Canadian Environmental Protection Act

Priority Substances List
Assessment Report No. 3

Chlorobenzene

Government of Canada / Gouvernement du Canada
Environment Canada / Environnement Canada
Health Canada / Santé Canada

Canada

CANADA'S GREEN PLAN

Canadian Environmental Protection Act

PRIORITY SUBSTANCES LIST
ASSESSMENT REPORT NO. 3

CHLOROBENZENE

Government of Canada
Health and Welfare Canada
Environment Canada

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Overview of Findings

Chlorobenzene (also referred to as monochlorobenzene (MCB), the term most often used by the scientific community and throughout this report) is used in Canada in a variety of ways that lead to the direct (via pesticide application) and indirect (via effluents, emissions, and leachate waters) entry of this substance into the Canadian environment. These releases result in measurable or predicted concentrations of monochlorobenzene in the various media to which humans and other organisms may be exposed, albeit at low levels.

Concentrations predicted in surface water are lower by six orders of magnitude than those which induce adverse effects in the most sensitive aquatic species, the largemouth bass, following long-term exposure. The average level found in a study of raw effluent from selected organic chemical manufacturing facilities is six times lower than this effect level while the highest concentrations recorded in these raw effluent samples were 80 times higher than the level found to be acutely lethal to aquatic invertebrates.

Studies on effects of monochlorobenzene following short- or long-term exposure of wildlife were not identified. However, the effect levels reported in inhalation studies conducted in laboratory animals are considered relevant to wild mammals. The highest measured airborne concentration in Canada to which wild mammals may be exposed is more than five orders of magnitude less than the lowest reported effect level in the longest term inhalation study in laboratory animals.

Because of its short persistence in the atmosphere, and relatively low rate of release, monochlorobenzene is not associated with ozone layer depletion. Also, the magnitude of any potential indirect effects of monochlorobenzene on global warming and photochemical smog formation, although difficult to quantify, is not believed to be significant.

Data on concentrations of monochlorobenzene to which humans are exposed in food are limited, though it is likely that intake from this source is negligible compared to that from air. Based on data on concentrations of monochlorobenzene in air and drinking water, total average daily intakes of monochlorobenzene for various age groups in the general population have been estimated. These estimated intakes are much less than (from approximately 60 to 175 times) the intake to which it is believed that a person can be exposed over a lifetime without deleterious effect (i.e., the Tolerable Daily Intake derived on the basis of the most relevant study in laboratory animals exposed by the most appropriate route).

Based on these considerations, the Ministers of Environment Canada and of Health and Welfare Canada have concluded that concentrations of monochlorobenzene present in the environment do not constitute a danger in Canada to the environment or to the environment on which human life depends or to human life or health. Therefore, monochlorobenzene is not considered to be "toxic" as defined under section 11 of the *Canadian Environmental Protection Act* (CEPA).

1.0 Introduction

CEPA requires the federal Ministers of Environment Canada and of Health and Welfare Canada to prepare and publish a Priority Substances List that identifies substances, including chemicals, groups of chemicals, effluents and wastes which may be harmful to the environment or constitute a danger to human health. The Act also requires both Ministers to assess these substances and determine whether they are "toxic" as interpreted in section 11 of the Act which states:

> "[...] a substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions
>
> > *(a)* having or that may have an immediate or long-term harmful effect on the environment;
> >
> > (*b*) constituting or that may constitute a danger to the environment on which human life depends; or
> >
> > (*c*) constituting or that may constitute a danger in Canada to human life or health."

Substances which are assessed to be "toxic" according to this section may be placed on Schedule I of the Act, and considered for possible development of regulations to control any aspect of their life cycle, from the research and development stage through manufacture, use, storage, transport and ultimate disposal.

The assessment of whether monochlorobenzene is "toxic", as interpreted in CEPA, was based on the determination of whether it **enters** or may enter the Canadian environment in a concentration or quantities or conditions that could lead to **exposure** of humans or other biota to the degree where adverse **effects** could result.

The assessment of whether monochlorobenzene is "toxic" to human health under CEPA, is based principally on documentation prepared by staff of Health and Welfare Canada (HWC) for the International Programme on Chemical Safety (IPCS). Between 1984 and 1987, original data relevant to the assessment of risks to health associated with exposure to the chlorinated benzenes (excluding hexachlorobenzene) were reviewed by staff of Health and Welfare Canada in the preparation of a draft IPCS Environmental Health Criteria Document (EHC). The current assessment has been updated and expanded to emphasize data most relevant to the assessment of the risks associated with exposure of Canadians to monochlorobenzene in the general environment.

In preparation of the World Health Organization (WHO)-IPCS document, a wide variety of scientific databases were searched to update information provided in earlier contractors' reports, including an annotated bibliography on the monochlorobenzenes (excluding hexachlorobenzene) by Peter Strahlendorf (1978), and a criteria document on monochlorobenzenes (including hexachlorobenzene) by Michael Holliday and Associates (1984a; 1984b). Additional information was identified during peer review of the draft Environmental Health Criteria Document by IPCS focal points and a task group of experts which met in June 1990. More recently, in February 1991, a search of Enviroline, Chemical Abstracts, Pollution Abstracts, Environmental Bibliography, IRIS, MEDLINE and BIOSIS databases to identify recent data relevant to assessment in particular, of the risks to Canadians, was conducted

Data relevant to assessment of whether MCB is "toxic" to the environment were identified through the evaluation of existing review documents, supplemented with information from published reference texts and literature identified through on-line searches of commercial databases (ASFA, BIOSIS, CAB Abstracts, Chemical Abstracts, CESARS, CIS, Enviroline, Hazardous Substances Database and IRPTC) conducted in November 1990. Although much of the research on monochlorobenzene has been conducted outside of Canada, data on sources, use patterns, fate and effects of monochlorobenzene on the Canadian environment were emphasized, where available.

Data relevant to assessment of whether MCB is "toxic" to human health obtained after completion of these sections of the report (i.e., May 1991) were not considered for inclusion. Similarly, data relevant to assessment of whether MCB is "toxic" to the environment obtained after February 1992 have not been incorporated.

Although review articles were consulted where considered appropriate, all original studies which form the basis for the determination of "toxic" under CEPA have been critically evaluated by the following staff of the Departments of National Health and Welfare (effects on human health) and of the Environment (effects on the environment):

B. Elliott (Environment Canada)
C. Fortin (Environment Canada)
M. Giddings (Health and Welfare Canada)
K. Lloyd (Environment Canada)
M.E. Meek (Health and Welfare Canada)

In this report, a brief summary of the conclusions which will appear in the *Canada Gazette* is presented. In addition, an extended summary of the technical information which is critical to the assessment, and which is included in greater detail in a Supporting Document, is presented in section 2. The assessment of whether monochlorobenzene is "toxic" under CEPA is presented in section 3.

Sections of the Supporting Document related to the assessment of environmental effects were peer reviewed by a number of experts from Environment Canada and Agriculture Canada and by Dr. Barry Oliver from Zenon Environmental Laboratories (Burnaby, B.C.). The sections related to assessment of effects on human health were approved by the Standards and Guidelines Rulings Committee of the Bureau of Chemical Hazards of Health and Welfare Canada. The Assessment Report was reviewed and approved by Environment Canada/Health and Welfare Canada CEPA Management Committee.

Copies of this Assessment Report and the unpublished Supporting Document are available upon request from:

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2.0 Summary of Critical Supporting Data

2.1 Identity and Physical/Chemical Properties

Monochlorobenzene (CAS No. 108-90-7) is a monocyclic aromatic compound with one hydrogen atom on the benzene ring substituted with one chlorine. It is produced by chlorination of benzene in the liquid phase with a catalyst. Monochlorobenzene is a colourless liquid at ambient temperature with a relatively high vapour pressure (1 573.2 Pa), moderate octanol-water partition coefficient (log 2.8) and moderate to low water solubility (497.9 mg/L @ 25°C). Technical grade monochlorobenzene is typically 99% pure with < 0.05% benzene and < 0.1% dichlorobenzenes as contaminants. Analytical methods used to quantify monochlorobenzene in environmental media include gas chromatography/mass spectrometry with flame ionization or electron capture detection.

2.2 Production and Uses

Based on the results of a survey of commercial uses, monochlorobenzene is not produced in Canada (Camford, 1991). Over the last five years, imports of monochlorobenzene into Canada averaged 63 000 kg/year from sources in the United States, West Germany and the United Kingdom. Canadian demand for monochlorobenzene was reported to have remained steady for the last five years, averaging approximately 60 000 kg/year. For 1990, the latest year for which data were available, the demand was 50 000 kg broken down as follows: 29 000 kg as a carrier in pesticides; 20 000 kg in the formulation of rubber polymers; and 1 000 kg as a carrier for textile dyes. Based on the results of the Camford survey, demand over the next five years is expected to be similar. At the time of writing this report, there was only one pesticide in Canada (under temporary registration) in which monochlorobenzene is used as a carrier solvent.

2.3 Sources and Releases

Based on the quantities of monochlorobenzene reported to be used as a carrier solvent for pesticides, and considering that all the monochlorobenzene used for this purpose is released directly onto soil during application, this represents the largest single source of release of monochlorobenzene to the Canadian environment. Quantitative data on other sources of release in Canada have not been identified; such sources are believed to include effluents from certain organic chemical manufacturing facilities, and leachate from disposal in landfill sites (Camford, 1991; OME, 1992; Jackson *et al*., 1985, 1991; Reinhard *et al*., 1984).

Another potential source identified, but not confirmed in Canada, is emissions from waste incinerators. The formation and emission of monochlorobenzene as a product of incomplete combustion has been documented in pilot- and full-scale tests with hazardous waste incinerators and co-fired boilers in the United States (U.S. EPA, 1991). Monochlorobenzene was one of the most prevalent products of incomplete combustion emitted in at least 75% of all tests, with a geometric mean emission rate of 494.8 µg/min from hazardous waste incinerators. For full-scale boilers, a geometric mean emission rate of 2 732.8 µg/min was reported. Monochlorobenzene is stable at temperatures up to 700°C as a pure compound, and up to 900°C when in a mixture with other chlorinated compounds (Graham *et al*., 1986).

Monochlorobenzene is included in the group of substances termed "Volatile Organic Compounds" (VOCs). Currently, there are initiatives by the Federal and Provincial Governments directed at limiting the release of these substances from industrial and other sources as the means of controlling ground-level ozone (CCME, 1990).

2.4 Environmental Fate and Concentrations

2.4.1 *Fate*

Based on its relatively high vapour pressure and moderate to low water solubility, it is likely that the atmosphere plays an important role in the distribution and ultimate fate of monochlorobenzene (Mackay *et al*., 1979; Mackay and Shiu, 1990; Garrison and Hill, 1972; Callahan *et al*., 1979; Mackay and Yeun, 1983; Thomas, 1982). Once released to the atmosphere, either directly or by volatilization from other media, monochlorobenzene is expected to photooxidize relatively quickly in a reaction with hydroxyl radicals producing phenols and their subsequent degradation products (Atkinson *et al*., 1985). It has been reported that 18.5% of the airborne monochlorobenzene irradiated over a 17-hour period was oxidized by this reaction (Singh *et al*., 1983; Atkinson *et al.*, 1985). The hydroxyl radical consumed by this reaction may impact negatively on the atmospheric fate of a number of greenhouse gases since it represents an important sink for these substances (IPCC, 1990). Photolysis, another prevalent atmospheric process, is considered an unlikely transformation process because monochlorobenzene does not absorb in the range of wavelengths reaching the surface of the earth (Dulin *et al*., 1986).

The bulk of the monochlorobenzene released onto soil during, for example, pesticide application, is expected to volatilize, either directly or subsequently, to the atmosphere. The one monochlorobenzene-containing pesticide under temporary registration in Canada is used on dry bulb onions which are typically grown in rich organic soils (muck soils). No studies have been found concerning the fate of monochlorobenzene in these soils. Based on its organic carbon sorption coefficient (K_{OC} of 389) [Schwarzenbach and Westall, 1981], the soil mobility potential of monochlorobenzene is medium (McCall *et al*., 1981). It was reported that monochlorobenzene volatilizes readily from sandy soil (0.15% organic matter) [Wilson *et al*., 1981].

On the basis of several studies in which the behaviour of monochlorobenzene in the aquatic environment has been examined, it has been concluded that none of microbiological degradation, hydrolysis or photolysis were significant transformation processes (Morrison and Boyd, 1987; Ellington *et al*., 1988; Dulin *et al*., 1986; Lee and Ryan, 1979). Furthermore, monochlorobenzene was not found to bioconcentrate in significant quantities in aquatic biota. Bioconcentration factors of 70 and 50 have been reported for exposure periods of 72 and 24 hours for the golden ide (*Leuciscus idus melanotus*) and the green alga (*Chlorella*) respectively (Freitag *et al*., 1985).

2.4.2 *Concentrations*

The presence of monochlorobenzene in atmospheric samples from urban, suburban and industrial sites across Canada has been confirmed in a recent ongoing monitoring study (Environment Canada, 1991a, unpublished). Mean concentrations of monochlorobenzene in 608 (24-hour) samples of ambient air from 18 sites in five provinces during the period October

1988 through April 1990 ranged from 0.10 to 0.21 µg/m^3; the overall mean value was 0.15 µg/m^3. For the 11 urban and one rural sites included in this program with data for at least 25 days during 1988-89, median concentrations ranged from 0.05 to 0.13 µg/m^3. Daily maximum concentrations ranged from 0.15 to 1.74 µg/m^3 with the higher values recorded at sites having nearby industrial areas. Although data on concentrations of monochlorobenzene found in indoor air in Canada are not available, limited information from other countries indicates that they are similar to those in ambient air (Lebret, 1985; Pellizzari *et al*., 1986).

Monochlorobenzene was not detected (detection limit of 0.5 to 1.0 µg/L) in extensive monitoring of surface and raw drinking water supplies across Canada between May 1984 and October 1988 (Environment Canada, 199lb) nor in two samples of river water in Canada (Oliver and Bothen, 1980). There is evidence that monochlorobenzene may be produced during treatment of raw drinking water supplies by reaction of chlorine (or one of its aqueous species) with organic material (both natural and man-made). Although levels were too low to permit quantification (detection limit of 1.0 µg/L), the frequency of detection of monochlorobenzene was less for samples of raw than for treated water at 30 Canadian water treatment plants (5 and 18%, respectively) [Otson *et al*., 1982a; 1982b]. In treated water samples from 30 water treatment plants across Canada, monochlorobenzene was detected in 16/90 samples; mean concentrations were less than l µg/L, and the maximum value recorded was 5 µg/L (Otson *et al*., 1982b).

In several studies, measurable concentrations of monochlorobenzene have been reported in industrial effluents, and in leachate and ground water near specific sites that received industrial wastes. Monochlorobenzene was detected in samples from effluents being discharged from four organic chemical manufacturing plants near the St. Clair and St. Lawrence Rivers and Lake Ontario monitored between October 1989 and July 1990 (OME, 1992, unpubl.). Concentrations ranged from 0.2 to 50.0 µg/L with a weighted average for all seven sites (N = 68) of 7.4 µg/L. Reinhard *et al*. (1984) reported concentrations of monochlorobenzene in leachate water samples taken in the vicinity of a landfill site in North Bay, Ontario, ranging from 16-33 µg/L. In a study of ground water under another landfill site in Gloucester, Ontario, levels in 530 samples were reported to range from 0.1 to 315 µg/L (Jackson *et al*., 1985; 1991). High concentrations of monochlorobenzene ranging from 280 to 5 310 µg/L were found in samples from six monitoring wells situated within 12 metres of four former wastewater treatment ponds near Elmira, Ontario (CH2M Hill Engineering Ltd., 1991). Disposal of industrial organic wastes near Ville Mercier, Quebec, has resulted in contamination of the surrounding ground water with monochlorobenzene (Pakdel *et al*., in press). Concentrations of monochlorobenzene in 16 samples from sand and gravel and bedrock aquifers at this site ranged from 224 to 1 382 µg/L, and 445 to 1 787 µg/L, respectively. Waste disposal practices ceased in 1980 and 1972 at the Gloucester and Ville Mercier sites, respectively. Waste disposal at the tar pits and lagoons located near Elmira was suspended in 1979 and 1986, respectively. The Gloucester, Ville Mercier and Elmira sites are undergoing or are targeted for remediation.

Monochlorobenzene was not detected in nine sediment samples from Lake Ontario (detection limit of 1.5 µg/g) [Oliver and Bothen, 1982]. Concentrations of monochlorobenzene ranging from 3.4 to 138.1 µg/kg were detected in soil samples collected during sampling for ground water in the wastewater treatment pond area near Elmira, Ontario (CH2M Hill Engineering Ltd., 1991). The highest levels of soil contamination (3.4 to 138.1 µg/kg) of monochlorobenzene occurred approximately five metres from a treatment pond, at depths of 6.1 to 6.7 m at the base of one of the shallow aquifers. Reports of concentrations of monochlorobenzene in biota in Canada were not identified.

In view of the possible relative significance of monochlorobenzene released to the environment resulting from pesticide application to soil, and the lack of field data, concentrations of monochlorobenzene that may occur in the soil, the atmosphere, and other media were predicted based on models developed by Mackay and Shiu (1990). Two scenarios were examined: one in which concentrations of monochlorobenzene in the immediate vicinity of pesticide application (near-field model) were predicted, and the other in which concentrations in the broader region surrounding the treated field (regional model) were estimated. Details including modelling parameters, assumptions and results are presented in the Supporting Document to this report. For the near-field model, the soil concentration following application of the pesticide was predicted to be 5.5 µg/g of soil. Airborne concentrations of monochlorobenzene over the field were predicted to be 1 µg/m^3. For the regional model under worst-case conditions, the following concentrations were also predicted: 8.4 x 10^{-4} µg/m^3 in air, 4.8 x 10^{-5} µg/L in surface water, 0.93 µg/g in soil and 3.0 x 10-^{7} µg/g in sediment. For the air compartment, where comparison can be made, the predicted concentrations are considerably less than those measured during monitoring programs.

Information on concentrations of monochlorobenzene in food has not been identified. Monochlorobenzene has, however, been detected in five of eight samples of human breast milk in the United States, although levels were not quantified (Pellizzari *et al*., 1982).

2.5 Toxicokinetics and Metabolism

Monochlorobenzene is readily absorbed through the lungs and gastrointestinal tract. Given its lipophilic nature, it is likely that it is also absorbed well through the skin; however, quantitative data on uptake are not available for any of these routes of exposure. Once absorbed, monochlorobenzene is rapidly distributed to many tissues with concentrations being greatest in adipose tissue. It is primarily metabolized by oxidative reactions involving the mixed-function oxidase mediated enzymes to ortho-, meta- or parachlorophenols, the glutathione, glucuronic acid or sulphate conjugates of which are excreted in the urine (Selander *et al*., 1975; Smith-Lindsay *et al*., 1972; Yoshida and Hara, 1985). Reactive intermediates of the metabolism of monochlorobenzene, possibly arene oxides and chlorophenols, can bind to cellular proteins; binding of these metabolites appears to be correlated with necrotic pathological damage in the kidneys and liver of rodents (U.S. EPA, 1985).

2.6 Mammalian Toxicology

Monochlorobenzene is acutely toxic following administration by all routes of exposure examined to date (i.e., dermal, oral, intraperitoneal). Acute exposure to monochlorobenzene by inhalation causes sensory irritation of the respiratory system after several minutes; prolonged exposure (several minutes to several hours) causes narcosis and central nervous system depression which can be lethal. Lethal concentrations which killed 50% of the animals (LC_{50}s) in male rats and female mice have been reported to be 13 490 and 8 581 mg/m^3, respectively (Bonnet *et al*., 1979; 1982). Lethal doses which killed 50% of the animals (LD_{50}s) for ingestion (gavage in corn oil) were approximately 4 000 mg/kg in rats (both sexes); mice were more sensitive, with 100% lethality above 1 000 mg/kg and 2 000 mg/kg for males and females, respectively (NTP, 1983; KIuwe *et al*., 1985). Systemic effects following acute or short-term exposure include damage to the liver and kidneys, and effects on bile and pancreatic flow.

In subchronic studies, administration of MCB by inhalation or ingestion to rats, mice, rabbits and dogs has caused reductions in both body weight gain and survival at high doses, and hepatic and renal toxicity, as indicated by increases in serum enzymes, liver and kidney weights, histopathological changes and necrosis (Dilley, 1977; Irish, 1963; NTP, 1983; Knapp *et al*, 1971). At high doses, depression of bone marrow activity in mice (Zub, 1978) and myeloid depletion of the thymus, spleen or bone marrow in rats and mice (NTP, 1983) have also been observed. In subchronic inhalation studies in which analyses of at least body weight gain, survival, clinical signs of toxicity, clinical chemistry, haematology and histopathology of major organs and tissues have been conducted, no-observed-effect-levels (NOELs) were approximately 1 000 to 2 000 mg/m^3 in rats (Irish, 1963). For ingestion, no-observed-effect-levels were 50 to 125 mg/kg in rats, and 125 mg/kg in mice (NTP, 1983; KIuwe *et al*., 1985).

The lowest reported effect level in inhalation studies conducted to date was 341 mg/m^3 (a "marginal toxic concentration") which resulted in increased kidney weight and tubular and interstitial lesions in the kidney, lesions in the adrenal cortex, and small changes in red blood cell parameters in male rats exposed for 24 weeks (Dilley *et al*., 1977).

The carcinogenicity of monochlorobenzene has been investigated in only one study, which was conducted by the National Toxicology Program in which groups of male and female rats and female mice (50/group) were administered doses of 0, 60, or 120 mg/kg bw daily by gavage in corn oil, five days per week for 103 weeks. Male mice were administered 0, 30, or 60 mg/kg bw on the same schedule (NTP, 1983; KIuwe *et al*., 1985). There was no convincing evidence in this study of compoundrelated toxicity in either rats or mice. There was a significant increase in hepatic neoplastic nodules noted in the high-dose group of male rats (120 mg/kg bw). The increase was significant in comparison with both concurrent vehicle and pooled controls, and there was a marginally significant dose-response trend. However, there were no hepatocellular carcinomas in exposed male rats, and analysis of combined data on neoplastic nodules and hepatocellular carcinomas reduced the significance of the observed increase in tumour incidence. No other significant increases in tumour incidence were observed in either rats or mice. It was concluded that the study provided some evidence of carcinogenicity in male F344/N rats, but no evidence of carcinogenicity in either female F344/N rats or B6C3F$_1$ mice of either sex. The no-observed-effect-levels in this study were 120 mg/kg/day for female rats and mice and 60 mg/kg/day for male rats and mice. The doses administered in this bioassay were not significantly less than those at which toxic effects were observed in the subchronic studies by the same authors (lowest-observed-adverse-effect-level (LOAEL) = 250 mg/kg/day for 13 weeks), indicating little potential for progressive toxicity with continued monochlorobenzene administration beyond 13 weeks.

Monochlorobenzene has not been teratogenic in rats or rabbits, although slight delays in foetal skeletal development (ossification) have been observed in foetuses of pregnant rats exposed by inhalation to 2 864 mg/m^3, a concentration which was also toxic to the mothers (John *et al*., 1984). In the only reproductive study identified, hepatocellular hypertrophy and renal changes were reported in F_0 and F_1 male rats exposed to 150 ppm (683 mg/m^3). At 450 ppm (2 048 mg/m^3), there was an increase in the incidence of bilateral degeneration of the testicular germinal epithelium of the F_0 adults which was not, however, observed in the F_1 group; its relationship to monochlorobenzene administration is unclear (Nair *et al*., 1987).

Monochlorobenzene has induced chromosomal aberrations in plants and bacteria but not in mammalian systems. Indeed, limited available data indicate that monochlorobenzene has little genotoxic potential.

2.7 Effects on Humans

Available data on the effects of exposure to monochlorobenzene in humans are restricted to case reports, three limited epidemiological studies of occupationally-exposed populations, and a limited clinical investigation of the threshold for effects on the electrical activity in the brain of a very small number of subjects. Although effects on the nervous system, neonatal development and skin have been reported in occupationally-exposed populations, available studies are inadequate for assessing potential risks associated with exposure to monochlorobenzene due to methodological weaknesses such as a lack of documentation of the nature or magnitude of exposure, concomitant exposure to other compounds and, in some cases, lack of control groups.

2.8 Effects on the Environment

The information available on acute and chronic toxicity of monochlorobenzene includes data for a number of trophic levels from bacteria through to fish in the aquatic environment. Information on toxicity to terrestrial species is very limited. Although no data were found on wild mammals, the toxicity of monochlorobenzene to these organisms can be assessed by extrapolation from the results of toxicity studies conducted with laboratory mammals (reported in section 2.6). No data were available on effects on birds or terrestrial plants.

In the following two paragraphs, the results of acute toxicity studies considered representative of data available for different trophic levels are summarized. For the bacteria, *Pseudomonas putida*, a 16-h toxicity threshold for inhibition of cell multiplication was reported by Bringmann and Kuhn (1980) to be 17 mg/L. Calamari *et al*. (1983) reported a 96-h concentration which was effective in inhibiting growth by 50% (EC_{50}) of 12.5. mg/L for growth inhibition in the algae, *Selenastrum capricornutum*. The latter authors also reported a 24-h $1C_{50}$ of 4.3 mg/L for *Daphnia magna*. Other authors reported, also for *Daphnia magna*, 48-h LC_{50}s ranging between 5.8 and 25.8 mg/L (Bobra *et al*., 1985; Hermens *et al*., 1984; Abernathy *et al*., 1986; Gersich *et al*., 1986; Cowgill *et al*., 1985). For the rainbow trout (*Oncorhynchus mykiss*), 96-h LC_{50}s for tests conducted in flow-through systems and with measured concentrations were reported by Dalich *et al*. (1982) and Hodson *et al*. (1984) to be 4.7 and 7.46 mg/L, respectively.

Only one acute toxicity study was found concerning terrestrial organisms. Neuhauser *et al*. (1986) exposed earthworms (*Eisenia fetida*) by contact with filter papers soaked in graduated concentrations of monochlorobenzene and reported, under these conditions, a 24-h LC_{50} of 29 $\mu g/cm^2$. However, the protocol followed for this study does not allow for extrapolation of these results to field conditions.

With respect to longer term studies, two reports were found concerning the toxicity of monochlorobenzene on various species of fish exposed continually, in closed, flow-through systems, from shortly after fertilization of the egg to four days after hatching. The lowest reported LC_{50} for aquatic species was 0.05 mg/L for the largemouth bass (*Micropterus salmoi-des*). The total exposure period averaged seven days (Birge *et al*., 1979). Black *et al*. (1982) reported an LC_{50} of 0.11 mg/L for the same early life stages of rainbow trout (*Oncorhynchus mykiss*), where the total exposure time was approximately 27 days.

In this paragraph, the results of chronic studies conducted with monochlorobenzene on aquatic organisms are summarized. Hermens *et al*. (1984; 1985) reported a 16-day EC_{50} of

1.1 mg/L for sub-lethal reproductive effects for *Daphnia magna*. They also reported for growth reduction in the same species, a 16-day EC_{50} of 3.3 mg/L and a 16-day LC_{50} of 3.9 mg/L. De Wolf *et al*. (1988) reported no-observed-effect-levels for growth and reproductive effects of 0.32 mg/L and 1.0 mg/L, respectively, for *Daphnia magna* that were exposed until the control daphnids had produced four broods. van Leeuwen *et al*. (1990) studied the effects of monochlorobenzene on the growth of the zebra fish (*Brachydanio rerio*). They reported a 28-day no-observed-effect-concentration (NOEC) of 4.8 mg/L.

3.0 Assessment of "Toxic" under CEPA

As described in the Introduction of this report, the following assessment is organized according to the sources of monochlorobenzene, the exposure of humans and other biota, and potential resulting harmful effects.

3.1 Entry

Monochlorobenzene is released directly onto soil during pesticide application, to the general environment via emissions from industrial manufacturing and processing, and in leachate from selected landfill sites. There is also reason to believe that monochlorobenzene is formed and released during incineration of hazardous wastes. Monochlorobenzene has been measured in the atmosphere, in selected industrial effluents, and in ground water and leachate near specific waste disposal sites in Canada. It was also detected in treated drinking water.

3.2 Exposure

Monochlorobenzene was not found in measurable concentrations in Canadian surface waters nor in sediments from the Great Lakes as would be expected due to its physical and chemical properties. Monochlorobenzene was measured in raw effluent from four organic chemical manufacturing plants in Ontario. Concentrations averaged 7.4 µg/L with a reported maximum of 50 µg/L. Monochlorobenzene is not believed to bioaccumulate to any significant extent in biota.

The concentrations of monochlorobenzene in atmospheric samples from across Canada averaged 0.15 $\mu g/m^3$ (range of mean values, 0.10 to 0.21 $\mu g/m^3$) with the highest measured concentration being 1.74 $\mu g/m^3$.

The use of monochlorobenzene as a carrier solvent for pesticides may result in temporarily high concentrations in the top layers of soil as well as in the atmosphere above the treated field. Concentrations following pesticide application were predicted by modelling techniques to be 5.5 µg/g in soil and 1 $\mu g/m^3$ in air above the field. On a regional scale, concentrations were predicted to be under 1 µg/g and 1 x 10^{-3} $\mu g/m^3$ in soil and air, respectively.

Since humans are exposed to monochlorobenzene in all media, total intake has been assessed on a multimedia basis. Although available data on concentrations of monochlorobenzene in environmental media to which the general public is exposed are limited, it is possible to estimate the intake of monochlorobenzene from various sources, with the exception of food (Table 1). However, on the basis of available data on concentrations of the other monochlorobenzenes in food, physical/chemical properties, and limited information on levels of monochlorobenzene in air and drinking water, it is likely that the intake of monochlorobenzene from air is greater than that from food or drinking water. For suckling infants, mothers' milk may also be an important source of exposure, though quantitative data are not available to serve as a basis for estimation of intake via this route. Based on available data, and as indicated in Table 1, it has been estimated that the total daily intake of monochlorobenzene (in air and drinking water) ranges from 0.047 to 0.087 µg/kg bw, 0.102 to 0.142 µg/kg bw, 0.081 to 0.131 µg/kg bw, 0.06 to 0.1 µg/kg bw, and 0.051 to 0.081 µg/kg bw for Canadians aged less than 6 months, 6 months to 4 years, 5 to 11 years, 12 to 19 years, and 20 to 70 years, respec-

tively. These estimated intakes which are expected to be typical for the majority of the general population are based on mean values measured in the general environment. Elevated levels present, for example, in ground water as a result of poor waste disposal practices in isolated cases, were not considered relevant to estimation of exposure for the general population.

Table 1 - Estimated Daily Intake (µg/kg) of MCB by Canadians from Various Sources

Medium	**Estimated Intake (µg/kg-bw/day)**				
	0-0.5 yr[a]	**0.5-4 yr**[b]	**5-11 yr**[c]	**12-19 yr**[d]	**20-70 yr**[e]
Ambient Air[f]	0.03-0.07	0.04-0.08	0.04-0.09	0.04-0.08	0.03-0.06
Drinking Water[g]	<0.017	<0.062	<0.041	<0.020	<0.021
Food	N/A	N/A	N/A	N/A	N/A
Total Intake*	0.047-0.087	0.102-0.142	0.081-0.131	0.06-0.1	0.051-0.081

a Assumed to weigh 6 kg, breathe 2 m^3 of air per day and drink 0.1 L of water per day (Environmental Health Directorate, 1988)

b Assumed to weigh 13 kg, breathe 5 m^3 of air per day and drink 0.8 L of water per day (Environmental Health Directorate, 1988)

c Assumed to weigh 27 kg, breathe 12 m^3 of air per day and drink 1.1 L of water per day (Environmental Health Directorate, 1988)

d Assumed to weigh 55 kg, breathe 21 m^3 of air per day and drink 1.1 L of water per day (Environmental Health Directorate, 1988)

e Assumed to weigh 70 kg, breathe 20 m^3 of air per day and drink 1.5 L of water per day (Environmental Health Directorate, 1988)

f Based on range of mean concentrations reported in a survey of concentrations in ambient air from 18 Canadian sites in five provinces (0.10-0.21 µg/m^3) [Environment Canada, 1991a, unpublished]

g Based on a mean concentration of MCB in drinking water of <1.0 µg/L (Otson *et al*., 1982a; 1982b)

N/A No data available

* Data on concentrations of MCB in indoor air in Canada were not identified; based on information from other countries, concentrations in indoor air appear to be similar to those in ambient air (Lebret, 1985; Pellizzari *et al*., 1986).

3.3 Effects

3.3.1 *Human Health*

Based on the increased incidence of hepatic neoplastic nodules in F344/N male rats observed in the NTP carcinogenesis bioassay (NTP, 1983; Kluwe *et al*., 1985), monochlorobenzene has been classified in Group IIIB - (possibly carcinogenic to man) of the classification scheme developed for use in the derivation of the "Guidelines for Canadian Drinking Water Quality" (Environmental Health Directorate, 1989).

For compounds classified in Group IIIB, a Tolerable Daily Intake (TDI) is derived on the basis of division of the no-or lowest-observed-(adverse)-effect-level (NOAEL) or LO(A)EL observed in an animal species conducted by the most appropriate route of administration by an uncertainty factor that takes into account, where appropriate, the limited evidence of carcinogenicity. Data on concentrations of monochlorobenzene in food and breast milk are not available, and information on levels in drinking water in Canada are sparse. However, on the basis of available data on concentrations of the other monochlorobenzenes in food, physical/ chemical properties, and limited information on levels of monochlorobenzene in air and drinking water, it is likely that for most of the population, the intake of monochlorobenzene from air is greater than that from food or drinking water. Therefore, a TDI based on the results of inhalation studies was derived as follows:

$$\text{TDI} = \frac{341\ \text{mg/m}^3 \times (7/24) \times (5/7) \times 0.144\ \text{m}^3\text{/d}}{5\,000 \times 0.25\ \text{kg}}$$

$$= 0.0081\ \text{mg/kg/d}\ \textbf{(8.1 µg/kg/d)}$$

where:

- 341 mg/m^3 is the lowest reported effect level ("marginal toxic concentration") based on increased kidney weight and tubular and interstitial lesions in the kidney, lesions in the adrenal cortex and small changes in red cell parameters in male rats in the limited available studies (Dilley, 1977);
- 7/24 and 5/7 is the conversion of 7 hours/day, 5 days per week dosing to continuous exposure;
- 0.144 m^3/d is the assumed inhaled air volume of rats (NIOSH, 1985);
- 0.25 kg is the assumed body weight of adult rats (NIOSH, 1985);
- 5 000 is the uncertainty factor (x 10 for interspecies variation; x 10 for intraspecies variation; x 10 for less-than-chronic and limited study; x 5 for use of a LOAEL rather than a NOAEL, though effects at the LOAEL were considered to be only marginally adverse).

Owing to limitations of the critical study on which this TDI is based, a TDI was also derived based on the more extensive long-term NTP study conducted by the oral route, as follows:

$$\text{TDI} = \frac{60\ \text{mg/kg bw/d} \times 5}{500 \times 7} \approx 0.086\ \text{mg/kg bw/d}\ (86\ \mu\text{g/kg bw/d})$$

where:

- 60 mg/kg bw/d is the lowest NOEL or NOAEL (male rats and mice) in the only chronic and/or carcinogenesis bioassay (NTP, 1983; Kluwe *et al*., 1985);

- 5/7 is the conversion of 5 days per week of dosing to 7 days per week;
- 500 is the uncertainty factor (x 10 for interspecies variation; x 10 for intraspecies variation; x 5 for limited evidence of carcinogenicity - i.e., the increase in hepatic neoplastic nodules in male rats in the NTP carcinogenesis bioassay).

This value is less conservative than that derived above on the basis of studies conducted by the most relevant route of exposure (i.e., inhalation).

3.3.2 *Environment*

For aquatic biota, the most sensitive organism identified was the early stages of the largemouth bass (*Micropterus salmoides*). The reported LC_{50} was 0.05 mg/L for this species following an exposure period of approximately 7 days. The lowest LC_{50} reported for acute toxicity of monochlorobenzene was 4.1 mg/L for *Daphnia magna*.

Neither acute nor chronic studies were found for wildlife. However, the effect levels reported in inhalation studies conducted in laboratory animals are considered relevant to wild mammals. The lowest reported effect level in the longest term inhalation study conducted to date was 341 mg/m^3 which resulted in increased kidney weight and tubular and interstitial lesions in the kidney, lesions in the adrenal cortex, and small changes in red blood cell parameters in male rats exposed for 24 weeks (Dilley *et al*., 1977).

3.4 Conclusions

Monochlorobenzene is used in Canada in a variety of applications that lead to the direct (pesticides) and indirect (via effluents, emissions, and leachate waters) entry of this substance into the Canadian environment. These releases result in measurable or predictable concentrations of monochlorobenzene in the various media to which humans and other organisms may be exposed, albeit at low levels.

3.4.1 *Paragraph 11(a) - Effects on the Environment*

The LC_{50} (0.05 mg/L) for the most sensitive aquatic species, the largemouth bass (*Micropterus salmoides*), under chronic exposure conditions, is higher than concentrations predicted by computer modelling in surface water by six orders of magnitude. It is also six times higher than the average concentration found in raw effluent from organic chemical manufacturing facilities. The lowest acute IC_{50} (4.3 mg/L for *Daphnia magna*) is 80 times higher than the highest reported concentration in the same raw effluent.

The lowest reported effect level in the longest term inhalation study conducted to date in laboratory animals was 341 mg/m^3. This value is more than five orders of magnitude higher than the highest measured concentration (1.74 $\mu g/m^3$) and more than six orders of magnitude greater than mean concentrations (0.15 $\mu g/m^3$) reported in the atmosphere in Canada to which wild mammals may be exposed.

Therefore, on the basis of available data, monochlorobenzene is not considered to be "toxic" as interpreted under paragraph 11(*a*) of the *Canadian Environmental Protection Act*.

3.4.2 *Paragraph 11(b) -- Effects on the Environment on which Human Life Depends*

Because of its short persistence in the atmosphere, and relatively low levels of release, monochlorobenzene cannot be associated with ozone layer depletion. Similarly, the magnitude of potential effects on global warming and photochemical smog formation, although difficult to quantify, is not believed to be significant.

Therefore, on the basis of available data, monochlorobenzene is not considered to be "toxic" as interpreted under paragraph 11(*b*) of the *Canadian Environmental Protection Act*.

3.4.3 *Paragraph 11(c) -- Effects on the Human Life or Health*

Based on the limited available data, total estimated average daily intakes of monochlorobenzene for various age groups in the Canadian population range from 0.047 to 0.142 µg/kg bw (Table 1). These estimated average daily intakes are considerably less (from about 60 to 170 times) than the most conservative TDI derived above on the basis of the results of studies by the most appropriate route of exposure (inhalation, 8.1 µg/kg bw).

Therefore, on the basis of available data, monochlorobenzene is not considered to be "toxic" as interpreted under paragraph 11(*c*) of the *Canadian Environmental Protection Act*.

3.4.4 *General Conclusions*

Therefore, on the basis of available data, monochlorobenzene is not considered to be "toxic" as interpreted under paragraphs 11(*a*), (*b*) and (*c*) of the *Canadian Environmental Protection Act*.

4.0 Recommendations for Research

1. To permit a more complete assessment of exposure of the Canadian population to monochlorobenzene, additional monitoring data are desirable, particularly for food and breast milk, though the priority for this research is considered to be low.

2. In one study, monochlorobenzene was toxic to earthworms, though these results could not be extrapolated to predicted field conditions for MCB used in pesticides. Data on the fate and toxicity of MCB in soil as a result of this use are, therefore, desirable; however, the priority for this research is considered to be low.

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