Appendix G. Value of the Haber's Law Exponent (n) for various gases and vapors for acute RELs developed using OEHHA (1999) procedures

TABLE G1. VALUE OF THE HABER'S LAW EXPONENT (N) FOR VARIOUS GASES AND VAPORS FOR ACUTE RELS[1]

Chemical	*n*	Species/Effect (site of action)	References, Comments
Acrolein	1.2	rat/lethality (local irritant)	U.S. EPA (1992a; U.S.EPA, 1992b)[2]
Acrylonitrile	1.1	rat/lethality (systemic)	(Dudley and Neal, 1942; Appel et al., 1981)[3]
Allyl chloride	0.5	rat/lethality (local irritant)	Adams *et al.* (1940)[2]
Ammonia	4.6	Human/irritation	Rosenbaum *et al.*(1993)
	2.02	rat/lethality (local irritant)	Appelman *et al.*(1982)
Arsine	2.2	rat/lethality (systemic)	IRDC (1985)[2] for 0.5 to 1 hr (n dependent on exposure duration)
	1.0	rat/lethality (systemic)	IRDC (1985)[2] for 4 hr to 1 hr (n dependent on exposure duration)
	2	mice/lethality (systemic)	Levvy (1947)
Benzene	2	not given	AICE (1989)
Bromine	2.2	mice/lethality (local irritant)	Bitron & Aharoson (1978)[3]
Carbon monoxide	1	not given	AICE (1989)
Carbon tetrachloride	2.8	rat/lethality (systemic)	Adams *et al.*(1952)[3]
Chlorine	2.8	rat/lethality (local irritant)	Zwart & Woutersen (1988)[2] for 0.5 hr to 1 hr (n dependent on exposure duration)
	1.0	rat/lethality (local irritant)	Zwart & Woutersen (1988)[2] for 4 hr to 1 hr (n dependent on exposure duration)
	1.3	mouse/lethality (local irritant)	Zwart & Woutersen (1988)[2]
	3.5	mouse/lethality (local irritant)	Bitron & Aharoson (1978)[3]
Chlorine pentafluoride	2	rat, mouse, dog, monkey/lethality (local irritant)	Darmer *et al*. (1972) [3]
Crotonaldehyde	1.2	rat/lethality (local irritant)	Rinehart (1967) [3]
Dibutyl hexamethylene-diamine	1	rat/lethality (local irritant)	Kennedy & Chen (1984)[3]
1,2-dichloro-ethylene	2	(not applicable)/lethality (systemic)	U.S.EPA (1996), based on the mid-point range of n values from lethality data of [3]
Dimethyldichloro-silane	2	(not applicable)/lethality (local irritant)	U.S.EPA (1996), based on the mid-point range of n values from lethality data of [3]
Ethylene dibromide	1.2	rat/lethality (systemic)	(Rowe *et al.,* 1952b)[3]
Ethylene imine	1.1	rat, guinea pig/lethality (local irritant)	(Carpenter *et al.,* 1948)[3]
Fluorine	1.9	rat/lethality (local irritant)	U.S.EPA (1996), derived from LC_{50} data of Keplinger & Suissa (1968)
	1.8	mouse/lethality (local irritant)	U.S. EPA (1996), derived from LC_{50} data of Keplinger & Suissa (1968)
	1.6	guinea pig/lethality (local irritant)	U.S.EPA (1996), derived from LC_{50} data of Keplinger & Suissa 1968)
Formaldehyde	2	not given	AICE (1989)

Chemical	*n*	Species/Effect (site of action)	References, Comments
Hydrazine	2	(not applicable)/lethality (systemic)	U.S.EPA (1996), based on the mid-point range of n values from lethality data of [3]
Hydrogen chloride	1	rat, mouse/lethality (local irritant)	Darmer (1972)[3]
	1.5	rat/lethality (local irritant)	Hartzell & Johnson (1985)[2]
Hydrogen cyanide	2.7	numerous species/lethality (systemic)	Barcroft (1931)[3]
Hydrogen fluoride	2	rabbits, guinea pigs/ lethality (local irritant)	Machle (1934)[3]
Hydrogen fluoride (low humidity)	1	rat/lethality (local irritant)	Haskell Lab. (1988)[2]
Hydrogen sulfide	2.2	cat, rabbit/lethality (systemic/local irritant)	Lehmann (1892)[3]
	8.2	lethality (systemic/local irritant)	Arts (1989)
Methyl bromide	4.0	severe morbidity (systemic/local irritant)	Pharmaco: LSR, (1994) as cited in DPR (2004)[2], DPR (1996)
	1	not given	AICE (1989)
Methylene chloro-bromide	1.6	rat/lethality (systemic)	Torkelson (1960)[3]
Methyl hydrazine	1.0	squirrel monkey/lethality (systemic and local irritant)	Haun (1970)[2]
	1.0	dog/lethality (systemic and local irritant)	Haun (1970)[2]
Methyl isocyanate	1.1	human/eye irritation	Mellon Institute (1963)[2]
	0.5	rat/lethality (local irritant)	Kimmerle & Eben (1964)[2]
	0.7	rat/lethality (local irritant)	DOW Chemical (1990)[2]
Methyl mercaptan	2	(Not applicable)/lethality (systemic and local irritant)	U.S.EPA (1996), based on the mid-point range of n values from lethality data of [3]
Methyl t-butyl ether	2.0	lethality (systemic)	Snam Progretti (1980) as cited in ten Berge et al., (1986)[3]
Nitrogen dioxide	3.5	guinea pig, mouse, dog, rat, rabbit/lethality (local irritant)	Hine *et al.*, (1970)[3]
Nitric acid	3.5	not applicable (local irritant)	U.S.EPA (1996), based on NO_2 from Hine *et al.* (1970)
Perfluoroisobutylene	1.2	rat/lethality (local irritant)	Smith *et al.* (1982)[3]
Phosgene	1	lethality (local irritant)	Rinehart & Hatch (1964)
Propylene oxide	2.2	rat/lethality (local irritant)	Rowe *et al.* (1956)[2]
	1.5	guinea pig/lethality (local irritant)	Rowe *et al.* (1956)[2]
Sulfur dioxide	1	not given	AICE (1989)
Tetrachloroethylene	2.0	rat/lethality (systemic)	Rowe *et al* (1952a)[3]
Toluene	2.5	not given	AICE (1989)
Trichloroethylene	0.8	rat/lethality (systemic)	Adams *et al.* (1951)[3]

[1] developed using procedures specified in OEHHA (1999a). [2]derived by OEHHA.
[3]derived by ten Berge (1986).

References

Adams EM, Spencer HC and Irish DD (1940). The acute vapor toxicity of allyl chloride. J Ind Hyg Toxicol 22(2): 79-86.

Adams EM, Spencer HC, Rowe VK, Mc CD and Irish DD (1952). Vapor toxicity of carbon tetrachloride determined by experiments on laboratory animals. A M A Arch Ind Hyg Occup Med 6(1): 50-66.

Adams EM, Spencer HC, Rowe VK, Mc CDD and Irish DD (1951). Vapor toxicity of trichloroethylene determined by experiments on laboratory animals. A M A Arch Ind Hyg Occup Med 4(5): 469-481.

AICE. (1989). *Guidelines for Chemical Process Quantitative Risk Analysis*. pp. 148-159. New York (NY): Center for Chemical Process Safety, American Institute of Chemical Engineers.

Appel KE, Peter H, Bolt M and Bolt HM (1981). Interaction of acrylonitrile with hepatic microsomes of rats and men. Toxicol Lett 7(4-5): 335-339.

Appelman LM, ten Berge WF and Reuzel PG (1982). Acute inhalation toxicity study of ammonia in rats with variable exposure periods. Am Ind Hyg Assoc J 43(9): 662-665.

Arts JH, Zwart A, Schoen ED and Klokman-Houweling JM (1989). Determination of concentration-time-mortality relationships versus LC_{50}'s according to OECD guideline 403. Exp Pathol 37(1-4): 62-66.

Barcroft J (1931). The toxicity of atmospheres containing hydrocyanic acid gas. J Hyg 31(1): 1-34.

Bitron MD and Aharonson EF (1978). Delayed mortality of mice following inhalation of acute doses of CH_2O, SO_2Cl_2, and Br_2. Am Ind Hyg Assoc J 39(2): 129-138.

Carpenter CP, Smyth Jr. HF and Shaffer CB (1948). The acute toxicity of ethylene imine to small animals. J Ind Hyg Toxicol 30: 2-6.

Darmer Jr. KI, Haun CC and MacEwen JD (1972). The acute inhalation toxicology of chlorine pentafluoride. Am Ind Hyg Assoc J 33(10): 661-668.

Dow Chemical (1990). Unpublished experiments on methyl isocyanate. Dow Chemical Company.

DPR. (1996). *Summary of Pesticide Use Report Data 1996 Indexed by Commodity*. Sacramento (CA): Department of Pesticide Regulation, California Environmental Protection Agency.

Dudley HC and Neal PA (1942). Toxicology of acrylonitrile (vinyl cyanide). I. A study of the acute toxicity. J Ind Hyg Toxicol 24(2): 27-36.

Hartzell CR and Johnson GV (1985). In vivo MAC values and in vitro experimentation. Anesth Analg 64(4): 386-387.

Haun CC, MacEwen JD, Vernot EH and Eagan GF (1970). Acute inhalation toxicity of monomethylhydrazine vapor. Am Ind Hyg Assoc J 31(6): 667-677.

Hine CH, Meyers FH and Wright RW (1970). Pulmonary changes in animals exposed to nitrogen dioxide, effects of acute exposures. Toxicol Appl Pharmacol 16(1): 201-213.

IRDC. (1985). *Three Acute Inhalation Toxicity Studies of Arsine on Rats (Final Report)*

Report No. 533-001, 533-002, and 533-003. Mattawan (MI): International Research & Development Corporation.

Kennedy Jr. GL and Chen HC (1984). Inhalation toxicity of dibutylhexamethylenediamine in rats. Food Chem Toxicol 22(6): 425-429.

Keplinger ML and Suissa LW (1968). Toxicity of fluorine short-term inhalation. Am Ind Hyg Assoc J 29(1): 10-18.

Kimmerle G and Eben A (1964). [On the toxicity of methylisocyanate and its quantitative determination in the air]. Arch Toxikol 20: 235-241.

Lehmann KB (1892). Experimentele Studien uber den Einfluss technisch und hygienisch wichtiger Gase und Dampfe auf den Organismus [German]. Arch Hyg 14: 135-189.

Levvy GA (1947). A study of arsine poisoning. Quart J Exp Physiol 34: 47-67.

Machle W, Thamann F, Kitzmiller K and Cholak J (1934). The effects of the inhalation of hydrogen fluoride. I. The response following exposure to high concentrations. J Ind Hyg 16(2): 129-145.

Mellon Institute (1963). Special report 26-23: Methyl Isocyanate. Pittsburgh (PA): Mellon Institute.

OEHHA. (1999a). *The Air Toxics Hot Spots Program Risk Assessment Guidelines. Part I: Technical Support Document for Determination of Acute Reference Exposure Levels for Airborne Toxicants*. Air Toxicology and Epidemiology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. http://www.oehha.ca.gov/air/acute_rels/acuterel.html#download.

Pharmaco: LSR I (1994). An Up-and-Down Acute Inhalation Toxicity Study of Methyl Bromide in the Dog (Four Exposure Phase). E. Millstone(NJ), Pharmaco: LSR, Inc.

Rinehart WE (1967). The effect on rats of single exposures to crotonaldehyde vapor. Am Ind Hyg Assoc J 28(6): 561-566.

Rinehart WE and Hatch T (1964). Concentration-time product (Ct) as an expression of dose in sublethal exposures to phosgene. Am Ind Hyg Assoc J 25: 545-553.

Rosenbaum JR, Alexeeff GV and Lewis DC (1993). Use of benchmark dose methodology to combine data sets in the development of an acute REL for ammonia [Abstract]. The Toxicologist 13: 282.

Rowe VK, Dd M, Spencer HC, Adams EM and Irish DD (1952a). Vapor toxicity of tetrachloroethylene for laboratory animals and human subjects. A M A Arch Ind Hyg Occup Med 5(6): 566-579.

Rowe VK, Hollingsworth RL, Oyen F, McCollister DD and Spencer HC (1956). Toxicity of propylene oxide determined on experimental animals. AMA Arch Ind Health 13(3): 228-236.

Rowe VK, Spencer HC, Mc CD, Hollingsworth RL and Adams EM (1952b). Toxicity of ethylene dibromide determined on experimental animals. A M A Arch Ind Hyg Occup Med 6(2): 158-173.

Smith LW, Gardner RJ and Kennedy Jr. GL (1982). Short-term inhalation toxicity of perfluoroisobutylene. Drug Chem Toxicol 5(3): 295-303.

Snam Progretti (1980). Research reports on MTBE: Toxicological data.

ten Berge WF, Zwart A and Appelman LM (1986). Concentration-time mortality response relationship of irritant and systemically acting vapours and gases. J Hazard Mater 13: 301-309.

Torkelson TR, Oyen F and Rowe VK (1960). The toxicity of bromochloromethane (methylene chlorobromide) as determined on laboratory animals. Am Ind Hyg Assoc J 21: 275-286.

U.S.EPA. (1992a). *Acute Inhalation Toxicity of Acrolein in Hamsters*. EPA/OTS: 88-920002323. Washington (DC), United States Environmental Protection Agency.

U.S.EPA. (1992b). *Acute Inhalation Toxicity of Acrolein Vapor by One and Four-Hour Exposures* EPA/OTS: 88-920001468S. Washington (DC), United States Environmental Protection Agency.

U.S.EPA (1996). Integrated Risk Information System (IRIS) Database

Washington (DC), United States Environmental Protection Agency. http://www.epa.gov/IRIS. August 7, 2006.

Zwart A and Woutersen RA (1988). Acute inhalation toxicity of chlorine in rats and mice time-concentration-mortality relationships and effects on respiration. Journal of Hazardous Materials 19(2): 195-208.