Maximum Allowable Concentrations of Industrial Atmospheric Contaminants

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THE following table presents a list of maximum allowable concentrations of industrial atmospheric contaminants as set up by a number of states, and includes the values recommended by the U. S. Public Health Service and the American Standards for substances so far promulgated by the American Standards Association. A list of accepted and tentative values is also presented for practical use in the control of occupational disease and for the provision of both healthful and comfortable working conditions where toxic or obnoxious materials may be present. A number of these values are soundly founded on a combination of animal experimentation and experience with workers under actual industrial conditions. Others of these values have a basis only in animal experimentation, some of which is so limited as merely to give an indication of the approximate concentrations which should be permitted. Still others of these values are based on judgment which has its foundation in sensory response of persons to known concentrations of the atmospheric contaminant or in human experience under occupational conditions of insufficient extent to be truly significant.

The final column of accepted and tentative values is offered with the hope that further work both in the experimental laboratory and under industrial conditions may be stimulated. Already correlation of medical findings, both clinical and laboratory, with the results of determinations of concentrations of atmospheric contaminants have given us much information. Only through further correlated activity of this type can we arrive at more complete dependable information on these maximum allowable concentrations. It is advised that there be medical observation of workers whose exposure to an atmospheric contaminant may be close to the allowable concentration especially where it may be one of those values based on such limited data as to be of questionable reliability.

More complete discussions of the use and limitations of maximum allowable concentrations are given by J. H. STERNER in INDUSTRIAL MEDICINE, 12, 514-518 (August, 1943), "Determining Margins of Safety—Criteria for Defining a 'Harmful' Substance"; by LUDWIG TELEKY in Industrial Hygiene Supplement of INDUSTRIAL MEDICINE, 9, 63-71 (October, 1940), "Toxic Limits"; and in an editorial on pages 53, of this latter issue. It is advised that these be carefully read as a background to the application of maximum allowable concentrations.

It is to be emphasized that the intent in presenting these maximum allowable concentrations is to provide a handy yardstick to be used as guid...

From the Appendix of the forthcoming book, "Job Placement of the Physically Handicapped," by CLARK D. BRIDGES, Director of Conservation Services, Zurich Insurance Companies, to be published by the McGraw-Hill Book Company early in 1946.

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IN ALL columns except I, the figures in this table refer to parts of gas or vapor per million parts of air (abbreviated in the discussion which follows as ppm) with the exception of the figures for dusts, fumes and mists which are expressed as milligrams of the substance per cubic meter of air (abbreviated as mg./m³). All figures expressed in units of mg./m³ in columns A through H are designated with an asterisk.

Under H, the first column includes values normally expressed as parts per million. The second column gives round number equivalents in milligrams per cubic meter so that there may be a comparison between the toxicities of the various substances on the basis of mass per unit volume.

	A	B	C	D	E	F	G	H	I	
									ppm	mg/m³
Acetaldehyde									200	400
Acetic acid				10					10	25
Acetone	500		500	1000	500	200			500	1000
Acetylene tetrachloride (See 1, 1, 2, 2—Tetrachloroethane)										
Acrolein	1				1	3.3	1		0.5	1
Acrylonitrile	20			20	20		20		20	50
Ammonia	100		100	100	100	100	100		100	50
Amyl acetate	400		200	400	400	400	400		200	1000
iso-Amyl alcohol	200			200		55.6			100	400
Aniline	5		5	5	5	5–7	5		5	20
Arsenic		0.15*	0.15*	0.15*	0.15*	0.5*		(.15*)		0.15
Arsine	1		0.05	1	0.5	1	1		1	2
Barium peroxide (as Ba)				0.5*			0.5*			0.5
Benzene (Benzol)	100	100	75	50	75	75–100	100	100	100	200
Benzine (Gasoline)	1000	1000	1000	1000		1000	1000		500	2000
Bromine	1			1		1			1	5
1, 3-Butadiene									5000	10000
n-Butanol (Butyl alcohol)	200		50	200		100	100		50	200
2-Butanone	500		300						200	500
n-Butyl acetate	400		200	400	400	400	400		200	1000
Butyl cellosolve	50								200	1000
Cadmium	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	(0.1*)		0.1
Carbon dioxide	5000			5000	5000	5550	5000		5000	10000
Carbon disulfide	20	20	20	20	20	20	20	20	20	50
Carbon monoxide	100	100	100	100	100	100	100	100	100	100
Carbon tetrachloride	100	100	50	75	50	100	100		100	500
Carrene No. 2 (See Monofluorotrichloromethane)										
Cellosolve	500					500			200	1000
Cellosolve acetate									100	500
Chlorine	1	1	1	1	1	1		2	5	10
2-Chlorobutadiene (Chloroprene)						83			25	100
Chlorodiphenyl	1*		5*	1*	0.3*	1*				1
Chloroform	100			100		100			100	500
Chloronaphthalenes (See Penta and trichloronaphthalenes)			1–5							
1-Chloro-1-nitropropane									20	100
Chromic acid	0.1*	0.1	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*		0.1
Cyclohexane									400	1000
Cyclohexanol									100	400
Cyclohexanone									100	400
Cyclohexene									400	1000
o-Dichlorobenzene	75		75	75	75		75		75	500
Dichlorodifluoromethane (Freon-12)									100000	500000
1, 1-Dichloroethane (ethylidine chloride)									100	400
1, 2-Dichloroethane (ethylene dichloride)	100		75	100	100	100	100		100	400
1, 2-Dichloroethylene	200					100			100	400
Dichloroethyl ether	15		15	15		15			15	100
Dichloromethane	200			500					500	2000
Dichloromonofluoromethane (Freon-21)									5000	20000
1, 1-Dichloro-1-nitroethane									10	50
Dichlorotetrafluoroethane (Freon-114)									10000	50000
Difluoromonochloromethane (Freon-22)									20000	50000
Dimethylaniline	5			5	5		5		5	25
Dimethylsulfate									1	5
Dinitrotoluene				1.5*			1.5*			1.5
Dioxane						1000			500	2000
Ethyl acetate			400						[illegible]	[illegible]
Ethyl alcohol	1000			1000					[illegible]	[illegible]
Ethyl benzene						[illegible]				

	A	B	C	D	E	F	G	H	I ppm	I mg/m³
Ethyl bromide	1700					1700			400	2000
Ethyl chloride	20000					20000			5000	10000
Ethylene chlorhydrin									10	25
Ethylene dichloride (Commercial name for 1, 2-Dichloroethane)										
Ethylene oxide						<250			100	200
Ethyl ether	400		400	400	400	400			500	2000
Ethyl formate									200	500
Ethyl silicate						<500			100	2000
Fluoride dusts, smokes			1*		2*					
Formaldehyde	10	10	10	5	10	20		10	10	10
Freon (See respective Dichloro, Difluoro and Monofluoro Compounds)										
Furfural									See note	
Gasoline	1000	1000	1000	1000	500	1000	1000		500	2000
Heptane									500	2000
Hexane									1000	4000
Hexanone (See methyl butanone)										
Hexone (See methyl iso-butanone)										
Hydrochloric acid (hydrogen chloride)	10	10	10	10	10	10	10		10	10
Hydrogen cyanide	20	20	20	20	20	20	20		20	20
Hydrogen fluoride	3	3	1.5	3	3	3	3		3	2
Hydrogen selenide									0.1	.2
Hydrogen sulfide	20	20	20	20	20	20	20	20	20	20
Iodine				1	.05-1.0				0.1	1
Iron oxide				30*						30
Isophorone									25	100
Lead	0.15*	0.15*	0.15*	0.15*	0.15*	0.15*	0.15*	0.15*		0.15
Magnesium						15*				15
Manganese	6*	6*	6*	6*	6*	5–50*		(6*)		6
Mercury	0.1*	0.1*	0.1*	0.1*	0.1*	0.1–0.2*	0.1*	0.1*		0.1
Mesityl oxide									50	200
Methanol (methyl alcohol)	200	200	200	200	100	100–200	200	200	200	200
Methyl acetate	400								100	200
Methyl bromide	500			35	35	50–100			20	50
Methyl butanone						<1500			200	500
Methyl cellosolve						<25			100	1000
Methyl cellosolve acetate									100	500
Methyl chloride	500				100	500			200	400
Methylcyclohexane									1000	4000
Methyl cyclohexanol									100	500
Methylcyclohexanone									100	500
Methyl ethyl ketone (See 2-Butanone)										
Methyl formate						<1500			400	1000
Methyl iso-butanone						1000			200	500
Monochlorobenzene	75		75	75		75	75		75	400
Monofluorotrichloromethane (Freon-11—Carrene #2)									10000	50000
Mononitrotoluene				5			5		5	25
Naphtha (Coal tar)	100		200		200				100–200	200–500
Naphtha (Petroleum)					500	5000			500	2000
Nitrobenzene	5		5	5	5	1–5	5		5	25
Nitroethane									200	500
Nitrogen dioxide			10							
Nitrogen oxides	25	25		40	25	10–40	25	25	25	100
Nitroglycerine						10–40	0 5		0.5	5.
Nitromethane									200	500
Octane									500	2000
Ozone	1		1	1	0.5	1			1	2
Pentachloronaphthalene	1.0*			0.5*	0.5*	0.5*				0.5
Pentane									5000	10000
Pentanone (methyl propanone)	500					1500			400	1000
Perchlorethylene (Commercial name for tetrachloroethylene)										
Phosgene	1	1		1	1	1	1		1	5
Phosphine	1		1	1	1	2	1		1	1
Phosphorus trichloride	1					0.7			0.5	4
iso-Propanol (iso-Propyl alcohol)									400	1000
Propyl acetate									200	1000
iso-Propyl ether									500	2000
Radon (radium emanation)									10^{-11} curie/l	
Stibine									10	50
Stoddard solvent				750					500	2000
Styrene monomer	400	400	400	400	400			(400)	400	1000
Sulphur chloride									1	5
Sulphur dioxide	10	10	10	10	10	10	10		10	25
Sulphuric acid				5*		2*				5
Tellurium										0.01
1, 1, 2, 2-Tetrachloroethane	10		5	10	10	10	10		10	50
Tetrachloroethylene	200		200	200	200	200	200		200	1000
Tetryl	1.5*						1.5*			1.5
Toluene (Toluol)	200	200	200	200	200	200	200	200	200	500
Toluidine									5	20
Trichloroethylene	200	200	200	200	200	200	200		200	1000
Trichloronaphthalene	10*		5*	5*	5*	5*				5
Trinitrotoluene (TNT)	1.5*		2*	1.5*		1.5*				1.5
Turpentine	200	700	200	200	200	200–700	200		100	500
Vinyl chloride						500			1000	1000
Vinyl cyanide (See acrylonitrile)										
X-Ray								(0.1r)	0.1 roentgen	
Xylene (Xylol)	200	200	200	200	200	200	200	(200)	200	500
Zinc oxide	15*		15*	15*		15*	15*			15

NOTE: A number of gases, such as acetylene, butane, ethane, ethylene, hydrogen, methane, propane, helium and nitrogen, are considered to be essentially non-toxic but act as simple asphyxiants at high concentrations.

ance for the routine industrial control of these health hazards—not that compliance with the figures listed would guarantee protection against ill health on the part of exposed workers, nor should the maintenance of the suggested concentrations be considered a substitute for medical control.

In every case, the concentrations given are considered allowable for prolonged exposures, usually assuming a 40-hour week.

The several lists in the table refer to the following sources:

A. California Industrial Accident Commission, September, 1945.

B. *Connecticut State Department* of Health. Bureau of Industrial Hygiene. Regulation 281 of the Sanitary Code, September, 1945.

C. Massachusetts Department of Labor and Industries. Not official, but used by the Division of Occupational Hygiene as a guide. September, 1945.

D. New York State Department of Labor. Not official, but used by the Division of Industrial Hygiene as a guide. June, 1945.

E. Oregon State Board of Health. Rules and Regulations for the Prevention and Control of Occupational Diseases, August, 1945.

F. Utah Department of Health. Compiled by the Industrial Hygiene Division as part of a booklet on "Useful Criteria in the Identification of Certain Occupational Health Hazards," 1945.

G. United States Public Health Service. Presented as a guide for occupational disease control, as published in "Manual of Industrial Hygiene," W. B. Saunders Company, Philadelphia, 1943, with revisions here to show U. S. Public Health Service opinion as of September, 1945.

H. American Standards promulgated by the American Standard Association up to September, 1945. Parentheses indicate value is an "American War Standard" only.

I. Accepted and tentative values based on industrial experience, animal experimentation, sensory responses of persons, or a combination of these.

Following the table is an indication of the basis and reliability of each of the values given in Column I. Since there is no fine line of demarcation between physiological response to small differences in concentrations of any of these atmospheric contaminants, round numbers are used in most instances. For example, if 1000 parts per million of a contaminant such as gasoline vapor cause irritation but somewhat lesser concentrations—perhaps 750 or 825 parts per million—do not cause irritation of some group of persons under observation, the allowable concentration is given as 500 parts per million rather than an intermediate value.

Basis of Values in Column I.

ACETALDEHYDE: Iwanoff, in *Arch. f. Hyg.*, 73, 32 (1911), reported that cats showed no noticeable effects on [illegible] hours exposure to 200 parts per million. The value of 200 ppm is based on this brief exposure since the immediate irritative effect of low concentrations appears to be more prominent than systemic effects.

Acetic Acid: 10 ppm is based on sensory response to this irritant.

Acetone: This substance is one of the least toxic of the commercially used solvents as has been shown both by industrial exposures involving many hundreds of persons and also through animal experimentation. From the point of view of toxicity, an allowable concentration of even 2000 or 3000 ppm may be lower than necessary. H. Specht, J. W. Miller and P. J. Valaer, in Reprint No. 2076, Pub. Health Repts., 54, 944-955 (June 2, 1939), "Acute Response of Guinea Pigs to the Inhalation of Dimethyl Ketone (Acetone) Vapor in Air," reported that 1% acetone vapor in air for approximately 48 hours caused systemic injury to experimental animals. The tentative value of 500 ppm is based on sensory response to acetone vapor which caused irritation of the eyes, nose and throat of a group of human subjects at concentrations of 500 ppm as reported by K. W. Nelson, J. F. Ege, Jr., Morwick Ross, L. E. Woodman, and Leslie Silverman, in *J. Ind. Hyg. & Tox.*, 25, 282-285 (September, 1943), "Sensory Response to Certain Industrial Solvent Vapors." Although the exposed group estimated 200 ppm as the highest satisfactory exposure for eight hours, it is felt that some habituation usually develops on daily exposure to moderately irritative atmospheres. In war industries where hundreds of workers were exposed to acetone, it was found necessary to maintain vapor concentrations below 700 ppm to avoid irritation. A number of state departments have found it necessary to require limitation of acetone vapor to 500 ppm to avoid irritation. There is no published evidence that concentrations of 1000 ppm are regularly tolerated without irritation, though in some large industries such concentrations are said to exist with no complaints by those exposed. Where irritative qualities of a substance are the deciding factor in recommending a concentration which may be appreciably lower than the toxic limit. this fact should be fully recognized in the application of the suggested value.

Acrolein: Since a concentration of 1 ppm of acrolein produces marked irritation of eyes and nose in five minutes or less, as shown by W. P. Yant, H. H. Schrenk, F. A. Patty, and R. R. Sayers. in U. S. Bureau of Mines Report of Investigations No. 3027 (193), "Acrolein as a Warning Agent for Detecting Leakage of Methyl Chloride from Refrigerators," a concentration of half this value is tentatively suggested for prolonged exposure.

Acrylonitrile: The U. S. Public Health Service suggests 20 ppm as not definitely established but to serve as a guide following animal experimentations published under the general title "Toxicology of Acrylonitrile (Vinyl Cyanide)" as follows: H. C. Dudley and P. A. Neal, "(I) A Study of the Acute Toxicity," *J. Ind. Hyg. & Tox.*, 24, 27-36 (February, 1942); H. C. Dudley, T. R. Sweeney and J. W. Miller, "(II) Studies of Effects of Daily Inhalation," *J. Ind. Hyg. & Tox.*, 24, 255-258 (November, 1942); A. H. Lawton, T. R. Sweeney and H. C. Dudley, "(III) Determination of Thiocyanates in Blood and Urine," *J. Ind. Hyg. & Tox.*, 25, 13-19 (January, 1943).

Ammonia: The authority for 100 ppm goes back to K. B. Lehmann, in *Arch. f. Hyg.*, 5, 68 (1886). This concentration is generally accepted today.

Amyl Acetate: The value of 200 ppm is based on irritative effects as reported by Nelson, et al. in the "Sensory Response" paper, *J. Ind. Hyg. & Tox.*, 25, 282-285 (September, 1943).

Amyl Alcohol: The value of 100 ppm is based on irritative effects as shown by Nelson, et al., *J. Ind. Hyg. & Tox.*, 25, 282 (September, 1943).

Aniline: W. F. von Oettingen, in Pub. Health Bull. 271 (1941), "The Aromatic Amino and Nitro Compounds, their Toxicity and Potential Dangers — A Review of the Literature," stated that the available literature is not sufficient to allow the establishment of definite standards, but quoted the table from Henderson and Haggard, "Noxious Gases," 1927, in which 7.0 to 25.0 ppm are described as giving slight symptoms after several hours. Workers exposed to concentrations approaching the suggested value of 5 ppm should be under medical observation—particularly as aniline is readily absorbed through the skin.

Arsenic and Arsenic Trioxide: The allowable concentration of 0.15 mgs. per cubic meter for metallic arsenic and arsenic trioxide was based on analogy with other metals such as cadmium and lead in setting up the American War Standard by the American Standards Association. On the basis of long experience involving many occupational exposures, at least one large concern considers it permissible to increase this limit to 5. mg. per cubic meter. R. M. Watrous, M.D., and M. B. McCaughey, in INDUSTRIAL MEDICINE, 14, 639-646 (August, 1945) "Occupational Exposure to Arsenic — In the Manufacture of Arsphenamine and Related Compounds—" reported that exposures in manufacturing operations ranging from 0.007 to 0.60 milligrams per cubic meter as As_2O_3 resulted in no clinical symptoms attributable to arsenic except in a few isolated workers during a short period of unusually heavy exposure.

Arsine: The value of 1 ppm is suggested as a guide by the U. S. Public Health Service. Flury and Zernik in "Schädliche Gase," 1931, stated in an unidentified reference to K. B. Lehmann that 3.1 ppm is tolerable for six hours without apparent symptoms.

Barium Peroxide: The maximum allowable concentration of 0.5 mgs. per cubic meter (as barium) has been suggested by the U. S. Public Health Service as a guide. Where workers are exposed to concentrations approaching this value they should be placed under medical observation.

Benzene (Benzol): Though 100 ppm has been adopted as the American Standard, there is evidence that poisoning has occurred at less than 100 ppm. The National Safety Council Study of Benzol Poisoning, as summarized by C-E. A. Winslow in *J. Ind. Hyg. & Tox.*, 9, 61 (1927), the technical data of which was published by L. Greenburg, in Reprint No. 1096, Pub. Health Repts., 41 1367, 1410, 1519 (1926), concluded that a substantial hazard is involved even where the average exposure is below 100 ppm. M. Bowditch and H. B. Elkins, in *J. Ind. Hyg. & Tox.*, 21, 321-330 (October, 1939), "Chronic Exposures to Benzene (Benzol). I. The Industrial Aspects," suggested 75 ppm as a maximum allowable concentration but cited two cases of poisoning where they believed the average exposure was below this concentration. It is accordingly suggested that exposures be kept below 50 ppm until further experience either substantiates the suggested limit of 100 ppm as safe or causes it to be decreased.

Benzine: This term is applied to petroleum distillates such as gasoline. See "Gasoline" for discussion.

Bromine: Zederbaum, in Gig. Truda, page 68 (1927), referred to by Koelsch in *Munch. med. Wochschr.*, No. 33 (1928), found 4 ppm in a workroom to be productive of no noteworthy injury. An unidentified reference to K. B. Lehmann by Flury and Zernik in "Schädliche Gase," 1931, stated six hours' exposure to bromine was without noticeable symptoms at a concentration of 0.75 parts per million. The value of 1 ppm should receive further substantiation.

Butadiene: C. P. Carpenter, C. B. Shaffer, C. S. Weil and H. F. Smyth, Jr., in *J. Ind. Hyg. & Tox.*, 26, 69-78 (March, 1944) "Studies on the Inhalation of 1, 3-Butadiene," concluded that concentrations of 600, 2300, and 6700 ppm caused no significant progressive injury to small animals during an eight months' exposure, although the highest concentration retarded growth slightly and caused light cloudy swelling in some livers.

n-Butanol: H. F. Smyth and H. F. Smyth, Jr., in *J. Ind. Hyg.*, 10, 261-271 (October, 1928), "Inhalation Experiments with Certain Lacquer Solvents," reported development of pathology on animal experimentation with exposures at 100 ppm. I. R. Tabershaw, J. P. Fahy, and J. B. Skinner, *J. Ind. Hyg. & Tox.*, 26, 328-330 (December, 1944) "Industrial Exposure to Butanol," found that eye inflammation will result when atmospheric concentrations exceed 50 ppm and that no systemic effects may be expected below 100 parts per million.

-Butanone: Although the acute re- nse of guinea pigs to butanone, as erved by F. A. Patty, H. H. renk and W. P. Yant, in Reprint . 1702 from Pub. Health Repts., -1228 (September 6, 1935), at 3000 parts per million ld be tolerated by animals for sev- l hours without serious disturbance, son, et al., in *J. Ind. Hyg. & Tox.*, 282 (1943), demonstrated sufficient tation to humans at concentrations 350 ppm to recommend 200 ppm as practical limit.

-Butyl Acetate: The acute response guinea pigs to normal butyl acetate, shown by R. R. Sayers, H. H. renk, and F. A. Patty in Reprint . 1769 from Pub. Health Repts., 1229-1236 (September 4, 1936), in- ated the maximum exposure for eral hours with slight or no symp- s to be 3300 ppm. Sensory response this vapor, as shown by Nelson, al., in *J. Ind. Hyg. & Tox.*, 25, 282 43), was severe throat irritation which all subjects complained at a centration of 300 ppm. Though 100 n was recommended by the exposed sons, a concentration of 200 ppm is g suggested, as this group was not stomed to occupational exposure he material.

utyl Cellosolve: H. W. Werner, V. Nawrocki, J. L. Mitchell, J. W. ler, and W. F. von Oettingen, in *nd. Hyg. & Tox.*, 25, 374-379 (Oc- r, 1943), "Effects of Repeated Ex- ure of Rats to Vapors of Mono- l ene Glycol Ethers," found exposures of rats to a range of to 400 ppm of n-butyl glycol ether luced small but measurable toxi- gical effects on daily exposure of n hours, five days a week for five ks.

admium: L. Prodan, in *J. Ind.* ., 14, 174-196 (May, 1932), "Cad- n Poisoning. II. Experimental mium Poisoning," reported on ex- ive animal experimentation in- ing inhalation. Although the low- concentrations used were much in s of those considered poisonous continued exposure, it is to be con- d from Prodan's work that cad- n is as poisonous as lead or some- more so. In view of the rapidity which excessive cadmium expo- s can cause serious pulmonary a and death, as shown by L. W. ar, J. F. Keppler, and H. G. r, in *J. Ind. Hyg. & Tox.*, 26, 40 (September, 1944), "Cadmi- Poisoning in Industry: Report of Cases, Including One Death," new exposure to cadmium dust or should be carefully watched. mination of concentrations to workers are exposed together medical observation of the rs important both for avoid- injury and to gain more formation concerning the mum allowable concentration.

bon Dioxide: Flury and Zernik, liche Gase," 1931, refer to Leh- -Hess as authority that six exposure to 5550 ppm carbon dioxide caused no noticeable symptoms.

Carbon Disulfide: F. H. Wiley, W. C. Kueper, W. S. von Oettingen, in *J. Ind. Hyg. & Tox.*, 18, 733-740, (1936), "On the Toxic Effects of Low Concentration of Carbon Disulfide," reported that animals exposed to con- centrations of 30 ppm over a long term showed no significant toxic effects. N. L. Barthelemy, in *J. Ind. Hyg. & Tox.*, 21, 141-151 (1939), "Ten Years Experience with Industrial Hy- giene in Connection with the Manu- facture of Viscose Rayon," reported that no trouble whatever was experi- enced where carbon disulfide exposures were kept in less than 30 ppm.

Carbon Monoxide: Y. Henderson, H. W. Haggard, M. C. Teague, A. L. Prince, and R. M. Wunderlich, in *J. Ind. Hyg. & Tox.*, 3, 79-137 (1921), "Physiological Effects of Automobile Exhaust Gas and Standards of Ven- tilation for Brief Exposure," showed that 100 ppm could be considered al- lowable for an exposure of several hours. R. R. Sayers, W. P. Yant, E. Levy, and W. B. Fulton, in Public Health Bulletin No. 186 (1929), "Effects of Repeated Daily Exposure of Several Hours to Small Amounts of Automobile Exhaust Gas," re- ported that the daily exposure of six men over a period of 68 days to 200 ppm of carbon monoxide caused some of the more susceptible persons to develop slight but not discomforting symptoms after two hours. R. F. Sievers, T. I. Edwards, A. L. Murray, and H. H. Schrenk, in *J.A.M.A.*, 118, 585-588 (February 21, 1942), "Effect of Exposure to Known Concentrations of CO," reported that a group of 156 Holland Tunnel traffic officers ex- posed over a 13 year period to an average of 70 parts per million of carbon monoxide did not reveal any evidence of injury to health attribut- able to the exposure.

Carbon Tetrachloride: H. F. Smyth, H. F. Smyth, Jr., and C. P. Carpenter, in *J. Ind. Hyg. & Tox.*, 18, 277-298 (1936), "The Chronic Toxicity of Car- bon Tetrachloride: Animal Exposures and Field Studies," concluded on the basis of animal experiments over a period of 10½ months that 100 ppm is safe for continuous exposure of workmen throughout the day, and day after day. There has been an in- creasing amount of evidence since the date of that publication that con- centrations of less than 100 ppm may cause injury to health. As in the case of benzol, it is recommended that ex- posures be kept at less than half the maximum allowable limit for carbon tetrachloride until such time as fur- ther experience either provides justi- fication of the present suggested limit or causes it to be revised downward.

Cellosolve: H. W. Werner, C. W. Nawrocki, J. L. Mitchell, J. W. Miller, and W. F. von Oettingen, in *J. Ind. Hyg. & Tox.*, 25, 374-379 (October, 1943), "Effects of Repeated Exposures of Rats to Vapors of Monoalkyl Ethy- lene Glycol Ethers," found that ex- posures of rats to a range of 300 to 400 ppm of ethyl glycol ether (cello- solve) produced small but measurable toxicological effects on daily exposures of seven hours five days a week for five weeks.

Cellosolve Acetate: The maximum allowable concentration of 100 ppm is based on an unpublished report of tests made by the Chemical Hygiene Fellowship at Mellon Institute, re- ported in July, 1945.

Chlorine: Early work has indicated that 1 ppm should be taken as the maximum allowable concentration and this has been generally followed. Ron- zani, *Arch. f. Hygiene*, 67, 285 (1909), showed that 1.7 ppm caused impaired nutrition and blood changes in ani- mals, but that 0.7 ppm caused no disturbances. K. B. Lehmann listed in a table in 1912, quoted in U. S. Bureau of Mines Tech. Paper 248 (1921), that 1 ppm causes slight symptoms after several hours and 4 ppm is the maximum concentration without symptoms for one hour ex- posure. As long ago as 1899, Lehmann observed that an increase in resistance occurs on acclimatization (*Arch. f. Hyg.*, 34, 302). Capable research of more recent date in this country con- ducted by the American University Experiment Station of the Chemical Warfare Service, referred to in U. S. Bureau of Mines Tech. Paper 248 (1921), showed the least concentra- tion to give detectable odor was 3.5 ppm; to cause throat irritation, 15.1 ppm; and to cause coughing, 30.2 ppm. On the basis of these data, it is con- sidered in order to suggest 5 ppm rather than 1 ppm as the allowable concentration.

Chloro-butadiene (Chloroprene): W. F. von Oettingen, W. C. Hueper, W. Deichmann-Gruebler, and F. H. Wiley, in *J. Ind. Hyg. & Tox.*, 18, 240 (1936), "2-Chlorobutadiene (Chloro- prene): Its Toxicity and Pathology and Mechanism of its Action," re- ported that animal experimentation indicates that continued exposure to 0.3 mgs. per liter (83 ppm) and even less may cause toxic effects. It is consequently considered desirable to suggest 25 ppm until further data are available as to effects on man on prolonged exposure.

Chlorodiphenyl: C. K. Drinker, in *J. Ind. Hyg. & Tox.*, 21, 155-159 (May, 1939), "Further Observations on Pos- sible Systemic Toxicity of Certain of the Chlorinated Hydrocarbons with Suggestions for Permissible Concen- trations in the Air of Workrooms," lists a table of 14 chlorinated hydro- carbons with permissible limits. Ex- posure of rats to 0.5 mgs./m³ in one test and 10.0 mgs./m³ in another was found to cause no injury. A maximum allowable concentration of 1 mg./m³ is suggested, though it is very pos- sible that exposure to this substance may extend to 5 mgs./m³ without in- jury to health.

Chloroform: Since there is no pub- lished work on prolonged exposures of animals under experimental condi- tions or of humans in industrial occupations to known low concentrations of chloroform, a value of 100 ppm is generally accepted on the basis of analogy with carbon tetrachloride. The value as given should be further substantiated and there should be close medical observation of any group of workers exposed to chloroform concentrations approximating 100 ppm. As is the case with carbon tetrachloride, it would be wise to retain exposures to less than 50 ppm until more data are available.

Chloronaphthalenes: Results of animal experiments with chloronaphthalenes are given in the reference cited under "Chlorodiphenyl." Inhalation of a concentration of 10 mgs./m³ of trichloronaphthalene by rats caused no pathology. In view of the fact that industrial experience has indicated that there is an unusually marked difference in susceptibility, 5 mgs.m/³ is generally accepted as the allowable concentration. As the chlorine content of the compound increases, a lower allowable limit is necessary to avoid poisoning. For a combination of tetra and penta chloronaphthalenes, a limit of 1 mg./m³ was suggested; for a mixture of penta and hexachloronaphthalenes, a limit of 0.5 mgs./m³.

1-Chloro-1-nitropropane: Willard Machle, E. W. Scott, J. F. Treon, F. F. Heyroth, and J. V. Kitzmiller, in *J. Ind. Hyg. & Tox.*, 27, 95-102 (April, 1945), "The Physiological Response of Animals to Certain Chlorinated Mononitroparaffins," showed by animal experiment that this substance is considerably less toxic than 1,1-dichloro-1-nitroethane. The longest exposure to the propane derivative was for two hours only. The allowable concentration of 20 ppm for long exposures is based on a comparison with that of the ethane derivative on which more extensive research was done. Longer animal experimentation or human experience under medical observation may indicate that a somewhat higher concentration is not injurious.

Cyclohexane: J. F. Treon, W. E. Crutchfield, J., and K. V. Kitzmiller, in *J. Ind. Hyg. & Tox.*, 25, 323-347 (October, 1943), "The Physiological response of Animals to Cyclohexane, Methycyclohexane, and Certain Derivatives of these Compounds," reported that animal experimentation of 50 periods of exposure of six hours each showed barely demonstrable microscopic changes in the liver and kidneys of rabbits that had been exposed to 786 ppm and no toxic changes after similar periods of exposure to 434 ppm. As the pathological effects of the higher exposures were so slight, it is considered permissible to set the allowable concentration at 400 ppm.

Cyclohexanol: The reference quoted under "Cyclohexane" includes similar data on cyclohexanol. These authors showed that 693 ppm caused barely demonstrable pathological changes on a monkey and that 145 ppm caused scanty but definite changes in the liver and kidneys of rabbits, with the conclusion that this latter exposure is very near to the maximum safe level for rabbits. One hundred ppm is being suggested as the maximum allowable concentration but, until there is more experience with human exposure, there should be medical observation of workers exposed to these compounds where concentrations approach the allowable limits.

Cyclohexanone: In the preceding reference these authors reported the maximum allowable concentration for cyclohexanone is slightly below 190 ppm. A maximum allowable limit of 100 ppm is suggested for this compound. In the experimental human exposures to cyclohexanone carried on by Nelson, et al., and described in *J. Ind. Hyg. & Tox.*, 25, 282 (September, 1943), irritation was experienced at 75 ppm. If actual industrial exposures show similar irritation to workmen, the permissible exposure should be adjusted downward.

Cyclohexene: The only quantitative toxicological work conducted on this compound is that on acute exposures which N. W. Lazarew reported in *Arch. exptl. Path. Pharmakol.*, 143 223 (1929), "On the Toxicity of Vapors of Different Hydrocarbons," showing that 9000 ppm caused experimental animals to assume "side-position," indicating mild narcosis. On analogy to the toxicity of cyclohexane which it closely resembles structurally, though introduction of a double bond may increase its toxicity somewhat, the maximum allowable concentration of 400 ppm is suggested. With this inadequate basis for setting an allowable concentration, medical observation should be afforded workers who may be exposed to concentrations approaching this value.

o-Dichlorobenzene: A value of 75 ppm is recommended by the U. S. Public Health Service as a guide.

Dichlorodifluoromethane (Freon-12): R. R. Sayers, W. P. Yant, John Chornyak, and H. W. Shoaf stated in U. S. Bureau of Mines Report of Investigations No. 3013 "Toxicity of Dichlorodifluoromethane: A New Refrigerant," (May, 1930) that a 12 week daily exposure of animals to 20% by volume of this vapor caused no gross pathology attributable to the exposure. Since generalized tremor and a gait simulating alcoholic ataxia were observed in some of the animals, it is recommended that the maximum exposure be no more than 10% or 100,000 ppm.

1,1-Dichloroethane (Ethylidine Chloride): The value of 100 ppm is set up for this compound as its action is considered by Flury and Zernik, "Schädliche Gase," 1931, to be analogous to chloroform though less severe. The only reported animal experimentations are those by Lazarew and Mueller, who determined narcotic action of concentrations only as low as 7400 ppm and 4400 ppm respectively. Their work is reported in *Arch. exptl. Path. Pharmakol.*, 141, 19 (1924), and 109, 276 (1925), respectively.

1,2-Dichloroethane (Ethylene Dichloride): The value of 100 ppm is recommended by the U. S. Public Health Service as a guide and is generally accepted though there is some indication that somewhat lower concentrations should be used as the maximum allowable limit. Where exposures approach this value, medical observation of workers is recommended.

Dichloroethylene: The value of 100 ppm is suggested as a tentative value but no specific work has been done on prolonged exposure to known concentrations of this material. There has been some suggestion that the unsaturated chlorinated hydrocarbons do not cause liver damage at as low concentrations as do the saturated compounds, but specific information should be developed on this particular unsaturated chlorinated hydrocarbon before the suggested value is increased to possibly 200 ppm.

Dichloroethyl Ether: H. H. Schrenk, F. A. Patty, and W. P. Yant, in Reprint No. 1602 from Public Health Repts., 48, 1389-1398 (November 17, 1933) "Acute Response of Guinea Pigs to Vapors of Dichloroethyl Ether," reported that slight nasal irritation was noted among experimental animals at 35 ppm. It has been generally accepted that where prolonged exposures are contemplated, the exposure should not exceed 15 ppm.

Dichloromethane: L. A. Heppel, P. A. Neal, T. L. Perrin, M. L. Orr, and V. T. Porterfield, in *J. Ind. Hyg. & Tox.*, 26, 8-16 (January, 1944), "Toxicology of Dichloromethane (Methylene Chloride)," concluded that on the basis of animal experimentation the maximum allowable limit be tentatively set at 500 ppm for eight hours daily exposure. Although Henderson and Haggard, in "Noxious Gases," 1943, quote F. Flury in Lehmann and Flury, "Toxicology and Hygiene of Industrial Solvents," (Williams & Wilkins, 1943) that 290 ppm should be a maximum allowable concentration, it is to be noted that the animal experimentation by Heppel, et al., of the U. S. Public Health Service, cited above, showed that even at 5000 parts per million, repeated seven hours exposures, five days a week for six months, caused no evidence of toxic action by rats, rabbits or dogs.

Dichloromonofluoromethane (Freon-21): Shown by the Underwriters' Laboratories Report MH 2630 (1935) and U. S. Bureau of Mines Report R. I. 3185 (1933) to be somewhat more toxic than monofluorotrichloromethane (Freon 11) for which the value of 10,000 ppm is suggested.

1,1-Dichloro-1-nitroethane: Willard Machle, E. W. Scott, J. F. Treon, F. F. Heyroth, and K. V. Kitzmiller, in *J. Ind. Hyg. & Tox.*, 27, 95-102 (April, 1945), "The Physiological Response of Animals to Certain Chlorinated Mononitroparaffins," reported that exposure of animals to 25 ppm was without lethal effect for 204 hours. They observed that the irritation on exposure to this compound was greater than

..t caused by equivalent concentra-..ns of diethyl ether but definitely ..s than that resulting from equiva-..nt exposure to acid gases.

Dichlorotetrafluoroethane (Freon ... A. H. Nuckolls, in Underwriters' ..a ...ories Report MH-2375 (No-..emb... 1923), reported that animals ..owed occasional retching movements ..om which they recovered quickly ..ter two hours' exposure to 2.5% of ..is material, though no pathological ..nditions were found on autopsy after ..e two hours' exposure. There has ..een no published work on prolonged ..xposure.

Dimethylsulfate: Flury and Zernik, ..Schädliche Gase," 1931, reported ..ithout giving specific reference to ..riginal work, that 20 ppm killed ..ats in 11 minutes and that 13 ppm ..aused severe poisoning on 20 minutes' ..xposure. On the basis of these ani-..mal experiments, a value of 1 ppm is ..uggested as the maximum allowable ..oncentration. However, there should ..y all means be close medical super-..ision wherever there may be exposure ..o this dangerous substance.

Difluoromonochloromethane (Freon ..2): Underwriters' Laboratories Re-..ort MH 3134 (1940) concluded that ..his substance is less toxic than Freon ..1 and than carbon dioxide but more ..oxic than Freon 12.

Dimethylaniline: The U. S. Public ..Health Service suggests that this com-..pound is similar to aniline in its ..oxicity.

...otoluene: The toxicity of dini-..rot...ene is considered similar to that ..f TNT for which the U. S. Public ..Health Service suggests 1.5 mgs. per ..ubic meter as a guide.

Dioxane: A. Fairley, E. C. Linton, ..nd A. H. Ford-Moore, in *J. Hyg.*, 34, ..86 (1934), "The Toxicity to Animals ..f 1,4-Dioxan," report kidney and ..ver damage to animals on exposures ..o 100 ppm over periods for the most ..art of 100 to 200 hours' duration. ..ersons who are exposed to dioxane at ..oncentrations approaching that con-..sidered allowable should be under ..medical observation until more data ..re available concerning effects of ..nown concentrations.

Ethyl Acetate: This material is ..mong the lesser toxic of organic sol-..ents but causes irritation of eyes, ..ose and throat to experimental hu-..man subjects at 400 ppm according to ..Nelson, et al., in *J. Ind. Hyg. & Tox.*, ..5, 282 (September, 1943). Atten-..on should be given to complaints at ..xposures even less than this concen-..ration as experimental subjects esti-..ated that the concentration would ..ave to be reduced to 100 ppm to ..e considered satisfactory for eight ..urs' exposure.

Eth... Alcohol: Although as reliable ..n ...rity as Lehmann and Flury, ..T... ...logy and Hygiene of Indus-..rial Solvents," (Williams & Wilkins, ..43) observed, without specific refer-..nce, that 1000 ppm in the air is con-..sidered a dangerous concentration, ..rge numbers of workers in this country have been exposed over long periods of time to concentrations of 1000 ppm with no demonstrable injury to health and with no increase in accident frequency. There is an occasional initial complaint of eye irritation but this is only on very first introduction to the exposure.

Ethyl Benzene: W. P. Yant, H. H. Schrenk, C. P. Waite, and F. A. Patty, in Reprint No. 1379 from Public Health Repts., 45, 1241-1250 (May 30, 1930) "Acute Response of Guinea Pigs to Ethyl Benzene," found no symptoms other than eye and nose irritation on exposures of 1000 ppm for as long as 480 minutes. N. W. Lazarew, in *Arch. exptl. Path. Pharmakol.*, 143, 223 (1929), "On the Toxicity of Vapors of Different Hydrocarbons," reported that ethyl benzene has greater narcotic action than benzene. Ethyl benzene thus compares with toluene in its relation to benzene on high exposure and, from its structural formula, can be expected to correspond to toluene on extended exposure to lower concentrations. A value of 200 ppm is accordingly suggested. Where exposures approach this concentration, there should be medical observation of persons exposed in view of the lack of specific data supporting this value.

Ethyl Bromide: R. R. Sayers, W. P. Yant, B. H. G. Thomas, and L. B. Berger, in Public Health Bulletin No. 185 (March, 1929), "Physiological Response Attending Exposure to Vapors of Methyl Bromide, Methyl Chloride, Ethyl Bromide and Ethyl Chloride," observed that exposures of animals to 1700 ppm for 540 minutes caused no symptoms. In view of the lack of experimental data covering exposure over prolonged periods or quantitative information on exposure of workers, a value of approximately one-quarter of the above concentration or 400 ppm is arbitrarily suggested as a tentative allowable concentration. Where workers may be exposed to concentrations approaching this value, they should be under medical observation.

Ethyl Chloride: Public Health Bulletin No. 185 (March, 1929), cited as reference for "Ethyl Bromide," recommended 20,000 ppm as the maximum amount for long exposures. Following the same arbitrary rule as for ethyl bromide, 5000 ppm is suggested for ethyl chloride. Here again persons who may be regularly exposed to concentrations approaching this value should be under medical observation.

Ethlene Chlorhydrin: Hugh Dierker and Paul G. Brown, in *J. Ind. Hyg. & Tox.*, 26, 277-279 (October, 1944), "Study of a Fatal Case of Ethylene Chlorohydrin Poisoning," found that the victim had been exposed to a concentration of 305 ppm for only two hours. Animal exposure to a concentration of 265 for two hours caused pathological conditions to develop. Until further data on effects of prolonged exposures are available, it is recommended that concentrations not exceed 10 ppm. Particularly in view of the considerable skin absorption of ethylene chlorohydrin, as observed by H. F. Smyth, Jr., and C. P. Carpenter, in *J. Ind. Hyg. & Tox.*, 27, 93 (March, 1945), "Note upon the Toxicity of Ethylene Chlorohydrin by Skin Absorption," workers exposed to this solvent should be under medical observation.

Ethylene Oxide: C. P. Waite, F. A. Patty, and W. P. Yant, in Rept. No. 1401, Pub. Health Repts., 45, 1832-1843 (August 8, 1930), "Acute Response of Guinea Pigs to Ethylene Oxide," found that 250 ppm caused no symptoms on exposure of animals for 480 minutes. With lack of long-time animal experiments and no published data on prolonged exposures of the workers at known concentrations, a value of 100 ppm is arbitrarily suggested. Where workers are exposed to concentrations in the vicinity of this value, they should be under medical observation.

Ethyl Ether: In this country, large numbers of persons are at work in operations involving exposures of 500 to 1000 ppm and as high as 2000-3000 ppm without demonstrable effect on health. Unfortunately there has been no publication correlating prolonged exposures to these concentrations with medical findings—or lack of them. Nelson, et al., in *J. Ind. Hyg. & Tox.*, 25, 282 (1943), reported nasal irritation at 200 ppm to persons under experimental conditions who considered that 300 ppm would be objectionable as a working atmosphere. However, this experimental group had no opportunity for occupational acclimatization. The concentration of 500 ppm is suggested as the maximum allowable, not that appreciably more than this concentration cannot be regularly tolerated without injury to health, but to avoid irritation and complaint.

Ethyl Formate: Flury and Zernik in "Schädliche Gase," 1931, reported that 330 ppm causes slight irritation of the eyes and rapidly increasing nasal irritation. In view of the inadequate data available concerning exposure to this material, there should be medical observation of workers who may be exposed to concentrations in the vicinity of the suggested limit of 200 ppm.

Ethyl Silicate (Tetraethyl ortho-Silicate): J. A. Kasper, C. P. McCord, and W. G. Fredrick, in INDUSTRIAL MEDICINE, 6, 660-664 (1937), "The Toxicity of Organic Silicon Compounds. I. Tetraethyl ortho-Silicate," reported that animals exposed to 164 ppm, eight hours a day for 17 days did not shown weight increases equal to the controls, but mentioned no other indications of injury from this exposure. H. F. Smyth, Jr., and J. Seaton, in *J. Ind. Hyg. & Tox.*, 22, 288-296 (September, 1940) "Acute Response of Guinea Pigs and Rats to Inhalation of the Vapors of Tetraethyl Orthosilicate (Ethyl Silicate)," found that concentrations as low as 245 ppm gave rise to some pathology in animals after several hours exposure. An allowable limit of 100 ppm is suggested for prolonged exposure, but with the lack of industrial experience at known concentrations, any workers subjected to an exposure approaching 100 ppm should be under medical observation.

Formaldehyde: The principal effect of exposure to low concentrations of formaldehyde is irritation, especially in the nose and eyes with lachrymation. E. C. Barnes and H. W. Speicher, in *J. Ind. Hyg. & Tox.*, 24, 10-17 (January, 1942) "The Determination of Formaldehyde in Air," stated that they exposed themselves to 20 ppm for a short length of time. From the discomfort and lachrymation produced, it was their opinion that somewhat lower concentrations would be desirable for continued exposure. It is generally accepted that exposures should not exceed 10 ppm.

Furfural: According to the producer, with reasonably good ventilation, the health hazard presented by the use of furfural is slight under practically all industrial conditions. Over the 20 years of its industrial use, there has not been a single case of injury to health from industrial exposures, its low vapor pressure presumably maintaining atmospheric concentrations at less than injurious levels under normal industrial conditions.

Gasoline: Philip Drinker, C. P. Yaglou, and M. F. Warren, in *J. Ind. Hyg. & Tox.*, 25, 225-232 (June, 1943), "The Threshold Toxicity of Gasoline Vapor," concluded "that 0.1 per cent gave the beginning of real effects in our group." The human subjects used in these experiments complained only of subjective symptoms such as irritation or headache. R. R. Sayers, A. C. Fieldner, W. P. Yant, and B. G. H. Thomas, in "Experimental Studies on the Effect of Ethyl Gasoline," Rept. of the U. S. Bureau of Mines (1927), reported that 0.07 to 0.28% gasoline vapor caused dizziness. The concentration of 500 ppm is suggested as the maximum so that these subjective symptoms may be avoided. Furthermore, present-day gasoline contains varying amounts of aromatic hydrocarbons which tend to increase its toxicity.

Heptane: Since 1000 ppm was shown to cause slight dizziness in the experimentation carried on by the U. S. Bureau of Mines as given in the Report of Investigations No. 2979 (1929), an allowable limit of 500 ppm is suggested. However, exposures somewhat in excess of this concentration are not considered toxic.

Hexane: Philip Drinker, C. P. Yaglou, and M. F. Warren, in *J. Ind. Hyg. & Tox.*, 25, 225-232 (June, 1943) "The Threshold Toxicity of Gasoline Vapor," reported on exposure to a petroleum distillate, 90% of which boiled between 107°F and 260°F, thus including the hexane range. Two groups of persons were exposed to concentrations in one case of 1500 ppm and in the other 1400 ppm. Sickness at the stomach, headache, throat irritation and eye irritation were complained of, but no one considered the exposure disagreeable or felt unwilling to work in such atmosphere. Nelson, et al., in *J. Ind. Hyg. & Tox.*, 25, 282 (1943), exposed a group of persons to 500 ppm of hexane which proved to be quite innocuous. Though higher concentrations were not used, the opinion was that much greater amounts could be tolerated. A maximum allowable concentration of 1000 ppm is accordingly suggested.

Hydrochloric Acid (Hydrogen Chloride): Willard Machle, K. V. Kitzmiller, E. W. Scott, and J. F. Treon, in *J. Ind. Hyg. & Tox.*, 24, 222-225 (October, 1942), "The Effect of the Inhalation of Hydrogen Chloride," concluded on exposure of animals six hours a day, five days a week for four weeks that the upper limit of safety is about 30 ppm though it is possible that even this concentration would be harmful if daily exposures were continued for periods longer than a month. The maximum allowable concentration of 10 ppm is generally accepted.

Hydrogen Cyanide: Reference is made by Flury and Zernik in "Schädliche Gase," 1931, to Lehmann-Hess that 18 to 36 ppm could be tolerated over a six hour period without apparent symptoms. A value of 20 ppm is generally accepted as the maximum allowable concentration.

Hydrogen Fluoride: E. Ronzani, in *Arch.f.Hygiene*, 70, 217-269 (1909), found no injurious action on animals exposed for 30 days to 3 ppm. K. Roholm, in "Fluorine Intoxication. A Clinical, Hygiene Study," (Lewis & Company, London, 1937), and "Fluoride Compounds" Occupation and Health Supplement, International International Labor Office (September, 1938), reported that fluorosis of the bones occurred among cryolite workers after prolonged exposure to 2 to 3 ppm. Three ppm has been generally accepted as a maximum allowable concentration.

Hydrogen Selenide: H. C. Dudley and J. W. Miller, in Reprint No. 1855, from Publ. Health Repts., 52, 1217 (1937), found that animals exposed to six parts per million for 60 minutes all died within 24 days. These workers, in a subsequent study in *J. Ind. Hyg. & Tox.*, 23, 470-477 (1941), "Toxicology of Selenium. VI. Effects of Subacute Exposures to Hydrogen Selenide," reported that death occurred in 50% of animals exposed for eight hours to a concentration of from 0.3 to 1.2 ppm. A concentration of 1.5 ppm was intolerable to man, producing eye and nasal irritation, but .3 ppm caused no such irritation. In view of the great toxicity of this gas, the allowable concentration of 0.1 ppm is suggested with the recommendation that wherever men may be exposed they be under medical observation and information be maintained concerning exposures.

Hydrogen Sulfide: H. L. Barthelemy, in *J. Ind. Hyg. & Tox.*, 21, 141-151 (April, 1939), "Ten Years' Experience with Industrial Hygiene in Connection with the Manufacture of Viscose Rayon," concluded that with hydrogen sulfide at less than 20 ppm no trouble whatsoever was experienced. This value is generally accepted as causing neither poisoning or eye irritation.

Iodine: Henderson and Haggard, "Noxious Gases," 1943, and Flury and Zernik, "Schädliche Gase," 1931, both quote Matt, Dissertation at Wurzburg, 1889, as authority for 0.1 ppm being the concentration at which "work is not disturbed." The infrequent exposure of iodine vapor hardly justifies much research on this material but added data are needed to substantiate this tentative value of 0.1.

Iron Oxide: It has been shown through determination of iron oxide concentrations at many welding operations that the condition is satisfactory where the iron oxide fume is kept below 30 mgs. per cubic meter. Although exposures to iron oxide in excess of this value will not cause poisoning, continued exposure to higher concentrations may produce a chronic bronchitis. This suggested allowable concentration is given by Philip Drinker and A. G. Cranch in "Control of Welding Hazards in Defense Industries," Special Bulletin No. 5, U. S. Division of Labor Standards (1942).

Isophorone: H. F. Smyth, Jr., J. Seaton, and L. Fischer, in *J. Ind. Hyg. & Tox.*, 24, 46-50 (March, 1942), "Response of Guinea Pigs and Rats to Repeated Inhalation of Vapors of Mesityl Oxide and Isophorone," concluded on the basis of animal experimentation of 30 eight-hour exposures that no effect whatever results from exposure of 25 ppm of isophorone.

Lead: The American Public Health Association Committee on Lead Poisoning—R. A. Kehoe, Chairman, J. C. Aub, E. L. Belknap, W. C. Dreessen, G. H. Gehrman, M. H. Kronenberg, May R. Mayers, and W. P. Yant—in the 1943 Committee Report "Occupational Lead Exposure and Lead Poisoning" stated that, when the air of workrooms regularly contain no more than 0.15 mgs. per cubic meter, cases of disabling lead intoxication do not occur and cases of questionable or mild intoxication are rare. This conclusion is based on such extensive studies as those by the U. S. Public Health Service in storage battery plants as reported by A. E. Russell, R. R. Jones, J. J. Bloomfield, R. H. Britten, and L. R. Thompson in Public Health Bulletin No. 205 (1933), and by W. C. Dreessen, T. I. Edwards, W. H. Reinhart, R. T. Page, S. H. Webster, D. W. Armstrong and R. R. Sayers, Public Health Bulletin No. 262 (1941).

Manganese: R. H. Flinn, P. A. Neal, W. H. Reinhart, J. M. Dallavalle, W. B. Fulton, and A. E. Dooley, in Public Health Bulletin No. 247 (1940) "Chronic Manganese Poisoning in an

Ore-Crushing Mill," showed that workers exposed to less than 30 mgs. per cubic meter of manganese developed no symptoms of poisoning but that workers exposed to more than 90 mgs. per cubic meter were found to h- the disease. Since only a small -r of men with limited exposure wer .cluded in the study, and as the exposure could be readily reduced to mgs. per cubic meter, the U. S. Public Health Service has recommended, in National Institute of Health Bulletin No. 182 (1943), "Industrial Manganese Poisoning" by L. T. Fairhall and P. A. Neal, that the maximum allowable concentration be tentatively placed at 6 mgs. per cubic meter.

Magnesium: Philip Drinker, R. M. Thomson, and J. L. Flinn, in *J. Ind. Hyg.*, 9, 187 (1927), "Metal Fume Fever. III. The Effects of Inhaling Magnesium Oxide Fume," reported on experimental production of metal fume fever from excessive inhalation of this fume. It was considered that exposure to less than 16 mgs. per cubic meter will cause no such manifestation.

Mercury: P. A. Neal, R. H. Flinn, T. I. Edwards, W. H. Reinhart, J. W. Hough, J. M. Dallavalle, H. Goldman, W. Armstrong, A. S. Gray, A. L. Coleman, B. F. Postman, Pub. Health Bull. No. 263 (1941), "Mercurialism and Its Control in the Felt Hat Industry," found on the basis of examination of 534 hatters in five representative felt hat factories that no injury to health occurred where the exposure was less tha- 1 mg. per cubic meter.

-yl Oxide: H. F. Smyth, Jr., J. Seaton and L. Fisher, in *J. Ind. Hyg. & Tox.*, 24, 46-50 (March, 1942), "Response of Guinea Pigs and Rats to Repeated Inhalation of Vapors of Mesityl Oxide and Isophorone," report that no effect whatever was found from 50 ppm of mesityl oxide after -0 eight-hour exposures of all animals.

Methanol: R. R. Sayers, W .P. Yant, . H. Schrenk, J. Chornyak, S. J. -earce. F. A. Patty, and J. G. Linn, in . S. Bureau of Mines Report of -vestigation No. 3617 (1942), "Methanol Poisoning. I. Exposure of Dogs 450-500 ppm Methanol Vapor in -ir," observed no symptoms or un-ual behavior among dogs exposed -ht hours daily seven days a week - 379 days to 450-500 ppm. It is -ordingly considered that 200 ppm -n be accepted as a maximum allow-e concentration.

Methyl Acetate: Although no ani-al experimentation work has been -ported on low concentrations of this -vent, work done by Nelson, et al., *J. Ind. Hyg. & Tox.*, 25, 282 (1943), ethyl, butyl and amyl acetate indi-tes that 100 ppm is the highest con-tration which would be satisfactory eight hour exposure from the -ew of sensory response to the view of the possibility of poi-, -hrough hydrolysis of this ester -hin the body and the consequent -uction of methanol, workers ex-ed to concentrations exceeding the suggested limit should be under medical observation.

Methyl Bromide: D. D. Irish, E. M. Adams, H. C. Spencer, and V. K. Rowe, in *J. Ind. Hyg. & Tox.*, 22, 218-230 (June, 1940), "The Response Attending Exposure of Laboratory Animals to Vapors of Methyl Bromide," reported that six months' exposure of rats, guinea pigs and monkeys to 33 ppm was without gross symptoms or histopathological changes. However, the rabbits developed paralysis on repeated exposures. With concentrations dropped to 17 ppm, no abnormal conditions were noted. R. M. Watrous, in INDUSTRIAL MEDICINE, 11, 575-579 (December, 1942), "Methyl Bromide —Local and Mild Systemic Toxic Effects," discussed an industrial exposure where 90 persons were at work at concentrations generally less than 35 ppm and mild systemic symptoms occurred in 33 of these workers. A maximum allowable limit of 20 ppm is suggested. Workers exposed to or working with methyl bromide should be under medical observation and exposures checked quantitatively.

Methyl Butanone: H. H. Schrenk, W. P. Yant, and F. A. Patty, in Reprint No. 1747 from Pub. Health Repts., 51, 624-631 (May 15, 1936), "Acute Response of Guinea Pigs to Vapors of Hexanone (Methyl Butyl Ketone)," found that animals exposed to 1000 ppm for 810 minutes showed but slight or no symptoms although human beings noted a strong odor and developed moderate eye and nasal irritation at this exposure. Arbitrarily placing the maximum allowable limit for prolonged exposure at less than quarter of the amount suggested for acute response, the maximum allowable concentration of 200 ppm is suggested. Medical observation of workers exposed to vapors at this concentration may result in a more liberal limit.

Methyl Cellosolve: H. W. Werner, J. L. Mitchell, J. W. Miller, and W. F. von Oettingen, in *J. Ind. Hyg. & Tox.*, 25, 409-414 (November 19, 1943), "Effects of Repeated Exposure of Dogs to Monoalkyl Ethylene Glycol Ether Vapors," reported on findings after exposure of seven hours daily, five days a week for 12 weeks to a concentration of 800 parts per million of ethyl cellosolve. Blood changes are recorded at this concentration. L. Greenburg, M. R. Mayers, L. J. Goldwater, W. J. Burke, and S. Moskowitz, in *J. Ind. Hyg. & Tox.*, 20, 134-147 (February, 1938), "Health Hazards in the Manufacture of 'Fused Collars.' I. Exposure to Ethylene Glycol Monomethyl Ether," reported on workrooms concentrations where poisoning occurred. The ventilation was functioning ineffectively following the poisoning cases but was placed in proper condition when atmospheric analyses were made. The methyl cellosolve portion of the combined solvent concentration was then found to be 25 ppm with all windows wide open and 76 ppm with windows partly closed to represent conditions in cold weather. Though it was concluded by these investigators that the concentration should be kept below 25 ppm, it would seem, in view of the more favorable conditions under which the analyses were made, that the maximum allowable concentration of 100 ppm should be permissible. This suggested limit is supported by an unpublished report of tests made by the Chemical Hygiene Fellowship at Mellon Institute, reported in July, 1945.

Methyl Cellosolve Acetate: The maximum allowable concentration of 100 ppm is suggested on the basis of an unpublished report of tests made by the Chemical Hygiene Fellowship at Mellon Institute, reported in July, 1945.

Methyl Chloride: R. R. Sayers, W. P. Yant, B. G. H. Thomas, L. B. Berger, in Pub. Health Bull. No. 185 (1929), "Physiological Response Attending Exposure to Vapors of Methyl Bromide, Methyl Chloride, Ethyl Bromide and Ethyl Chloride," found on exposing animals for a period of 800 minutes that from 500 to 1000 ppm caused slight symptoms after several hours exposure. Arbitrarily taking one-fourth of this value for continued exposure, a maximum allowable concentration of 200 ppm is suggested. Workers exposed to concentrations in this vicinity should be under medical observation.

Methylcyclohexane: J. F. Treon, W. E. Crutchfield, Jr., and K. V. Kitzmiller, in *J. Ind. Hyg. & Tox.*, 25, 323-347 (October, 1943), "The Physiological Response of Animals to Cyclohexane, Methylcyclohexane, and Certain Derivatives of these Compounds," concluded that a maximum safe concentration for prolonged exposure of rabbits lies between 1162 and 2886 ppm. A concentration of 1000 ppm is suggested as a maximum allowable limit but if workers are exposed to such a concentration, medical observation is recommended until data are obtained on effects of human exposure within this range.

Methylcyclohexanol: In the reference cited above for methylcyclohexane, the maximum safe concentration for prolonged exposure of rabbits to methylcyclohexanol was found to be slightly below 145 ppm. One hundred ppm is suggested as allowable, but workers exposed to such a concentration should be under medical observation.

Methylcyclohexanone: The foregoing reference cited for methylcyclohexane is authority for the conclusion that the maximum safe concentration for prolonged exposure of rabbits to methylcyclohexanone lies between 182 and 514 ppm. A maximum allowable concentration of 100 ppm is suggested but here again medical observation is recommended where exposures are of this order.

Methyl Formate: H. H. Schrenk, W. P. Yant, John Chornyak, and F. A. Patty, in Reprint No. 1773 from Publ. Health Reports, 51, 1329-1337 (September 25, 1926), "Acute Response of Guinea Pigs to Vapors of Methyl Formate," concluded that *the maximum* exposure for several hours without serious disturbance lies between 1500 *and 2000 ppm. Reducing this concentration* for acute exposure arbitrarily to one-fourth the value, a maximum allowable *concentration of 400 ppm* is suggested for prolonged exposure. Until information is obtained on re*sponse of humans to exposures of this* order, workers exposed to such concentrations should be under medical observation.

Methyl iso-butanone (Hexone): H. Specht, in Reprint No. 1911 of Pub. Health Reports, 53, 292-300 (February 25, 1938) "Acute Response of Guinea Pigs to Inhalation of Methyl Iso-butyl Ketone," concluded that a concentration below 1000 parts per million is well tolerated by guinea pigs but causes eye and nose irritation in man. Applying the arbitrary rule of reducing this concentration to one-fourth where there is prolonged exposure to the vapor, the maximum allowable limit of 200 ppm is suggested. Until further data are obtained on human response, medical observation is recommended where exposures may be of this order.

Monochlorobenzene: The maximum allowable concentration of 75 ppm is suggested by the U. S. Public Health Service as a guide.

Monofluorotrichloromethane (Freon-11—Carrene No. 2): A. H. Nuckolls, in Underwriters' Laboratories Miscellaneous Hazards Report No. 2375 (November, 1933), found that animals have occasional tremors and retching movements upon two hours' exposure to 2.2 to 2.5% in air. Consequently a maximum allowable limit of 10,000 ppm is suggested for prolonged exposure. In view of the lack of information on prolonged exposures on humans to this refrigerant, there should be medical observation if exposures approach this value.

Mononitrotoluene: The maximum allowable concentration for this compound is considered by the U. S. Public Health Service to be similar to that of nitrobenzene for which a value of 5 ppm is suggested as a guide.

Naphtha (Coal Tar): A maximum allowable concentration of 100 to 200 ppm is suggested, dependent upon the relative proportions of benzene, toluene and xylene present. If the boiling point range of a solvent naphtha obtained from coal tar or from by-product coke distillation includes any appreciable percentage between the boiling point of benzene and toluene, no more than 100 ppm should be permitted; but if the boiling point of the major portion of this naphtha is above that of toluene, then 200 ppm may be considered allowable. References are given under the respective chemical compounds.

Naphtha (Petroleum): A concentration of 500 ppm is suggested on the basis of the discussion and references included under gasoline.

Nitrobenzene: The U. S. Public Health Service suggests a maximum allowable concentration of 5 ppm to serve as a guide. A value of 1 ppm has been used in the past, based presumably on this value as listed without specific reference in Henderson and Haggard, "Noxious Gases," 1927, as a maximum amount that can be inhaled for one hour without serious disturbance.

Nitroethane: Willard Machle, E. W. Scott, and Joseph Treon, *J. Ind. Hyg. & Tox.*, 22, 315-332 (October, 1940), "The Physiological Response of Animals to Some Simple Mononitroparaffins and to Certain Derivatives of These Compounds," exposed animals to concentrations of as low as 1000 ppm and 500 ppm. At the former concentration, death resulted in some of the animals and no fatalities at the latter concentration. Since no data are given as to the possibility of symptoms or of pathology on long exposure of these animals to 500 ppm, a tentative allowable concentration of 200 ppm is suggested. In view of the lack of quantitative data on experience with persons where nitroethane may be present in industrial atmospheres, there should be medical observation of workers exposed to such concentrations.

Nitrogen Oxide: L. W. LaTowsky, E. L. MacQuiddy, and J. P. Tollman, in *J. Ind. Hyg. & Tox.*, 23, 129-133 (April, 1941), "Toxicology of Oxides of Nitrogen. I. Toxic Concentrations," concluded on animal experimentation that the concentration of 30 ppm of NO_2 on three hour exposure produces no immediate or delayed harmful effects on guinea pigs and that a concentration of 55 ppm on two to three hour exposure may or may not produce harmful effects on rats and mice but no effect on rabbits, cats and guinea pigs. This and other recent data support the American Standard of 25 ppm.

Nitroglycerine: The U. S. Public Health Service have found no systemic effects occur even at exposures of 10 ppm, but after absence of exposure for as little as a 40 hour period over a week-end, severe headaches occur on being first exposed to as little as 0.5 ppm for a brief period. Skin absorption is a major source of intake where there is contact with nitroglycerine.

Nitromethane: In the reference quoted for "Nitroethane," Willard Machle, E. W. Scott, and Joseph Treon found that no deaths have occurred on daily six hour exposure for a total of 140 hours to 500 ppm. *A maximum* allowable concentration of 200 ppm is suggested in view of lack of specific data *on effect of nitromethane on per*sons under industrial exposures. Where exposures approach the suggested allowable *concentration*, there should be medical observation of such exposed persons.

Octane: A suggested allowable limit of 500 ppm is based on the U. S. Bureau of Mines Report of Investigations No. 2979 (1929), in which it was stated that 1000 ppm of heptane caused slight dizziness. Octane is considered to be somewhat more narcotic than heptane but to cause substantially the same physiological reaction.

Ozone: C. E. Thorp, in *News Edition*, American Chemical Society, 19, 686-689 (June 25, 1941), "Influence of Nitrogen Oxides on the Toxicity of Ozone," reported that 1 ppm of pure ozone becoming annoying to 25% of exposed persons but even at seven hours a day for five days did not cause irritation of nose or throat. Thorp refers to earlier work in which oxides of nitrogen are presumably contaminating the ozone and headaches and sore throats are produced in two hours to three hours at concentrations of 1.0 ppm.

Pentachloronaphthalene: References on these compounds are given under the heading, "Chloronaphthalenes."

Pentane: U. S. Bureau of Mines Reports of Investigations No. 2979 (1929) reports that 5000 ppm produces no effect after 10 minutes' exposure. Since the allowable concentration of this almost non-toxic hydrocarbon is properly to be based more on sensory response rather than on systemic poisoning, this concentration of 5000 ppm is tentatively suggested as allowable.

Pentanone (Methyl Propanone): W. P. Yant, F. A. Patty, H. H. Schrenk, in Reprint No. 1739, Pub. Health Reports, 51, 392-399 (April 3, 1936), "Acute Response of Guinea Pigs to Vapors of Pentanone (Methylpropylketone)," concluded on exposure of animals for 810 minutes that the maximum amount for several hours with slight or no symptoms is 1500 ppm. This concentration was found to be very irritating to men even for short exposures. A maximum allowable concentration of 400 ppm for prolonged exposure is arbitrarily taken at one-fourth of the suggested limit for several hours exposure. With lack of quantitative information on human subjects at these concentrations, there should be medical observation of workers exposed to vapor in the vicinity of this limit.

Phosgene: U. S. Bureau of Mines, *Technical Paper No. 248 (1921)*, "Gas Masks for Gases Met in Fighting Fires," by A. C. Fieldner, S. H. Katz, and S. P. Kinne, *referred to the* work of the American College Experiment Station, Chemical Warfare Service, as *authority for considering* 1 ppm as the maximum concentration allowable for prolonged exposure. Flury and *Zernik*, "*Schädliche Gase,*" 1931, gave in a table without specific reference to original work that the perceptible concentration was between 1.4 and 2.8 ppm.

Phosphorus Trichloride: Butjag, in *Arch. f. Hyg.*, 49, 307 (1904), reported on the basis of animal experimentation that 0.7 ppm caused only slight irritation.

iso-Propanol (iso-Propyl alcohol): Although brief exposures to animals have been conducted at high concentions, there has been no toxicoical work done on low exposures r prolonged periods of time. Nelson, al, in *J. Ind. Hyg. & Tox.*, 25, 282, ber, 1943), reported that mild of the eyes, nose and throat s caused at 400 ppm among human jects experimentally but that even 500 ppm the effects were not severe ugh the majority declare the atmosre unsuitable. Iso-propyl alcohol is newhat more toxic than ethyl alco- but it is believed that no difficulty uld be experienced at concentrans of 400 ppm. Workers exposed to centrations approaching this value uld be under medical observation.

Propyl Acetate: A maximum allowle concentration of 200 ppm is sugsted, not that somewhat higher posures are toxic but to avoid irritan. Although Nelson, et al. in *J. Ind. g. & Tox.*, 25, 282 (1943), did not lude this ester among the solvents which sensory responses were obned, on analogy with ethyl and tyl acetates, it is considered that suggested limit is in order.

Iso-Propyl Ether: Willard Machle, W. Scott, and Joseph Treon, in *Ind. Hyg. & Tox.*, 21, 72-95 (March, 39), "The Physiological Response Isopropyl Ether and to a Mixture Isopropyl Ether and Gasoline," reted on exposure of animals for 20 o-hour and three-hour periods to ncentrations down to 3000 ppm and 00 ppm. No noticeable effect folwed exposure. The toxicity of opropyl ether and gasoline were conlered to be closely parallel on the sis of these animal experimentans. Although it appears possible at exposures may be appreciably eater than the suggested limit bere toxic action occurs, any increase this value should be based on antitative results of exposures to rkers.

Radon (Radium Emanation): An visory committee to the National reau of Standards, composed of F. Curtiss, R. D. Evans, G. Failla, ederick B. Flinn, Harrison S. Martd, J. E. Paul, J. S. Rogers, C. S. ephenson and G. T. Taylor, recomnded in National Bur. of Stand. ndbook H 27 (1941), "Safe Hanng of Radioactive Luminous Comunds," that the radon concentration the atmosphere of workrooms uld not exceed 10^{-11} curie per liter, d that the whole-body exposure of e worker to gamma radiation should t exceed 0.1 roentgen per working y. These figures, noted as being cording to present knowledge" in 41, continue to be accepted in 1945.

Stibine (Hydrogen Antimonide): ck, Guttmann, and Gergell, *Ber. sch. Chem. Ges.*, 37, 893 (1904), re- at 100 parts per million on for 20 minutes causes death ter a few days. The maximum allowle concentration of 10 ppm is tentaely suggested. Wherever there may possibility of exposure to stibine, rkers should be under medical obvation.

Stoddard Solvent: A maximum allowable concentration of 500 ppm is suggested on the basis of the discussion on gasoline. Although the higher boiling constituents which are included in Stoddard Solvent are somewhat more toxic than those included in gasoline, it is believed that exposures could be considerably greater than the suggested concentration without causing toxic effect. The limit is set up largely to avoid subjective symptoms. Nelson, et al., in *J. Ind. Hyg. & Tox.*, 25, 282 (1943), report that experimental human subjects complain of no marked effects of Stoddard Solvent vapor up to 400 ppm and conclude that the exposure can exceed this amount somewhat and still be considered a satisfactory atmosphere.

Styrene Monomer: H. C. Spencer, D. D. Irish, E. M. Adams, and V. K. Rowe, in *J. Ind. Hyg. & Tox.*, 24, 295-301 (1942), "The Response of Laboratory Animals to Monomeric Styrene," concluded on the basis of lack of effect on animals exposed for seven hours a day over a period of six months to 650 ppm that this concentration would probably produce no serious disturbances in man but is definitely irritating to the eyes and nose. It was considered that 400 ppm which Spencer, et al., considered as giving a disagreeable odor but not producing appreciable eye or nose irritation, could be suggested tentatively as a permissible limit for repeated exposures. This has been accepted as an "American War Standard." Experience has already indicated that this concentration causes sufficient irritation under actual working conditions to revise this Standard downward. Until broader experience is available, it is suggested that concentrations be not allowed to exceed half the tentative value of 400 ppm.

Sulfur Chloride: Adler-Herzmark, in *Zentr. Gewerbehyg. u. Unfallverhüt.*, 6, 97 (1929), reported that cats tolerated 12 parts per million for 15 minutes without death. At 48 ppm for 15 minutes, death occurred after several days. A maximum allowable concentration of 1 ppm is suggested as a tentative limit.

Sulfur Dioxide: Fieldner and Katz, in *Eng. & Mining J.*, 107, 693 (1909), considered 10 ppm as the highest concentration tolerable for prolonged exposure. Flury and Zernik in "Schädliche Gase," 1931, include an unidentified reference to Lehmann-Hess in which a concentration of 8 to 12 ppm is suggested as permissible for several hours' exposure.

Sulfuric Acid: The individual susceptibility to irritation by sulphuric acid differs widely among individuals, much higher concentrations being tolerated by workers habitually exposed. Flury and Zernik, "Schädliche Gase," 1931, includes one reference indicating 40 milligrams per cubic meter and even two to three times this concentration as being non-injurious or hardly injurious and another reference indicating that 0.5 to 2 milligrams per cubic meter caused slight trouble with 3 to 4 milligrams per cubic meter causing definite trouble. J. H. Sterner, in INDUSTRIAL MEDICINE, 12, 514-518 (August, 1943), "Determining Margins of Safety—Criteria for Defining a 'Harmful' Exposure," lists 5.0 milligrams per cubic meter in his well considered table of maximum allowable concentrations.

1,1,2,2-Tetrachloroethane: On the basis of severe poisoning of workers in industry resulting in a number of deaths together with animal experimentation showing it to cause narcosis with smaller amounts than are necessary for carbon tetrachloride, a maximum allowable concentration of 10 ppm has been suggested for tetrachloroethane. Such cases are cited by A. Hamilton in "Industrial Toxicology," pp. 212, *et seq.*, Harper and Co., 1934, and more recently by H. A. Coyer in INDUSTRIAL MEDICINE, 13, 230-233 (March, 1944). Medical observation of persons exposed to known concentrations of tetrachloroethane under industrial conditions are necessary to substantiate this tentative maximum allowable concentration.

Tetrachloroethylene: C. P. Carpenter, in *J. Ind. Hyg. & Tox.*, 19, 323-336, (September, 1937), "The Chronic Toxicity of Tetrachloroethylene," reported on animal exposure to low concentrations for periods up to 1200 hours and on exposures of humans to concentrations of 500 ppm and above. No injurious exposure was observed at 70 ppm but at 230 ppm some of the animals showed effects of the solvent on kidneys, spleen and liver though there were no signs of progressive injury to the liver. This author concluded that on the basis of the findings, a concentration somewhere between 100 and 500 ppm is considered safe for daily exposure not in excess of 40 hours a week. Until more evidence is available on human exposures under industrial conditions, workers exposed to concentrations in the vicinity of the suggested allowable limit of 200 ppm should be under medical observation.

Tellurium: H. H. Steinberg, S. C. Massari, A. C. Miner, and R. Rink, in *J. Ind. Hyg. & Tox.*, 24, 183-192 (September, 1942), "Industrial Exposure to Tellurium: Atmospheric Studies and Clinical Evaluation," reported on industrial exposure of workers to tellurium and tellurium oxide fume together with clinical and laboratory findings. At exposures ranging for the most part from 0.01 to 0.1 milligrams per cubic meter, no evidence of tellurium as such was found but a social stigma resulted from the presence of garlic odor of the breath and of the sweat. On the basis of these findings, the maximum allowable concentration of 0.01 milligrams per cubic meter is suggested, not that concentrations 10 times this limit will cause poisoning but to avoid the development of the exceedingly distasteful garlic odor eminated by the exposed person.

Tetryl: The U. S. Public Health Service states, in "Manual of Industrial Hygiene" (W. B. Saunders Company, 1943) that "no specific information is available but 1.5 milligrams per cubic meter is believed to present no health hazard."

Toluene (Toluol): W. F. von Oettingen, P. A. Neal, D. D. Donahue, J. L. Svirbely, H. D. Baernstein, A. R. Monaco, P. J. Valaer, and J. L. Mitchell, in Pub. Health Bull. No. 279, (1942) "The Toxicity and Potential Dangers of Toluene, with Special Reference to Its Maximal Permissible Concentration," concluded that it appears, as far as toxicity is concerned, the maximal permissible concentration for toluene in air for eight hours exposure daily is 200 ppm. Since the exposure causes slight but definite impairment of coordination and reaction time, it was suggested that where the occupation may cause specific accident hazards, this concentration might prove to be too high.

Trichloroethylene: Joseph Seifter, in *J. Ind. Hyg. & Tox.*, 25, 250-252 (September, 1944), "Liver Injury in Dogs Exposed to Trichloroethylene," reported that an exposure of 500 to 750 ppm four to six hours daily, five days a week for eight weeks resulted in liver injury to experimental dogs. There is no published animal experimentation at concentrations lower than this value. It has been rather generally accepted that a concentration of 200 ppm can be tolerated without injury to health. K. M. Morse and Louis Goldberg, in Indust. Hyg. Supplement, INDUSTRIAL MEDICINE, 12, 706-713 (October, 1943), "Chlorinated Solvent Exposures at Degreasing Operations," reported that 18% of some 336 vapor degreasing tanks provided with condensers exposed the operators to more than 200 ppm. Although this paper does not include clinical findings on exposed workers, the fact that no reference is made to cases of poisoning among operators of these tanks would indicate that 200 ppm is not greatly out of line as the maximum allowable concentration. There is evidence, however, that a concentration of this order may cause difficulty among a sufficient number of operators to require that it be reduced. Morse and Goldberg, cited above, report that some men will complain of headaches, nausea and dizziness even at concentrations of 100 ppm. Consequently, it is recommended that, until further clinical evidence is available concerning possible injury at concentrations lower than 200 ppm exposures be not allowed to exceed half the value suggested as the maximum allowable concentration.

Trichloronaphthalene: This compound was discussed under the heading "Chloronaphthalene."

Trinitrotoluene (TNT): The U. S. Public Health Service recommends that 1.5 milligrams per cubic meter be used as a guide. W. F. von Oettingen, D. D. Donahue, R. K. Snyder, and A. R. Monaco in Public Health Bull. No. 285 (1944), "Experimental Studies on the Toxicity and Potential Dangers of Trinitrotoluene (TNT). IV. Toxicity of TNT for Dogs with Inhalation of Its Fumes," stated that an attempt was made to determine the effect of various concentrations of TNT vapor on dogs but it was found very difficult if not impossible to volatilize TNT in sufficient quantities to produce definite systemic and toxic effects on them. Experience has shown that where there is exposure to TNT dust, fume or vapor, workers should be under medical observation.

Toluidine: Henderson and Haggard, "Noxious Gases," 1927, include a table, without specific reference to original work, which states that slight symptoms after several hours exposure are caused by concentrations in the range of 7 to 26 ppm. This same table refers to similar response being caused by a range of 7 to 53 parts per million of anilin. Since a broader experience with aniline indicates that 5 ppm can be considered as a maximum allowable limit, a similar concentration is suggested for toluidine. In view of the lack of specific data on prolonged exposure, persons subjected to toluidine should be under medical observation.

Turpentine: H. F. Smyth and H. F. Smyth, Jr., in *J. Ind. Hyg.*, 10, 261 (1928), "Inhalation Experiments with Lacquer Solvents," found that continued inhalation of 750 ppm caused no injury to experimental animals. K. B. Lehmann, in *Arch. f. Hyg.*, 83 239 (1914), "Comparative Research on the Toxicity of Turpentine," reported that inhalation by himself and his assistant of concentrations of 750 to 1000 ppm for several hours caused eye irritation, headache, dizziness and nausea. Nelson, et al., in *J. Ind. Hyg. & Tox.*, 25, 282 (1943), found eye and nose irritation at 175 ppm and throat irritation at 125 ppm. A maximum allowable concentration of 100 ppm has been suggested not that an appreciably higher concentration will cause poisoning but to avoid irritation.

Vinyl Chloride: F. A. Patty, W. P. Yant, and C. P. Waite, in Reprint No. 1405 from Pub. Health Repts., 45, 1963-1971 (August 22, 1930), "Acute Response of Guinea Pigs to Vapor of Vinyl Chloride," found on exposure of animals to periods as long as 500 minutes that the maximum amount for several hours without serious disturbance was 5000 ppm. Arbitrarily using approximately a fourth of this value as the maximum allowable concentration for prolonged exposure, a value of 100 ppm has been suggested. In view of the lack of animal experimentation over a long period and of industrial exposure to known concentrations, there should be medical observation of exposed workers where concentrations may be in the vicinity of the suggested limit.

X-ray: Although the International X-ray and Radium Protection Commission recommended in 1937 that about 0.2 roentgen per day or one roentgen per week could be tolerated by a person in normal health as published in *Radiology*, 30, 511 (April, 1938), an able and representative committee under the chairmanship of George Singer, National Bureau of Standards, set up the American War Standard of 0.1 roentgen as the permissible daily dose under the American Standards Association procedure, May, 1945. This maximum allowable limit is now generally accepted.

Xylene (Xylol): On the basis of analogy of the action of xylene with that of toluene, a maximum allowable concentration of 200 ppm is suggested. Xylene vapor is somewhat more irritating to the eyes than that of toluene and it is probable that a somewhat lower limit of exposures may be required to permit comfort of the worker.

Zinc: Philip Drinker, R. M. Thomson, and J. L. Finn, in *J. Ind. Hyg. & Tox.*, 9, 331-345 (August, 1927), "Metal Fume Fever: IV. Threshold Doses of Zinc Oxide," found that concentrations of 14 milligrams of zinc oxide per cubic meter (measured as zinc) produced no reaction on the average subject after an exposure of eight hours. They add that if the dosage of zinc oxide is insufficient to cause fever, there is no evidence that daily inhalation of the fumes does chronic damage. D. Mark Hegsted, J. M. McKibbin, and C. K. Drinker, in Supplement No. 179 to Pub. Health Repts., (1945), "The Biological, Hygienic, and Medical Properties of Zinc and Zinc Compounds," include the statement that "15 mg. zinc oxide per cubic meter of air are considered as representing a safe maximum, there being no possibility of harm from prolonged exposure at this level of concentration in the air breathed."

Georgia Section Organized

THE Georgia Section of the American Industrial Hygiene Association was formally organized at a meeting held in Atlanta on June 1, 1945. Attending the meeting were representatives from industry, governmental agencies and professional groups concerned with industrial hygiene in this state. Prior to the meeting, a trip was made through the Marietta Plant of the Bell Aircraft Corporation where the meeting was held.

The following officers were elected: President, N. V. HENDRICKS, Georgia Department of Public Health; Vice-President, R. L. BROWN, M.D., Physician, Bell Aircraft Corporation; Secretary-Treasurer, C. G. BENDER, Bell Aircraft Corporation. L. M. PETRIE, Director of the Industrial Hygiene Division of the Georgia Department of Public Health, introduced the principal speaker of the evening, MAJOR T. R. THOMAS of the United States Public Health Service.