

5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

The major source of BDCM in the environment is formation as a byproduct during chlorination of water, and many people are exposed to low levels of BDCM in their drinking water. Industrial use of BDCM is sufficiently limited that exposures to industrial emissions outside the workplace are not expected to be of general concern. BDCM has been detected in water and soil at some chemical waste sites, and human exposure may potentially occur in such cases.

BDCM is a volatile chemical, so most of the BDCM that is formed in water or released by industry tends to evaporate into air. BDCM does not adsorb strongly to soils or sediments, nor does it tend to bioaccumulate in fish or other animals.

In the atmosphere, BDCM is thought to undergo slow destruction through oxidative pathways, with a half-life of about two to three months. BDCM remaining in soil or water may undergo microbial degradation. However, these fate processes have not been studied in detail.

5.2 RELEASES TO THE ENVIRONMENT

5.2.1 Air

No studies were located regarding industrial release of BDCM into air. Because of the low volume of BDCM currently in use, it is expected that releases from industrial activities are probably small.

5.2.2 Water

The principal source of BDCM in the environment is from chlorination of water. EPA (1980a) estimated that over 800 kkg (1 kkg = 1 metric ton) are produced annually in this way. It is presumed that essentially all of this is ultimately released into the environment, mainly through volatilization. This may occur either indoors (e.g., while showering, washing, cooking, etc.) or outdoors after discharge of the water to the surface.

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Class et al. (1986) observed trace levels (<1 parts per trillion (ppt)) of BDCM and other brominated methanes in seawater and in the air above the ocean at several locations in the Atlantic. The presence of BDCM can be attributed to biosynthesis and release of BDCM by macroalgae (Class et al. 1986; Gschwend et al. 1985). BDCM from this source accounts for less than 1% of the anthropogenic burden of bromomethanes in the atmosphere (Class et al. 1986).

BDCM has been detected in wastewater from a number of industrial discharges and municipal wastewater treatment facilities, usually at concentrations between 1 and 100 µg/L (Staples et al. 1985; Perry et al. 1979; Dunovant et al. 1986). These levels of BDCM are similar to those found in many chlorinated drinking water supplies (see Section 5.4.2, below), and probably most discharges of this sort do not represent a major source of BDCM release to the environment.

5.2.3 Soil

No studies were located regarding release of BDCM to soil.

5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

Because of the relatively high vapor pressure of BDCM (50 mm Hg at 20°C), the principal transport process in the environment is volatilization (Class et al. 1986; Gschwend et al. 1985). Over 99% of all BDCM in the environment is estimated to exist in air (EPA 1980a).

Volatilization from surface waters depends on factors such as turbulence and temperature. The volatilization half-life from rivers and streams has been estimated to range from 33 minutes to 12 days, with a typical half-life of 35 hours (Kaczmar et al. 1984). Volatilization rates from surface soils have not been studied in detail, but Wilson et al. (1981) found that about 50% of BDCM applied to a soil column in the laboratory escaped by volatilization.

BDCM may be removed from air by washout in rainfall (Class et al. 1986), but the average rate of this transport process has not been estimated. It is expected that BDCM removed from air in this way would be largely returned to air through volatilization.

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BDCM is moderately soluble in water (4,500 mg/L), and significant transport of BDCM can occur in water, especially in groundwater where volatilization is restricted. This transport pathway may be important at waste sites or other locations where BDCM spills lead to groundwater contamination.

In soil, the relatively low log octanol-water partition coefficient (K_{ow}) indicates that adsorption is not likely to be a dominant factor, and that BDCM spilled into soil will be relatively mobile and may migrate into groundwater (EPA 1985a; Piet et al. 1981). In support of this, Wilson et al. (1981) found that BDCM was not significantly retarded during percolation through a column of sandy soil.

The moderate solubility and low log K_{ow} indicate that bioaccumulation of BDCM by fish or other aquatic species is likely to be minor, but no estimate of a bioaccumulation factor in aquatic species was located.

5.3.2 Transformation and Degradation

5.3.2.1 Air

Pathways responsible for BDCM destruction in the atmosphere are not well studied, but probably involve oxidative reaction with hydroxyl radicals or singlet oxygen (EPA 1980a; Mabey et al. 1982). Direct photochemical decomposition is not likely to be significant (EPA 1980a). The typical atmospheric lifetime of BDCM has been estimated to be two to three months (EPA 1980a). This relatively persistent tropospheric half-life of BDCM suggests that a small percentage of the BDCM present in air will eventually diffuse into the stratosphere where it will be destroyed by photolysis. In addition, long-range global transport is possible.

5.3.2.2 Water

Hydrolysis of BDCM in aqueous media is very slow, with an estimated rate constant at neutral pH of $5.76 \times 10^{-8} \text{ hr}^{-1}$ (Mabey et al. 1982). This corresponds to a half-life of more than 1,000 years.

Biodegradation in aqueous media may be significant in some cases. For example, Tabak et al. (1981) reported 35% transformation after seven days incubation in a medium inoculated with sewage. Repeated culturing lead to increased losses, indicating gradual adaptation of the degradative microbes.

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Under aquatic conditions where volatilization cannot occur, biodegradation may be the predominant mechanism for degradation of BDCM. Bouwer et al. (1981) and Bouwer and McCarty (1983a) studied the degradation of BDCM under aerobic and anaerobic conditions in both static and continuous flow systems inoculated with mixed methanogenic bacterial cultures from sewage. Degradation was found to be very limited under aerobic conditions, but essentially complete within 2 days under anaerobic conditions. Slow degradation (50% to 70% in 16 weeks) occurred in sterile media, indicating that a chemical mechanism (hypothesized to be reductive dehalogenation) was operative in addition to the rapid microbial degradation. Microbial degradation was also observed under anaerobic conditions in media inoculated with denitrifying bacteria (Bouwer and McCarty 1983b).

5.3.2.3 Soil

Biodegradation of BDCM in soil has not been studied, but studies in aqueous media indicate that biodegradation might occur under anaerobic conditions (Bouwer et al. 1981; Bouwer and McCarty 1983a, 1983b; Tabak et al. 1981). This suggests that, in regions of soil where volatilization is restricted, biodegradation could be a major removal process.

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

5.4.1 Air

Ambient air monitoring data compiled by Brodzinsky and Singh (1983) identified BDCM at four of six sites investigated. Concentrations ranged from 0.76 to 180 ppt, with a mean value of 1.1 ppt. BDCM levels from four sites monitored in California were reported to range from 20 to 100 ppt (Shikiya et al. 1984). BDCM was not detected in a survey of bromine-containing gasses in the atmosphere at the South Pole (Rasmussen and Khalil 1984), although trace levels (1 ppt) were detected in air at several locations in the Atlantic Ocean (Class et al. 1986). This was judged by the authors to be due to releases from macroalgae.

5.4.2 Water

BDCM occurs in water primarily as a by-product of chlorination. Surveys of BDCM levels in chlorinated public drinking water systems across the United States have revealed that BDCM is present in most

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systems at concentrations averaging around 1 to 20 µg/L, but ranging up to 125 µg/L in some cases (Coleman *et al.* 1975; EPA 1979; Furlong and D'itri 1986; Symons *et al.* 1975).

The concentration of BDCM in chlorinated water depends on reaction conditions during the chlorination process. Important parameters include temperature, pH, bromide ion concentration in the source water, fulvic and humic substance concentration in the water, and the chlorination treatment practices (EPA 1985b). The amount of BDCM tends to increase as a function of increasing organic content and bromide ion in the source water (Bellar *et al.* 1974; Arguelli *et al.* 1979). Studies by Brett and Calverly (1979) and Arguelli *et al.* (1979) indicate that BDCM levels increased by 30 to 100% in water system distribution pipes, presumably because formation continues as long as a chlorine residual and organic precursors remain.

BDCM is also formed in chlorinated swimming pools. Beech *et al.* (1980) measured THM levels in several swimming pools in Miami, and found total THM concentrations averaged from 120 to 660 µg/L. In freshwater pools, most of the total THM was chloroform, with BDCM levels ranging from 13 to 34 µg/L. In saltwater pools, bromoform was the principal THM present, and BDCM concentrations were roughly the same as in freshwater pools.

Monitoring studies of groundwater and surface water at chemical waste sites indicate that BDCM is a relatively infrequent contaminant. BDCM was detected at only 4 of 818 sites on the National Priority List (NPL), and at 7% of a number of other sites being investigated under Superfund (CLPSD 1988). The average concentration of BDCM in groundwater at these sites was 30 µg/L. Quantitative data for surface water were not available.

5.4.3 Soil

No studies were located on BDCM levels in ambient soil. Because of its volatility, it is likely that BDCM would be present only at low levels in most soils. BDCM was detected in 2% of soil samples taken near chemical waste sites being investigated under Superfund (CLPSD 1988), but quantitative estimates of soil concentration are not available.

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5.4.4 Other Media

BDCM is not a common contaminant of food, occurring only in trace quantities in some samples. A market basket study of 39 food items detected BDCM in one dairy composite at 1.2 ppb and in butter at 7 ppb (Entz et al. 1982). A study of BDCM in food processing water and processed foods revealed no detectable levels except in ice cream at one processing plant (0.6 to 2.3 ppt) (Uhler and Diachenko 1987). Soft drinks have been found to contain BDCM (Abdel-Rahman 1982; Entz et al. 1982), but usually at concentrations (0.1 to 6 µg/L) below those found in municipal water supplies. Cooking foods in water containing BDCM is unlikely to lead to contamination, since BDCM would rapidly volatilize (Kool et al. 1981).

BDCM is biosynthesized by marine macroalgae, and has been measured in these organisms at 7-22 ng/g dry weight (Gschwend et al. 1985). Whether BDCM enters and accumulates in the food chain from this source appears to be unlikely, but has not been studied.

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The estimated exposure of the general human population to BDCM from drinking water, assuming a median BDCM concentration of 0.014 mg/L and a water intake for an adult of 2.18 L/day, would be 0.03 mg/day (EPA 1980a). Low levels of exposure might also occur by inhalation of BDCM volatilized from chlorinated water (e.g., while showering, cooking, or swimming), or by dermal contact with such water. Based on a chemical structure analogy to chloroform, an estimated dermal exposure to BDCM in a child swimming two hours/day in a saline pool would typically be 0.003 mg/day, with a maximum of 0.04 mg/day (Beech 1980). Higher exposure levels might occur through ingestion of water contaminated with BDCM near a waste site, but available data suggest that this is not a common occurrence.

No studies were located on human exposure levels in the workplace.

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

The environmental medium most likely to be contaminated with BDCM is chlorinated water, so any person with above-average contact with such water could have above-average exposures. This includes individuals who drink very large quantities of water, such as diabetics, workers in hot climates, and so on. It may also include persons with swimming pools or saunas, where exposure could occur by inhalation (especially if the pool

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or sauna is indoors) or by dermal contact. Since BDCM levels depend on the organic content of the source water before chlorination, persons whose water source is high in organics are likely to have finished water with higher-than-average BDCM levels.

People working in chemical plants or laboratories where BDCM is made or used would also have potentially high exposures to the chemical, most likely by inhalation exposure. Persons living near waste sites may have potentially high exposure to BDCM, but this can only be evaluated on a case-by-case basis.

5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of BDCM is available. Where adequate information is not available, ATSDR, in cooperation with the National Toxicology Program (NTP), is required to assure the initiation of a program of research designed to determine these health effects (and techniques for developing methods to determine such health effects). The following discussion highlights the availability, or absence, of exposure and toxicity information applicable to human health assessment. A statement of the relevance of identified data needs is also included. In a separate effort, ATSDR, in collaboration with NTP and EPA, will prioritize data needs across chemicals that have been profiled.

5.7.1 Data Needs

Physical and Chemical Properties. The physical and chemical properties of BDCM have been determined (see Table 3-2), and further studies on these parameters do not appear to be essential.

Environmental Fate. There are very few quantitative data on the environmental fate and transport of BDCM, and most evaluations are based, entirely or in part, on extrapolations from studies of other similar compounds such as chloroform. Consequently, studies to obtain reliable quantitative rate values for the key fate processes of BDCM would be valuable. Of particular importance would be studies on the volatilization of BDCM from chlorinated drinking water, and on the atmospheric reactions of BDCM. Studies of chemical and biological transformation and degradation rates in soil and water under conditions comparable to those around waste sites would also be helpful.

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Exposure Levels in Environmental Media. Data are available on BDCM levels in drinking water and on how these levels depend on water organic content and treatment conditions. Nevertheless, continued monitoring will be valuable in revealing whether changes in drinking water treatment and disinfection procedures are effective in reducing levels of BDCM and other contaminants.

Studies of BDCM levels in air (especially indoor air) in the vicinity of open bodies of chlorinated water would also be helpful. This would include water treatment plants, swimming pools, and perhaps even home bathtubs or showers. In view of the ready volatilization of BDCM from water, airborne levels in such locations might be significant.

Further monitoring of groundwater, soil and ambient air in the vicinity of chemical waste sites is also needed to determine whether emissions of BDCM from such sites adds significantly to total BDCM exposure.

Exposure Levels in Humans. Current data on BDCM levels in air are not adequate to estimate inhalation exposure in ambient air or the workplace. Collection of such information would be helpful in evaluating the relative contribution of this exposure pathway to the total intake of BDCM. Similar data would be useful for airborne levels of BDCM around swimming pools (especially indoor pools). Data on the presence of BDCM in drinking water appears to be adequate for estimating exposure from consumption of water immediately after taking it from the tap. However, it would be helpful to know how rapidly the BDCM would volatilize from a glass of water or from a bathtub full of water, and what concentration would then be in the breathing zone of occupants of the house.

Exposure Registries. No registry exists for humans known to have been exposed to BDCM. Although exposure to BDCM through drinking water is common, a registry of humans exposed in this way is not likely to help identify BDCM-related diseases in humans, since exposure to BDCM in water are usually low and typically involve exposure to other trihalomethanes and many other byproducts of disinfection as well. A registry of individuals exposed to BDCM during manufacture or use of this chemical might be helpful in identifying possible health effects in humans, although the size of the exposed population is believed to be small.

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5.7.2 On-going Studies

No information was located on any on-going studies on the potential for human exposure to BDCM.

As part of the Third National Health and Nutrition Evaluation Survey (NHANES III), the Environmental Health Laboratory Sciences Division of the Center for Environmental Health and Injury Control, Centers for Disease Control, will be analyzing human blood samples for BDCM and other volatile organic compounds. These data will give an indication of the frequency of occurrence and background levels of these compounds in the general population.