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Monohalomethanes

Methyl Chloride CH_3Cl
Methyl Bromide CH_3Br
Methyl Iodide CH_3I

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

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FOREWORD

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It is recommended that methyl chloride, methyl bromide, and methyl iodide be regarded as potential occupational carcinogens. Additionally, it is recommended that methyl chloride be considered a possible teratogen. These recommendations are based upon animal studies which have demonstrated the carcinogenic potential of these compounds and in the case of methyl chloride, teratogenic effects as well. Consequently, appropriate engineering and work practice controls should be used to reduce worker exposure. The excess risk of cancer to workers or the induction of a teratogenic response in the children of workers exposed to specific airborne concentrations of these compounds has not yet been determined, but the probability of developing these adverse effects would be decreased by reducing exposure.

On the basis of this information, it is recommended that producers and users of methyl chloride, methyl bromide, and methyl iodide disseminate this information to their workers and customers and that professional and trade associations and unions inform their members of the potential hazards of working with these compounds.

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CURRENT INTELLIGENCE BULLETIN #43

MONOHALOMETHANES:

Methyl Chloride, Methyl Bromide, Methyl Iodide

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ABSTRACT

The monohalomethanes (methyl chloride, methyl bromide, and methyl iodide) are alkylating agents and thus have generated concern as to their potential for inducing mutations and cancer. All three compounds were found to be direct-acting mutagens in the Ames assay. In experimental studies in either rats or mice using various routes of administration, these three compounds have also demonstrated the ability to produce cancer. Methyl chloride produced a teratogenic effect (heart defects) in the offspring of pregnant mice exposed by inhalation at 500 and 750 ppm.

Based on these data, the National Institute for Occupational Safety and Health (NIOSH) recommends that methyl chloride, methyl bromide, and methyl iodide be considered as potential occupational carcinogens and that methyl chloride be considered a potential occupational teratogen.

BACKGROUND

Physical and Chemical Properties

The three chemicals addressed in this document are commonly called the monohalogenated derivatives of methane (monohalomethanes): chloromethane, bromomethane, and iodomethane. Fluoromethane is not included since there are no data on the extent of exposure in the workplace and little to no information on toxic effects in animals or humans. These derivatives are represented by the general formula CH_3X, where X represents chlorine, bromine, or iodine. Some of the physical and chemical properties of these compounds are summarized in Table 1. In this document, these compounds are referred to by their common names: methyl chloride, methyl bromide, and methyl iodide.

TABLE 1. CHEMICAL AND PHYSICAL PROPERTIES OF THE MONOHALOMETHANES [1-4]

Chemical Identity	Methyl Chloride	Methyl Bromide	Methyl Iodide
CAS[a] Registry No.	74-87-3	74-83-9	74-88-4
RTECS[b] Accession No.	PA6300000	PA4900000	PA9450000
Empirical Formula	CH_3Cl	CH_3Br	CH_3I
Formula Weight	50.49	94.95	141.95
Physical Form	Gas	Gas	Liquid
Boiling Point, °C	-24.2	3.5	42.5
Freezing Point, °C	-97.7	-93.7	-66.1
Vapor Pressure	5 atm at 22.0°C	2 atm at 23.3°C	0.5 atm at 25.3°C
Color	Colorless	Colorless	Colorless, turns brown when exposed to light
Odor	Faint, sweet odor which is not noticeable at dangerous concentrations	Chloroformlike odor at high concentrations	Pungent
Specific Gravity	0.973 (-10°C)	1.736 (-10°C)	2.279 (20°C)
Flammability	Flammable, forms explosive mixture with air at 8-17%	Nonflammable in air, burns in oxygen	Nonflammable

[a]Chemical Abstract Service
[b]Registry of Toxic Effects of Chemical Substances

Production, Use, and Potential for Occupational Exposure

Commercially, methyl chloride, methyl bromide, and methyl iodide have been used as methylating agents, laboratory reagents, refrigerants, aerosol propellants, pesticides, fumigants, fire-extinguishing agents, anesthetics, degreasers, blowing agents for plastic foams, and chemical intermediates.

Relatively little data concerning environmental concentrations of these monohalomethanes in the workplace have been reported. Because of their high volatility, they are frequently contained in closed systems. Health Hazard Evaluation surveys and other field studies conducted by the National Institute for Occupational Safety and Health (NIOSH) have found that workplace environmental concentrations of these monohalomethanes were generally quite low. Methyl chloride concentrations ranged from not detectable to 300 parts per million (ppm) [5-8]; methyl bromide from not detectable to 30 ppm [9-12]; and methyl iodide from not detectable to 6 ppm [12,13]. Possible exposures during the production of these monohalomethanes may develop from leaks in connecting or flexible joints, pump seals, sight glasses, and quality control sampling sites [14].

Approximately 146,000 U.S. workers are potentially exposed to these monohalomethanes (Table 2). This estimate is based on data collected during the National Occupational Hazard Survey (NOHS) conducted by NIOSH during 1972-1974 [15].

Methyl Chloride

In the United States, methyl chloride is produced primarily by the hydrochlorination of methanol [2,4,16]. Although the primary use of methyl chloride is in the manufacture of silicones, this process is a closed system operation with minimal worker exposure. The manufacture of tetramethyl lead and triptane (2,2,3-trimethyl butane), both antiknock fuel additives [2], is the next largest use of methyl chloride. Other uses of methyl chloride include the production of butyl rubber; di-, tri-, and tetra-halogenated methanes; methyl cellulose; quaternary ammonium compounds; methyl mercaptan; methionine; and fungicides and pesticides (primarily methyl arsenate herbicides) [16]. A former high volume use of methyl chloride as a refrigerant and propellant has declined significantly in recent years with the substitution of chlorofluorinated alkane derivatives (chlorinated fluorocarbons). In 1981, approximately 362 million pounds of methyl chloride were produced in the United States, and domestic consumption is projected to expand by approximately 6.5% per year through the mid-1980's [16]. Approximately 41,000 U.S. workers (Table 2) are potentially exposed to methyl chloride [15].

Methyl Bromide

Methyl bromide is produced by direct bromination of methane and by the hydrobromination of methanol [2]. In the United States, methyl bromide is

TABLE 2. NUMBER OF WORKERS POTENTIALLY EXPOSED TO THE MONOHALOMETHANES BY INDUSTRY [15]

SIC* Code	Description	Number of Workers Potentially Exposed		
		Methyl Chloride	Methyl Bromide	Methyl Iodide
07	Agriculture Services and Hunting	647	5,922	-
13	Oil and Gas Extraction	24	129	-
15	General Building Contractors	1,301	934	-
16	Heavy Construction Contractors	405	-	-
17	Special Trade Contractors	1,143	1,936	-
20	Food and Kindred Products	2,720	4,356	-
21	Tobacco Manufacturers	90	108	-
22	Textile Mill Products	8	237	-
23	Apparel and Other Textile Products	-	52	-
24	Lumber and Wood Products	112	471	-
26	Paper and Allied Products	-	1,270	-
27	Printing and Publishing	212	80	-
28	Chemicals and Allied Products	980	4,859	394
29	Petroleum and Coal Products	16	11	-
30	Rubber and Plastics Products, NEC	-	89	-
31	Leather and Leather Products	85	38	-
33	Primary Metal Industries	1,223	44	-
34	Fabricated Metal Products	238	65	-
35	Machinery, Except Electrical	1,292	357	-
36	Electrical Equipment and Supplies	451	345	-
37	Transportation Equipment	1,660	643	-
38	Instruments and Related Products	453	174	-
39	Miscellaneous Manufacturing Industries	418	34	-
41	Local and Interurban Passenger Transit	73	27	-
44	Water Transportation	93	1,047	-
45	Transportation by Air	1,115	11,496	-
48	Communication	424	-	-
49	Electric, Gas, and Sanitary Service	-	10,069	-
50	Wholesale Trade	486	4,713	-
53	Retail General Merchandise	402	1,356	-
54	Food Stores	-	1,481	-
55	Automotive Dealers & Service Stations	14,734	-	-
58	Eating and Drinking Places	-	17,958	-
65	Real Estate	-	4,665	-
73	Miscellaneous Business Services	8,960	12,600	20
78	Motion Pictures	-	597	-
79	Amusement and Recreation Services	342	4,147	-
80	Medical and Other Health Services	431	12,015	-
89	Miscellaneous Services	-	354	-
	TOTALS	40,538	104,679	414

*Standard Industrial Classification Code

used primarily as a soil and spore fumigant [17]. Methyl bromide is also used as a disinfectant, rodenticide, methylating agent, and wool degreaser and in ionization chambers [2,18,19].

Most of the exposure data available on methyl bromide come as a result of the uses of methyl bromide as an agricultural fumigant. These include use as a nematocide, fungicide, herbicide, and insecticide [17]. Methyl bromide is applied into the soil under plastic sheets or used in space fumigation under tarpaulins. It is also applied to a variety of agricultural commodities in specially designed fumigation chambers. Worker exposure may result from leaks in the plastic sheets or the tarpaulin or from failure to allow adequate time for the methyl bromide to dissipate following fumigation.

In 1979, the latest year for which any production quantities are available, between 60 and 80 million pounds of methyl bromide were domestically produced for use as a pesticide; however, approximately 50% of this amount was exported to other nations [20]. Approximately 105,000 U.S. workers (Table 2) are potentially exposed to methyl bromide [15].

Methyl Iodide

Methyl iodide is produced on a limited commercial scale by any of the following methods: 1) the reaction of methanol and iodine in the presence of phosphorous; 2) the reduction of an aqueous solution of iodine with bisulfate ion to yield hydriodic acid, which reacts with dimethyl sulfate to form methyl iodide; or 3) the reaction of hydrogen gas, elemental iodine, and aqueous methanol [2], which is similar to the production method of methyl chloride and methyl bromide. Methyl iodide is used primarily as a methylating agent [2] with approximately 400 U.S. workers (Table 2) potentially exposed [15].

EXPOSURE STANDARDS AND GUIDES

The current Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL's) (29 CFR 1910.1000) for occupational exposure to these monohalomethanes are as follows [21]:

Methyl Chloride	100 ppm, 8-hr time-weighted average (TWA) concentration
	200 ppm, acceptable ceiling concentration
	300 ppm, acceptable maximum peak for 5 minutes in any 3-hr period above the acceptable ceiling for an 8-hr shift
Methyl Bromide	20 ppm (80 mg/m^3), ceiling concentration; Skin
Methyl Iodide	5 ppm (28 mg/m^3), 8-hr TWA; Skin

The OSHA PEL's for occupational exposure to methyl chloride and methyl iodide are intended to protect against the neurotoxic effects of these compounds. For methyl bromide, the OSHA PEL is intended to protect against the development of pulmonary edema as well as neurotoxic effects. The PEL for methyl chloride is based upon ANSI Z37.18-1969 as developed by the American National Standards Institute (ANSI) [22], while the PEL's for methyl bromide and methyl iodide are based upon the 1968 Threshold Limit Values (TLV®'s) of the American Conference of Governmental Industrial Hygienists (ACGIH) [23]. At the present time, NIOSH has no recommended exposure limit for the monohalomethanes.

ACGIH in its 1984-85 edition of TLV's makes the following recommendations [24]:

Methyl Chloride	50 ppm (105 mg/m^3), 8-hr TWA; 100 ppm (205 mg/m^3), 15-minute TWA Short Term Exposure Limit (STEL)
Methyl Bromide	5 ppm (20 mg/m^3), 8-hr TWA; 15 ppm (60 mg/m^3), 15-minute STEL; Skin
Methyl Iodide	2 ppm (10 mg/m^3), 8-hr TWA; 5 ppm (30 mg/m^3), 15-minute STEL; A2; Skin

The ACGIH has included methyl iodide in its list of suspected carcinogens, designated as Appendix A2 in the TLV listing [24].

The "Skin" notation for methyl bromide and methyl iodide in both the OSHA PEL's and the ACGIH TLV's refers to the potential contribution to the overall exposure by the cutaneous route by either airborne or direct skin contact with the substance.

TOXICITY

Results of Animal Studies

Acute Effects

It has been reported that under similar testing conditions, the acute lethal concentrations capable of killing 50% of rats (LC_{50}) exposed by inhalation for 30 minutes to methyl chloride, methyl bromide, or methyl iodide were 72,000 ppm, 2,800 ppm and 1,750 ppm, respectively [25]. These data suggest that by this route of exposure methyl chloride is 26 times less toxic than methyl bromide and 41 times less toxic than methyl iodide.

Target organs have been reported to be the liver, kidneys, spleen, or brain in mice, rats, and guinea pigs exposed to methyl chloride [26], methyl bromide [27,28], or methyl iodide [29].

Mutagenic Effects

Methyl chloride, methyl bromide, and methyl iodide were mutagenic for Salmonella typhimurium bacterial strains TA1535 and TA100 [30-32]. Because strain TA100 carries the same gene base-pair mutation as strain TA1535 and because both of these strains are sensitive to direct-acting, alkylating agents, a common mode of action for the three methylating agents is implied. An independent analysis of these data indicated that the relative mutagenic potencies of methyl chloride, methyl bromide, and methyl iodide were approximately in the ratios of 1:40:10 [33]. In addition, methyl bromide was found to be mutagenic in Escherichia coli bacteria [34], and methyl iodide was reported to be a direct-acting mutagen for mouse lymphoma L5178Y/TK+/-cells [35].

Carcinogenic and Other Chronic Effects

In a 2-year methyl chloride inhalation study [26], male and female mice were exposed at concentrations of 0, 50, 225, or 1,000 ppm for six hours per day, five days per week. A statistically significant increase in both malignant and nonmalignant renal tumors occurred in only male mice exposed at the 1,000 ppm concentration. These tumors included cortical adenomas and adenocarcinomas, papillary cystadenomas and cystadenocarcinomas, plus tubular cystadenomas. In addition, 1,000 ppm of methyl chloride induced a functional limb muscle impairment and brain lesions in male and female mice, the latter being characterized by degeneration and atrophy of the granular layer of the cerebellum. Also, the male and female mice exposed at 1,000 ppm exhibited atrophy of the spleen.

Rats exposed to methyl chloride under the same experimental conditions, concentrations, and duration did not exhibit induction of cancer or the other lesions observed in the exposed mice [26].

In a 90-day study [36], methyl bromide dissolved in arachis oil was administered by gastric gavage at levels of 0, 0.4, 2, 10, or 50 milligrams of methyl bromide per kilogram of body weight (mg/kg) five days per week to groups of 10 male and 10 female Wistar rats. Squamous cell carcinomas of the forestomach developed in a total of 13 of the 20 male and female rats treated with the 50 mg/kg dose. A dose-related incidence of hyperplasia was also noted in the rats at all levels except at 0 and 0.4 mg/kg [36].

Methyl bromide is currently being studied in two laboratories [37]. The National Institute for Public Health in the Netherlands is exposing rats by inhalation five days per week for their natural lifetimes at concentrations of 0, 3, 30, or 90 ppm. Final necropsies will be completed in 1985. The U.S. National Toxicology Program plans to begin a 2-year carcinogenicity study in late 1984 with mice exposed to methyl bromide [37].

In a study designed to test the carcinogenic potential of methyl iodide in mice susceptible to the induction of lung tumors [38], doses of 0, 0.36, 0.9 or 1.8 mg/kg were administered by intraperitoneal injection (IP) three

days per week for eight weeks. Among the mice given the highest dose (1.8 mg/kg), 9 of 20 animals died. The surviving 11 mice were killed 24 weeks after the first injection. Five of these 11 mice had developed lung tumors (statistically significant at $p<0.05$). Because of the early deaths of 45% of the mice, the experiment may not have demonstrated statistically convincing evidence of the carcinogenicity of methyl iodide.

In another study of methyl iodide [39], groups of 16 and 8 rats were given weekly subcutaneous injections (SC) of 10 mg/kg and 20 mg/kg of body weight, respectively, for approximately one year. Four of the rats in the 10 mg/kg group and two of the rats in the 20 mg/kg group died prematurely of pneumonia. Of the animals that survived, 9 of 12 in the 10 mg/kg group and 6 of 6 in the 20 mg/kg group developed sarcomas at the site of injection. In addition, two sarcomas at distant sites (a paravertebral osteogenic sarcoma and a differentiated sarcoma of the uterus) were identified in the 10 mg/kg group. The authors also reported that multiple metastases were seen in the lungs and lymph nodes. In a second part of this study, 14 rats were administered a single SC injection of 50 mg/kg methyl iodide and were observed for their lifetimes. Four of the rats developed local sarcomas between 446 and 654 days after the administration of the test material; two other rats developed differentiated sarcomas at distant sites (colon and vagina).

Teratogenicity and Reproductive Effects

Methyl chloride was reported to be teratogenic to the offspring of pregnant mice exposed by inhalation at concentrations of 0, 100, 250, 500, 750, or 1,500 ppm on days 6-18 of gestation. Exposure at the 1,500 ppm concentration was terminated early due to morbidity and death of the treated dams. A statistically significant number of fetal heart malformations was observed in the offspring exposed *in utero* at the 500 or 750 ppm concentrations. These malformations consisted of reduction in size or absence of the atrioventricular valves and attendant structures (chordae tendineae and papillary muscles). Exposure concentrations at 250 and 100 ppm were not teratogenic [40,41].

Rats exposed to methyl chloride [40] and rats and rabbits exposed to methyl bromide in another study [42] showed no teratogenic effects. No teratology studies employing methyl iodide were found in the literature reviewed.

In addition to the previously described teratogenic effects, degeneration and atrophy of the seminiferous tubules were induced in male rats exposed by inhalation to methyl chloride at a concentration of 1,000 ppm [26]. These effects were absent in rats exposed at 0, 50, and 225 ppm concentrations. Mice similarly exposed to methyl chloride exhibited no adverse reproductive effects [26].

No studies on reproductive effects from exposure to methyl bromide or methyl iodide have been reported.

Human Health Effects

Most of the available information related to the toxic effects on humans exposed to methyl chloride, methyl bromide, methyl iodide is derived from accidental exposures to relatively high concentrations.

Symptoms of acute exposure to these compounds are relatively similar, consisting of headache, nausea, vomiting, drowsiness, dizziness, giddiness, diarrhea, confusion, ataxia, slurred speech, paralysis, convulsions, delirium, coma, and death [43-47]. The lungs, liver, kidney, and brain appear to be the primary target organs in cases of severe poisoning.

Liquid methyl bromide and methyl iodide have been reported to cause burning and blistering upon contact with the skin [48,49] and conjunctivitis when splashed into the eyes [19].

No human studies to evaluate the possible mutagenic, carcinogenic, or teratogenic effects from exposure to these compounds are currently available.

CONCLUSIONS

The chemicals discussed in this bulletin, methyl chloride, methyl bromide, and methyl iodide, are alkylating agents that have been shown to induce cancer in rats and mice.

The studies which indicated the potential for these compounds to induce cancer in experimental animals are not without their shortcomings. The strains of animals used, the doses and routes selected for administration of the test compounds, and the fact that there was no coordinated study designed to test these compounds as a class impose limitations on the interpretation of the results. However, in NIOSH's judgement the collective data of these studies are sufficient to indicate the potential for carcinogenicity of these substances.

Also, methyl chloride induced degeneration and atrophy of the seminiferous tubules in treated male rats. It has also demonstrated teratogenicity in mice but not rats. No teratogenic effects were found in rats and rabbits exposed to methyl bromide.

RECOMMENDATIONS

There are several classifications for identifying a substance as a carcinogen. Such classifications have been developed by the National Toxicology Program [50], the International Agency for Research on Cancer [51], and OSHA in its "Identification, Classification, and Regulation of Potential Occupational Carcinogens" 29 CFR 1990 [52], also known as "The OSHA Cancer Policy" [53]. NIOSH considers the OSHA classification the most

appropriate for use in identifying potential occupational carcinogens* [54]. All three of the monohalomethanes discussed in this document have been shown to produce malignant neoplasms in experimental studies in either rats or mice. Methyl chloride has been tested in mice and found to be a teratogen. Based on this evidence, NIOSH recommends that methyl chloride, methyl bromide, and methyl iodide be considered as potential occupational carcinogens and that methyl chloride be considered a potential occupational teratogen.

The excess risk of cancer to workers or the induction of a teratogenic response in the children of workers exposed to specific airborne concentrations of these compounds has not yet been determined, but the probability of developing these adverse effects would be decreased by reducing exposure. As prudent public health policy, employers should voluntarily assess the conditions under which workers may be exposed to these monohalomethanes and take all reasonable precautions to reduce exposures to the fullest extent feasible.

NIOSH is particularly concerned that the occupational exposure to methyl bromide may increase as a result of using this compound as a substitute fumigant for the recently restricted use of the fumigant ethylene dibromide (EDB) [55]. Chronic toxicology studies of methyl bromide are currently being conducted [37], and NIOSH recommends that the results of these studies be thoroughly evaluated before significantly expanding the use of methyl bromide.

Guidelines recommended in the Appendix for minimizing worker exposure to these monohalomethanes are general in nature and should be adapted to specific work situations as required.

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*"'Potential occupational carcinogen' means any substance, or combination or mixture of substances, which causes an increased incidence of benign and/or malignant neoplasms, or a substantial decrease in the latency period between exposure and onset of neoplasms in humans or in one or more experimental mammalian species as the result of any oral, respiratory or dermal exposure, or any other exposure which results in the induction of tumors at a site other than the site of administration. This definition also includes any substance which is metabolized into one or more potential occupational carcinogens by mammals" (29 CRF 1990.103).

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APPENDIX

GUIDELINES FOR MINIMIZING WORKER EXPOSURE TO THE MONOHALOMETHANES

It is recommended that methyl chloride, methyl bromide, and methyl iodide be regarded as potential occupational carcinogens and that methyl chloride be considered a potential occupational teratogen. This recommendation is based on the ability of these compounds to induce cancer in experimental animals and the ability of methyl chloride to induce teratogenicity in exposed mice. Consequently, appropriate engineering and work practice controls should be used to reduce worker exposure to the fullest extent feasible. The areas in which these monohalomethanes are produced or used should be restricted to only those workers who are essential to the process or operation. The guidelines and recommendations which follow are general in nature and should be adapted to specific situations as required.

EXPOSURE MONITORING

Initial and periodic worker exposure surveys should be made by qualified industrial hygiene and engineering personnel. These surveys are necessary to determine the extent of worker exposure and to ensure that controls already in place are operational and effective. NIOSH's Occupational Exposure Sampling Strategy Manual may be helpful in developing appropriate strategies to monitor worker exposure to these monohalomethanes [56]. The manual discusses how to determine the need for exposure measurements and to select sampling times.

Worker exposures should be estimated by 8-hour TWA and short-term (15-minute) exposures calculated from personal or breathing zone samples. Short-term samples should be taken during periods of maximum expected exposure by using all available knowledge of the work areas, procedures, and processes. Area and source measurements may be useful in identifying problem areas, processes, and operations.

Detailed descriptions of sampling and analysis techniques for methyl chloride, methyl bromide, and methyl iodide may be found in the NIOSH Manual of Analytical Methods, Second Edition [57].

CONTROLLING WORKER EXPOSURE

Proper maintenance procedures, good housekeeping in the work area, and worker education are all vital aspects of a good control program. Workers should be informed of the materials to which they are exposed, the nature of their hazard, the methods for their control, and appropriate personal hygiene procedures. There are four basic methods of limiting worker

exposure to these monohalomethanes, none of which is a simple industrial hygiene or management decision. Careful planning and thought should be used prior to implementation.

Product Substitution

When feasible, substitution of an alternative material with a lower potential health risk is an important method for reducing exposure. Extreme care must be used when selecting substitutes. Possible health effects from potential exposure to alternatives for these monohalomethanes should be fully evaluated prior to selection.

Contaminant Controls

Engineering controls should be used to eliminate the potential for monohalomethane exposure in the workplace and to prevent fires and explosions. Achieving and maintaining reduced concentrations of airborne monohalomethanes in the workplace depend upon the implementation of engineering control measures, such as properly constructed and maintained closed system operations and ventilation, with appropriate safety designs.

Closed system operations provide the most effective means for minimizing worker exposures to these monohalomethanes. Closed system equipment should be used for manufacturing, storing, and processing these monohalomethanes because of their volatility. Where closed systems cannot be employed or do not effectively control monohalomethane emissions, local exhaust ventilation should be provided to direct vapors and gases away from workers and to prevent the recirculation of contaminated exhaust air. Exhaust ventilation systems for quality control laboratories or laboratories where samples are prepared for analyses should be designed to adequately capture and contain monohalomethane vapors or gases. Special consideration should be given to the releasing of these compounds from pressurized sampling containers. Guidance for designing local exhaust ventilation systems can be found in Recommended Industrial Ventilation Guidelines [58], Industrial Ventilation--A Manual of Recommended Practice [59], and Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z92-1971 [60].

Ventilation equipment should be checked at least every three months to ensure adequate performance. System effectiveness should also be checked when there are any changes in production, process, or control that might result in significant increases in airborne exposure to these monohalomethanes.

Worker Isolation

If feasible, workers may be isolated from direct contact with the work environment by the use of automated equipment operated from a closed control booth or room. The control room should be maintained at a greater air

pressure than that surrounding the process equipment so that air flows out of, rather than into, the room. This type of control will not protect workers who must perform process checks, adjustments, maintenance, assembly-line tasks, and related operations. Therefore, special precautions are often necessary to prevent or limit worker exposure in these situations and frequently involve the use of personal protective equipment.

Personal Protective Equipment

In a liquid state, all of the monohalomethanes discussed in this document may be injurious to both the skin and eyes upon direct contact. Liquefied methyl chloride and bromide are injurious to the skin because of rapid evaporation and the subsequent cooling effect which produces localized "burns" or "frostbite." Liquid methyl bromide has reportedly produced skin lesions and itching after skin contact and has resulted in conjunctivitis when accidentally splashed into the eyes [61]. Other similar cases have been attributed to penetration of clothing by liquid methyl bromide [19,48,62].

In one report on methyl iodide [29], it was noted that a soaked cloth pad applied to the forearm produced severe persistent lesions. These lesions were described as resembling those caused by mustard gas. These reports emphasize the importance of avoiding direct skin or eye contact with any liquid form of these monohalomethanes [29,63]. This may be accomplished through the proper use of monohalomethane-resistant gloves, aprons, boots, or entire worksuits, depending on the nature and extent of the hazard. Faceshields or chemical safety goggles should be used wherever the potential for splashing exists.

The use of respiratory protection requires that a respiratory protection program be instituted which at a minimum meets the requirements of 29 CFR 1910.134 [64]. In addition to selection of respirators approved by the Mine Safety and Health Administration (MSHA) and NIOSH, a complete respiratory protection program should include at least regular training of personnel, maintenance, inspection, quantitative fit testing, and cleaning of equipment. The program should be evaluated regularly.

It must be stressed that the use of respiratory protection is the least preferred method of controlling worker exposures and should not be used as the only means of preventing or minimizing exposures during routine operations. However, NIOSH recognizes that respirators may be required to provide protection under certain situations (e.g., implementation of engineering controls, certain short-duration situations, emergencies, etc.). NIOSH maintains that only the most reliable respirators should be used to protect workers from exposure to workplace carcinogens. Such

respirators consist of supplied-air, full facepiece, positive pressure respirators where odor warning and filter sorbent properties are not considered. Specifically, the following respirators are recommended for those situations.

- A self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode or

- A combination respirator that includes a type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.

MEDICAL SURVEILLANCE

A medical surveillance program should be available that can evaluate both the acute and chronic effects of exposure to these monohalomethanes. The physician responsible should be provided with an estimate of the worker's potential exposure to these monohalomethanes, including any available workplace sampling results and a description of any protective devices or equipment the worker may be required to use. A thorough medical and work history should be taken initially and updated periodically. As part of this medical surveillance program, workers who are or may be exposed to these monohalomethanes should have preplacement and periodic evaluations focusing on a history of previous exposure to these and other toxic agents. The examining physician should direct particular attention to the hepatic, renal, respiratory, and central nervous systems, as these are most likely to be affected by these monohalomethanes.

CUMULATIVE LIST OF NIOSH CURRENT INTELLIGENCE BULLETINS

1.	Chloroprene	- January 20, 1975
2.	Trichloroethylene (TCE)	- June 6, 1975
3.	Ethylene Dibromide (EDB)	- July 7, 1975
4.	Chrome Pigment	- June 24, 1975 - October 7, 1975 - October 8, 1976
5.	Asbestos - Asbestos Exposure during Servicing of Motor Vehicle Brake and Clutch Assemblies	- August 8, 1975
6.	Hexamethylphosphoric Triamide (HMPA)	- October 24, 1975
7.	Polychlorinated Biphenyls (PCB's)	- November 3, 1975 - August 20, 1976
8.	4,4'-Diaminodiphenylmethane (DDM)	- January 30, 1976
9.	Chloroform	- March 15, 1976
10.	Radon Daughters	- May 11, 1976
11.	Dimethylcarbamoyl Chloride (DMCC) Revised	- July 7, 1976
12.	Diethylcarbamoyl Chloride (DECC)	- July 7, 1976
13.	Explosive Azide Hazard	- August 16, 1976
14.	Inorganic Arsenic - Respiratory Protection	- September 27, 1976
15.	Nitrosamines in Cutting Fluids	- October 6, 1976
16.	Metabolic Precursors of a Known Human Carcinogen, Beta-Naphthylamine	- December 17, 1976
17.	2-Nitropropane	- April 25, 1977
18.	Acrylonitrile	- July 1, 1977
19.	2,4-Diaminoanisole in Hair and Fur Dyes	- January 13, 1978
20.	Tetrachloroethylene (Perchloroethylene)	- January 20, 1978
21.	Trimellitic Anhydride (TMA)	- February 3, 1978
22.	Ethylene Thiourea (ETU)	- April 11, 1978
23.	Ethylene Dibromide and Disulfiram Toxic Interaction	- April 11, 1978
24.	Direct Black 38, Direct Blue 6, and Direct Brown 95 Benzidine Derived Dyes	- April 17, 1978
25.	Ethylene Dichloride (1,2-Dichloroethane)	- April 19, 1978
26.	NIAX Catalyst ESN	- May 22, 1978
27.	Chloroethanes - Review of Toxicity	- August 21, 1978
28.	Vinyl Halides - Carcinogenicity	- September 21, 1978
29.	Glycidyl Ethers	- October 12, 1978
30.	Epichlorohydrin	- October 12, 1978
31.	Adverse Health Effects of Smoking and the Occupational Environment	- February 5, 1979
32.	Arsine (Arsenic Hydride) Poisoning in the Workplace	- August 3, 1979
33.	Radiofrequency (RF) Sealers and Heaters: Potential Health Hazards and Their Prevention	- December 4, 1979
34.	Formaldehyde: Evidence of Carcinogenicity	- April 15, 1981

CUMULATIVE LIST OF NIOSH CURRENT INTELLIGENCE BULLETINS (CONTINUED)

35.	Ethylene Oxide (EtO): Evidence of Carcinogenicity	- May 22, 1981
36.	Silica Flour: Silicosis	- June 30, 1981
37.	Ethylene Dibromide (EDB) Revised	- October 26, 1981
38.	Vibration Syndrome	- March 29, 1983
39.	The Glycol Ethers, with Particular Reference to 2-Methoxyethanol and 2-Ethoxyethanol: Evidence of Adverse Reproductive Effects	- May 2, 1983
40.	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD, "Dioxin")	- January 23, 1984
41.	1,3-Butadiene	- February 9, 1984
42.	Cadmium	- September 27, 1984
43.	Monohalomethanes: Methyl Chloride Methyl Bromide Methyl Iodide	- September 27, 1984

NOTE: For the convenience of those who desire a complete series of Current Intelligence Bulletins, #1 through #18 and #19 through #30 have been reprinted as NIOSH publications #78-127 and #79-146, respectively. These publications and single copies of Bulletins #31 and following are available from NIOSH Publications Dissemination, Division of Standards Development and Technology Transfer, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

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