular weight	157.11	HSDB 2007d
Physical state	Colorless liquid	HSDB 2007d
Melting point	-96.5°C	HSDB 2007d
Boiling point	129°C	HSDB 2007d
Vapor density (air = 1)	5.14	HSDB 2007d
Liquid density/specific gravity	1.0504 at 20°C	HSDB 2007d
Solubility in water	Hydrolyzes to form HCl	HSDB 2007d
Vapor pressure	11.9 mm Hg at 25°C	HSDB 2007d
Conversion factors	1 ppm = 6.4 mg/m^3 1 mg/m^3 = 0.16 ppm	

TABLE A-7 Chemical and Physical Properties for Dimethyl Chlorosilane

Parameter	Value	References
Synonyms	Chlorodimethylsilane	ChemFinder 2007a
CAS registry no.	1066-35-9	ChemFinder 2007a
Chemical formula	C_2H_7ClSi	ChemFinder 2007a
Molecular weight	94.62	ChemFinder 2007a
Melting point	-111°C	ChemFinder 2007a
Boiling point	36.4°C	ChemFinder 2007a
Conversion factors	1 ppm = 3.9 mg/m^3 1 mg/m^3 = 0.26 ppm	

TABLE A-8 Chemical and Physical Properties for Dimethyl Dichlorosilane

Parameter	Values	Reference
Synonyms	Dichlorodimethylsilane	AIHA 2001a
CAS registry no.	75-78-5	HSDB 2010a
Chemical formula	$C_2H_6Cl_2Si$	HSDB 2010a
Molecular weight	129.06	HSDB 2010a
Physical state	Colorless liquid	HSDB 2010a
Melting point	<-70°C	AIHA 2001a
Boiling point	70.3°C	HSDB 2010a
Flash point	-9°C	AIHA 2001a
Density	1.07 g/cm^3 at 25°C	HSDB 2010a
Solubility in water	Reacts and decomposes	AIHA 2001a
Vapor pressure	115 mm Hg at 20°C	AIHA 2001a
Conversion factors	1 mg/m^3 = 0.19 ppm 1 ppm = 5.3 mg/m^3	

TABLE A-9 Chemical and Physical Properties for Diphenyl Dichlorosilane

Parameter	Value	References
Synonyms	Dichlorodiphenyl silane; diphenylsilicon dichloride; diphenylsilyl dichloride	HSDB 2007e
CAS registry no.	80-10-4	HSDB 2007e
Chemical formula	$C_{12}H_{10}Cl_2Si$	HSDB 2007e
Molecular weight	253.2	HSDB 2007e
Physical state	Colorless liquid	HSDB 2007e
Melting point	-22°C	HSDB 2007e
Boiling point	305°C	HSDB 2007e
Vapor density (air = 1)	8.45	HSDB 2007e
Liquid density/specific gravity	1.204 at 25°C	HSDB 2007e
Solubility in water	Hydrolyzes to form HCl	HSDB 2007e
Vapor pressure	4.986 kPa at 192°C	HSDB 2007e
Conversion factors	1 ppm = 10.3 mg/m^3 1 mg/m^3 = 0.097 ppm	

TABLE A-10 Chemical and Physical Properties for Dodecyl Trichlorosilane

Parameter	Value	References
Synonyms	Trichlorododecyl silane	HSDB 2007f
CAS registry no.	4484-72-4	HSDB 2007f
Chemical formula	$C_{12}H_{25}Cl_3Si$	HSDB 2007f
Molecular weight	303.77	HSDB 2007f
Physical state	Colorless to yellow liquid	HSDB 2007f
Boiling point	288°C	HSDB 2007f
Liquid density/specific gravity	1.026 at 25°C	HSDB 2007f
Solubility in water	Hydrolyzes to form HCl	HSDB 2007f
Conversion factors	1 ppm = 12 mg/m^3 1 mg/m^3 = 0.081 ppm	

TABLE A-11 Chemical and Physical Properties for Ethyl Trichlorosilane

Parameter	Value	References
Synonyms	Ethyl silicon trichloride; trichloro ethylsilane; trichloroethylsilicane; trichloroethyl silicon	HSDB 2007g
CAS registry no.	115-21-9	HSDB 2007g
Chemical formula	$C_2H_5Cl_3Si$	HSDB 2007g
Molecular weight	163.51	HSDB 2007g
Physical state	Colorless liquid	HSDB 2007g
Melting point	-105.6°C	HSDB 2007g
Boiling point	100.5°C	HSDB 2007g
Vapor density (air = 1)	5.6	HSDB 2007g
Liquid density/specific gravity	1.238 at 20°C	HSDB 2007g
Solubility in water	Hydrolyzes to form HCl	HSDB 2007g
Vapor pressure	47.18 mm Hg at 25°C	HSDB 2007g
Conversion factors	1 ppm = 6.7 mg/m^3 1 mg/m^3 = 0.15 ppm	

TABLE A-12 Chemical and Physical Properties for Hexyl Trichlorosilane

Parameter	Value	References
Synonyms	Trichlorohexylsilane	HSDB 2007h
CAS registry no.	928-65-4	HSDB 2007h
Chemical formula	$C_6H_{13}Cl_3Si$	HSDB 2007h
Molecular weight	219.61	HSDB 2007h
Physical state	Colorless liquid	HSDB 2007h
Boiling point	190°C	HSDB 2007h
Liquid density/specific gravity	1.1100 g/cm^3 at 20°C	HSDB 2007h
Solubility in water	Hydrolyzes to form HCl	HSDB 2007h
Conversion factors	1 ppm = 8.9 mg/m^3 1 mg/m^3 = 0.11 ppm	

TABLE A-13 Chemical and Physical Properties for Methyl Chlorosilane

Parameter	Values	Reference
Synonyms	Chloromethylsilane	ESIS 2011
CAS registry no.	993-00-0	SRC 2011
Chemical formula	CH_5ClSi	ESIS 2011
Molecular weight	77.57	SRC 2011
Physical state	Liquid	SRC 2011
Melting point	-135°C	SRC 2011
Boiling point	7° C	SRC 20114
Solubility in water	Reacts and decomposes in water	NJ DHSS 2009
Log P (octanol-water partition coefficient)	1.33	SRC 2011
Conversion factors	1 mg/m^3 = 0.32 ppm 1 ppm = 3.2 mg/m^3	

TABLE A-14 Chemical and Physical Properties for Methyl Dichlorosilane

Parameter	Values	Reference
Synonyms	Dichloromethylsilane; monomethyl dichlorosilane	IPCS 2002b
CAS registry no.	75-54-7	IPCS 2002b
Chemical formula	CH_4Cl_2Si	IPCS 2002b
Molecular weight	115.0	IPCS 2002b
Physical state	Colorless liquid	IPCS 2002b
Melting point	-92°C	IPCS 2002b
Boiling point	41°C	IPCS 2002b
Vapor Density (air = 1)	3.97	IPCS 2002b
Solubility in water	Reacts and decomposes in water; soluble in benzene, ether, and heptane	IPCS 2002b
Vapor pressure	47.1 kPa at 20°C	IPCS 2002b
Flash point	-22°C	IPCS 2002b
Auto-ignition temperature	290°C	IPCS 2002b
Conversion factors	1 mg/m^3 = 0.21 ppm 1 ppm = 4.7 mg/m^3	

TABLE A-15 Chemical and Physical Properties for Methyl Trichlorosilane

Parameter	Value	Reference
Synonyms	Trichloromethylsilane	AIHA 2001b
CAS registry no.	75-79-6	HSDB 2007i
Chemical formula	CH_3Cl_3Si	HSDB 2007i
Molecular weight	149.48	HSDB 2007i
Physical state	Liquid	AIHA 2001b
Melting point	-90°C	HSDB 2007i
Boiling point	65.6°C	HSDB 2007i
Density	5.17 g/cm^3	Bisesi 1994
Solubility in water	Reacts and decomposes	AIHA 2001b
Vapor pressure	134 mm Hg at 20°C	AIHA 2001b
Flash point	3°C	Bisesi 1994
Conversion factors	1 mg/m^3 = 0.16 ppm 1 ppm = 6.1 mg/m^3	

TABLE A-16 Chemical and Physical Properties for Methylvinyl Dichlorosilane

Parameter	Value	References
Synonyms	Dicloro methylvinylsilane; Vinyl methyl dichlorosilane	ChemFinder 2007b
CAS registry no.	124-70-9	ChemFinder 2007b
Chemical formula	$C_3H_6Cl_2Si$	ChemFinder 2007b
Molecular weight	141.1	ChemFinder 2007b
Boiling point	92°C	ChemFinder 2007b
Liquid density/specific gravity	1.08 at 20°C	ChemFinder 2007b
Conversion factors	1 ppm = 5.8 mg/m^3 1 mg/m^3 = 0.17 ppm	

TABLE A-17 Chemical and Physical Properties for Nonyl Trichlorosilane

Parameter	Value	References
Synonyms	Trichlorononylsilane	HSDB 2007j
CAS registry no.	5283-67-0	HSDB 2007j
Chemical formula	$C_9H_{19}Cl_3Si$	HSDB 2007j
Molecular weight	261.72	HSDB 2007j
Physical state	Water-white liquid	HSDB 2007j
Liquid density/specific gravity	1.072 g/cm^3 at 25°C	HSDB 2007j
Solubility in water	Hydrolyzes to form HCl	HSDB 2007j
Conversion factors	1 ppm = 10.7 mg/m^3 1 mg/m^3 = 0.094 ppm	

TABLE A-18 Chemical and Physical Properties for Octadecyl Trichlorosilane

Parameter	Value	References
Synonyms	Silane, trichlorooctadecyl, trichlorooctadecylsilane	HSDB 2010b
CAS registry no.	112-04-9	HSDB 2010b
Chemical formula	$C_{18}H_{37}Cl_3Si$	HSDB 2010b
Molecular weight	387.93	HSDB 2010b
Physical state	Water-white liquid	HSDB 2010b
Melting point	About 20°C	HSDB 2010b
Boiling point	380°C	HSDB 2010b
Liquid density/specific gravity	0.984 g/cm^3 at 25°C	HSDB 2010b
Conversion factors	1 ppm = 16 mg/m^3 1 mg/m^3 = 0.063 ppm	

TABLE A-19 Chemical and Physical Properties for Octyl Trichlorosilane

Parameter	Value	References
Synonyms	Trichlorooctylsilane	HSDB 2007k
CAS registry no.	5283-66-9	HSDB 2007k
Chemical formula	$C_8H_{17}Cl_3Si$	HSDB 2007k
Molecular weight	247.67	HSDB 2007k
Physical state	Fuming liquid	HSDB 2007k
Boiling point	232°C	HSDB 2007k
Liquid density/specific gravity	1.073 g/mL	HSDB 2007k
Solubility in water	Hydrolyzes to form HCl	HSDB 2007k
Conversion factors	1 ppm = 10 mg/m^3 1 mg/m^3 = 0.099 ppm	

TABLE A-20 Chemical and Physical Properties for Propyl Trichlorosilane

Parameter	Value	References
Synonyms	Trichloropropylsilane; *n*-propyl trichlorosilane	HSDB 2007l
CAS registry no.	141-57-1	HSDB 2007l
Chemical formula	$C_3H_7Cl_3Si$	HSDB 2007l
Molecular weight	177.53	HSDB 2007l
Physical state	Colorless liquid	HSDB 2007l
Boiling point	123.5°C	HSDB 2007l
Vapor density (air = 1)	6.1215	HSDB 2007l
Liquid density/specific gravity	1.195 g/cm^3 at 20°C	HSDB 2007l
Solubility in water	Hydrolyzes to form HCl	HSDB 2007l
Vapor pressure	28.8 mm Hg at 20°C	HSDB 2007l
Conversion factors	1 ppm = 7.2 mg/m^3 1 mg/m^3 = 0.14 ppm	

TABLE A-21 Chemical and Physical Properties for Tetrachlorosilane

Parameter	Value	References
Synonyms	Silicon tetrachloride; silicon chloride	HSDB 2002b
CAS registry no.	10026-04-7	HSDB 2002b
Chemical formula	$SiCl_4$	HSDB 2002b
Molecular weight	169.9	HSDB 2002b
Physical state	Colorless, clear, mobile, fuming liquid	HSDB 2002b
Melting point	-70°C	HSDB 2002b
Boiling point	59°C	HSDB 2002b
Vapor density (air = 1)	7.59 g/L	HSDB 2002b
Liquid density/specific gravity	1.52 g/cm^3 at 0°/4°C	HSDB 2002b
Solubility in water	Decomposes to HCl and silicic acid	HSDB 2002b
Vapor pressure	236 mm Hg at 25°C	HSDB 2002b
Flammability limits	Nonflammable	HSDB 2002b
Conversion factors	1 ppm = 6.9 mg/m^3 1 mg/m^3 = 0.14 ppm	

TABLE A-22 Chemical and Physical Properties for Trichloro(dichlorophenyl)silane

Parameter	Value	References
Synonyms	Dichlorophenyltrichlorosilane	HSDB 2007m
CAS registry no.	27137-85-5	HSDB 2007m
Chemical formula	$C_6H_3Cl_5Si$	HSDB 2007m
Molecular weight	280.43	HSDB 2007m
Physical state	Straw-colored liquid	HSDB 2007m
Boiling point	260°C	HSDB 2007m
Liquid density/specific gravity	1.562 g/cm^3	HSDB 2007m
Conversion factors	1 ppm = 11.4 mg/m^3 1 mg/m^3 = 0.087 ppm	

TABLE A-23 Chemical and Physical Properties for Trichlorophenylsilane

Parameter	Value	References
Synonyms	Phenyltrichlorosilane; phenylsilicon trichloride	HSDB 2007n
CAS registry no.	98-13-5	HSDB 2007n
Chemical formula	$C_6H_5Cl_3Si$	HSDB 2007n
Molecular weight	211.55	HSDB 2007n
Physical state	Colorless liquid	HSDB 2007n
Boiling point	201°C	HSDB 2007n
Vapor density (air = 1)	7.36	HSDB 2007n
Liquid density/specific gravity	1.321 g/cm^3 at 20°C	HSDB 2007n
Solubility in water	Hydrolyzes to form HCl	HSDB 2007n
Vapor pressure	0.426 mm Hg at 25°C	HSDB 2007n
Conversion factors	1 ppm = 8.6 mg/m^3 1 mg/m^3 = 0.12 ppm	

TABLE A-24 Chemical and Physical Properties for Trichlorosilane

Parameter	Value	References
Synonyms	Silicochloroform	HSDB 2007o
CAS registry no.	10025-78-2	HSDB 2007o
Chemical formula	Cl_3HSi	HSDB 2007o
Molecular weight	135.47	HSDB 2007o
Physical state	Colorless liquid	HSDB 2007o
Melting point	-126.5°C	HSDB 2007o
Boiling point	31.8°C	HSDB 2007o
Vapor density (air = 1)	4.67	HSDB 2007o
Liquid density/specific gravity	1.3417 g/cm^3 at 20°C	HSDB 2007o
Solubility in water	Hydrolyzes to form HCl	HSDB 2007o
Vapor pressure	594 mm Hg at 25°C	HSDB 2007o
Conversion factors	1 ppm = 5.3 mg/m^3 1 mg/m^3 = 0.18 ppm	

TABLE A-25 Chemical and Physical Properties for Trimethyl Chlorosilane

Parameter	Value	References
Synonyms	Chlorotrimethylsilane; monochlorotrimethylsilicon	HSDB 2007p
CAS registry no.	75-77-4	HSDB 2007p
Chemical formula	C_3H_9ClSi	HSDB 2007p
Molecular weight	108.642	HSDB 2007p
Physical state	Colorless liquid	HSDB 2007p
Melting point	-40°C	HSDB 2007p
Boiling point	57°C	HSDB 2007p
Vapor density (air = 1)	3.75	HSDB 2007p
Liquid density/specific gravity	0.854 g/cm^3 at 25°C	HSDB 2007p
Solubility in water	Hydrolyzes rapidly	HSDB 2007p
Flash point	0°F (open cup)	HSDB 2007p
Conversion factors in air	1 mg/m^3 = 0.23 ppm 1 ppm = 4.4 mg/m^3	

TABLE A-26 Chemical and Physical Properties for Vinyl Trichlorosilane

Parameter	Value	References
Synonyms	Trichlorovinylsilane; vinylsilicon tetrachloride; trichlorovinyl silicon	HSDB 2007q
CAS registry no.	75-94-5	HSDB 2007q
Chemical formula	$C_2H_3Cl_3Si$	HSDB 2007q
Molecular weight	161.49	HSDB 2007q
Physical state	Fuming liquid	HSDB 2007q
Melting point	-95°C	HSDB 2007q
Boiling point	91.5°C	HSDB 2007q
Vapor density (air = 1)	5.61	HSDB 2007q
Liquid density/specific gravity	1.2426 g/cm^3 at 20°C	HSDB 2007q
Solubility in water	Hydrolyzes to form HCl	HSDB 2007q
Vapor pressure	65.9 mm Hg at 25°C	HSDB 2007q
Conversion factors	1 ppm = 6.6 mg/m^3 1 mg/m^3 = 0.15 ppm	

APPENDIX B

DERIVATION OF AEGL VALUES FOR SELECTED CHLOROSILANES

Derivation of AEGL-1

Monochlorosilanes

Key study:	AEGL-1 values for HCl (Stevens et al. 1992; NRC 2004)
10-min AEGL-1:	1.8 ppm
30-min AEGL-1:	1.8 ppm
1-h AEGL-1:	1.8 ppm
4-h AEGL-1:	1.8 ppm
8-h AEGL-1:	1.8 ppm

Dichlorosilanes

Key study:	AEGL-1 values for HCl (Stevens et al. 1992; NRC 2004) divided by a molar adjustment factor of 2
10-min AEGL-1:	1.8 ppm ÷ 2 = 0.90 ppm
30-min AEGL-1:	1.8 ppm ÷ 2 = 0.90 ppm
1-h AEGL-1:	1.8 ppm ÷ 2 = 0.90 ppm
4-h AEGL-1:	1.8 ppm ÷ 2 = 0.90 ppm
8-h AEGL-1:	1.8 ppm ÷ 2 = 0.90 ppm

Trichlorosilanes

Key study:	AEGL-1 values for HCl (Stevens et al. 1992; NRC 2004) divided by a molar adjustment factor of 3
10-min AEGL-1:	1.8 ppm ÷ 3 = 0.60 ppm
30-min AEGL-1:	1.8 ppm ÷ 3 = 0.60 ppm
1-h AEGL-1:	1.8 ppm ÷ 3 = 0.60 ppm
4-h AEGL-1:	1.8 ppm ÷ 3 = 0.60 ppm
8-h AEGL-1:	1.8 ppm ÷ 3 = 0.60 ppm

Tetrachlorosilane

Key study: AEGL-1 values for HCl (Stevens et al. 1992; NRC 2004) divided by a molar adjustment factor of 4

10-min AEGL-1: 1.8 ppm ÷ 4 = 0.45 ppm
30-min AEGL-1: 1.8 ppm ÷ 4 = 0.45 ppm
1-h AEGL-1: 1.8 ppm ÷ 4 = 0.45 ppm
4-h AEGL-1: 1.8 ppm ÷ 4 = 0.45 ppm
8-h AEGL-1: 1.8 ppm ÷ 4 = 0.45 ppm

Derivation of AEGL-2

Monochlorosilanes

Key study: AEGL-2 values for HCl (Barrow et al. 1977; Stavert et al. 1991; NRC 2004).

10-min AEGL-1: 100 ppm
30-min AEGL-1: 43 ppm
1-h AEGL-1: 22 ppm
4-h AEGL-1: 11 ppm
8-h AEGL-1: 11 ppm

Dichlorosilanes

Key study: AEGL-2 values for HCl (Barrow et al. 1977; Stavert et al. 1991; NRC 2004) divided by a molar adjustment factor of 2

10-min AEGL-2: 100 ppm ÷ 2 = 50 ppm
30-min AEGL-2: 43 ppm ÷ 2 = 22 ppm
1-h AEGL-2: 22 ppm ÷ 2 = 11 ppm
4-h AEGL-2: 11 ppm ÷ 2 = 5.5 ppm
8-h AEGL-2: 11 ppm ÷ 2 = 5.5 ppm

Trichlorosilanes

Key study: AEGL-2 values for HCl (Barrow et al. 1977; Stavert et al. 1991; NRC 2004) divided by a molar adjustment factor of 3

10-min AEGL-2:	100 ppm ÷ 3 = 33 ppm
30-min AEGL-2:	43 ppm ÷ 3 = 14 ppm
1-h AEGL-2:	22 ppm ÷ 3 = 7.3 ppm
4-h AEGL-2:	11 ppm ÷ 3 = 3.7 ppm
8-h AEGL-2:	11 ppm ÷ 3 = 3.7 ppm

Tetrachlorosilane

Key study:	AEGL-2 values for HCl (Barrow et al. 1977; Stavert et al. 1991; NRC 2004) divided by a molar adjustment factor of 4
10-min AEGL-2:	100 ppm ÷ 4 = 25 ppm
30-min AEGL-2:	43 ppm ÷ 4 = 11 ppm
1-h AEGL-2:	22 ppm ÷ 4 = 5.5 ppm
4-h AEGL-2:	11 ppm ÷ 4 = 2.8 ppm
8-h AEGL-2:	11 ppm ÷ 4 = 2.8 ppm

Derivation of AEGL-3

Monochlorosilanes

Key study:	AEGL-3 values for HCl (Wohlslagel et al. 1976; Vernot et al. 1977; NRC 2004)
10-min AEGL-1:	620 ppm
30-min AEGL-1:	210 ppm
1-h AEGL-1:	100 ppm
4-h AEGL-1:	26 ppm
8-h AEGL-1:	26 ppm

Dichlorosilanes

Key study:	AEGL-3 values for HCl (Wohlslagel et al. 1976; Vernot et al. 1977; NRC 2004) divided by a molar adjustment factor of 2
10-min AEGL-3:	620 ppm ÷ 2 = 310 ppm
30-min AEGL-3:	210 ppm ÷ 2 = 105 ppm (rounded to 110)
1-h AEGL-3:	100 ppm ÷ 2 = 50 ppm
4-h AEGL-3:	26 ppm ÷ 2 = 13 ppm
8-h AEGL-3:	26 ppm ÷ 2 = 13 ppm

Trichlorosilanes

Key study:	AEGL-3 values for HCl (Wohlslagel et al. 1976; Vernot et al. 1977; NRC 2004) divided by a molar adjustment factor of 3
10-min AEGL-3:	620 ppm ÷ 3 = 210 ppm
30-min AEGL-3:	210 ppm ÷ 3 = 70 ppm
1-h AEGL-3:	100 ppm ÷ 3 = 33 ppm
4-h AEGL-3:	26 ppm ÷ 3 = 8.7 ppm
8-h AEGL-3:	26 ppm ÷ 3 = 8.7 ppm

Tetrachlorosilane

Key study:	AEGL-3 values for HCl (Wohlslagel et al. 1976; Vernot et al. 1977; NRC 2004) divided by a molar adjustment factor of 4
10-min AEGL-3:	620 ppm ÷ 4 = 160 ppm
30-min AEGL-3:	210 ppm ÷ 4 = 53 ppm
1-h AEGL-3:	100 ppm ÷ 4 = 25 ppm
4-h AEGL-3:	26 ppm ÷ 4 = 6.5 ppm
8-h AEGL-3:	26 ppm ÷ 4 = 6.5 ppm

APPENDIX C

DERIVATION OF AEGL VALUES FOR HYDROGEN CHLORIDE (NRC 2004)

Derivation of AEGL-1 Values

Key study:	Stevens et al. 1992
Toxicity end point:	No-observed-adverse-effect level in exercising asthmatic subjects
Time-scaling:	$C^n \times t = k$ (default of n = 1 for shorter to longer exposure period) $(1.8 \text{ ppm})^1 \times 0.75 \text{ h} = 1.35 \text{ ppm-h}$
Uncertainty factors:	None
10-min AEGL-1:	1.8 ppm
30-min AEGL-1:	1.8 ppm
1-h AEGL-1:	1.8 ppm
4-h AEGL-1:	1.8 ppm
8-h AEGL-1:	1.8 ppm

Derivation of AEGL-2 Values

10-min AEGL-2

Key study:	Barrow et al. (1977)
Toxicity end point:	Mouse RD_{50} of 309 ppm
10-min AEGL-2:	309 ppm ÷ 3 = 100 ppm One-third of the RD_{50} corresponds to an approximate decrease in respiratory rate of 30%, and decreases in the range of 20-50% correspond to moderate irritation (ASTM 1991).

30-min, 1-, 4-, and 8-h AEGL-2

Key study:	Stavert et al. 1991
Toxicity end point:	Severe nasal (nose breathers) or pulmonary (mouth breathers) effects in rats exposed at 1,300 ppm for 30 min
Time-scaling:	$C^1 \times t = k$ (n = 1 for shorter to longer exposure periods) $(1{,}300 \text{ ppm})^1 \times 0.5 \text{ h} = 650 \text{ ppm-h}$
Uncertainty factors:	3 for intraspecies variability 3 for interspecies variability Combined uncertainty factor of 10
Modifying factor:	3 for sparse database
30-min AEGL-2:	$C^1 \times 0.5 \text{ h} = 650 \text{ ppm-h}$ C = 1,300 ppm 1,300 ppm ÷ 30 = 43 ppm
1-h AEGL-2:	$C^1 \times 1 \text{ h} = 650 \text{ ppm-h}$ C = 650 ppm 650 ppm ÷ 30 = 22 ppm
4-h AEGL-2:	1-h AEGL-2 ÷ 2 = 11 ppm
8-h AEGL-2:	1-h AEGL-2 ÷ 2 = 11 ppm

Derivation of AEGL-3 Values

Key studies:	Wohlslagel et al. (1976); Vernot et al. (1977)
Toxicity end point:	One-third of the rat 1-h LC_{50} (an estimated no-effect level for death) LC_{50} = 3,124 ppm ÷ 3 = 1,041 ppm
Time-scaling:	$C^1 \times t = k$ (n = 1 for shorter to longer exposure periods) $(1{,}041 \text{ ppm})^1 \times 1 \text{ h} = 1{,}041 \text{ ppm-h}$
Uncertainty factors:	3 for intraspecies variability 3 for interspecies variability Combined uncertainty factor of 10

10-min AEGL-3:	$C^1 \times 0.167$ h = 1,041 ppm-h C = 6,234 ppm 6,234 ppm ÷ 10 = 623.4 ppm
30-min AEGL-3:	$C^1 \times 0.5$ h = 1,041 ppm-h C = 2,082 ppm 2,082 ppm ÷ 10 = 208 ppm
1-h AEGL-3:	$C^1 \times 1$ h = 1,041 ppm-h C = 1,041 ppm 1,041 ppm ÷ 10 = 104.1 ppm
4-h AEGL-3:	$C^1 \times 4$ h = 1,041 ppm-h C = 260.25 ppm 260.25 ppm ÷ 10 = 26 ppm
8-h AEGL-3:	Set equal to 4-h AEGL-3 = 26 ppm

SUMMARY OF KEY STUDY AND RATIONALE USED TO DERIVE AEGL VALUES FOR HYDROGEN CHLORIDE (Excerpted from NRC 2004)

AEGL-1 Values

Because appropriate human data exist for exposure to HCl, they were used to identify AEGL-1 values. Exposure to HCl at 1.8 ppm for 45 min resulted in a no-observed-adverse-effect level in 10 exercising young adult asthmatic subjects (Stevens et al. 1992). Because exercise will increase HCl uptake and exacerbate irritation, those asthmatic subjects are considered a sensitive subpopulation. Therefore, because the test subjects were a sensitive subpopulation and the end point was essentially a no-effect level, no uncertainty factor was applied to account for sensitive human subpopulations. Adequate human data were available, so no uncertainty factor was applied for animal to human extrapolation. The no-effect level was held constant across the 10- and 30-min and 1-, 4-, and 8-h exposure time periods. That approach was considered appropriate because mild irritant effects generally do not vary greatly over time, and the end point of a no-effect level in a sensitive population is inherently conservative.

AEGL-2 Values

The AEGL-2 for the 30-min and 1-, 4-, and 8-h time points was based on severe nasal or pulmonary histopathology in rats exposed to HCl at 1,300 ppm for 30 min (Stavert et al. 1991). A modifying factor of 3 was applied to account for the relatively sparse database describing effects defined by AEGL-2. The AEGL-2 values were further adjusted by a total uncertainty factor of 10—3 for intraspecies variability, supported by the steep concentration-response curve, which implies little individual variability; and 3 for interspecies variability. Using the default value of 10 for interspecies variability would bring the total adjustment to 100 instead of 30. That would generate AEGL-2 values that are not supported by data on exercising asthmatic subjects, an especially sensitive subpopulation. Exercise increases HCl uptake and exacerbates irritation; no effects were noted in exercising young adult asthmatic subjects exposed to HCl at 1.8 ppm for 45 min (Stevens et al. 1992). Using a total uncertainty factor of 30 would yield 4- and 8-h values of 3.6 ppm (instead of 11 ppm). The prediction that humans would be disabled by exposure for 4 or 8 h to 3.6 ppm cannot be supported when exercising asthmatic subjects exposed to one-half that concentration for 45 min exhibited no effects. The shorter time points would yield values 4 to 7 times the 1.8-ppm value; however, confidence in the time-scaling for HCl is good for times up to 100 min, because the value of n was derived from a regression analysis of rat and mouse mortality data with exposure durations ranging from 1 min to 100 min. The 30-min value of 43 ppm derived with a total uncertainty factor of 10 is reasonable in light of the fact that baboons exposed at

500 ppm for 15 min experienced only a slightly increased respiratory rate. Therefore, a total uncertainty factor of 10, accompanied by the modifying factor of 3, is most consistent with the database. Thus, the total factor is 30. Time-scaling for the 1-h AEGL exposure period used the $C^n \times t = k$ relationship, where n = 1 based on regression analysis of combined rat and mouse LC_{50} data (1 to 100 min) as reported by ten Berge et al. (1986). The 4- and 8-h AEGL-2 values were derived by applying a modifying factor of 2 to the 1-h AEGL-2 value, because time-scaling would yield a 4-h AEGL-2 of 5.4 ppm and an 8-h AEGL-2 of 2.7 ppm, close to the 1.8 ppm tolerated by exercising asthmatic subjects without observed adverse health effects. Repeated-exposure rat data suggest that the 4- and 8-h values of 11 ppm are protective. Rats exposed to HCl at 10 ppm for 6 h/day, 5 days/week for life exhibited only tracheal and laryngeal hyperplasia, and rats exposed to HCl at 50 ppm for 6 h/day, 5 days/week for 90 days exhibited only mild rhinitis.

The 10-min AEGL-2 was derived by dividing the mouse RD_{50} of 309 ppm by a factor of 3 to obtain a concentration causing irritation (Barrow et al. 1977). It has been determined that human response to sensory irritants can be predicted on the basis of the mouse RD_{50}. For example, Schaper (1993) has validated the correlation of $0.03 \times RD_{50}$ = TLV (threshold limit value) as a value that will prevent sensory irritation in humans. The 0.03 represents the half-way point between 0.1 and 0.01 on a logarithmic scale, and Alarie (1981) has shown that the RD_{50} multiplied by 0.1 corresponds to "some sensory irritation," whereas the RD_{50} value itself is considered "intolerable to humans." Thus, it is reasonable that one-third of the RD_{50}, a value half-way between 0.1 and 1 on a logarithmic scale, might cause significant irritation to humans. Furthermore, one-third of the mouse RD_{50} for HCl corresponds to an approximate decrease in respiratory rate of 30%, and decreases in the range of 20-50% correspond to moderate irritation (ASTM 1991).

AEGL-3 Values

The AEGL-3 was based on a 1-h rat LC_{50} study (Wohlslagel et al. 1976; Vernot et al. 1977). One-third of the 1-h LC_{50} value of 3,124 ppm was used as an estimated concentration causing no deaths. That estimate is inherently conservative (no deaths observed in the same study at 1,813 ppm). A total uncertainty factor of 10 will be applied—3 for intraspecies variation, because the steep concentration-response curve implies limited individual variability; and 3 to protect susceptible individuals. Using a full value of 10 for interspecies variability (total uncertainty factor of 30) would yield AEGL-3 values that are inconsistent with the overall data set.

A number of factors argue for the use of an uncertainty factor of 10 instead of 30, they are: (1) the steep concentration-response curve for lethality observed in the Wohlslagel et al. (1976) study in which the estimated LC_0 (one-third of the LC_{50} of 3,124 ppm) is lower than the experimental LC_0 of 1,813

ppm. The LC_0 selection is conservative, and the steep concentration-response curve argues for little interindividual variability; (2) AEGL-3 values generated from a total uncertainty factor of 30 would be close (within a factor of 2) to the AEGL-2 values generated from data on exercising asthmatic subjects; (3) Sellakumar et al. (1985) exposed rats to HCl at 10 ppm for 6 h/day, 5 days/week for life and only observed increased trachael and laryngeal hyperplasia. The estimated 6-h AEGL-3 using an intraspecies uncertainty factor of 3 is 17 ppm, close to the concentration inhaled in the lifetime study in which only mild effects were induced; and (4) rats exposed to HCl at 50 ppm for 6 h/day, 5 days/week for 90 days exhibited mild rhinitis (Toxigenics Inc. 1984). This level is already twice the AEGL-3 value, which is intended to protect against death.

Thus, the total uncertainty factor was set at 10. It was then time-scaled to the specified 10- and 30-min and 4-h AEGL exposure periods using the $C^n \times t = k$ relationship, where n = 1 based on regression analysis of combined rat and mouse LC_{50} data (1 min to 100 min) as reported by ten Berge et al. (1986). The 4-h AEGL-3 also was adopted as the 8-h AEGL-3 because of the uncertainty of time-scaling to 8 h with an n value derived from exposure durations of up to 100 min.

The 5-min rat LC_0 of 30,000 ppm (Higgins et al. 1972) supports the 10-min AEGL-3 value. Extrapolating that value across time (n = 1) to 10 min and applying an uncertainty factor of 10 yields a value of 1,500 ppm, suggesting that the proposed AEGL-3 value is protective. Also, if the 5-min rat LC_{50} of 41,000 ppm for HCl vapor (Darmer et al. 1974) is divided by 3 to estimate a no-effect level for death, extrapolated to 10 min, and an uncertainty factor of 10 is applied, a supporting value of 683 ppm is obtained.

APPENDIX D

ACUTE EXPOSURE GUIDELINE LEVELS FOR SELECTED CHLOROSILANES

Derivation Summary

AEGL-1 VALUES FOR MONOCHLOROSILANES

10 min	30 min	1 h	4 h	8 r
1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 22-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-1 values for HCl were adopted as AEGL-1 values for monochlorosilanes. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Data adequacy: Mechanism-of-action data were considered adequate for the derivation of AEGL-1 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-1 values for chlorosilanes is low, reflecting the lack of data on AEGL-1 end points after chlorosilane exposure and reliance on HCl data. Additional research on AEGL-1 effects of chlorosilanes would reduce uncertainty.

AEGL-1 VALUES FOR DICHLOROSILANES

10 min	30 min	1 h	4 h	8 h
0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm	0.90 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-1 values for dichlorosilanes were derived by adjusting the AEGL-1 values for HCl by the molar ratio of HCl to trichlorosilanes. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar Adjustment Factor: 2

Data adequacy: Mechanism-of-action data were considered adequate for the derivation of AEGL-1 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-1 values for chlorosilanes is low, reflecting the lack of data on AEGL-1 end points after chlorosilane exposure and reliance on HCl data. Additional research on AEGL-1 effects of chlorosilanes would reduce uncertainty.

AEGL-1 VALUES FOR TRICHLOROSILANES

10 min	30 min	1 h	4 h	8 h
0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm	0.60 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-1 values for trichlorosilanes were derived by adjusting the AEGL-1 values for HCl by the molar ratio of HCl to trichlorosilanes. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar Adjustment Factor: 3

Data adequacy: Mechanism-of-action data were considered adequate for the derivation of AEGL-1 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-1 values for chlorosilanes is low, reflecting the lack of data on AEGL-1 end points after chlorosilane exposure and reliance on HCl data. Additional research on AEGL-1 effects of chlorosilanes would reduce uncertainty.

AEGL-1 VALUES FOR TETRACHLOROSILANE

10 min	30 min	1 h	4 h	8 h
0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm	0.45 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-1 values for tetrachlorosilane were derived by adjusting the AEGL-1 values for HCl by the molar ratio of HCl to tetrachlorosilane. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar adjustment factor: 4

Data adequacy: Mechanism-of-action data were considered adequate for the derivation of AEGL-1 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-1 values for chlorosilanes is low, reflecting the lack of data on AEGL-1 end points after chlorosilane exposure and reliance on HCl data. Additional research on AEGL-1 effects of chlorosilanes would reduce uncertainty.

AEGL-2 VALUES FOR MONOCHLOROSILANES

10 min	30 min	1 h	4 h	8 h
100 ppm	43 ppm	22 ppm	11 ppm	11 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-2 values for HCl were adopted as AEGL-2 values for monochlorosilanes. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Data adequacy: Mechanism-of-action data were considered adequate for the derivation of AEGL-2 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-2 values for chlorosilanes is moderate, reflecting the limited data on AEGL-2 end points after chlorosilane exposure and reliance on HCl data. Additional research on AEGL-2 effects of chlorosilanes would reduce uncertainty.

AEGL-2 VALUES FOR DICHLOROSILANES

10 min	30 min	1 h	4 h	8 h
50 ppm	22 ppm	11 ppm	5.5 ppm	5.5 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-2 values for dichlorosilanes were derived by adjusting the AEGL-2 values for HCl by the molar ratio of HCl to dichlorosilane. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar adjustment factor: 2

Data adequacy: Mechanism-of-action data were considered adequate for the derivation of AEGL-2 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-2 values for chlorosilanes is moderate, reflecting the limited data on AEGL-2 end points after chlorosilane exposure and reliance on HCl data. Additional research on AEGL-2 effects of chlorosilanes would reduce uncertainty.

AEGL-2 VALUES FOR TRICHLOROSILANES

10 min	30 min	1 h	4 h	8 h
33 ppm	14 ppm	7.3 ppm	3.7 ppm	3.7 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-2 values for trichlorosilanes were derived by adjusting the AEGL-2 values for HCl by the molar ratio of HCl to trichlorosilane. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar adjustment factor: 3

Data adequacy: Mechanism-of-action data were considered adequate for the derivation of AEGL-2 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-2 values for chlorosilanes is moderate, reflecting the limited data on AEGL-2 end points after chlorosilane exposure and reliance on HCl data. Additional research on AEGL-2 effects of chlorosilanes would reduce uncertainty.

AEGL-2 VALUES FOR TETRACHLOROSILANE

10 min	30 min	1 h	4 h	8 h
25 ppm	11 ppm	5.5 ppm	2.8 ppm	2.8 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-2 values for tetrachlorosilane were derived by adjusting the AEGL-2 values for HCl by the molar ratio of HCl to tetrachlorosilane. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar adjustment factor: 4

Data adequacy: Mechanism-of-action data were considered adequate for the derivation of AEGL-2 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-2 values for chlorosilanes is moderate, reflecting the limited data on AEGL-2 end points after chlorosilane exposure and reliance on HCl data. Additional research on AEGL-2 effects of chlorosilanes would reduce uncertainty.

AEGL-3 VALUES FOR MONOCHLOROSILANES

10 min	30 min	1 h	4 h	8 h
620 ppm	210 ppm	100 ppm	26 ppm	26 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press..

End point/Concentration/Rationale: AEGL-3 values for HCl were adopted as AEGL-3 values for monochlorosilanes. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Data adequacy: Data were considered adequate for the derivation of AEGL-3 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-3 values for chlorosilanes is high, reflecting the availability of lethality data on 11 of the 26 chlorosilanes considered and evidence for the role of HCl as the proximate toxicant. No additional research is needed on AEGL-3 end points.

AEGL-3 VALUES FOR DICHLOROSILANES

10 min	30 min	1 h	4 h	8 h
310 ppm	110 ppm	50 ppm	13 ppm	13 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-3 values for dichlorosilanes were derived by adjusting the AEGL-3 values for HCl by the molar ratio of HCl to dichlorosilane. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar adjustment factor: 2

Data adequacy: Data were considered adequate for the derivation of AEGL-3 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-3 values for chlorosilanes is high, reflecting the availability of lethality data on 11 of the 26 chlorosilanes considered and evidence for the role of HCl as the proximate toxicant. No additional research is needed on AEGL-3 end points.

AEGL-3 VALUES FOR TRICHLOROSILANES

10 min	30 min	1 h	4 h	8 h
210 ppm	70 ppm	33 ppm	8.7 ppm	8.7 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-3 values for trichlorosilanes were derived by adjusting the AEGL-3 values for HCl by the molar ratio of HCl to trichlorosilane. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar adjustment factor: 3

Data adequacy: Data were considered adequate for the derivation of AEGL-3 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-3 values for chlorosilanes is high, reflecting the availability of lethality data on 11 of the 26 chlorosilanes considered and evidence for the role of HCl as the proximate toxicant. No additional research is needed on AEGL-3 end points.

AEGL-3 VALUES FOR TETRACHLOROSILANE

10 min	30 min	1 h	4 h	8 h
160 ppm	53 ppm	25 ppm	6.5 ppm	6.5 ppm

Key reference: NRC (National Research Council). 2004. Hydrogen chloride. Pp. 77-122 in Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vol. 4. Washington, DC: National Academies Press.

End point/Concentration/Rationale: AEGL-3 values for tetrachlorosilane were derived by adjusting the AEGL-3 values for HCl by the molar ratio of HCl to tetrachlorosilane. This approach is considered reasonable because qualitative and quantitative data on chlorosilanes suggest that the HCl hydrolysis product is largely responsible for the acute toxicity of the chlorosilanes.

Molar adjustment factor: 4

Data adequacy: Data were considered adequate for the derivation of AEGL-3 values for chlorosilanes based on analogy to HCl. Confidence in the AEGL-3 values for chlorosilanes is high, reflecting the availability of lethality data on 11 of the 26 chlorosilanes considered and evidence for the role of HCl as the proximate toxicant. No additional research is needed on AEGL-3 end points.

APPENDIX E

DERIVATION SUMMARY TABLES FOR HYDROGEN CHLORIDE (Excerpted from NRC 2004)

Derivation Summary

AEGL-1 VALUES FOR HYDROGEN CHLORIDE

10 min	30 min	1 h	4 h	8 h
1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm

Key reference: Stevens, B., J.Q. Koenig, V. Rebolledo, Q.S. Hanley, and D.S. Covert, D.S. 1992. Respiratory effects from the inhalation of hydrogen chloride in young adults with asthma. J. Occup. Med. 34(9): 923-929.

Test species/Strain/Number: Human adults with asthma, 10

Exposure route/Concentrations/Durations: Inhalation at 0, 0.8, or 1.8 ppm for 45 min while exercising (1.8 ppm was determinant for AEGL-1)

Effects: No treatment-related effects were observed in any of the individuals tested

End point/Concentration/Rationale: The highest concentration tested was a no-effect level for irritation in a sensitive human population (10 asthmatic individuals tested) and was selected as the basis of AEGL-1. Effects assessed included sore throat, nasal discharge, cough, chest pain or burning, dyspnea, wheezing, fatigue, headache, unusual taste or smell, total respiratory resistance, thoracic gas volume at functional residual capacity, forced expiratory volume, and forced vital capacity. All subjects continued the requisite exercise routine for the duration of the test period.

Uncertainty factors/Rationale:
Total uncertainty factor:
Interspecies: 1, test subjects were human
Intraspecies: 1, test subjects were sensitive population (exercising asthmatic subjects)

Modifying factor: Not applicable

Animal-to-human dosimetric adjustment: Insufficient data

Time-scaling: The AEGL-1 values for a sensory irritant were held constant across time because it is a threshold effect and prolonged exposure will not result in an enhanced effect. In fact one might become desensitized to the respiratory-tract irritant over time. Also, this approach was considered valid since the end point (no treatment-related effects at the highest concentration tested in exercising asthmatic subjects) is inherently conservative.

Data quality and research needs: The key study was well-conducted in a sensitive human population and is based on no treatment-related effects. Additionally, the direct-acting irritation response is not expected to vary greatly among individuals. Therefore, confidence in the AEGL values is high.

AEGL-2 VALUES FOR HYDROGEN CHLORIDE

10 min	30 min	1 h	4 h	8 h
100 ppm	43 ppm	22 ppm	11 ppm	11 ppm

Key references: Stavert, D.M., D.C. Archuleta, M.F. Behr, and B.E. Lehnert. 1991. Relative acute toxicities of hydrogen chloride, hydrogen fluoride, and hydrogen bromide in nose- and pseudo-mouth-breathing rats. Fundam. Appl. Toxicol. 16(4):636-655. (30-, 1-, 4-min and 8-h AEGLs)
Barrow, C.S., Y. Alarie, M. Warrick, and M.F. Stock. 1977. Comparison of the sensory irritation response in mice to chlorine and hydrogen chloride. Arch. Environ. Health 32(2):68-76. (10-min AEGL)

Test species/Strain/Number: F344 rats, 8 males/concentration (30-min, 1-, 4-, and 8-h); Male Swiss Webster mice (10-min)

Exposure route/Concentrations/Durations: inhalation at 0 or 1,300 ppm for 30 min (1,300 ppm was determinant for 30-min, 1-, 4-, and 8-h AEGL-2)

Effects (30-min, 1-, 4-, and 8-h): 0 ppm, no effects; 1,300 ppm, severe necrotizing rhinitis, turbinate necrosis, thrombosis of nasal submucosa vessels in nose-breathers; 1,300 ppm, severe ulcerative tracheitis accompanied by necrosis and luminal ulceration in mouth-breathers (determinant for AEGL-2); RD_{50} = 309 ppm (determinant for 10-min AEGL-2)

End point/Concentration/Rationale: 1,300 ppm for 30 min; severe lung effects (ulcerative tracheitis accompanied by necrosis and luminal ulceration) or nasal effects (necrotizing rhinitis, turbinate necrosis, thrombosis of nasal submucosa vessels histopathology) in pseudo-mouth breathing male F344 rats (30-min, 1-, 4-, and 8-h); RD_{50} of 309 ppm ÷ 3 to estimate irritation (10-min)

Uncertainty Factors/Rationale (30-min, 1-, 4-, and 8-h):
Total uncertainty factor: 10
Intraspecies: 3, steep concentration-response curve implies limited individual variability.
Interspecies: 3, use of an intraspecies uncertainty factor of 10 would bring the total uncertainty/modifying factor to 100 instead of 30. That would generate AEGL-2 values that are not supported by data on exercising asthmatic subjects, an especially sensitive subpopulation because exercise increases HCl uptake and exacerbates irritation. No effects were noted in exercising young adult with asthma exposed to HCl at 1.8 ppm for 45 min (Stevens et al. 1992). Using a total uncertainty factor of 30 would yield 4- and 8-h values of 3.6 ppm (instead of 11 ppm). It is not supportable to predict that humans would be disabled by exposure at 3.6 ppm for 4- or 8-h when exercising asthmatic subjects exposed to one-half this level for 45 min had no effects. The shorter time points would yield values 4- to 7 times above 1.8 ppm; however, the confidence in the time scaling for HCl is good for times up to 100 min because the value of n value was derived from a regression analysis of rat and mouse mortality data with exposure durations ranging from 1 min to 100 min. The 30-min value of 43 ppm derived with the total uncertainty factor of 10 is reasonable in light of the fact that baboons exposed to 500 ppm for 15 min experienced only a slightly increased respiratory rate.

(Continued)

AEGL-2 VALUES FOR HYDROGEN CHLORIDE Continued

10 min	30 min	1 h	4 h	8 h
100 ppm	43 ppm	22 ppm	11 ppm	11 ppm

Modifying factor:
30-min, 1-, 4-, and 8-h AEGLs: 3 based on sparse database for AEGL-2 effects and that the effects observed at the concentration used as the basis for AEGL-2 values were somewhat severe.
10-min AEGL-2: the 10-min AEGL-2 value was derived by dividing the mouse RD_{50} of 309 ppm by a factor of 3 to obtain a concentration causing irritation (Barrow et al. 1977). One-third of the mouse RD_{50} for HCl corresponds to an approximate decrease in respiratory rate of 30%, and decreases in the range of 20% to 50% correspond to moderate irritation (ASTM 1991).

Animal-to-human dosimetric adjustment: Insufficient data

Time-scaling: $C^n \times t = k$, where n=1, based on regression analysis of combined rat and mouse LC_{50} data (1 min to 100 min) reported by ten Berge et al. (1986). Data point used to derive AEGL-2 was 30 min. AEGL-2 values for 1-h exposure period was based on extrapolation from the 30-min value. The 4- and 8-h AEGL-2 values were derived by applying a modifying factor of 2 to the 1-h AEGL-2 value because time scaling would yield a 4-h AEGL-2 value of 5.4 ppm and an 8-h AEGL-2 of 2.7 ppm, close to the 1.8 ppm tolerated by exercising asthmatic subjects without adverse health effects.

Data quality and research needs: Confidence is moderate since the species used is more sensitive than primates to the effects of HCl, the chemical is a direct-acting irritant, and a modifying factor was included to account for the relative severity of effects and sparse data base.

AEGL-3 VALUES FOR HYDROGEN CHLORIDE

10 min	30 min	1 h	4 h	8 h
620 ppm	210 ppm	100 ppm	26 ppm	26 ppm

Key reference: Vernot, E.H., J.D. MacEwen, C.C. Haun, and E.R. Kinkead. 1977. Acute toxicity and skin corrosion data for some organic and inorganic compounds and aqueous solutions. Toxicol. Appl. Pharmacol. 42(2):417-423. Wohlslagel, J., L.C. DiPasquale, and E.H. Vernot. 1976. Toxicity of solid rocket motor exhaust: Effects of HCl, HF, and alumina on rodents. J. Combust. Toxicol. 3:61-69.

Test species/Strain/Sex/Number: Sprague-Dawley rats, 10 males per concentration

Exposure route/Concentrations/Durations: inhalation at 0, 1,813, 2,585, 3,274, 3,941, or 4,455 ppm for 1 h

(Continued)

AEGL-3 VALUES FOR HYDROGEN CHLORIDE Continued

10 min	30 min	1 h	4 h	8 h
620 ppm	210 ppm	100 ppm	26 ppm	26 ppm

Effects:

Concentration	Mortality
0 ppm	0/10
1,813 ppm	0/10
2,585 ppm	2/10
3,274 ppm	6/10
3,941 ppm	8/10
4,455 ppm	10/10

LC_{50}: reported as 3,124 ppm (determinant for AEGL-3)

End point/Concentration/Rationale: One-third of the 1-h LC_{50} (3,124 × 1/3 = 1,041 ppm) to estimate a concentration causing no deaths.

Uncertainty factors/Rationale:
Total uncertainty factor: 10
Intraspecies: 3, a steep concentration-response curve implies limited individual variability.
Interspecies: 3, (1) the steep concentration-response curve for lethality observed in the Wohlslagel et al. (1976) study in which 1,041 ppm (one-third of the LC_{50} of 3,124 ppm) was lower than the LC_0 of 1,813 ppm. This is a conservative selection of the LC_0 and the steep concentration-response curve argues for little interindividual variability; (2)AEGL-3 values generated from a total uncertainty factor of 30 would be close to the AEGL-2 values (within a factor of 2) generated above which are reasonable when compared with data on exercising asthmatic subjects; (3) Sellakumar et al. (1985) exposed rats to 10 ppm of HCl for 6 h/day, 5 days/week for life and only observed increased trachael and laryngeal hyperplasia. The estimated 6-h AEGL-3 using an intraspecies uncertainty factor of 3 is 17 ppm, close to the level used in the lifetime study in which only mild effects were induced; and (4) rats exposed at 50 ppm for 6 h/day, 5 days/week for 90 days exhibited mild rhinitis (Toxigenics Inc. 1984). This level is already 2 times that of the AEGL-3 value for death. Thus, the total uncertainty factor is 10.

Modifying factor: Not applicable

Animal-to-human dosimetric adjustment: Insufficient data

Time-scaling: $C^n \times t = k$, where n = 1, based on regression analysis of rat and mouse mortality data (1 min to 100 min) reported by ten Berge et al. (1986). Reported 1-h data point was used to derive AEGL-3 values. AEGL-3 values for 10-min, 30-min, and 4-h were based on extrapolation from the 1-h value. The 4-h value was adopted as the 8-h value.

Data quality and research needs: Study is considered appropriate for AEGL-3 derivation because exposures are over a wide range of HCl concentrations and utilize a sufficient number of animals. Data were insufficient to derive a no-effect level for death. One-third of the LC_{50} has been utilized previously for chemicals with steep concentration-response curves. Also, in the key study, no deaths were observed in rats exposed at 1,813 ppm.

APPENDIX F

CATEGORY PLOTS FOR SELECTED CHLOROSILANES

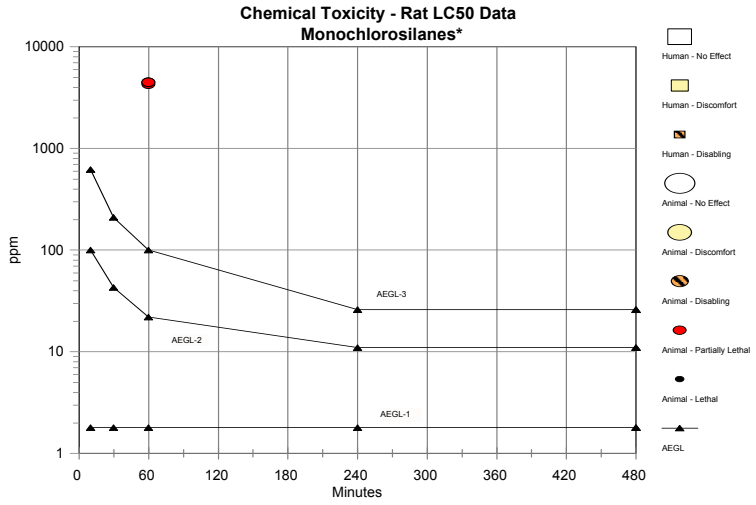

FIGURE F-1 Category plot for monochlorosilanes. *Data plotted are for trimethyl chlorosilane and dimethyl chlorosilane.

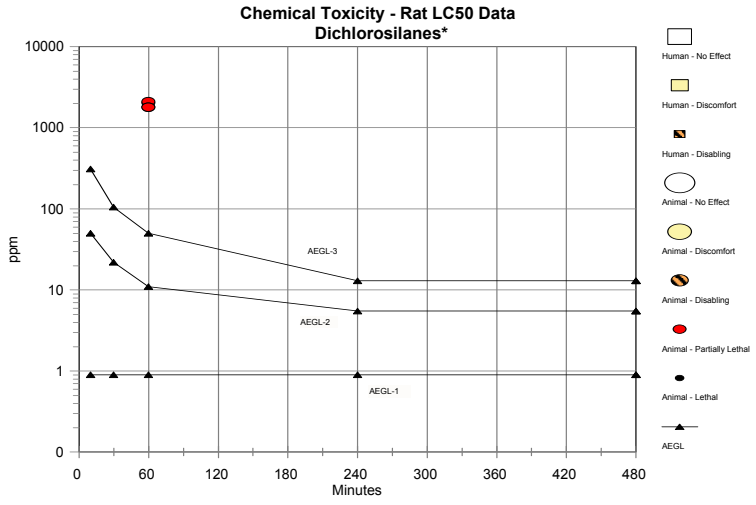

FIGURE F-2 Category plat of dichlorosilanes. *Data plotted are for methylvinyl dichlorosilane, dimethyl dichlorosilane, and methyl dichlorosilane.

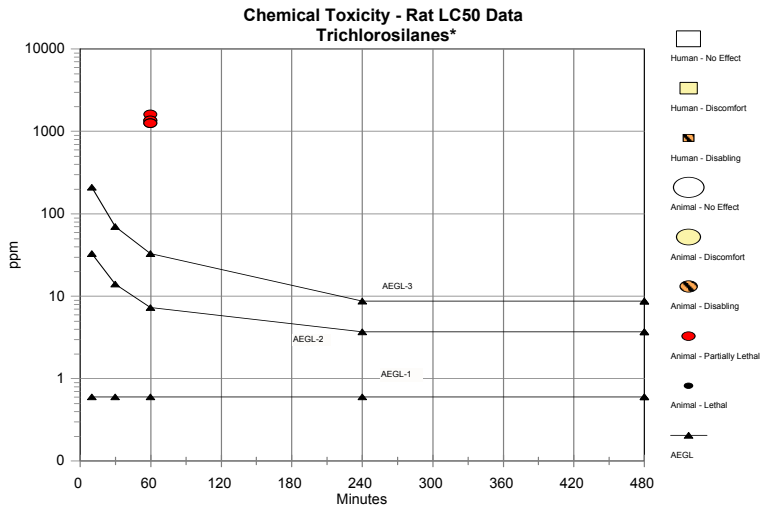

FIGURE F-3 Category plot for trichlorosilanes. *Data plotted are for propyl trichlorosilane, vinyl trichlorosilane, methyl trichlorosilane, and ethyl trichlorosilane.

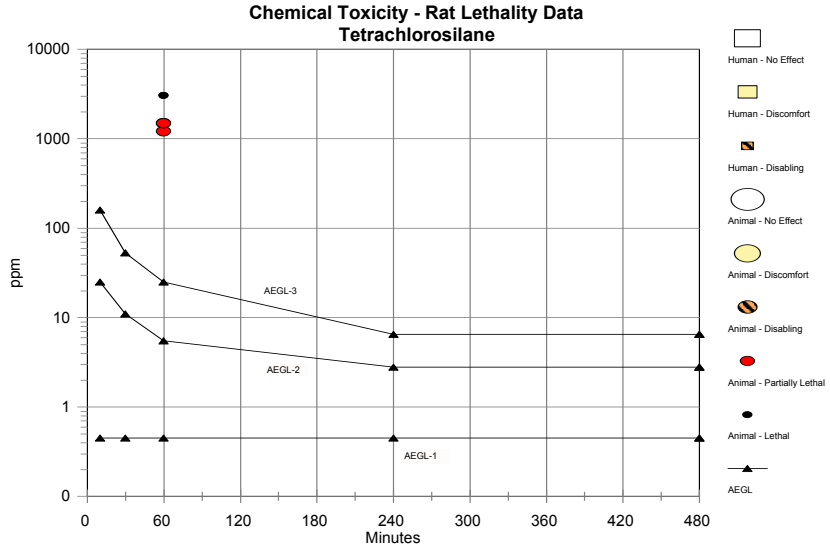

FIGURE F-4 Category plot for tetrachlorosilane.