Canadian Environmental Protection Act

Priority Substances List
Assessment Report

Trichlorobenzenes

Government of Canada
Environment Canada
Health Canada

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Table of Contents

Synopsis

Trichlorobenzenes (of which there are 3 isomers, 1,2,4-, 1,2,3- and 1,3,5-trichlorobenzene) are not produced in Canada. Approximately 50 tonnes of these substances are imported each year into Canada for use primarily as chemical intermediates and industrial solvents. Substantial quantities are also present in some electrical transformers and capacitors as a result of their past use in dielectric fluids. Trichlorobenzenes have been detected frequently in samples of Canadian surface water, sediment and biota collected in the Great Lakes region. They have been found less often in samples of ambient air, ground water and soil. Trichlorobenzenes are not persistent in air or surface water but are slowly biodegraded in soil and persist under anaerobic conditions in sediment.

The maximum concentration of trichlorobenzenes (total of all 3 isomers) measured in surface waters in Canada was more than 1 000 times less than the effects threshold estimated for the most sensitive aquatic species identified. The dietary intake estimated for piscivorous mammals is approximately 50 times less than the effects threshold determined for these biota. Suitable data were not identified on the toxicological effects of trichlorobenzenes to benthic organisms, and available data on the concentrations of trichlorobenzenes in Canadian soils were limited. Therefore, it was not possible to conclude whether the presence of these substances could result in harmful effects to sediment- or soil-dwelling biota in Canada.

Trichlorobenzenes are present in low concentrations and have a relatively short half-life in the atmosphere. As such, they are not expected to contribute significantly to the formation of ground-level ozone, global warming or depletion of stratospheric ozone.

Based on data on concentrations of each of the isomers of trichlorobenzene in ambient and indoor air, drinking water and food, the total daily average intakes for various age groups in the general population have been estimated. These average daily intakes are approximately 2 to 23 times less than conservative tolerable daily intakes for each of the isomers derived on the basis of studies in laboratory animals. The tolerable daily intake is the intake to which it is believed that a person can be exposed over a lifetime without deleterious effect.

Based on these considerations, it has been determined that available information is insufficient to conclude whether trichlorobenzenes are entering the environment in quantities or under conditions that may be harmful to the environment. It has been concluded, however, that trichlorobenzenes are not entering the environment in quantities or under conditions that may constitute a danger to the environment on which human life depends, or to human life or health.

1.0 Introduction

The *Canadian Environmental Protection Act* (CEPA) requires the federal Ministers of the Environment and of Health to prepare and publish a Priority Substances List that identifies substances, including chemicals, groups of chemicals, effluents and wastes, that 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 defined 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 assessed as "toxic" according to section 11 may be placed on Schedule I of the Act, and considered for possible development of regulations, guidelines or codes of practice 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 trichlorobenzenes (comprising the isomers 1,2,3-, 1,2,4-, and 1,3,5-trichlorobenzene) are "toxic", as defined under CEPA, was based on the determination of whether it **enters** or is likely to enter the Canadian environment in a concentration or quantities or under conditions that could lead to **exposure** of humans or other biota at levels that could cause adverse **effects**.

The assessment of whether the trichlorobenzenes are "toxic" to human health under CEPA is based principally on documentation prepared by staff of Health Canada 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 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 to trichlorobenzenes in the general environment in Canada. Since there were sufficient

data on each isomer, the potential health effects of each of the isomers have been addressed separately. The large uncertainty factors applied in the development of the tolerable daily intakes are sufficiently conservative to account for potential additive effects of the isomers. Moreover, industrial use is restricted primarily to only one (1,2,4-trichlorobenzene) with concentrations of the others in the environment being quite small.

In preparation of the IPCS document, a wide variety of scientific databases were searched to update information provided in earlier contractors' reports, including an annotated bibliography on the chlorobenzenes (excluding hexachlorobenzene) by Peter Strahlendorf (1978) and a criteria document on chlorobenzenes (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 the trichlorobenzenes are "toxic" to human health obtained after completion of these sections of this report (i.e., May 1992) were not considered for inclusion.

Information considered relevant to the assessment of whether trichlorobenzenes are "toxic" to the environment was identified from on-line searches completed in November 1990 of ASFA, BIOSIS, CAB Abstracts, Chemical Abstracts, Chemical Evaluation Search and Retrieval System (CESARS), CIS, ENVIROLINE, Hazardous Substances and the International Register of Potentially Toxic Chemicals (IRPTC) databases. A summary of information on the environmental toxicity, fate and levels of trichlorobenzenes, prepared under contract by Diane Koniecki (November 1991), was also consulted in the preparation of this report. Information relevant to the assessment of environmental effects obtained after October 1992 was not considered for inclusion.

Although review articles were consulted where considered appropriate, original studies that form the basis for the determination of "toxic" under CEPA were critically evaluated by staff of Health Canada (human exposure and effects on human health) and Environment Canada (entry and environmental exposure and effects). The following officials contributed to preparation of the report:

D. Boersma (Environment Canada)
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L. Shutt (Environment Canada)

W. Dormer and R.G. Liteplo of Health Canada also contributed to the consolidation of the Assessment Report.

In this report, a synopsis that will appear in the *Canada Gazette* is presented. A summary of the technical information that is critical to the assessment, and which is presented in greater detail in unpublished Supporting Documentation, is presented in Section 2.0. The assessment of whether trichlorobenzenes are “toxic” as defined under CEPA is presented in Section 3.0.

As part of the review and approvals process established by Environment Canada, the environmental sections of this Assessment Report were reviewed by B. Betts (Washington State Department of Ecology) and U. Borgmann (Department of Fisheries and Oceans). Sections related to the effects on human health were approved by the Standards and Guidelines Rulings Committee of the Bureau of Chemical Hazards of Health Canada. The entire Assessment Report was reviewed and approved by the Environment Canada and Health Canada CEPA Management Committee.

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

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2.0 Summary of Information Critical to Assessment of "Toxic"

2.1 Identity, Properties, Production and Uses

The 3 isomers of trichlorobenzene (1,2,4-, 1,2,3- and 1,3,5-trichlorobenzene) [molecular formula, $C_6H_3Cl_3$], are cyclic aromatic hydrocarbons with 3 chlorine atoms substituting for hydrogen atoms in the benzene ring. Wherever possible in this report, information is presented on each of the isomers in the order in which they appear above. Moreover, unless otherwise specified, "trichlorobenzenes" refers to the total of the 3 isomers.

1,2,4-Trichlorobenzene (CAS No. 120-82-1), the most common isomer, is a colourless liquid at ambient temperatures with a melting point of 17°C (Mackay *et al.*, 1992). 1,2,3-Trichlorobenzene (CAS No. 87-61-6) and 1,3,5-trichlorobenzene (CAS No. 108-70-3) are white, crystalline solids with melting points of 64°C and 53°C, respectively (Mackay *et al.*, 1992). Trichlorobenzenes are moderately volatile, with vapour pressures of 61 Pa for 1,2,4-trichlorobenzene, 28 Pa for 1,2,3-trichlorobenzene and 32 Pa for 1,3,5-trichlorobenzene at 25°C (Mackay *et al.*, 1992). Solubilities in water at 25°C are 40 mg/L for 1,2,4-trichlorobenzene, 21 mg/L for 1,2,3-trichlorobenzene and 5.3 mg/L for 1,3,5-trichlorobenzene. Log octanol-water partition coefficients (log K_{ow}'s) for the 3 isomers were reported to range from approximately 3.85 to 4.30 (Mackay *et al.*, 1992). Organic carbon partition coefficients, calculated from log K_{ow} values as suggested by Mackay *et al.* (1992), range from approximately 3 to 5. Sadtler Research Laboratories (1982) reported that trichlorobenzenes absorb infrared radiation, including wavelengths in the 7 to 13 μm region.

Trichlorobenzenes are typically formed by catalytic chlorination of 1,2-, 1,3- and 1,4-dichlorobenzene at 20° to 30°C in the presence of ferric chloride, followed by fractional distillation (U.S. EPA, 1986). Concentrations of trichlorobenzenes in environmental media are normally quantified using gas chromatography combined with, for example, mass spectrometric or electron capture detection (Oliver and Bothen, 1982; U.S. CFR, 1990). Detection limits are normally 0.02 to 0.1 ng/L for water and 0.1 to 1.0 μg/kg for sediment (dry weight [dw]) and biota (wet weight [ww]) [Oliver and Nicol, 1982; Merriman, 1987; Stevens and Neilson, 1989].

Although there are currently no producers of trichlorobenzenes in Canada, an estimated 40 to 50 tonnes per year were imported between 1987 and 1990 (Camford Information Services, 1991). Imports were higher in the 1970s, averaging about 140 tonnes per year from 1976 to 1978 (Statistics Canada, 1978, 1980). At present, about 30 tonnes of trichlorobenzenes are used annually in Canada as solvents in textile manufacturing, and about 15 tonnes are used annually as intermediates in the

production of other chemicals (Camford Information Services, 1991). In the past, trichlorobenzenes were used in combination with polychlorinated biphenyls (PCBs) in dielectric fluids for transformers and capacitors; however, after regulations prohibiting new uses of PCB-containing dielectric fluids were introduced in 1980 (*Canada Gazette*, 1980), this application for trichlorobenzenes declined considerably. Results of a recent survey (Brien, 1993) indicate that small amounts (< 2 tonnes during 1992) of trichlorobenzenes were still used in dielectric fluids for transformer maintenance in Canada. In the United States, trichlorobenzenes are also used as degreasing agents and lubricants (Slimak *et al.*, 1980).

2.2 Entry into the Environment

There are no known natural sources of trichlorobenzenes. Trichlorobenzenes enter soil (primarily as a result of spills of dielectric fluids) and water from discharges of industrial effluents and landfill leachates. Emissions to air result from volatilization following industrial use of trichlorobenzenes as solvents, and from incomplete incineration of trichlorobenzene-containing materials. There is also evidence that trichlorobenzenes may be produced by biodegradation of more highly chlorinated benzenes in anaerobic sediments (Fathepure *et al.*, 1988; Holliger *et al.*, 1992), and by metabolism of the fungicide lindane in roots of treated wheat seedlings (Balba and Saha, 1974).

Based on reported spills and recovery rates of PCB-containing fluids (Menzies, 1992) and the assumption that the unrecovered liquids contained 18.6% of combined trichlorobenzene isomers (NRCC, 1980), it is estimated that as much as 23 tonnes of trichlorobenzenes have been released to soils in various parts of Canada in association with spilled PCBs.

Quantities of trichlorobenzenes released to surface waters in industrial effluents have been estimated for the period 1987 to 1991 under the Ontario Municipal/Industrial Strategy for Abatement (MISA) program. Two isomers (1,2,4- and 1,2,3-trichlorobenzene) were detected in effluent from organic and inorganic chemical manufacturing plants (OME, 1992a, 1992b), pulp mills (OME, 1991a, 1991b), iron and steel manufacturing plants (OME, 1991c) and municipal water pollution control plants (OME, 1988). Loadings of individual isomers to receiving waters (St. Clair River, Lake Erie and St. Mary's River) ranged from 0.01 kg/day to in excess of 0.05 kg/day depending on the source (OME, 1991c, 1992a). Long-term (6- to 12-month) average concentrations in effluents were commonly at or below the detection limit (10 ng/L) and rarely exceeded 100 ng/L 1,2,4- or 1,2,3-trichlorobenzene (OME, 1988, 1991a, 1991b, 1991c, 1992a, 1992b). Data from the late 1970s and early 1980s also indicate that concentrations (> 10 000 ng/L) of trichlorobenzene were significantly higher in effluents from specific textile mills (Chen, 1989; Day and Power, 1981; MacLaren

Marex Inc., 1979). Concentrations ranged up to 17 000 ng/L 1,2,4-trichlorobenzene in untreated leachate from a landfill site at a chemical plant in Sarnia (King and Sherbin, 1986).

No information was identified on amounts of trichlorobenzenes released to the atmosphere as a result of their use in industrial processes in Canada; however, trichlorobenzenes were detected in stack gases of municipal-waste incinerators in Quebec and Prince Edward Island (maximum 4 130 ng/m^3 [total trichlorobenzenes]) [Environment Canada, 1985, 1987], and of 2 sewage sludge incinerators in Ontario (range = 105 to 780 ng/m^3 trichlorobenzenes) [Environment Canada, 1988a, 1988b]. Considerably higher concentrations (means ranging from 32 650 to 143 790 ng/m^3) were reported recently for stack gases from a mobile incinerator burning soil contaminated with up to 10% PCB-containing dielectric fluids (Western Research, 1991). Based on recent estimates, up to 2 585 tonnes of trichlorobenzenes are present with PCBs in dielectric fluids currently in use, and 32 tonnes of trichlorobenzenes are associated with PCBs in storage to be destroyed (Environment Canada, 1991a; NRCC, 1980). Based on an incineration destruction efficiency of 99.999% (Dibbs, 1991), the total amount of trichlorobenzenes released to the atmosphere from the incineration of all PCBs currently in use or storage in Canada would be less than 3 tonnes. This estimate does not include fugitive releases, which can be significant (Western Research, 1991), or releases resulting from spillage of PCB-containing fluids.

2.3 Exposure-related Information

2.3.1 Fate

The fate of trichlorobenzenes is governed by transport processes, such as volatilization and adsorption, and transformation processes, such as photooxidation and aerobic biodegradation. Although trichlorobenzenes are removed from aerobic environments (e.g., air and surface water) by degradation processes, they persist and accumulate under anaerobic conditions in buried sediments and soils.

Based on a comparison of concentrations of trichlorobenzenes in airborne gas- and particulate-phases in southwestern Ontario in 1987 and 1988, virtually all (> 99%) trichlorobenzenes in the atmosphere are in the vapour phase (Environment Canada, 1989e). In the atmosphere, trichlorobenzenes react with photochemically produced hydroxyl radicals with an estimated half-life ranging from 5 to 53 days for 1,2,4-trichlorobenzene (Howard *et al.*, 1991). In the case of 1,3,5-trichlorobenzene, atmospheric hydroxyl radical reaction half-lives of 20 days (GDCh, 1989) and 185 days (Howard, 1989) were reported. Mackay *et al.* (1992) estimated a mean half-life in the atmosphere of approximately 3 weeks for trichlorobenzenes on the basis of photooxidation and advection processes. Since 1,2,4-trichlorobenzene absorbs radiation weakly at wavelengths greater than 300 nm, direct photolysis in the

atmosphere is not likely (Bunce *et al.*, 1987). Given atmospheric reaction half-lives of several weeks, trichlorobenzenes may be transported significant distances in the atmosphere. The presence of 1,2,4-trichlorobenzene in rainwater indicates that it persists long enough to be returned to the earth's surface by atmospheric washout (Ligocki *et al.*, 1985).

Most trichlorobenzenes released to water (in industrial effluents or leachates) will escape to the atmosphere by volatilization (Oliver, 1984). Results of both modelling and experimental studies suggest that the volatilization half-lives of trichlorobenzenes from water range from 10 to 20 days (Wakeham *et al.*, 1983; Lay *et al.*, 1985; Mackay *et al.*, 1992). Trichlorobenzenes that remain in the water column will partition between the aqueous phase, suspended and bottom sediments, and biota. Bartholomew and Pfaender (1983) reported that although radiolabelled 1,2,4-trichlorobenzene was removed from water by uptake by microorganisms, the compound was not bio-transformed within 12 hours (observation period of study). Removal half-lives from water by microbial uptake of 24 to 58 days were calculated based on rate constants reported by Battersby (1990).

Analysis of dated sediment cores suggests that trichlorobenzenes have been accumulating in sediment in Lake Ontario since the early 1900s, and that rates of input peaked in the 1970s (Oliver and Nicol, 1982). These authors compared the relative proportions of different chlorobenzene congeners in surface and buried (older) sediments, and concluded that there was little evidence of either microbial oxidation or anaerobic dehalogenation of chlorobenzenes in sediments from Lake Ontario (Oliver and Nicol, 1983). Results of laboratory experiments by Peijnenburg *et al.*, (1992) and Bosma *et al.*, (1988) suggest, however, that trichlorobenzenes can be transformed to dichlorobenzenes in some sediments under anaerobic conditions, with half-lives ranging from only a few days to over 200 days.

Trichlorobenzenes released to soil (in spilled transformer fluid, for example) have limited mobility (Wilson *et al.*, 1981), due partly to their adsorption by organic matter (Lee *et al.*, 1989). Volatilization half-lives from surface soil (0 to 10 cm depth) with 2% organic carbon were estimated by Mackay *et al.* (1992) to be approximately 320 and 365 days for 1,2,4- and 1,2,3-trichlorobenzene, respectively, and 80 days for 1,3,5-trichlorobenzene. Evaporation rates are less at depths of greater than 10 cm and in soils with higher levels of organic matter (Marinucci and Bartha, 1979). Howard *et al.* (1991) estimated that the unacclimated biodegradation half-life of 1,2,4-trichlorobenzene in aerobic soil ranges from about 28 to 180 days, but would be even longer in anaerobic soils.

Whole-body bioconcentration factors (BCFs) for trichlorobenzenes ranging from 100 to 4 000 have been reported for a variety of aquatic biota (Oliver and Niimi, 1983; Knezovich and Harrison, 1988; Howard, 1989; Mackay *et al.*, 1992); however, Oliver and Niimi (1988) reported no evidence of biomagnification of trichlorobenzenes.

2.3.2 Concentrations

Trichlorobenzenes have been detected frequently in samples of Canadian surface water, sediment and biota collected in the Great Lakes region. They have been found less often in samples of ambient air and ground water. Data on concentrations in soil and groundwater are restricted to those determined at single contaminated sites. Levels of trichlorobenzenes in coastal marine waters in Canada have not been reported.

In surveys of ambient air from up to 18 sites in Canada taken between October 1988 and April 1990, mean concentrations of 1,2,4-trichlorobenzene ranged from not detected (detection limit 0.1 $\mu g/m^3$) to 0.27 $\mu g/m^3$ (Environment Canada, 1991c; Dann, 1992). Concentrations of 1,2,4-trichlorobenzene in samples of ambient air collected between January 1989 and December 1990 in 11 Canadian cities and one rural station were generally less than the detection limit of about 0.1 $\mu g/m^3$, although a maximum level of 0.92 $\mu g/m^3$ was reported (Dann, 1992). Reported mean concentrations of the 1,2,4-isomer in ambient air in the Netherlands and 3 urban centres in the United States were < 0.8 $\mu g/m^3$ (Lebret, 1985) and ® 0.05 $\mu g/m^3$ (Singh *et al.*, 1981), respectively. Limited monitoring data from areas outside Canada suggest that this isomer comprises 60 to 80% of the total trichlorobenzene content of ambient air (Bruckmann *et al.*, 1988; Atlas and Schauffler, 1990). The mean concentration of trichlorobenzenes in samples of air collected in 1989 and 1990 near a stationary PCB incineration facility was reported to be 6 100 ng/m^3 (maximum of 24 100 ng/m^3) [Western Research, 1991].

Data on concentrations of 1,2,3- and 1,3,5-trichlorobenzene in Canadian ambient air have not been identified; however, both 1,2,3- and 1,3,5-trichlorobenzene have been detected in an unspecified number of samples of ambient air in Ede and Rotterdam in the Netherlands (median < 0.8 $\mu g/m^3$ for both isomers) and in 89 samples in Bochum, Germany (1,2,3-trichlorobenzene: mean = 0.4 $\mu g/m^3$; 1,3,5-trichlorobenzene: mean = 0.5 $\mu g/m^3$) [Lebret, 1985; Bauer, 1981].

Concentrations of 1,2,4-trichlorobenzene in indoor air in Canada have been determined in 2 studies. Based on preliminary data for 757 randomly selected homes, the mean concentration of 1,2,4-trichlorobenzene in indoor air was approximately 2.6 $\mu g/m^3$, with a maximum value of 20 $\mu g/m^3$ (method detection limit and number of homes in which 1,2,4-trichlorobenzene was not detected were not stated) [Otson *et al.*, 1992]. In a small study of samples collected in the metropolitan Toronto area between June and August 1990, 1,2,4-trichlorobenzene was detected (detection limit = 0.6 $\mu g/m^3$) in 3 of 4 samples taken from homes (mean = 3.1 $\mu g/m^3$; maximum

value = 7.2 μg/m^3) and 7 of 8 samples from offices (mean = 0.5 μg/m^3; maximum value = 3.2 μg/m^3) [Bell *et al.*, 1991]. Average concentrations of 1,2,4-trichlorobenzene in commuting automobiles (1 to 2 hours each way morning [n = 11] and evening [n = 8]) were 0.7 μg/m^3. In all samples of outdoor air analyzed in this study, 1,2,4-trichlorobenzene was present in only trace amounts (0.6 < trace < 2.9 μg/m^3). The mean concentrations of 1,2,4-trichlorobenzene measured in indoor air in these studies were somewhat higher than those determined in a larger investigation conducted in the Netherlands (median < 0.8 μg/m^3) [Lebret, 1985].

The median concentrations of 1,2,3-trichlorobenzene in indoor air reported by Lebret (1985) for 134 samples taken in postwar homes in Ede, 96 samples from homes less than 6 years old in Ede and 89 samples from homes of unspecified age in Rotterdam were < 0.8 μg/m^3. The maximum value was 28 μg/m^3, measured in a home in Ede that was less than 6 years old; the maximum concentration in older homes in Ede and in homes in Rotterdam was 3 μg/m^3. Lebret (1985) also reported concentrations of 1,3,5-trichlorobenzene in indoor air in samples taken in Ede and Rotterdam. The median concentrations in 134 samples taken in postwar homes in Ede, 96 samples from homes less than 6 years old in Ede and 89 samples from homes of unspecified age in Rotterdam were < 0.8 μg/m^3. The maximum value was 8 μg/m^3, measured in a post-war home in Ede.

Data identified on the concentrations of trichlorobenzenes in surface waters are limited to the Great Lakes region. Maximum concentrations in whole-water samples collected from the Niagara River at Niagara-on-the-Lake during 1988 and 1989 were reported to be 2.5 ng/L for 1,2,4-trichlorobenzene, 0.60 ng/L for 1,2,3-trichlorobenzene and 0.09 ng/L for 1,3,5-trichlorobenzene (NRDIG, 1990). These concentrations are considerably less than those reported for the Niagara River in the early 1980s (Oliver and Nicol, 1984; Fox and Carey, 1986). Concentrations of individual trichlorobenzene isomers in surface waters from Lakes Superior, Huron and Erie in the early to mid-1980s were usually less than 1 ng/L (Oliver and Nicol, 1982; Stevens and Neilson, 1989).

Information concerning the levels of trichlorobenzene in Canadian drinking water is limited. 1,2,4-Trichlorobenzene was detected in the drinking-water supplies of 3 cities bordering on Lake Ontario; concentrations ranged from 1 to 4 ppt (ng/L), with a mean value of 2 ppt (ng/L) [Oliver and Nicol, 1982]. In a survey of 570 samples of drinking water from 139 locations in the 4 Atlantic provinces taken between 1985 and 1988, 1,2,4-trichlorobenzene was not detected (detection limit = 0.004 μg/L) [Environment Canada, 1989a, 1989b, 1989c, 1989d]. 1,2,3-Trichlorobenzene was detected in the drinking-water supplies of 3 cities bordering on Lake Ontario; concentrations ranged from “0.1 to 0.1 ppt” (ng/L); the mean value was 0.1 ng/L (Oliver and Nicol, 1982). In a survey of 594 samples of drinking water from 139 locations in the 4 Atlantic provinces taken between 1985 and 1988, 1,2,3-trichlorobenzene was not detected

(detection limit = 0.004 μg/L) [Environment Canada, 1989a, 1989b, 1989c, 1989d]. 1,3,5-Trichlorobenzene was not detected (detection limit 0.1 ppt [ng/L]) in the water supplies of 3 cities bordering on Lake Ontario (Oliver and Nicol, 1982). In a survey of 601 samples of drinking water from 139 locations in the 4 Atlantic provinces taken between 1985 and 1988, 1,3,5-trichlorobenzene was not detected (detection limit = 0.004 μg/L) [Environment Canada, 1989a, 1989b, 1989c, 1989d].

All trichlorobenzene isomers were detected in sediment collected in Lake Ontario near the mouth of the Niagara River (Oliver and Nicol, 1982; Oliver and Charlton, 1984). Mean concentrations ranging up to 110 ng/g (dw) for 1,2,4-trichlorobenzene, 9 ng/g (dw) for 1,2,3-trichlorobenzene and 53 ng/g (dw) for 1,3,5-trichlorobenzene were reported. A mean concentration of about 780 ng/g (dw) of trichlorobenzenes (maximum of 2 400 ng/g, dw) was present in sediment collected from the St. Clair River in 1985 along a 2-km stretch near petrochemical plants at Sarnia (Oliver and Pugsley, 1986). The mean concentrations of trichlorobenzenes in 6 samples of freshwater sediment collected 15 to 100 m downstream from the effluent outfall of a textile plant in Nova Scotia were estimated to be 44 ng/g (dw) for 1,2,4-trichlorobenzene, 12 ng/g (dw) for 1,2,3-trichlorobenzene and < 2 ng/g (dw) for 1,3,5-trichlorobenzene (MacLaren Marex Inc., 1979). The trichlorobenzene isomers were detected at relatively low concentrations (≤ 26 ng/g (dw) for 1,2,4-trichlorobenzene, ≤ 2 ng/g (dw) for 1,2,3-trichlorobenzene and ≤ 12 ng/g (dw) for 1,3,5-trichlorobenzene) in samples of bottom sediment collected from Lakes Superior, Huron, St. Clair and Erie, the St. Lawrence River, and Pictou Harbour, Nova Scotia during the late 1970s and early 1980s (MacLaren Marex Inc., 1979; Oliver and Nicol, 1982; Oliver and Bourbonniere, 1985; Merriman, 1987).

Average concentrations as high as 1 075 μg/g of 1,2,4-trichlorobenzene were present in near-surface soil (0 to 3 m depth) collected from test holes drilled at the site of a transformer manufacturing plant in Regina, Saskatchewan, where up to 30 tonnes of dielectric fluid containing PCBs and trichlorobenzenes had been spilled in the mid-1970s (NRCC, 1980). Remediation measures implemented at this site have reduced the possibility of lateral and vertical migration of spilled material (Chang, 1992). No other data on trichlorobenzene levels in Canadian soils were identified.

Trichlorobenzenes were measured in the aquifer below a decommissioned PCB storage facility in Smithville, Ontario, at concentrations exceeding 10 000 ng/L (total of 1,2,4- and 1,2,3-isomers) [Feenstra, 1992]. No other data on concentrations of trichlorobenzenes in Canadian groundwater were identified.

No recent data were identified on the concentrations of trichlorobenzenes in biota in Canada. Oligochaetes and amphipods collected in 1981 from Lake Ontario at the mouth of the Niagara River contained up to 330 ng/g (ww) 1,2,4-trichlorobenzene, 29 ng/g (ww) 1,2,3-trichlorobenzene and 140 ng/g (ww) 1,3,5-trichlorobenzene, (Fox *et al.*, 1983). Whole fish, mostly lake trout (*Salvelinus namaycush*), taken from each of the Canadian Great Lakes in the early 1980s contained up to 5 ng/g (ww) 1,2,4-trichlorobenzene, 1 ng/g (ww) 1,2,3-trichlorobenzene and 4 ng/g (ww) 1,3,5-trichlorobenzene (Oliver and Nicol, 1982; Fox *et al.*, 1983). Trichlorobenzene isomers were also present in eggs of herring gull (*Larus argentatus*) from the Detroit and Niagara River areas from 1978 to 1982 (maximum = 20 ng/g [ww] 1,2,4-trichlorobenzene) [Struger *et al.*, 1985], and in eggs of herring gull and double-crested cormorant (*Phalacrocorax auritus*) from 3 sites in the Maritime Provinces in 1979 (maximum = 37 ng/g [ww] 1,2,4-trichlorobenzene) [Matheson *et al.*, 1980].

Available data on the presence of trichlorobenzenes or the individual isomers in food are limited. All 3 isomers were determined in a limited study of fresh-food composites (leafy vegetables, fruit, 2% cows' milk, root vegetables [including potatoes], eggs and meat) prepared from samples obtained in 4 retail grocery stores in Ontario (detection limit for all isomers in all composites = 0.00001 μg/g) [Davies, 1988]. 1,2,4-Trichlorobenzene was detected in 4 of 5 food composites, with concentrations ranging from 0.00014 μg/g in fruit and 2% cows' milk to 0.00074 μg/g in eggs/meat. 1,2,3-Trichlorobenzene was detected only in the leafy-vegetable composite at a concentration of 0.00011 μg/g. In the same study, 1,3,5-trichlorobenzene was detected in 4 of 5 food composites, with concentrations ranging from 0.00028 μg/g in leafy vegetables to 0.0012 μg/g in 2% cows' milk.

All isomers of trichlorobenzene have been detected in the breast milk of Canadian women. The mean concentration of 1,2,4-trichlorobenzene in the breast milk of Canadian women in the general population taken 3 to 4 weeks after parturition was 0.6 ng/g (detected in 100% of 210 samples, although detection limit was not specified). The mean concentration in the breast milk of women of the Canadian indigenous population was 1.2 ng/g (detected in 89% of 18 samples; detection limit not stated) [Davies and Mes, 1987]. The mean concentration of 1,2,3-trichlorobenzene in the breast milk of women in the general Canadian population taken 3 to 4 weeks after parturition was 0.3 ng/g (detected in 97% of 210 samples, although detection limit was not specified). The mean concentration in the breast milk of women of the Canadian indigenous population was 0.1 ng/g (detected in 89% of 18 samples; detection limit not stated) [Davies and Mes, 1987]. Although not detected in the breast milk of Canadian women in the general population (210 samples; detection limit unspecified), the mean concentration of 1,3,5-trichlorobenzene in the breast milk of the Canadian indigenous population (3 to 4 weeks after parturition) was 0.4 ng/g (detected in 94% of the 18 samples though the detection limit was not specified) [Davies and Mes, 1987].

2.4 Effects-related Information

2.4.1 Experimental Animals and in Vitro

Reliable data on acute toxicity following inhalation of the trichlorobenzenes have not been identified. Reported LD_{50}s for CFE rats and CF_1 mice following ingestion of 1,2,4-trichlorobenzene were 756 mg/kg bw and 766 mg/kg bw, respectively (Brown *et al.*, 1969). Yamamato *et al.* (1978) reported LD_{50}s of approximately 300 mg/kg bw in male and female ddY mice following oral administration.

Available short-term, repeated-dose toxicity studies are primarily restricted to 1,2,4-trichlorobenzene (Rimington and Ziegler, 1963; Brown *et al.*, 1969; Robinson *et al.*, 1981). Necrotic foci in the liver following dermal application of 0.5 ml undiluted 1,2,4-trichlorobenzene to guinea pigs 5 days/week for 3 weeks (Brown *et al.*, 1969) and decreases in uterine weight and hepatomegaly, decreases in body weight and increases in adrenal weight in immature female rats administered 1,2,4-trichlorobenzene intraperitoneally (lowest-observed-effect-level [LOEL] = 250 mg/kg bw/day; Robinson *et al.*, 1981) have been reported. Administration of doses up to 730 mg/kg bw/day by gavage in 1% cellofas for 15 days of 1,2,4-trichlorobenzene resulted in hepatic porphyria, hepatomegaly in porphyric rats and severe liver damage (intense necrosis and fatty changes). In this investigation, the 1,2,3-isomer was less hepatotoxic, inducing only hepatic porphyria, non-necrotic liver cell degeneration in the central, midzonal and periportal regions, and weight and appetite loss (maximum dose = 785 mg/kg/day for 7 days) [Rimington and Ziegler, 1963]. Following inhalation of 1 000 mg/m^3 1,3,5-trichlorobenzene for 3 weeks, there was an increase in the liver to body weight ratio in rats (no-observed-effect-level [NOEL] = 100 mg/m^3) [Sasmore *et al.*, 1983].

In 3 sub-chronic studies, animals were exposed to 1,2,4-trichlorobenzene by inhalation (Kociba *et al.*, 1981; Watanabe *et al.*, 1978; Coate *et al.*, 1977). In male Sprague-Dawley rats, New Zealand white rabbits, and cynomolgus monkeys exposed to concentrations up to 742 mg/m^3 for 26 weeks, transient changes in the liver (hepatocytomegaly) and kidney (hyaline degeneration of the cortex in the kidney) in rats were observed at all concentrations; however, no exposure-related abnormalities were observed after 26 weeks in any species (NOEL = 742 mg/m^3) [Coate *et al.*, 1977]. In male Sprague-Dawley rats, New Zealand white rabbits, and beagle dogs exposed to concentrations up to 742 mg/m^3 for 44 days, liver (rats and dogs) and kidney (rats) weights were increased at the highest concentration, while increased excretion of porphyrins, considered to be a physiological rather than a toxic effect, was observed in rats at the lower concentration (223 mg/m^3) [NOEL in rabbits = 742 mg/m^3; no-observed-adverse-effect-level [NOAEL] in rats and NOEL in dogs = 223 mg/m^3] (Kociba *et al.*, 1981). In male and female Sprague-Dawley rats exposed for 3 months, there was a slight reversible increase in urinary porphyrins at 74.2 mg/m^3 (NOEL = 22.3 mg/m^3) [Watanabe *et al.*, 1978].

In only one sub-chronic study were animals exposed orally to each of the 3 trichlorobenzene isomers (Côté *et al.*, 1988). In this study, Sprague-Dawley rats exposed to concentrations of each of the trichlorobenzene isomers up to 1 000 ppm (mg/kg) in the diet for 13 weeks had significant increases in the liver/body weight ratios at the highest concentration in males for all isomers; and mild to moderate histopathological changes in the liver, thyroid and kidney, significant at the highest concentration and more severe in males for all 3 isomers, were also observed (NOELs for the 1,2,4-, 1,2,3- and 1,3,5-isomers were 7.8, 7.7 and 7.6 mg/kg bw/day, respectively).

Squamous metaplasia and hyperplasia in the respiratory epithelium of the nasal passages were reported at the highest concentration in rats exposed via inhalation to up to 1 000 mg/m^3 1,3,5-trichlorobenzene for 13 weeks (NOEL = 100 mg/m^3) [Sasmore *et al.*, 1983].

One limited study on the chronic toxicity and carcinogenicity of the trichlorobenzenes (1,2,4-trichlorobenzene) has been identified (Yamamoto *et al.*, 1982). Clinical signs of toxicity, decreased survival, increased organ weights, keratinization of the epidermis and minor haematological effects were reported in this study in Slc:ddy mice exposed dermally to 0.03 mL of a 30% or 60% solution of 1,2,4-trichlorobenzene, twice a week, over 2 years. No increase in tumour incidence was reported, although data on the protocol and results presented in the published account of this study were inadequate for evaluation.

The trichlorobenzenes have not been genotoxic in *in vitro* assays of a limited range of endpoints. 1,2,4-Trichlorobenzene was not mutagenic in 5 strains of *Salmonella typhimurium* and *Escherichia coli*-WP2, with and without metabolic activation (Lawlor *et al.*, 1979; Schoeny *et al.*, 1979). None of the 3 isomers induced chromosomal aberrations in Chinese hamster cells, with and without metabolic activation (Sofuni *et al.*, 1985).

In available studies in which the developmental toxicity of the trichlorobenzenes has been examined (1,2,4-isomer—Kitchin and Ebron, 1983; all isomers—Black *et al.*, 1988), in general, foetotoxic effects have sometimes been observed but only at doses that were toxic to the mothers and greater than those reported to induce effects in sub-chronic studies. In the only study identified in which the reproductive toxicity of any of the trichlorobenzenes was investigated, there were no significant effects on fertility, growth, viability, locomotor activity or chemical composition of the blood in pregnant rats administered 1,2,4-trichlorobenzene in drinking water through to weaning of the F_2 generation (Robinson *et al.*, 1981). Enlarged adrenal glands were observed in the F_0 and F_1 generations at 95 days at the highest dose (approximately 54 mg/kg bw/day).

2.4.2 Humans

Clinical studies in human volunteers or epidemiological studies of populations exposed to the trichlorobenzenes or the individual isomers have not been identified.

2.4.3 Ecotoxicology

The information identified on the toxicity of trichlorobenzenes or the individual isomers to aquatic biota includes acute and chronic data for bacteria, algae, invertebrates and fish; data for terrestrial biota were limited to 2 chronic studies on earthworms. Studies conducted under closed conditions, or where concentrations of trichlorobenzenes were measured, were considered most reliable, since trichlorobenzenes can volatilize relatively rapidly from water (Howard, 1989). No suitable toxicological data were identified for sediment-dwelling biota, or for wild mammals, birds or vascular plants. No empirical data were identified regarding adverse effects of trichlorobenzenes on wildlife due to decreased availability or quality of prey.

Following acute exposure, LC_{50}s ranging between 0.3 and 1.2 mg/L were reported for freshwater fish and invertebrates such as *Daphnia magna* (Calamari *et al.*, 1983; van Hoogen and Opperhuizen, 1988). Yoshitada *et al.* (1985) reported a 24-hour EC_{50} (for reduced growth) in the protozoan *Tetrahymena pyriformis* of 0.91 mg/L 1,2,4-trichlorobenzene and 30 mg/L 1,3,5-trichlorobenzene. Acute toxicity in the grass shrimp (*Palaemonetes pugio*) was reported by Clark *et al.* (1987) at a nominal concentration of 0.54 mg/L 1,2,4-trichlorobenzene (96-hour LC_{50}) [measured concentrations between 75% and 90% of nominal values].

Based on results of acute studies (Figueroa and Simmons, 1991; Calamari *et al.*, 1983; Wong *et al.*, 1984), algae such as *Cyclotella meneghiniana*, *Selenastrum capricornutum* and *Ankistrodesmus falcatus* are less sensitive to the various trichlorobenzene isomers than the aquatic species mentioned above.

Impairment of reproduction following chronic exposure to the various isomers of trichlorobenzene was the most sensitive endpoint identified for aquatic species. Calamari *et al.* (1983) reported a reduction in fertility in *Daphnia magna* after exposure to 0.45 mg/L 1,2,4-trichlorobenzene and 0.20 mg/L 1,2,3-trichlorobenzene (14-day EC_{50}s). De Wolf *et al.* (1988) reported a 16-day no-observed-effect-concentration (NOEC) [for reproduction] for *Daphnia magna* of 0.10 mg/L 1,2,4-trichlorobenzene. A 28-day NOEC (for growth and reproduction) of 0.36 mg/L 1,2,4-trichlorobenzene was reported by Richter *et al.* (1983) for *Daphnia magna*. A 16-day EC_{50} (for impaired reproduction) of 0.27 mg/L 1,2,4-trichlorobenzene for *Daphnia magna* was estimated by Hermens *et al.* (1984).

Lay *et al.* (1985) added 1,2,4-trichlorobenzene in a single application to a natural pond and observed the effects on resident biota for 21 days. At an average measured concentration of approximately 0.13 mg/L, these authors reported 90% to 100% mortality for *Daphnia pulex* but no effect on phytoplankton species diversity and cell numbers. *Daphnia pulex* began to regenerate on day 21 when the concentrations of 1,2,4-trichlorobenzene in the water column had dropped to an average of approximately 0.07 mg/L.

Larval growth was the most sensitive endpoint during early life-stage toxicity tests on fish. van Leeuwen *et al.* (1990) reported a 28-day NOEC (for survival, hatching and growth) in the zebra fish (*Brachydanio rerio*) of 0.25 mg/L 1,2,3-trichlorobenzene. Carlson and Kosian (1987) reported a 32-day NOEC (for reduced survival and weight) in embryo through early juvenile stages of the fathead minnow (*Pimephales promelas*) of 0.50 mg/L 1,2,4-trichlorobenzene.

Identified data on the toxicity of trichlorobenzenes or the individual isomers to terrestrial organisms are limited. van Gestel and Ma (1990) examined the chronic toxicity of 1,2,3-trichlorobenzene to earthworms in natural and artificial soil containing from 4% to 15% organic matter. They reported 14-day LC_{50}s for *Lumbricus rubellus* and *Eisenia andrei* ranging from 115 to 563 μg/g (dw) 1,2,3-trichlorobenzene. Greater tolerance was typically observed in soils with higher organic contents. Neuhauser *et al.* (1986) reported 14-day LC_{50}s in the range of 200 to 250 μg/g (dw) 1,2,4-trichlorobenzene for 2 earthworm species native to northern temperate regions (*Allolobophora tuberculata* and *Eisenia fetida*) exposed in artificial soil containing 10% organic matter.

3.0 Assessment of "Toxic" under CEPA

3.1 CEPA 11(*a*): Environment

Trichlorobenzenes are not produced in Canada, but are imported in quantities approaching 50 tonnes per year. Trichlorobenzenes have been measured in Canada in most environmental media (air, water, sediment and soil). Although trichlorobenzenes are removed from aerobic environments by degradation processes such as photo-oxidation and biotransformation, they can persist and accumulate under anaerobic conditions in buried sediments and soils.

Trichlorobenzene isomers have similar physical/chemical properties and mode of toxic action (i.e., narcotic) [Veith *et al.*, 1983]. Therefore, in the same species, differences among harmful effects of the 3 isomers are typically small (see, e.g., Kaiser and Palabrica, 1991), and effects of exposure to mixtures of trichlorobenzene isomers can be considered to be additive (McCarty *et al.*, 1992). Thus, exposure of biota was estimated by summing environmental concentrations reported for the 3 trichloro-benzene isomers. Estimated effects thresholds were based on data for the isomer with the lowest observed adverse effect level.

Benthic organisms are exposed to trichlorobenzenes in sediments from the Canadian Great Lakes and their connecting channels, the St. Lawrence River, and the Salmon River and Pictou Harbour in Nova Scotia; however, no toxicological data were identified that would permit estimation of an effects threshold. Similarly, because of the lack of information on concentrations in soils, it is not possible to determine whether soil-dwelling organisms in Canada are adversely affected by exposure to trichlorobenzenes.

The lowest identified chronic effect level for dissolved trichlorobenzenes to freshwater organisms was 130 μg/L (exposure to 1,2,4-trichlorobenzene for 21 days causing 90% to 100% mortality in *Daphnia pulex*). This concentration was divided by a factor of 30 (10 to account for extrapolation from laboratory to field conditions as well as possible effects to more sensitive untested species, and 3 because of the high mortality associated with the LOEL), resulting in an estimated effects threshold of 4.3 μg/L. The highest total concentration of the 3 trichlorobenzene isomers measured recently in Canadian surface waters was approximately 3.2 ng/L (measured in the late 1980s in the Niagara River), which is more than 1 000 times less than the estimated effects threshold. Therefore, no adverse effects are expected to result from exposure of pelagic organisms to trichlorobenzenes in Canadian surface waters.

A worst-case exposure scenario was developed for a representative fish-eating mammal (mink, *Mustela vison*) in southern Ontario to ascertain the most significant route of exposure. Mink are opportunistic carnivores with aquatic organisms comprising up to 100% of their diet. The total daily intake of trichlorobenzenes estimated for mink in Table 1 was approximately 1.78 μg/kg bw, with ingestion being the major route of exposure. In the absence of identified data on effects on wildlife, an effects threshold for mink was based on the results of a subchronic study, in which rats were exposed orally. In this study, no treatment-related effects were observed at 7.7 mg/kg bw/day 1,2,3-trichlorobenzene (Côté *et al.*, 1988). Using a factor of 10 to account for variability in extrapolating from a laboratory to a field situation and a factor of 10 to estimate a chronic NOEL from a subchronic NOEL, the effects threshold was estimated to be 77 μg/kg bw/day. The estimated intake from the diet for the 3 trichlorobenzene isomers (1.78 μg/kg bw) is approximately 50 times less than this effects threshold. Data on the toxicological effects of trichlorobenzenes on birds and terrestrial plants were not identified.

Table 1
Estimated Total Daily Intake of a Piscivorous Mammal Exposed to Trichlorobenzenes Under "Worst-case" Conditions

Medium	Concentration[a]	Daily Rate of Consumption[b]	Daily Intake (μg/kg bw)
Air	360.0 ng/m^3	0.55 m^3	0.198
Water	0.003 μg/L	0.1 L	0.0003
Fish	10.0 μg/kg ww	0.158 kg	1.58
Total	–	–	1.778

a. Sum of maximum levels of 1,2,3-, 1,2,4- and 1,3,5-trichlorobenzene in water recently collected from the Niagara River at Niagara-on-the-Lake (NRDIG, 1990), and in lake trout from Lake Ontario at the mouth of the Niagara River (Oliver and Nicol, 1982); maximum level of 1,2,4-trichlorobenzene in air in 1989/90 at Hamilton, Ontario (Dann, 1992).

b. Rate of daily consumption for air from Stahl (1967), for water from Calder and Braun (1983) and for fish from Nagy (1987), with the additional assumption that fish comprise 75% of mink diet.

Although, on the basis of available data, the levels of trichlorobenzenes present in air and surface water are not expected to cause adverse effects in aquatic biota or wildlife, data upon which to evaluate the significance of exposure in sediment and soil were not identified. Therefore, there is insufficient information to conclude whether trichlorobenzenes are entering the environment in quantities or under conditions that may be harmful to the environment.

3.2 CEPA 11(*b*): Environment on Which Human Health Depends

Although trichlorobenzenes are present as gases in the troposphere and absorb infrared radiation in wavelengths ranging from 7 to 13 μm, they are removed from the atmosphere by photooxidation (half-life for the dominant 1,2,4-trichlorobenzene isomer = 5 to 53 days), resulting in low steady-state concentrations in the atmosphere (< 0.1 μg/m^3). As such, trichlorobenzenes are not expected to contribute significantly to the formation of ground-level ozone, global warming or depletion of stratospheric ozone.

Therefore, on the basis of available data, it has been concluded that trichlorobenzenes are not entering the environment in quantities or under conditions that may constitute a danger to the environment on which human life depends.

3.3 CEPA 11(*c*): Human Life or Health

Identified data on the exposure of the general population and potential health effects were sufficient to permit assessments for each of the isomers of trichlorobenzenes. Uncertainty factors applied in the development of tolerable daily intakes (TDIs) for each of the isomers are also sufficiently conservative to account for potential additive effects of trichlorobenzenes.

Population Exposure

On the basis of available data, it is likely that the general population in Canada is exposed to the isomers of trichlorobenzene principally in air, particularly indoor air (Tables 2 to 4). Due to the lack of identified data on concentrations of the isomers of trichlorobenzene other than 1,2,4-trichlorobenzene in indoor air in Canada, intakes from this source for the 1,2,3- and 1,3,5-isomers were calculated on the basis of data collected in other countries (i.e., the Netherlands), for which median values were rather imprecisely specified (i.e., < 0.8 μg/m^3 for all isomers) [Lebret, 1985]. For isomers other than 1,2,4-trichlorobenzene, data on concentrations in ambient air in Canada were also not identified; it was therefore necessary to estimate intake from this source on the basis of data collected in Germany. The total daily intakes for various age groups in the population of each of the isomers of trichlorobenzene have been estimated as follows: 1,2,4-trichlorobenzene: 0.1 to 1.2 μg/kg bw/day; 1,2,3-trichlorobenzene: ≤ 0.24 to ≤ 0.33 μg/kg bw/day; 1,3,5-trichlorobenzene: ≤ 0.25 to ≤ 0.35 μg/kg bw/day.

Table 2
Estimated Daily Intake (μg/kg bw) of 1,2,4-Trichlorobenzene by Canadians from Various Sources

	Estimated Intake μg/kg bw/day				
Medium[1]	0 – 6 mo[a]	7 mo – 4 yr[b]	5 – 11 yr[c]	12 – 19 yr[d]	20 – 70 yr[e]
Ambient Air[f]	0.005 – 0.013	0.006 – 0.02	0.007 – 0.02	0.006 – 0.02	0.005 – 0.015
Indoor Air[g]	0.1 – 0.7	0.2 – 1.0	0.2 – 1.2	0.2 – 1.0	0.1 – 0.8
Drinking Water[h]	–	0.0001 – < 0.0002	0.00007 – < 0.0001	0.00005– < 0.00009	0.00004– < 0.00009
Breast Milk[i]	0.06 – 0.13	–	–	–	–
Food[j]	–	0.008	0.005	0.003	0.003
Total Intake	0.2 – 0.8	0.2 – 1.0	0.2 – 1.2	0.2 – 1.0	0.1 – 0.8

mo = months

a. Assumed to weigh 7 kg, breathe 2 m^3 of air per day, and drink 750 ml of breast milk (as food) per day (Environmental Health Directorate, 1992).
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, 1992).
c. Assumed to weigh 27 kg, breathe 12 m^3 of air per day, and drink 0.9 L of water per day (Environmental Health Directorate, 1992).
d. Assumed to weigh 57 kg, breathe 21 m^3 of air per day, and drink 1.3 L of water per day (Environmental Health Directorate, 1992).
e. Assumed to weigh 70 kg, breathe 23 m^3 of air per day, and drink 1.5 L of water per day (Environmental Health Directorate, 1992).
f. Based on range of mean concentrations reported in ambient air from 18 Canadian sites in 5 provinces (0.1 to 0.27 μg/m^3) [Environment Canada, 1991b], assuming 4 of 24 hours are spent outdoors daily (Environmental Health Directorate, 1992).
g. Based on a range of mean concentrations of 1,2,4-trichlorobenzene (0.5 to 3.1 μg/m^3) found in a limited study of indoor air in offices and homes in Metropolitan Toronto (Bell *et al.*, 1991); these values are similar to the mean concentration (2.6 μg/m^3) in 757 homes across Canada based on preliminary results of a national survey (Otson *et al.*, 1992). It is assumed that 20 of 24 hours are spent indoors daily (Environmental Health Directorate, 1992).
h. Based on a range of mean concentrations of 1,2,4-trichlorobenzene in Canadian drinking water of 0.002 μg/L (Oliver and Nicol, 1982) to < 0.004 μg/L (Environment Canada, 1989a, 1989b, 1989c, 1989d).
i. Based on a range of mean concentrations of 1,2,4-trichlorobenzene in breast milk (0.6 to 1.2 μg/kg) in the Canadian general and indigenous population (Davies and Mes, 1987) and assuming the density of breast milk is equal to 1.0 g/ml.
j. Based on concentrations of 0.0004 μg/g in leafy vegetables, 0.00014 μg/g in fruit, 0.0014 μg/g in milk and 0.00074 μg/g in eggs/meat (Davies, 1988), and intake of these foodstuffs by each age group (Environmental Health Directorate, 1992).

1. Data were insufficient to estimate intake from soil.

Table 3
Estimated Daily Intake (μg/kg bw) of 1,2,3-Trichlorobenzene by Canadians from Various Sources

	Estimated Intake μg/kg bw/day				
Medium[2]	0 – 6 mo[a]	7 mo – 4 yr[b]	5 – 11 yr[c]	12 – 19 yr[d]	20 – 70 yr[e]
Ambient Air[f]	0.02	0.03	0.03	0.02	0.02
Indoor Air[g]	< 0.19	< 0.26	< 0.30	< 0.25	< 0.22
Drinking Water[h]	–	0.000006 – < 0.0002	0.000003 – < 0.0001	0.000002 – < 0.00009	0.000002 – < 0.00009
Breast Milk[i]	0.01–0.03	–	–	–	–
Food[j]	–	0.0002	0.0002	0.0001	0.0001
Total Intake	® 0.24	® 0.29	® 0.33	® 0.27	® 0.24

mo = months

a. Assumed to weigh 7 kg, breathe 2 m^3 of air per day, and drink 750 ml of breast milk (as food) per day (Environmental Health Directorate, 1992).
b. Assumed to weigh 13 kg, breathe 5 m^3 of air per day, and drink 0.8 L of water per day and consume 27.88 g per day leafy vegetables (Environmental Health Directorate, 1992).
c. Assumed to weigh 27 kg, breathe 12 m^3 of air per day, and drink 0.9 L of water per day and consume 54.61 g per day leafy vegetables (Environmental Health Directorate, 1992).
d. Assumed to weigh 57 kg, breathe 21 m^3 of air per day, and drink 1.3 L of water per day and consume 63.71 g per day leafy vegetables (Environmental Health Directorate, 1992).
e. Assumed to weigh 70 kg, breathe 23 m^3 of air per day, and drink 1.5 L of water per day and consume 88.26 g per day leafy vegetables (Environmental Health Directorate, 1992).
f. Based on a mean concentration of 1,2,3-trichlorobenzene (0.4 $\mu g/m^3$) in 89 samples taken in Bochum, West Germany (Bauer, 1981), assuming 4 of 24 hours are spent outdoors daily (Environmental Health Directorate, 1992); these data considered more appropriate than less-specific median value of < 0.8 $\mu g/m^3$ reported for the Netherlands (Lebret, 1985). No data on concentrations in outdoor air in Canada were identified.
g. Based on a median concentration of 1,2,3-trichlorobenzene (< 0.8 $\mu g/m^3$) for 319 samples taken in the Netherlands (Lebret, 1985), assuming 20 of 24 hours are spent indoors daily (Environmental Health Directorate, 1992). No data on concentrations in indoor air in Canada were identified.
h. Based on a range of mean concentrations of 1,2,3-trichlorobenzene in Canadian drinking water as follows: 0.0001 μg/L (Oliver and Nicol, 1982) to < 0.004 μg/L (Environment Canada, 1989a, 1989b, 1989c, 1989d).
i. Based on a range of mean concentrations of 1,2,3-trichlorobenzene detected in breast milk (0.1 to 0.3 μg/kg) from the Canadian general and indigenous population (Davies and Mes, 1987) and assuming the density of breast milk is equal to 1.0 g/ml.
j. Based on a concentration of 0.00011 μg/g of 1,2,3-trichlorobenzene detected only in the leafy-vegetables composite from Ontario (Davies, 1988) and the intake of leafy vegetables by each age group (Environmental Health Directorate, 1992).

2. Data were insufficient to estimate intake from soil.

Table 4
Estimated Daily Intake (μg/kg bw) of 1,3,5-Trichlorobenzene by Canadians from Various Sources

	Estimated Intake μg/kg bw/day				
Medium[3]	0 – 6 mo[a]	7 mo – 4 yr[b]	5 – 11 yr[c]	12 – 19 yr[d]	20 – 70 yr[e]
Ambient Air[f]	0.02	0.03	0.04	0.03	0.03
Indoor Air[g]	< 0.19	< 0.26	< 0.30	< 0.25	< 0.22
Drinking Water[h]	–	< 0.00006 – < 0.0002	< 0.00003 – < 0.0001	< 0.00002 – < 0.00009	< 0.00002 – < 0.00009
Breast Milk[i]	0.04	–	–	–	–
Food[j]	–	0.03	0.01	0.006	0.003
Total Intake	® 0.25	® 0.32	® 0.35	® 0.29	® 0.25

mo = months

a. Assumed to weigh 7 kg, breathe 2 m^3 of air per day, and drink 750 ml of breast milk (as food) per day (Environmental Health Directorate, 1992).
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, 1992).
c. Assumed to weigh 27 kg, breathe 12 m^3 of air per day, and drink 0.9 L of water per day (Environmental Health Directorate, 1992).
d. Assumed to weigh 57 kg, breathe 21 m^3 of air per day, and drink 1.3 L of water per day (Environmental Health Directorate, 1992).
e. Assumed to weigh 70 kg, breathe 23 m^3 of air per day, and drink 1.5 L of water per day (Environmental Health Directorate, 1992).
f. Based on a mean concentration of 1,3,5-trichlorobenzene (0.5 $\mu g/m^3$) in 89 samples taken in Bochum, West Germany (Bauer, 1981), assuming 4 of 24 hours are spent outdoors daily (Environmental Health Directorate, 1992); these data considered more appropriate than less specific median value of < 0.8 $\mu g/m^3$ reported for the Netherlands (Lebret, 1985). No data on concentrations in outdoor air in Canada were identified.
g. Based on a median concentration of 1,3,5-trichlorobenzene (< 0.8 $\mu g/m^3$) for 319 samples taken in the Netherlands, assuming 20 of 24 hours are spent indoors daily (Environmental Health Directorate, 1992). No data on concentrations in indoor air in Canada were identified.
h. Based on a range of mean concentrations of 1,3,5-trichlorobenzene in Canadian drinking water of < 0.001 μg/L (Oliver and Nicol, 1982) to < 0.004 μg/L (Environment Canada, 1989a, 1989b, 1989c, 1989d).
i. Based on a mean concentration of 1,3,5-trichlorobenzene detected in breast milk (0.4 μg/kg) in the Canadian indigenous population (Davies and Mes, 1987) and assuming the density of breast milk is equal to 1.0 g/ml.
j. Based on concentrations of 0.00028 μg/g in leafy vegetables, 0.00012 μg/g in fruit, 0.0012 μg/g in milk, and 0.0007 μg/g in eggs/meat (Davies, 1988) and intake of these foodstuffs by each age group (Environmental Health Directorate, 1992).

3. Data were insufficient to estimate intake from soil.

Effects

Available data on the toxicity of the trichlorobenzenes are limited. Epidemiological studies of exposed populations are not available and information on chronic toxicity or carcinogenicity in adequate studies in experimental animals has not been identified. None of the trichlorobenzenes has been genotoxic in *in vitro* studies of a very limited range of endpoints. All 3 isomers of the trichlorobenzenes (1,2,4-, 1,2,3- and 1,3,5-trichlorobenzene) have been classified, therefore, in Group V (inadequate data for evaluation) of the classification scheme for carcinogenicity developed for use in the derivation of the "Guidelines for Canadian Drinking Water Quality" (Environmental Health Directorate, 1989).

With the exception of a one-generation study designed to investigate specifically reproductive and developmental effects for the 1,2,4-isomer (Robinson *et al.*, 1981), and a very limited study of the chronic toxicity and carcinogenicity of the same isomer following skin painting in mice, the longest-term studies of the effects of the trichlorobenzenes are sub-chronic investigations. Sub-chronic studies, in which the trichlorobenzenes have been administered by the principal route of exposure of the general population (i.e., inhalation), are restricted to the 1,2,4- and 1,3,5-isomers. For the 1,2,3-isomer, results of sub-chronic studies are restricted to one in which this compound was administered (mixed in corn oil) in the diet (Côté *et al.*, 1988).

1,2,4-trichlorobenzene

For 1,2,4-trichlorobenzene, the lowest concentration at which compound-related effects were observed following inhalation was 74.2 mg/m^3, which resulted in a slight reversible increase in urinary porphyrins in a 13-week study in rats; the NOEL in this investigation was 22.3 mg/m^3 (Watanabe *et al.*, 1978). It should be noted, however, that the effects observed were minor and transient; no effects were observed in other sub-chronic (some longer-term) inhalation studies in several species at concentrations at least an order of magnitude higher (223 mg/m^3—Kociba *et al.*, 1981; 742 mg/m^3—Coate *et al.*, 1977). A tolerable daily intake (TDI) has been conservatively (owing to the paucity of available data) derived, therefore, as follows:

$$\textbf{TDI} = \frac{223\ \text{mg/m}^3 \times (6/24) \times (5/7) \times 0.144\ \text{m}^3}{10\,000 \times 0.25\ \text{kg}}$$

$$= 0.0023\ \text{mg/kg bw/day}\ (2.3\ \mu\text{g/kg bw/day})$$

where:

- 223 mg/m^3 is the lowest NOAEL for meaningful effects (i.e., increased liver and kidney weights at next highest dose—442 mg/m^3 [Kociba *et al.*, 1981]) in sub-chronic studies conducted to date;

- 6/24 and 5/7 is the conversion of 6 hours/day, 5 days/week of administration to continuous exposure;
- 0.144 m^3 is the assumed inhaled air volume of rats (NIOSH, 1985);
- 0.25 kg is the assumed body weight of adult rats (NIOSH, 1985); and
- 10 000 is the uncertainty factor (× 10 for intraspecies variation; × 10 for interspecies variation; × 10 for less than chronic study; × 10 for lack of adequate data on carcinogenicity and chronic toxicity).

In sub-chronic, developmental and reproductive studies in which 1,2,4-trichlorobenzene has been administered by gavage or ingested in drinking water or the diet, it has not induced adverse effects at doses below those upon which the TDI derived above is based (Goto *et al.*, 1972; Côté *et al.*, 1988; Kitchen and Ebron, 1983; Black *et al.*, 1988; Robinson *et al.*, 1981).

The total daily intake of 1,2,4-trichlorobenzene for various age groups in the Canadian population is estimated to range from 0.1 to 1.2 μg/kg bw/day. It should be noted, however, that data on concentrations of 1,2,4-trichlorobenzene in food are restricted to a small study of a limited number of food composites (Davies, 1988).

These estimated average daily intakes, though based on limited data, are from 2- to 23-fold less than the TDI derived above. Although the lower end of the range of differences between the estimated intake for various age groups in the population and the TDI is small (i.e., 2), a relatively conservative uncertainty factor was incorporated into the TDI (10 000) to account for limitations of the database.

Therefore, on the basis of available data, it has been concluded that 1,2,4-trichlorobenzene is not entering the environment in quantities or under conditions that may constitute a danger in Canada to human life or health.

1,2,3-trichlorobenzene

For 1,2,3-trichlorobenzene, data on effects following inhalation in long-term (i.e., subchronic) studies are not available. The lowest dose at which compound-related effects were observed in the only sub-chronic bioassay in which this isomer was administered (orally; mixed with corn oil in the diet) was approximately 80 mg/kg bw/day, which resulted in an increase in the ratio of liver to body weight in males and significant mild to moderate histopathological changes in the liver, thyroid and kidney (more severe in males) in a 13-week study in rats; the NOEL in this investigation was 7.7 mg/kg bw/day (Côté *et al.*, 1988)[4]. On the basis of this NOEL, a TDI is conservatively (owing to the paucity of available data) derived as follows:

4. It is possible (though quantitative data are not available) that the toxicokinetics of 1,2,3-trichlorobenzene may differ somewhat following inhalation and ingestion; however, such differences should be accounted for by the large uncertainty factor.

$$\text{TDI} = \frac{7.7 \text{ mg/kg bw/day}}{10\,000}$$

$$= 0.00077 \text{ mg/kg bw/day } (0.77 \text{ μg/kg bw/day})$$

where:

- 7.7 mg/kg bw/day is the lowest NO(A)EL or lowest-observed-(adverse)-effect level (LO(A)EL) in sub-chronic studies conducted to date; and
- 10 000 is the uncertainty factor (× 10 for intraspecies variation; × 10 for interspecies variation; × 10 for less than chronic study; × 10 for lack of data on carcinogenicity and chronic toxicity).

In developmental studies in which 1,2,3-trichlorobenzene has been administered by ingestion (Black *et al.*, 1988), it has not induced adverse effects at doses below those upon which the TDI above is based.

The total daily intake of 1,2,3-trichlorobenzene for various age groups in the Canadian population is estimated to be ≤ 0.24 to ≤ 0.33 μg/kg bw/day. (It should be noted, however, that data on concentrations of this isomer in indoor and ambient air in Canada were not available and it was necessary to calculate intake from these sources based on data collected in other countries. Data on concentrations in food in Canada were restricted to a small study of a limited number of composites [Davies, 1988].)

Although based on limited data, these estimated average daily intakes are > 2-fold less than the TDI derived above. Although the range of differences between the estimated intake for various age groups in the population and the TDI is small, a relatively conservative uncertainty factor was incorporated into the TDI (10 000) to account for limitations of the database. Moreover, there was a wide variation (approximately 10-fold) between the NOEL on which this TDI was based and the dose in the critical study that induced effects. Estimated daily intake has also been overestimated, principally owing to the need to rely on a maximum value for the median concentration in indoor air; more accurate data were not identified.

Therefore, on the basis of available data, it has been concluded that 1,2,3-trichlorobenzene is not entering the environment in quantities or under conditions that may constitute a danger in Canada to human life or health.

1,3,5-trichlorobenzene

For 1,3,5-trichlorobenzene, the lowest concentration at which compound-related effects were observed following inhalation was 1 000 mg/m^3, which resulted in squamous metaplasia and hyperplasia in the respiratory epithelium of the nasal passages in a 13-week study in rats; the NOEL in this investigation was 100 mg/m^3 (Sasmore *et al.*, 1983). On the basis of this NOEL, a TDI is conservatively (owing to the paucity of available data) derived as follows:

$$\textbf{TDI} = \frac{100 \text{ mg/m}^3 \times (6/24) \times (5/7) \times 0.144 \text{ m}^3}{10\,000 \times 0.25 \text{ kg}}$$

$$= 0.001 \text{ mg/kg bw/day } (1.0 \text{ μg/kg bw/day})$$

where:

- 100 mg/m^3 is the lowest NO(A)EL or LO(A)EL in sub-chronic studies conducted to date;
- 6/24 and 5/7 is the conversion of 6 hours/day, 5 days/week of administration to continuous exposure;
- 0.144 m^3 is the assumed inhaled air volume of rats (NIOSH, 1985);
- 0.25 kg is the assumed body weight of adult rats (NIOSH, 1985); and
- 10 000 is the uncertainty factor (× 10 for intraspecies variation; × 10 for interspecies variation; × 10 for less than chronic study; × 10 for lack of data on carcinogenicity and chronic toxicity).

In sub-chronic and developmental studies in which 1,3,5-trichlorobenzene has been administered by gavage or ingested in drinking water or the diet, it has not induced adverse effects at doses below those upon which the TDI derived above is based (Côté *et al.*, 1988; Black *et al.*, 1988).

The total daily intake of 1,3,5-trichlorobenzene for various age groups in the Canadian population is estimated to be ≤ 0.25 to ≤ 0.35 μg/kg bw/day. (It should be noted, however, that data on concentrations of this isomer in indoor and ambient air in Canada were not available and it was necessary to calculate intake from these sources based on data collected in other countries. Data on concentrations in food in Canada were restricted to a small study of a limited number of composites [Davies, 1988]).

Although based on limited data, these estimated average daily intakes are > 3-fold less than the TDI derived above. Although the range of differences between the estimated intake for various age groups in the population and the TDI is small, a relatively conservative uncertainty factor was incorporated into the TDI (10 000) to account for limitations of the database. Moreover, there was a wide variation (approximately 10-fold) between the NOEL on which this TDI was based and the concentration in the

critical study that induced effects. Moreover, the NOEL is probably quite conservative, since it is based on effects observed at the site of entry only. A NOEL for systemic effects following inhalation, which would be more suitable for use in this assessment, might be considerably greater than this value. Estimated daily intake has also been overestimated, principally owing to the need to rely on a maximum value for the median concentration in indoor air; more accurate data were not identified.

Therefore, on the basis of available data, it has been concluded that 1,3,5-trichlorobenzene is not entering the environment in quantities or under conditions that may constitute a danger in Canada to human life or health.

3.4 Conclusion

Therefore, based on available data, there is insufficient information to conclude whether trichlorobenzenes are entering the environment in quantities or under conditions that may be harmful to the environment. It has been concluded that trichlorobenzenes are not entering the environment in quantities or under conditions that may constitute a danger to the environment on which human life depends, and that each of the isomers of trichlorobenzene is not entering the environment in quantities or under conditions that may constitute a danger in Canada to human life or health.

4.0 Recommendations

Several data gaps were identified that limited the assessment of environmental effects of trichlorobenzenes. It is thus recommended that the following studies be conducted on a high-priority basis:

(i) toxicity tests with benthic organisms representative of the Canadian environment to determine the effects of sediment-bound trichlorobenzenes; and

(ii) since data on concentrations of trichlorobenzenes in sediment are outdated and in soils are very limited, tests to determine the current concentrations of trichlorobenzenes in these media, particularly near point sources.

In addition, to permit a more complete assessment of the exposure of the general population in Canada, additional monitoring data are desirable, particularly for indoor (all isomers) and ambient (1,3,5 and 1,2,3-isomers) air and food (all isomers). Characterization of possible sources of 1,2,4-trichlorobenzene in indoor air is also recommended. Investigations of the chronic toxicity and carcinogenicity of all of the trichlorobenzenes in experimental animals exposed by inhalation are also required to permit a more complete assessment of their toxicity.

As well, in view of the small difference between the estimated total daily intakes and TDIs for each of the isomers of trichlorobenzene, it is important that exposure of the population of Canada to these compounds continue to be closely monitored.

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