ACUTE EXPOSURE GUIDELINE LEVELS (AEGLs)
FOR
Silicon Tetrafluoride
(CAS Reg. No. 7783-61-1)

Si-F4

INTERIM

ACUTE EXPOSURE GUIDELINE LEVELS (AEGLs) FOR SILICON TETRAFLUORIDE (CAS Reg. No. 7783-61-1)

INTERIM

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 to 8 hours. Three levels — AEGL-1, AEGL-2 and AEGL-3 — are developed for each of five exposure periods (10 and 30 minutes, 1 hour, 4 hours, and 8 hours) 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, non-sensory 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 health effects or death.

Airborne concentrations below the AEGL-1 represent exposure levels that could produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic, non-sensory 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 unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL

TABLE OF CONTENTS

LIST OF TABLES

SUMMARY

Silicon tetrafluoride is a colorless, irritating gas with a pungent, suffocating odor. Silicon tetrafluoride is prepared by direct halogenation of pure quartz or silicon carbide. It is used for silicon deposition in the semiconductor industry, for plasma etchings, and as a starting material for fluorosilic acid for water fluoridation. Silicon tetrafluoride causes severe skin and mucous membrane irritation.

Irritation in rats repeatedly exposed to 0.3 ppm silicon tetrafluoride 6 hours/day, 5 days/week for 4 weeks (IRI, 1988) was used as the basis of AEGL-1 values. An intraspecies uncertainty factor of 3 was applied because contact irritation is not expected to vary greatly within species. An interspecies uncertainty factor of 1 was applied because only irritation was noted and did not increase in severity throughout a 4-week study. Furthermore, the irritation partially resolved between exposures. A modifying factor of 2 was applied for the sparse data base. Therefore, the total adjustment was 6. Values were held constant across time because minor irritation does not vary over time.

In the absence of appropriate chemical-specific data, the AEGL-3 values were divided by 3 to derive AEGL-2 values for silicon tetrafluoride. This approach is justified by the relatively steep concentration-response curve (60% mortality in rats exposed to 100 ppm and 100% mortality at 150 ppm; exposures were 6 hr/day, up to 5 days) (IRI, 1988).

An estimated lethality threshold of 307 ppm (one-third the LC_{50} of 922 ppm) was used as the point-of-departure for AEGL-3 values (Scheel et al., 1968). This approach is justified by the relatively steep concentration-response with regard to lethality (60% mortality in rats exposed to 100 ppm and 100% mortality at 150 ppm; exposures were 6 hr/day, up to 5 days) (IRI, 1988). Values were scaled across time using the $C^n \times t = k$ equation, where n = 3 when extrapolating to shorter time points and n = 1 when extrapolating to longer time points in order to derive values protective of human health (NRC, 2001). Uncertainty factors of 3 each were applied for inter- and intraspecies variability because contact irritation is not expected to vary greatly between or within species (total UF = 10). A modifying factor of 3 was also applied for the sparse data base; therefore, the total adjustment was 30.

The calculated values are listed in the table below.

TABLE 1. Summary of AEGL Values for Silicon Tetrafluoride

Classification	10-min	30-min	1-h	4-h	8-h	Endpoint (Reference)
AEGL-1 (Nondisabling)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	Irritation in rats (IRI, 1998)
AEGL-2 (Disabling)	6.3 ppm (27 mg/m^3)	4.3 ppm (18 mg/m^3)	3.3 ppm (14 mg/m^3)	0.87 ppm (3.7 mg/m^3)	0.43 ppm (1.8 mg/m^3)	One third the AEGL-3 values (NRC, 2001)
AEGL-3 (Lethal)	19 ppm (80 mg/m^3)	13 ppm (55 mg/m^3)	10 ppm (42 mg/m^3)	2.6 ppm (11 mg/m^3)	1.3 ppm (5.5 mg/m^3)	Estimated 1-hr lethality threshold in rats (Scheel et al., 1968)

1. INTRODUCTION

Silicon tetrafluoride is a colorless, irritating gas with a pungent, suffocating odor. Silicon tetrafluoride is prepared by direct halogenation of pure quartz or silicon carbide. It is used for silicon deposition in the semiconductor industry, for plasma etchings, and as a starting material for fluorosilic acid for water fluoridation. Silicon tetrafluoride causes severe skin and mucous membrane irritation (Lemen and Bingham, 2001). Recent production and transport data were not located. Chemical and physical properties are listed in Table 2.

TABLE 2. Chemical and Physical Properties

Parameter	Value	References
Synonyms	Silicon (IV) fluoride; Tetrafluorosilane; Perfluorosilane	RTECS, 2006
Chemical formula	SiF_4	HSDB, 2006
Molecular weight	104.06	HSDB, 2006
CAS Reg. No.	7783-61-1	HSDB, 2006
Physical state	Colorless gas	HSDB, 2006
Solubility in water	Insoluble. Decomposes.	HSDB, 2006
Sublimation point	-95.7 °C	HSDB, 2006
Vapor density (air =1)	3.57	HSDB, 2006
Liquid density (water =1)	4.69 g/L at 760 mm Hg	
Melting point	-90.2 °C	HSDB, 2006
Boiling point	-86 °C	HSDB, 2006
Flammability limits	Nonflammable	IPCS, CEC, 2006
Conversion factors	1 ppm = 4.2 mg/m^3 1 mg/m^3 = 0.24 ppm	

2. HUMAN TOXICITY DATA

Silicon tetrafluoride is a strong irritant to the skin, eyes, mucous membranes, and respiratory tract (Lemen and Bingham, 2001). No information on the odor threshold or odor characterization was found.

The only human exposure data located were from a genotoxicity monitoring study of 40 workers (age and sex not reported) at a phosphate fertilizer factory in North China. Hydrogen fluoride and silicon tetrafluoride were the main pollutants at the factory; however, dust containing fluoride, and ammonia, and sulfur dioxide were also present. There was an increase ($p<0.01$) in the frequencies of chromosomal aberrations (rings, translocations, and dicentrics) and micronuclei in peripheral lymphoctyes of fertilizer factory workers compared to the control group of 40 employees of a university located in the same city (Meng and Zhang, 1997). There was also an increase ($p<0.01$) in sister chromatid exchange frequency in the factory workers compared to controls (Meng et al., 1995). Chromosome aberration, micronucleus, and sister chromatid frequencies all increased with the duration of employment up to 10 years.

3. ANIMAL TOXICITY DATA

3.1. Acute Toxicity

A group of four female Alderly Park SPF rats was exposed to 1000 ppm silicon tetrafluoride for 20 minutes (Gage, 1970). A metered stream of silicon tetrafluoride vapor from a cylinder was diluted with a metered stream of air. The diluted gas was then passed through a jet to produce efficient mixing by turbulence. Severe nose and eye irritation, respiratory difficulty and lethargy were noted. All organs were normal at necropsy. No further details were provided.

Groups of five male and five female Greenacres controlled-flora rats were exposed to unreported concentrations of silicon tetrafluoride for 1-hour, followed by a 14-day observation period (Scheel et al., 1968). An LC_{50} of 922 ppm was reported. No other experimental details were described.

An LC_{50} of 2272 ppm was reported for male Wistar rats and an LC_{50} of 2494 ppm was reported for female Wistar rats (Hirose et al., 1993). However, the exposure duration was not specified, and no experimental methods were described.

Two of six rats died when exposed to 72,500 ppm silicon tetrafluoride for 1 minute (Union Carbide, 1946). No other information was available.

Severe ocular injury was noted in rabbits exposed to 1180 ppm silicon tetrafluoride for 3 minutes (Union Carbide, 1946). No other information was available.

3.2. Repeated-Exposure Toxicity

Groups of male and/or female Alderly Park SPF rats were exposed to 15 ppm (twenty 6-hour exposures; 3 males and 4 females), 60 ppm (fourteen 6-hr exposures; 4 females), or 300 ppm (three 4.5-hr exposures; 4 females) silicon tetrafluoride (Gage, 1970). The silicon tetrafluoride vapor contained in a large polyethylene bag was introduced into a metered air stream at a known rate by using a peristaltic pump. There were no clinical signs or treatment-related effects noted at necropsy for the animals exposed to 15 ppm. Animals exposed to 60 ppm exhibited lethargy, nasal irritation, and decreased weight gain; however, there were no treatment-related effects noted at necropsy. One rat in the 300 ppm group died and clinical signs noted in this group included eye and nose irritation, respiratory difficulty, and progressive deterioration of condition. Distended lungs, lung congestion, emphysema, liver congestion, and degeneration of renal cortical tubules were noted at necropsy in animals exposed to 300 ppm silicon tetrafluoride. No further details were provided.

Groups of five male and five female Sprague Dawley rats were exposed nose-only to 0, 50, 100, or 150 ppm silicon tetrafluoride 6 hours/day for up to 5 days, followed by a 14-day observation period (IRI, 1988). The exposures were conducted in a stainless steel, Teflon-lined chamber, and the silicon tetrafluoride was supplied by passing the test material and supply air through a series of rotameters to assure a known flow rate. Chamber concentrations were determined by drawing a known volume of air from the chamber through an impinger filled with

a known volume of sodium acetate. The trapped fluoride was then measured in millivolts using a fluoride detector, and the silicon tetrafluoride concentration was calculated from the millivolt readings. All rats in the 150 ppm group died or were sacrificed moribund by day 4 of the study. All males and one female in the 100 ppm group also died or were sacrificed moribund by day 4 of the study, and one female died on day 6. In the 50 ppm group, one male died on day 5, two males were sacrificed moribund by day 4, and one female died on day 1. No other deaths were reported after day 6 and no mortality was noted in the control group. Signs noted during and immediately after exposure in all treatment groups included attempts to back away from the chamber inlet, frequent grooming of the nose and face, and bloody nasal discharge. At necropsy, treatment-related histopathology was noted in the nasal passages, teeth, bone of the skull, kidneys, and adrenals. The rostral portions of the nasal passages (levels 1 and 2 of nasal passages) were the most severely affected. Findings included necrosis of the nasal turbinates, mucopurulent exudate, attenuation of respiratory epithelium, epithelial microabcesses, and ulcers. Necrosis of nasal turbinates was noted in level 1 of the nasal passages in males in all 3 treatment groups; however, this effect was noted in only one high-dose female. Degeneration of the respiratory epithelium was noted in levels 3 and 4 of the nasal passages and nasopharynx in all treated males and one high-dose female. Increased basophilia of the dentin of the incisor teeth and skull bone occurred in males and females in all treated groups. Necrosis of the tubular epithelium of the outer medulla of the kidney accompanied by cast formation and tubular mineralization occurred in mid- and high-dose rats of both sexes and in one low-dose male rat. One control female also had this kidney lesion. Degeneration of the adrenal medulla was noted in most rats from all treatment groups that also had kidney necrosis.

IRI (1988) also exposed groups of ten male and ten female Sprague Dawley rats to 0, 0.3, 3.0, or 15 ppm silicon tetrafluoride 6 hours/day, 5 days/week for 4 weeks. The exposure protocol was similar to that described above for the 5 day study. There was no treatment-related mortality. Signs noted during and immediately after exposure in all treatment groups included frequent grooming of the nose and face and bloody nasal discharge. At necropsy, treatment-related histopathology was noted in the nasal passages, teeth, and bone of the skull in both males and females. Lesions in the rostral portions of the nasal turbinates included ulcers in the 3.0 and 15 ppm groups (males and females), attenuation of respiratory epithelium, squamous metaplasia of respiratory epithelium and degeneration of olfactory epithelium (males and females in all treatment groups). Ulcers were noted in mid- and high-dose males and females, and dose-related squamous metaplasia was noted in males and females in all treatment groups. Concentration-related increased basophilia of the dentin of the incisor teeth and skull bone occurred in males and females in all treated groups. No other treatment-related effects were noted.

Animal data are summarized in Table 3.

TABLE 3. Summary of Animal Inhalation Toxicity Data

Species	Concentration	Duration	Effects	Reference
Rat	72,500 ppm	1 min	2/6 dead	Union Carbide, 1946
Rabbit	1180 ppm	3 min	Severe eye injury	Union Carbide, 1946
Rat	1000 ppm	20 min	Severe eye and nose irritation; respiratory difficulty; lethargy	Gage, 1970
Rat	922 ppm	1 hour	LC_{50}	Scheel et al., 1968
Rat- male	2272 ppm	unknown	LC_{50}	Hirose et al., 1993
Rat- female	2494 ppm	unknown	LC_{50}	Hirose et al., 1993
Rat	15 ppm	20 exposures, 6 hr/exposure	No effects at necropsy	Gage, 1970
Rat	60 ppm	14 exposures, 6 hr/exposure	Lethargy; nasal irritation; decreased weight gain	Gage, 1970
Rat	300 ppm	3 exposures, 14.5 hr/exposure	1/4 dead; eye and nose irritation; respiratory difficulty; lung and renal pathology	Gage, 1970
Rat	50 ppm	6 hr/day, 5 days	4/10: mortality/sacrificed moribund; irritation; nasal, tooth, bone, kidney, and adrenal pathology	IRI, 1988
Rat	100 ppm	6 hr/day, 5 days	6/10: mortality/sacrificed moribund; irritation; nasal, tooth, bone, kidney, and adrenal pathology	IRI, 1988
Rat	150 ppm	6 hr/day, 5 days	10/10: mortality/sacrificed moribund; irritation; nasal, tooth, bone, kidney, and adrenal pathology	IRI, 1988
Rat	0.3 ppm	6 hr/day, 5 days/week, 4 weeks	Irritation	IRI, 1988
Rat	3.0 ppm	6 hr/day, 5 days/week, 4 weeks	Irritation; nasal, tooth, and bone pathology	IRI, 1988
Rat	15 ppm	6 hr/day, 5 days/week, 4 weeks	Irritation; nasal, tooth, bone pathology	IRI, 1988

3.3. Developmental/Reproductive Toxicity

No data on developmental/reproductive toxicity were located.

3.4. Genotoxicity

No data on genotoxicity were located.

3.5. Chronic Toxicity/Carcinogenicity

No data on chronic toxicity/carcinogenicity were located.

3.6. Summary

Animal toxicity data are limited. Clinical signs, from both acute and repeated-exposure studies, including ocular and nasal irritation, respiratory difficulty, and bloody nasal discharge, are consistent with severe irritation. Some necropsy findings were also consistent with severe irritation (nasal, tooth and bone histopathology, lung edema); whereas, others were consistent with repeated-exposure fluoride toxicity (renal effects). No data on developmental/reproductive toxicity, genotoxicity, or chronic toxicity/carcinogenicity were located.

4. SPECIAL CONSIDERATIONS

4.1. Metabolism and Disposition

No information was located concerning the metabolism and disposition of silicon tetrafluoride.

4.2. Mechanism of Toxicity

Acute inhalation exposure causes severe skin and mucous membrane irritation, and occupational hazards are reportedly qualitatively similar to hydrogen fluoride (Lemen and Bingham, 2001).

4.3. Structure Activity Relationships

Hydrogen fluoride is typically reported to be a hydrolysis product of silicon tetrafluoride (Lemen and Bingham, 2001). However, the limited data set suggests that this is not the case for a silicon tetrafluoride release in humid air.

In order to determine if hydrogen fluoride is a hydrolysis product of silicon tetrafluoride, Ricks et al. (1993) tested 20 ppm silicon tetrafluoride in a room temperature test chamber at relative humidity (RH) levels of 1.7%, 63%, and 82%. The reactions were allowed to proceed for approximately 20-25 minutes, and samples were collected on a filter and impinger. There was no reaction at 1.7% (RH), approximately 50% of the silicon tetrafluoride reacted at 63% RH, and the reaction was essentially complete at 82% RH. The study authors did not identify specific reaction products; however, they state that hydrogen fluoride was not detected as a reaction product. One likely product is silicic acid, SiF_6H_2. This study investigates silicon tetrafluoride hydrolysis only in humid air, and does not address the possible formation of hydrogen fluoride in water, such as that which may be present in the upper respiratory tract or lung.

4.4. Other Relevant Information

4.4.1. Species Variability

No information was available on species variability. However, clinical signs are consistent with contact irritation. Therefore, effects are not expected to vary widely between species.

4.4.2. Susceptible Populations

No information was available on populations especially sensitive to silicon tetrafluoride toxicity. However, clinical signs are consistent with contact irritation. Therefore, effects are not expected to vary widely among individuals.

4.4.3. Time Scaling

The concentration exposure time relationship for many irritant and systemically acting vapors and gases may be described by $C^n \times t = k$, where the exponent ranges from 0.8 to 3.5 (ten Berge et al. 1986). In lieu of a definitive data set allowing empirical derivation of the exponent n, temporal scaling was performed, using n = 3 when extrapolating to shorter time points and n = 1 when extrapolating to longer time points using the $C^n \times t = k$ equation (NRC 2001).

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 identified.

5.2. Summary of Animal Data Relevant to AEGL-1

Rats exposed to 0.3 ppm silicon tetrafluoride 6 hours/day, 5 days/week for 4 weeks showed signs of irritation (frequent grooming of the nose and face and bloody nasal discharge) during and after each exposure (IRI, 1988). Effects did not increase in severity throughout the study, and no other effects were noted, even at the end of the study period.

5.3. Derivation of AEGL-1

The irritation reported in rats repeatedly exposed to 0.3 ppm silicon tetrafluoride 6 hours/day, 5 days/week for 4 weeks (IRI, 1988) will be used as the basis of AEGL-1 values. An intraspecies uncertainty factor of 3 will be applied because contact irritation is not expected to vary greatly within species. An interspecies uncertainty factor of 1 will be applied because only irritation was noted and did not increase in severity throughout a 4-week study. Furthermore, the irritation partially resolved between exposures. A modifying factor of 2 will also be applied for the sparse data base. Therefore, the total adjustment is 6. Values were held constant across time because minor irritation does not vary over time. AEGL-1 values are presented in Table 4, and calculations are presented in Appendix A.

TABLE 4. AEGL-1 Values for Silicon Tetrafluoride

10-min	30-min	1-h	4-h	8-h
0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)

6. DATA ANALYSIS FOR AEGL-2

6.1. Summary of Human Data Relevant to AEGL-2

No human data relevant to development of AEGL-2 values were identified.

6.2. Summary of Animal Data Relevant to AEGL-2

No animal data relevant to development of AEGL-2 values were identified.

6.3. Derivation of AEGL-2

In the absence of appropriate chemical-specific data, the AEGL-3 values were divided by 3 to derive AEGL-2 values for silicon tetrafluoride. This approach is justified by the relatively steep concentration-response curve (60% mortality in rats exposed to 100 ppm and 100% mortality at 150 ppm; exposures were 6 hr/day, up to 5 days) (IRI, 1988). AEGL-2 values are presented in Table 5, and calculations are presented in Appendix A.

TABLE 5. AEGL-2 Values for Silicon Tetrafluoride

10-min	30-min	1-h	4-h	8-h
6.3 ppm (27 mg/m^3)	4.3 ppm (18 mg/m^3)	3.3 ppm (14 mg/m^3)	0.87 ppm (3.7 mg/m^3)	0.43 ppm (1.8 mg/m^3)

These values are considered protective because rats exposed to 3.0 or 15 ppm silicon tetrafluoride 6/hours/day, 5 days/week for 4 weeks showed signs of irritation during and after each exposure (IRI, 1988). Nasal, bone, and tooth histopathology was noted at the end of the study period.

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 identified.

7.2. Summary of Animal Data Relevant to AEGL-3

A 1-hour rat LC_{50} of 922 ppm was reported (Scheel et al., 1968). No other experimental details were described. Severe eye and nose irritation, respiratory difficulty, and lethargy, but no mortality, were noted in rats exposed to 1000 ppm for 20 min (Gage, 1970).

7.3. Derivation of AEGL-3

An estimated lethality threshold of 307 ppm (one-third the LC_{50} of 922 ppm) was used as the point-of-departure for AEGL-3 values (Scheel et al., 1968). This approach is justified by the relatively steep concentration-response with regard to lethality (60% mortality in rats exposed to 100 ppm and 100% mortality at 150 ppm; exposures were 6 hr/day, up to 5 days) (IRI, 1988). Values were scaled across time using the $C^n \times t = k$ equation, where n = 3 when extrapolating to shorter time points and n = 1 when extrapolating to longer time points in order to derive values protective of human health (NRC, 2001). Uncertainty factors of 3 each were applied for inter- and intraspecies variability because contact irritation is not expected to vary greatly between or within species (total UF = 10). A modifying factor of 3 was also be applied for the sparse data base; therefore, the total adjustment is 30. AEGL-3 values are presented in Table 6, and calculations are presented in Appendix A.

TABLE 6. AEGL-3 Values for Silicon Tetrafluoride				
10-min	**30-min**	**1-h**	**4-h**	**8-h**
19 ppm (80 mg/m^3)	13 ppm (55 mg/m^3)	10 ppm (42 mg/m^3)	2.6 ppm (11 mg/m^3)	1.3 ppm (5.5 mg/m^3)

The proposed AEGL-3 values are supported by the severe eye and nose irritation, respiratory difficulty, and lethargy, in the absence of death, in rats exposed to 1000 ppm for 20-min (Gage, 1970). Using 1000 ppm for 20-min as the POD and applying time scaling and uncertainty/modifying factors consistent with those used for the proposed AEGL-3 values, yields values of 42 ppm for 10-min, 22 ppm for 30-min, 11 ppm for 1-hr, 2.7 ppm for 4-hr, and 1.4 ppm for 8-hr; suggesting that the proposed AEGL-3 values are reasonable.

8. SUMMARY OF AEGLS

8.1. AEGL Values and Toxicity Endpoints

AEGL values are summarized in Table 7. AEGL-1 values were based on irritation in rats (IRI, 1988). AEGL-2 values were derived by taking one-third of the AEGL-3 values, and AEGL-3 values were based on a 1-hr estimated lethality threshold in rats (Scheel et al., 1968).

TABLE 7. Summary of AEGL Values					
Classification	**Exposure Duration**				
	10-min	**30-min**	**1-h**	**4-h**	**8-h**
AEGL-1 (Nondisabling)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)	0.05 ppm (0.21 mg/m^3)
AEGL-2 (Disabling)	6.3 ppm (27 mg/m^3)	4.3 ppm (18 mg/m^3)	3.3 ppm (14 mg/m^3)	0.87 ppm (3.7 mg/m^3)	0.43 ppm (1.8 mg/m^3)
AEGL-3 (Lethal)	19 ppm (80 mg/m^3)	13 ppm (55 mg/m^3)	10 ppm (42 mg/m^3)	2.6 ppm (11 mg/m^3)	1.3 ppm (5.5 mg/m^3)

8.2. Comparison with Other Standards and Guidelines

There are no other extant standards or guidelines for silicon tetrafluoride.

8.3. Data Adequacy and Research Needs

There are no human data, and animal data are limited. Additional acute inhalation toxicity studies would be most helpful.

9. REFERENCES

Gage, J. C. 1970. The subacute inhalation toxicity of 109 industrial chemicals. Brit. J. Industr. Med. 27: 1-18.

Hirose, A., Kaneko, T., Ogawa, Y., et al. 1993. Acute inhalation toxicity tests of dichlorosilane and tetrafluorisilane speciality gases. 20th Annual meeting of the Japanese Society of Toxicological Sciences. Chiba, Japan, July 29-30, 1993. J. Toxicol. Sci. 18:394.

HSDB (Hazardous Substances Data Bank). 2006. Silicon Tetrafluoride. Online data base, National Library of Medicine: http://toxnet.nlm.nih.gov/cgi-bin/sis.

IPCS, CEC. (International Programme on Chemical Safety). 2006. International Chemical Safety Card, Silicon tetrafluoride. Retrieved online 12-2006.

IRI (Inhausen Research Institute). 1988. Repeated-dose study of inhalation exposure of the rat to silicon tetrafluoride. FYI-OTS-0589-0694D.

Lemen, R. and Bingham E., 2001. Silicon Halides. In: Patty's Toxicology. Fifth Edition, Volume 1. E. Bingham, B. Cohrssen, and C. H. Powell, Eds. P. 448-450.

Meng, Z., Meng, H, and Cao, X. 1995. Sister-chromatid exchanges in lymphocytes of workers at a phosphate fertilizer factory. Mutation Res. 334: 243-246.

Meng, Z. and Zhang, B. 1997. Chromosomal aberrations and micronuclei in lymphocytes of workers at a phosphate fertilizer factory. Mutation Res. 393: 283-288.

NRC (National Research Council). 2001. Standing Operating Procedures for Acute Exposure Guideline Levels for Selected Airborne Chemicals. The National Academies Press, Washington, DC.

Ricks, G. M., Johnson, D. E., and Schaeffer, E. M. 1993. The possible formation of hydrogen fluoride from the reaction of silicon tetrafluoride with humid air. Am. Ind. Hyg. Assoc. J. 54: 272-276.

RTECS . 2006. Silicon Tetrafluoride. Retrieved Online. 1-10-2007. MDL Information Systems, Inc.

Scheel, L. D., Lane, W. C., and Coleman, W. E. 1968. The toxicity of polytetrafluoroethylene pyrolysis products-including carbonyl fluoride and a reaction product, silicon tetrafluoride. Am. Ind. Hyg. J. 29: 41-48.

ten Berge, W.F., Zwart, A., Appelman, L.M. 1986. Concentration-time mortality response relationship of irritant and systemically acting vapours and gases. J. Hazard. Materials: 13: 301-309.

Union Carbide Corporation. 1946. Repeated inhalation studies of ethyl silicate and summary of range-finding data on other silanes. FYI-OTS-0386-0469.

APPENDIX A: Derivation of AEGL Values

Derivation of AEGL-1

Key Study: IRI, 1988

Toxicity endpoint: Irritation in rats exposed to 0.3 ppm 6 hr/day, 5 days/week for 4 weeks

Time scaling: Values held constant across time

Uncertainty factors:

Intraspecies = 3: Contact irritation is not expected to vary greatly within a species.

Interspecies = 1: Only irritation was noted and did not increase in severity throughout the 4-week study. Irritation resolved between exposures.

Modifying Factor = 2: Sparse data base

10-min, 30-min, 1-hr, 4-hr, and 8-hr AEGL-1 = 0.30 ppm ÷ 6 = 0.05 ppm

Derivation of AEGL-2

Key Study: None. The AEGL-2 values are derived by taking one-third of the respective AEGL-3 values, because there were no data consistent with an AEGL-2 endpoint. The approach is justified by the relatively steep concentration-response.

10-minute AEGL-2: ⅓ 10-minute AEGL-3 = 19 ppm ÷ 3 = 6.3 ppm

30-minute AEGL-2: ⅓ 30-minute AEGL-3 = 13 ppm ÷ 3 = 4.3 ppm

1-hour AEGL-2: ⅓ 1-hour AEGL-3 = 10 ppm ÷ 3 = 3.3 ppm

4-hour AEGL-2: ⅓ 4-hour AEGL-3 = 2.6 ppm ÷ 3 = 0.87 ppm

8-hour AEGL-2: ⅓ 8-hour AEGL-3 = 1.3 ppm ÷ 3 = 0.43 ppm

Derivation of AEGL-3

Key Study: Scheel et al. 1968

Toxicity endpoint: Estimated lethality threshold; 1-hr Rat $LC_{50} \div 3 = 922$ ppm $\div 3 = 307$ ppm

Time scaling: Values were extrapolated using the relationship $C^n \times t = k$ (ten Berge et al., 1986), where n = 3 for time periods less than 1 hour and n = 1 for time periods greater than 1 hour.

10-min, 30-min

$C^3 \times t = k$

$(307 \text{ ppm})^3 \times 1 \text{ hr} = 28{,}934{,}443 \text{ ppm}^3 \cdot \text{hr}$

4 - hr, 8 - hr

$C^1 \times t = k$

$(307 \text{ ppm})^1 \times 1 \text{ hr} = 307 \text{ ppm} \cdot \text{hr}$

Uncertainty factors: 3 for interspecies variability.
3 for intraspecies variability.

Modifying Factor: 3 for sparse database

10-minute AEGL-3: $c^3 \times 0.167 \text{ hr} = 28{,}934{,}443 \text{ ppm}^3 \cdot \text{hr}$
$C^3 = 173260138$ ppm
C = 557 ppm
AEGL-3 = 557 ppm $\div$ 30 = 19 ppm

30-minute AEGL-3: $c^3 \times 0.5 \text{ hr} = 28{,}934{,}443 \text{ ppm}^3 \cdot \text{hr}$
$C^3 = 57868886$ ppm
C = 387 ppm
AEGL-3 = 387 ppm $\div$ 30 = 13 ppm

1-hour AEGL-3: AEGL-3 = 307 ppm $\div$ 30 = 10 ppm

4-hour AEGL-3: $C^1 \times 4 \text{ hr} = 307 \text{ ppm} \cdot \text{hr}$
C = 76.8 ppm
AEGL-3 = 76.8 ppm $\div$ 30 = 2.6 ppm

8-hour AEGL-3: $C^1 \times 8 \text{ hr} = 307 \text{ ppm} \cdot \text{hr}$
C = 38.4 ppm
AEGL-3 = 38.4 ppm $\div$ 30 = 1.3 ppm

APPENDIX B: Derivation Summary for Silicon Tetrafluoride AEGLs

1 AEGL-1 Values for Silicon Tetrafluoride
2
3

10-minute	30-minute	1-hour	4-hour	8-hour
0.05 ppm	**0.05 ppm**	**0.05 ppm**	**0.05 ppm**	**0.05 ppm**
Key Reference: IRI (Inhausen Research Institute). 1988. Repeated-dose study of inhalation exposure of the rat to silicon tetrafluoride. FYI-OTS-0589-0694D.				
Test Species/Strain/Number: Rat/Sprague Dawley/10/sex/concentration				
Exposure Route/Concentrations/Durations: Inhalation/0, 0.3, 3.0, 15 ppm/ 6 hr/day, 5 days/week, 4 weeks				
Effects: 0.3 ppm: Irritation 3.0 ppm: Irritation, nasal, tooth, and bone pathology 15 ppm: Irritation, nasal, tooth, and bone pathology				
Endpoint/Concentration/Rationale: Irritation/ 0.3 ppm				
Uncertainty Factors/Rationale: Total uncertainty factor: 3 Intraspecies = 3: Contact irritation is not expected to vary greatly within a species. Interspecies = 1: Only irritation was noted and did not increase in severity throughout the 4-week study. Irritation resolved between exposures.				
Modifying Factor: 2: Sparse data base				
Animal to Human Dosimetric Adjustment:				
Time Scaling: Values held constant across time because minor irritation does not vary over time.				
Data Adequacy: Sparse data set necessitated use of a repeated-exposure key study.				

1 **AEGL-2 Values for Silicon Tetrafluoride**

10-minute	30-minute	1-hour	4-hour	8-hour
6.3 ppm	**4.3 ppm**	**3.3 ppm**	**0.87 ppm**	**0.43 ppm**
Key Reference:				
Test Species/Strain/Number:				
Exposure Route/Concentrations/Durations: One-third the AEGL-3 values. Supported by steep concentration-response curve. (60% mortality in rats exposed to 100 ppm and 100% mortality at 150 ppm; exposures were 6 hr/day, up to 5 days) (IRI, 1988).				
Effects:				
Endpoint/Concentration/Rationale: One-third the AEGL-3 values.				
Uncertainty Factors/Rationale: Total uncertainty factor:				
Modifying Factor:				
Animal to Human Dosimetric Adjustment:				
Time Scaling				
Data Adequacy: Sparse data set. Values are considered protective because rats exposed to 3.0 or 15 ppm silicon tetrafluoride 6/hours/day, 5 days/week for 4 weeks showed signs of irritation during and after each exposure (IRI, 1988). Nasal, bone, and tooth histopathology was noted at the end of the study period.				

2

AEGL-3 Values for Silicon Tetrafluoride

10-minute	30-minute	1-hour	4-hour	8-hour
19 ppm	**13 ppm**	**10 ppm**	**2.6 ppm**	**1.3 ppm**

Key Reference: Scheel, L. D., Lane, W. C., and Coleman, W. E. 1968. The toxicity of polytetrafluoroethylene pyrolysis products- including carbonyl fluoride and a reaction product, silicon tetrafluoride. Am. Ind. Hyg. J. 29: 41-48.

Test Species/Strain/Number: Rat/Greenacres/five/sex/concentration

Exposure Route/Concentrations/Durations: Inhalation/1-hour

Effects: LC_{50} = 922 ppm

Endpoint/Concentration/Rationale: Estimated lethality threshold; one-third of the LC_{50} =307 ppm/Approach is justified by the steep concentration-response with regard to lethality (60% mortality in rats exposed to 100 ppm and 100% mortality at 150 ppm; exposures were 6 hr/day, up to 5 days) (IRI, 1988)

Uncertainty Factors/Rationale:
Interspecies: 3
Intraspecies: 3
Contact irritation is not expected to vary greatly between or within species

Total uncertainty factor: 10

Modifying Factor: 3: sparse data base

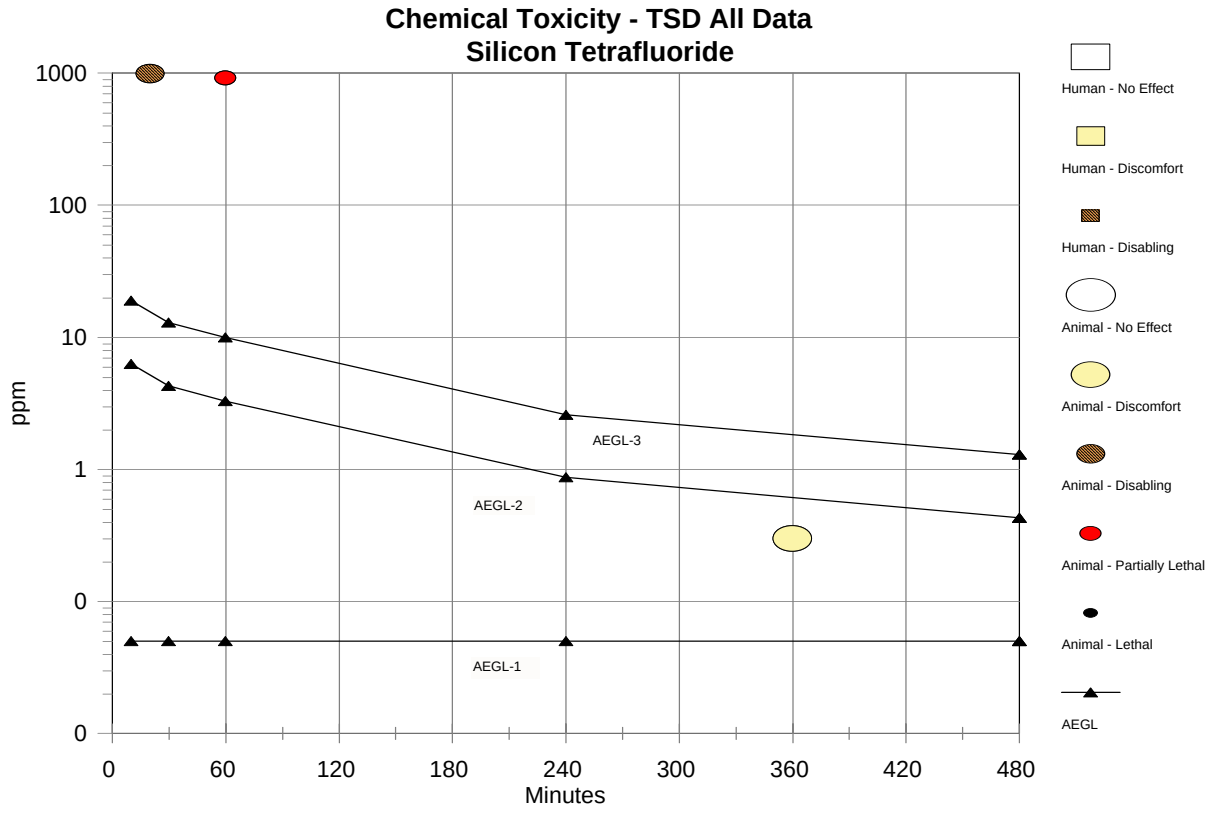
Animal to Human Dosimetric Adjustment:

Time Scaling: $C^n \times t = k$ equation, where n = 3 when extrapolating to shorter time points (10- and 30-min) and n = 1 when extrapolating to longer time points (4- and 8-hr) in order to derive values protective of human health (NRC, 2001).

Data Adequacy:
Sparse data set. The proposed AEGL-3 values are supported by the severe eye and nose irritation, respiratory difficulty, and lethargy, in the absence of death, in rats exposed to 1000 ppm for 20-min (Gage, 1970). Using 1000 ppm for 20-min as the POD and applying time scaling and uncertainty/modifying factors as for the proposed AEGL-3 values, yields values of 42 ppm for 10-min, 22 ppm for 30-min, 11 ppm for 1-hr, 2.7 ppm for 4-hr, and 1.4 ppm for 8-hr; suggesting that the proposed AEGL-3 values are reasonable.

APPENDIX C: Category Plot for Silicon Tetrafluoride

1
2
3


Chemical Toxicity - TSD All Data
Silicon Tetrafluoride
1000
100
10
1
0
0
ppm
0
60
120
180
240
300
360
420
480
Minutes
AEGL-3
AEGL-2
AEGL-1
Human - No Effect
Human - Discomfort
Human - Disabling
Animal - No Effect
Animal - Discomfort
Animal - Disabling
Animal - Partially Lethal
Animal - Lethal
AEGL

4