

**DRAFT**

**CANADIAN ENVIRONMENTAL PROTECTION ACT**

**PRIORITY SUBSTANCES LIST**

**SUPPORTING DOCUMENT**

**ENVIRONMENTAL SECTIONS**

**1,2-DICHLOROBENZENE**

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Environment Canada  
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## **1.0 IDENTITY OF SUBSTANCE**

### **1.1 Name of Substance**

IUPAC Name: 1,2-Dichlorobenzene

Synonyms and Trade Names:

orthodichlorobenzene  
ortho-dichlorobenzene  
ortho-dichlorobenzol  
1,2-dichlorobenzene  
ODB  
ODCB  
Dizene<sup>R</sup>  
Chloroben<sup>R</sup>  
Dowtherm<sup>R</sup> E  
"Special termite fluid"  
Termitekil  
Dilatin DB

CAS Number: 95-50-1

PSL Name: 1,2-Dichlorobenzene

### **1.2 Characteristics of Substance**

1,2-Dichlorobenzene is a neutral, colourless, flammable liquid (U.S. EPA, 1986). 1,2-Dichlorobenzene is a halogenated aromatic compound with two hydrogens in the benzene ring substituted with chlorine atoms. The molecular weight of 1,2-dichlorobenzene is 147.01. The empirical formula of 1,2-dichlorobenzene is C<sub>6</sub>H<sub>4</sub>Cl<sub>2</sub>. The structural formula is presented in Figure 1-1.

1,2-Dichlorobenzene is sold as two grades: (1) technical: monochlorobenzene <0.05%, trichlorobenzenes <1.0%, 1,2-dichlorobenzene 80.0%, other isomers <19.0%; (2) purified: produced by redistilling the technical product in a very efficient still: monochlorobenzene <0.05%, 1,2,4-trichlorobenzene <0.2%, 1,2-dichlorobenzene 98.0% (Kao and Poffenberger, 1979).

### **1.3 Analytical Methodology**

Analytical methods used to quantify 1,2-dichlorobenzene in environmental media include gas chromatography with flame ionization, or electron capture detection and gas chromatography/mass spectrometry (Oliver and Nicol, 1984; Oliver and Bothen, 1982).

## **2.0 PHYSICAL AND CHEMICAL PROPERTIES**

The physical and chemical properties affecting the

environmental fate and toxicity of 1,2-dichlorobenzene are presented in Table 2-1. It has a moderate to high vapour pressure (196 Pa @ 25°C), a moderate octanol/water partition coefficient (log = 3.40) and a low water solubility (118 mg/L @ 25°C) (Mackay et al., 1992).

### **3.0 SOURCES AND RELEASES TO THE ENVIRONMENT**

#### **3.1 Natural Sources**

No natural sources of 1,2-dichlorobenzene have been identified.

#### **3.2 Anthropogenic Sources**

##### **3.2.1 Quantities in Use**

###### **Production Volume and Trends**

1,2-Dichlorobenzene is produced in Canada and imported from the United States, China, Japan, Brazil, the United Kingdom and Argentina. In the past three years the number of companies which were listed as chemical suppliers for dichlorobenzenes in Canada have dropped from seven to three (Process Industries Canada, 1989 to 1991). From 1988 to 1990, available data on use of dichlorobenzenes in Canada (Table 3-1) suggest that the domestic production of 1,2-dichlorobenzene has declined while the amount imported into Canada has increased (Table 3-2). Overall, the Canadian demand for 1,2-dichlorobenzene has remained steady for the past five years, averaging approximately 350 tonnes per year, and this is not expected to change during the next five years (Camford Information Services, 1991).

Demand for 1,2-dichlorobenzene in the United States, in 1990, totalled 22 727 tonnes (Chemical Marketing Reporter, 1990). Production capacity of 1,2-dichlorobenzene increased from an estimated 29 500 tonnes in 1978 (U.S. EPA, 1982), to a production capacity of 34 500 tonnes in 1990 (Chemical Marketing Reporter, 1990).

##### **3.2.2 Imports and exports**

###### **Volume of Importation**

The total amount of 1,2-dichlorobenzene imported into Canada has increased since 1987 (Table 3-2), while domestic production has likely declined. In 1989, 1,2-dichlorobenzene was imported into Canada from the United States, Brazil, and the United Kingdom (Environment Canada, 1990 unpubl.).

### Volume of Exportation

No information on the volume of exportation of 1,2-dichlorobenzene is available.

#### **3.2.3      Manufacturing Processes**

1,2-Dichlorobenzene is produced by chlorinating benzene in the presence of a Friedel-Crafts catalyst (Kao and Poffenberger, 1979). The usual catalyst is ferric chloride, which can be generated in situ by exposing a large surface of iron to the liquid being chlorinated (U.S. EPA, 1986). By manipulation of process controls such as choice of catalyst, temperature and the benzene-chlorine ratio, it is possible to maximize the production of specific chlorobenzenes. However, each of the chlorinated benzenes, except hexachlorobenzene, can be chlorinated further, hence the compound produced is always a mixture of chlorinated benzenes. Pure compounds are obtained by distillation and crystallization.

#### **3.2.4      Uses**

Historically, 1,2-dichlorobenzene was used as a paint, carbon and grease remover and was registered in six products in Canada as the active ingredient in a pesticide. Three of these pesticide products were discontinued before 1975, two in 1985 and one, in 1990 (Davis, pers. comm., 1992). Quantitative use pattern information was identified only from 1977 to 1979 when 49% of 1,2-dichlorobenzene was used as a solvent for paint or carbon removers and degreasers, 31% for engine cleaning compounds, 19% for miscellaneous solvent use and 1% as photoresister solvents, dye carriers and fungicides (Environment Canada, 1983, unpubl.).

Currently in Canada, 1,2-dichlorobenzene is used to remove carbon and grease, primarily in engines and motors (Camford Information Services, 1991). It is also used as the active ingredient in an industrial strength deodorizer and cleaner. However, registration was discontinued for this product in 1990, and this use will end when supplies run out (Brien, pers. comm. 1992).

In the United States, 1,2-dichlorobenzene has a wider variety of applications, including: organic synthesis (mainly for 3,4-dichloroaniline herbicides, via 3,4-dinitrochlorobenzene) (84%); exports (8%); as a solvent in toluene diisocyanate processing (4%); and other solvent and miscellaneous uses (4%) (Chemical Marketing Reporter, 1990). In 1989, a total of 45 companies reported data to the U.S. EPA in the Toxic Release Inventory. In total, 34 uses were reported for 1,2-dichlorobenzene; the most common uses were in industrial organic and inorganic chemicals, cyclic crudes and intermediates, semi-conductors, soap and other detergents, agricultural chemicals and plastic materials and resins (Marcos,

1992, unpubl.).

1,2-Dichlorobenzene is used in the Federal Republic of Germany primarily (90%) as an intermediate in the manufacture of plant protection products, pharmaceutical products and dyes and to a lesser extent (about 10%) as a solvent (Gesellschaft Deutscher Chemiker, 1990).

### 3.2.5 Releases

There is limited quantitative information on anthropogenic releases of 1,2-dichlorobenzene to the Canadian environment. Because of its volatility and dispersive use patterns (carbon removal and as a degreaser in engines), it is estimated that most of the Canadian demand (350 tonnes) is released to the environment. Release of 1,2-dichlorobenzene to the environment may result from any stage in the production, transport, use and disposal of 1,2-dichlorobenzene-containing material. A summary of concentrations of 1,2-dichlorobenzene in various types of effluent released to the Canadian environment is summarized in Table 3-3.

### Organic and Inorganic Industries

Releases in effluents from organic and inorganic chemical manufacturing plants in Ontario were reported under the Municipal/Industrial Strategy for Abatement (MISA). Under the MISA program, estimated loadings to the St. Clair, St. Lawrence and Welland Rivers from organic and inorganic chemical manufacturing plants in Ontario were reported to be 0.772, 0.052 and 0.011 kg/day, respectively (OME, 1992 unpubl.; OME, 1992a; 1992b). It was also reported under MISA that concentrations of 1,2-dichlorobenzene ranged from 300 to 60 500 ng/L in the effluents discharged from organic chemical plants in the Sarnia, Maitland and Corunna, Ontario areas (OME, 1992, unpubl.).

Oliver and Pugsley (1986) reported that 1,2-dichlorobenzene had been released in substantial, but unquantified amounts into the St. Clair River, prior to the early 1980's. The source was related to leakage from an industrial chemical plant site and a landfill site in Sarnia, Ontario. Oliver and Charlton (1984) reported that the major source of 1,2-dichlorobenzene to Lake Ontario was from the Niagara River with an approximate loading of 14 kg/day 1,2-dichlorobenzene for the period between May and November, 1982. The source of 1,2-dichlorobenzene to the Niagara River was considered to be direct discharges from chemical manufacturers and over 200 chemical waste sites along the River (Oliver, 1987a). Based on concentrations found in Lake Ontario suspended sediments and raw water samples, Kuntz and Wary (1983) estimated the loading of 1,2-dichlorobenzene to Lake Ontario from Niagara River suspended sediments was 0.68 kg/day (250 kg/yr) for the period 1980 to 1981.

Data from sediment cores from Lake Ontario indicate that 1,2-dichlorobenzene has been accumulating in the sediments for approximately 60 years (Oliver and Nicol, 1984; Durham and Oliver, 1983). Durham and Oliver (1983) demonstrated that levels of 1,2-dichlorobenzene in sediment core samples followed known production and use patterns for this substance in the United States. Highest levels were in sediments from the 1960's period when production of chlorobenzenes was at its peak.

### Industrial and Municipal Wastewater

1,2-Dichlorobenzene was detected in effluents discharged from 4 of 27 pulp and paper mills in Ontario. Maximum concentrations of 1,2-dichlorobenzene ranged from 420 to 15 600 ng/L (OME, 1991a; 1991b) (Table 3-3). 1,2-Dichlorobenzene was also measured in a survey of ten Canadian textile mills conducted in 1985 and 1986; concentrations in effluents were reported to range up to a maximum of 95.5 µg/L (Environment Canada, 1989a). King and Sherbin (1986) conducted a one-day effluent survey of industrial, municipal and landfill effluent at the petrochemical industrial site at Sarnia. 1,2-Dichlorobenzene was detected in the leachate from the Dow Scott Road landfill at concentrations of 780 ng/L before carbon treatment and 10 ng/L after treatment. The landfill was used to dispose of solid wastes such as chlorinated tars.

In 1987, 1,2-dichlorobenzene was found in four of six samples of primary treated effluent from the Iona Island Wastewater Treatment Plant (Table 3-3). Two grab samples and four composite (5-day flow-proportional) samples were collected during June to December. Concentrations found in composite effluent samples ranged from less than the detection limit (10 ng/L) to 290 ng/L and had a mean values of less than 100 ng/L. The contaminant levels found in two grab effluent samples were <10 ng/L (detection limit) and 420 ng/L (Fanning et al., 1989). Since the 1987 data were collected, a deep sea outfall was put into service that replaces the previous surface discharge on Sturgeon Bank. The new outfall discharges primary treated effluent at depths of 70 to 100 metres into the Strait of Georgia, near Vancouver, British Columbia. Annual loading of contaminants in urban runoff from 12 urban centres in the Canadian Great Lakes basin was reported by Marsalek and Schroeter (1988). Mean annual loading of 1,2-dichlorobenzene into five sub-basins corresponding to Lakes Erie, Huron, Ontario, St. Clair and Superior ranged from 0.001 to 0.053 kg/day with the highest loading measured from Lake Ontario; the combined loading value was 0.085 kg/day.

### Other Sources

Other unquantified sources of 1,2-dichlorobenzene result from its formation as a product of anaerobic dechlorination of hexachlorobenzene and trichlorobenzenes in freshwater sediments, as

a product of the degradation of hexachlorobenzene in fresh anaerobic sewage sludge, and in emissions from incineration of organic matter containing chlorine.

Mousa and Rogers (1990) reported the dechlorination of hexachlorobenzene to 1,2-dichlorobenzene in anaerobic freshwater sediments under laboratory conditions. After 130 days of incubation, 1,2-dichlorobenzene was identified as a product of dechlorination in asphalt-containing sediment. Anaerobic transformation of the trichlorobenzenes (1,2,3-, 1,3,5-, 1,2,4-trichlorobenzenes) yielding dichlorobenzenes in laboratory columns packed with sediments from the Rhine river was reported by Bosma et al. (1988). After 300 days of continuous operation of the column at concentrations in the influent ranging from 300 to 500 nmol/L, the trichlorobenzenes were replaced by 1,2-, 1,3- and 1,4-dichlorobenzenes.

Fathepure et al. (1988) demonstrated the formation of 1,2-dichlorobenzene upon degradation of hexachlorobenzene in fresh anaerobic sewage sludge within 3 weeks. Hexachlorobenzene was dechlorinated via two routes, one leading to the formation of stable 1,3,5-trichlorobenzene and the other to the formation of 1,2-dichlorobenzene.

The effects of temperature, residence time and oxygen concentration on the thermal decomposition of 1,2-dichlorobenzene during incineration were reported by Young and Voorhees (1989). Low concentrations of 1,2-dichlorobenzene were formed where there was an excess of oxygen, temperatures of 750°C or higher, and about 2 seconds of residence time in the system. Intermediate concentrations of 1,2-dichlorobenzene were formed in tests using a stoichiometric concentration of oxygen. Varying the residence time (1 to 2 seconds) had little effect on formation of 1,2-dichlorobenzene as a product of incomplete combustion (PICs).

The formation of 1,2-dichlorobenzene as a result of incomplete combustion in flue gas samples collected from three municipal waste incinerator plants in the Federal Republic of Germany was reported by Ballschmiter et al. (1988). Concentrations varied from 0.04 to 0.18  $\mu\text{g}/\text{Nm}^3$ , with a mean of 0.095  $\mu\text{g}/\text{Nm}^3$ .

Three incinerator technologies were tested in the mid-1980's under Environment Canada's National Incinerator Testing and Evaluation Program (NITEP) (Environment Canada, 1985; 1988). The main objective of this program was to define the optimum design and operating conditions to minimize emissions of concern. However, as 1,2-dichlorobenzene was not separated from the rest of the chlorinated benzenes, data from this study are not relevant to this assessment.

## Sources in the United States and Elsewhere

As there are limited quantitative air or effluent emissions data available for chemical production plants in the United States, emission factors for 1,2-dichlorobenzene are presented in Table 3-4. A major source of 1,2-dichlorobenzene releases are volatile emissions from process vents, storage, loading and unloading and fugitive emissions from plant equipment leaks (U.S. EPA, 1987), however, use of 1,2-dichlorobenzene (e.g., as solvents) also results in widely dispersed releases to the environment (Slimak et al., 1980). 1,2-Dichlorobenzene is released to the environment from pesticide formulation sites (approximately 680 kg of 1,2-dichlorobenzene per year) (U.S. EPA, 1986), from its use as a solvent in 2,4-toluene diisocyanate (> 50%), and from its contribution to degreasers and solvents. Analysis of 9 hazardous waste incinerators and 4 co-fired boilers in the United States indicated that 1,2-dichlorobenzene was a frequently emitted compound from pilot scale stack emissions, with a mean emission rate of 307.9 µg/min (U.S. EPA, 1991).

The TRI database (Marcos, 1992), which monitors emissions from stationary industrial sources, indicated a release of 1 261 tonnes for the year 1989 into air, water and land (Table 3-5) compartments, and of that amount, the majority (85%) was released to off-site locations. Comparison of environmental release to U.S. demand (22 727 tonnes) in 1990, indicates that 6% of the total demand of 1,2-dichlorobenzene was released to the environment.

The manufacture of 1,2-dichlorobenzene as a main product and in part as a by-product during the production of chlorobenzenes amounted to a total of 12 000 tonnes in the Federal Republic of Germany in 1989 (Gesellschaft Deutscher Chemiker, 1990). Discharge of 1,2-dichlorobenzene to the environment via waste water and exhaust air results from its industrial production, use and application. Discharge through exhaust air was estimated at approximately 14 tonnes in 1989, whereas, release via waste water amounted to less than 1.9 tonnes.

#### **4.0 ENVIRONMENTAL TRANSPORT, TRANSFORMATION AND LEVELS**

Volatilization, photooxidation, partitioning to soil, sediment and biota, and aerobic degradation are the main processes affecting the distribution and transformation of 1,2-dichlorobenzene in the environment. Direct photolysis, hydrolysis and anaerobic degradation of 1,2-dichlorobenzene are not expected to play an important role in its environmental fate (U.S. EPA, 1987; Park et al. 1988; Callahan et al., 1979; Ellington et al., 1988; Weber et al., 1987).

#### **4.1 Transport and Distribution Between and Within Media**

##### **4.1.1 Air**

1,2-Dichlorobenzene was detected in the rain-dissolved phase during seven rain events from February to April, 1984 in Portland, Oregon. The presence of 1,2-dichlorobenzene in the rain phase indicates that the substance may be returned to the earth's surface by atmospheric washout (Ligocki et al., 1985).

##### **4.1.2 Water**

Transport and distribution of a substance between and within media in the aquatic environment is dependent upon its solubility, movement of the water, exchanges at the air-water interfaces, adsorption to sediment and particulate matter, and bioconcentration in aquatic organisms. The residence time in water is also dependent upon the type of environmental conditions encountered, including temperatures, wind speeds, currents, and ice cover.

##### **Surface Water**

Laboratory and field studies indicate that 1,2-dichlorobenzene volatilizes readily from the water column to the atmosphere. Garrison and Hill (1972) reported that 100 mg/L 1,2-dichlorobenzene volatilized almost completely (<1 mg/L of 1,2-dichlorobenzene remained) from non-aerated distilled water in less than 72 hours and from aerated distilled water in less than 4 hours. Volatilization half-lives for 1,2-dichlorobenzene were estimated to range from 0.94 hours in a shallow river or stream to 60 days in a deep, slow-moving river, and from 7.3 hours in a turbulent lake 1 m deep to 3 days in a lake 10 m deep (U.S. EPA, 1987).

1,2-dichlorobenzene was removed from (0.9 to 1.9  $\mu\text{g/L}$ ) surface water from the Rhine River in the Netherlands in 1979 by means of two filtration processes (Zoeteman et al., 1979). Dune filtration resulted in better removal (0.3  $\mu\text{g/L}$  remained) compared to bank filtration (0.8 to 1.1  $\mu\text{g/L}$  remained).

## Wastewater

Davis et al. (1983) reported a volatilization half-life of 14.6 hours for 1,2-dichlorobenzene from a model waste stabilization pond. A total of 240 mg/L of 1,2-dichlorobenzene was added to a synthetic waste feedstock with a 40 day dosing interval and a 12 day exposure period. At the end of the exposure period, a total of 21.8% 1,2-dichlorobenzene was lost through volatilization, and 71.1% was degraded; the remaining 7.1% was lost through sedimentation, and in effluent.

### **4.1.3      Soil**

Volatilization from a soil surface can be an important transport mechanism; however, volatilization may be attenuated by sorption and leaching (Howard et al., 1991). Mackay and Yuen (1983) stated that the presence of organic solids will reduce the volatilization rate by reducing the fugacity or partial pressure. Based on its estimated organic carbon sorption coefficient ( $K_{oc}$ ) of 1 030 (calculated using the formula of Mackay et al. (1992)), 1,2-dichlorobenzene has a slight soil mobility potential (McCall et al., 1981).

Volatilization from shallow soils is an important removal process for 1,2-dichlorobenzene (Lyman et al., 1982). Anderson et al. (1991) reported a half-life of 4.0 days for 1,2-dichlorobenzene from two different soil types, a silt loam and a sandy loam; the soil type appeared to have had no significant effect on the disappearance of 1,2-dichlorobenzene. The authors attributed the results to volatilization. Park et al. (1988) reported that although soil type (organic carbon content 0.2 to 1.2%) and concentration of the substance did not affect volatilization, volatilization increased with temperature. Volatilization ranged from 29.5% at 12°C, to 39.3% at 21°C over a 7 day period. Rates of volatilization from soil were reported to be 10 to 100 times lower than from surface water.

### **4.1.4      Sediment**

Based on physical/chemical properties, a small percentage of 1,2-dichlorobenzene (2%) entering Lake Ontario from the Niagara River, is expected to be deposited in bottom sediments (Oliver and Charlton, 1984). Releases from bottom sediments can occur by resuspension, redistribution and desorption (Oliver, 1985; Oliver and Charlton, 1984). Once in the bottom sediments, 1,2-dichlorobenzene is expected to equilibrate between the pore water or the organic phase (Di Toro et al., 1991).

Surveys of Lake Superior, Huron, Erie, and Ontario indicated that 1,2-dichlorobenzene has accumulated in bottom sediments, with highest concentrations occurring in samples obtained from 0 to 5 cm

below the sediment surface (Oliver and Nicol, 1982). Oliver and Charlton (1984) reported that sediments from the Niagara River adsorb contaminants from the river water, settle in the Lake Ontario and are resuspended and redistributed in sedimentation basins in the lake. The authors were able to estimate the approximate amount of 1,2-dichlorobenzene entering Lake Ontario from the Niagara River from May to November, 1982 (total 14 kg/day), the amount transferred to the lake sediments (310 g/day) and the downflux of contaminant to sediment as percentage of the total loading (2%) to the lake in 1982. Oliver and Charlton (1984) also suggested that due to its vapour pressure, volatilization would be a major removal mechanism for 1,2-dichlorobenzene from Lake Ontario.

Based on field observations, Oliver (1985) reported that a 1 mm thick sediment layer in the sedimentation basins (8 700 km<sup>2</sup>) in Lake Ontario is continually being resuspended then resettling to the bottom. With a near bottom temperature of 4°C and the active layer containing about 2% solids, the average desorption half-life under these conditions is about 60 days. Oliver (1985) demonstrated that desorption from sediments increases with increasing temperature and that an increase in desorption with decreasing suspended sediment concentration was also observed. The contribution of 1,2-dichlorobenzene loadings via desorption from bottom sediments in Lake Ontario was estimated to be minimal (0.005 kg/day) in comparison with the loading estimates from the Niagara River (7.1 kg/day) (Oliver, 1985).

#### 4.1.5 Biota

1,2-Dichlorobenzene has the potential to be available to organisms in the water column and sediments. However, based on its water solubility and vapour pressure, Oliver and Charlton (1984) suggested that 1,2-dichlorobenzene is more likely to remain dissolved in or volatilize from water.

Bioconcentration factors for a number of organisms have been reported for 1,2-dichlorobenzene.<sup>1</sup> Barrows et al. (1980) and Veith et al. (1980) reported bioconcentration factors (BCFs) in bluegill sunfish (Lepomis macrochirus) (whole fish basis) of log 1.95 (89). Bluegill sunfish were maintained at equilibrium in a flow-through

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<sup>1</sup> A bioconcentration factor is defined as:

$$\text{BCF} = \frac{\text{Concentration of chemical at steady state in organism (wet weight)}}{\text{Mean concentration of chemical in water}}$$

system for 14 days (mean water concentration: 7.89  $\mu\text{g/L}$ ) and exposed to pollutant-free water for a period of 7 days. Half-lives in tissue of less than one day were estimated by both authors. Oliver and Niimi (1983) and Oliver (1984) reported slightly higher BCFs of log 2.43 and 2.75 (270 and 560, respectively) for rainbow trout (Oncorhynchus mykiss) (whole fish basis) at exposure levels of 47 and 90 ng/L, respectively. Equilibrium was attained within seven to eight days over the 105 to 119 day studies.

Oliver (1987b) studied the uptake and depuration of 1,2-dichlorobenzene in spiked Lake Ontario sediments (4.6% organic carbon) by oligochaete worms. A half-life of less than 5 days was reported in the worms after a 79 day exposure period in the contaminated sediment and a 5 day depuration period in clean Lake Superior sediment. Oliver (1987b) observed that the pore water concentration of 1,2-dichlorobenzene was the main driving force for contaminant uptake by the worms.

Pereira et al. (1988) determined BCFs for four species of biota in a field study in the vicinity of an industrial outfall in the Calcasieu River estuary, Louisiana. BCFs (lipid basis) for the spotted sea trout (Cynoscion nebulosus), blue catfish (Ictalurus furcatus), Atlantic croakers (Micropogonias undulatus) and blue crabs (Callinectes sapidus), were log 3.79 (6166), log 3.82 (6607), log 3.94 (8709) and log 4.46 (28840), respectively. Davis et al. (1983) reported a comparable BCF (6212) in algae during a mass balance evaluation of 1,2-dichlorobenzene in a model waste stabilization pond.

## **4.2 Transformation**

### **4.2.1 Biodegradation**

1,2-Dichlorobenzene has been shown to be aerobically biodegraded in surface water, wastewater, ground water, soil, sediments, and sludge.

#### **Surface Water**

1,2-Dichlorobenzene spiked into treated river water was reduced from 20  $\mu\text{g/L}$  to non-detectable levels ( $<0.2 \mu\text{g/L}$ ) using granular activated carbon filters (Hyde, 1980). The author attributed the removal of 1,2-dichlorobenzene to adsorption and biodegradation.

#### **Wastewater**

The fate of 1,2-dichlorobenzene in a model waste stabilization pond was reported by Davis et al. (1983). A mass balance evaluation indicated losses from volatilization (21.8%), biodegradation (71.1%), sedimentation (3.8%), residue in the water

column (0.9%) and loss in effluent (2.4%). An experimental biodegradation half-life of 14.6 hours was determined by the authors. Tabak et al. (1981) reported significant biodegradation of 1,2-dichlorobenzene by domestic wastewater microbial populations over a period of 7 days, however, when the cultures were subcultured this ability diminished. The gradual reduction of biodegradation activity was ascribed either to loss of synergistic activity of the original heterogeneous population or to the build-up of toxic metabolites (Tabak et al., 1981).

Degradation of 1,2-dichlorobenzene in municipal wastewater was demonstrated by Davis et al. (1981) and McCarty et al. (1980). Degradation of 96% 1,2-dichlorobenzene in municipal and industrial wastewater containing four bacterial genera (Actinobacter, Alcaligenes, Flavobacterium, and Pseudomonas) and one yeast (Rhodotorula), occurred over 7 days (Davis et al., 1981). Greater than 97% 1,2-dichlorobenzene were removed during municipal wastewater treatment in a California advanced wastewater treatment plant after waste segregation and activated sludge treatment for the period from October 1976 to October 1978 (McCarty and Reinhard, 1980).

1,2-Dichlorobenzene was biotransformed during long-term (3 years) continuous-flow aerobic column studies with acetate as the primary substrate (Bouwer and McCarty, 1985). Average removal efficiencies of 1,2-dichlorobenzene in a 1 mg/L acetate-grown biofilm column, ranged between 96% (after 9 months removal) and 97% (between 9 and 36 months removal) and after an acclimation period of 20 days. An increased acclimation period (60 days) was required in 5 mg/L biofilms with removal efficiencies at 63% (after 5 months) and 93% (between 5 and 32 months). In similar studies with mixed bacterial cultures and under aerobic and methanogenic conditions, significant degradation (96-97%) was observed in aerobic biofilm columns (Bouwer and McCarty, 1984; Bouwer, 1985). Little transformation (0-4%) was reported in the methanogenic biofilm columns.

### Groundwater

Zoeteman et al. (1980) estimated that the half-life in ground water for 1,2-dichlorobenzene ranged between 30 and 300 days. Results of field studies indicated that 1,2-dichlorobenzene was persistent and somewhat mobile in groundwater contaminated by sewage effluent and municipal and industrial wastes (Barber et al., 1988; Barber, 1988; Roberts et al., 1980; Roberts et al., 1986; Reinhard et al., 1984).

1,2-Dichlorobenzene was reported to be both persistent and relatively mobile under anaerobic conditions in the leachate plume of a municipal landfill at North Bay, Ontario (Reinhard et al., 1984). 1,2-Dichlorobenzene was detected 800 m from the landfill

confirming the low sorption capacity of the North Bay sandy aquifer and the persistence of 1,2-dichlorobenzene under anaerobic conditions. Attenuation of 1,2-dichlorobenzene appeared to be by dispersion only (Reinhard et al., 1984). 1,2-Dichlorobenzene was also reported to be persistent and relatively mobile during field studies of groundwater contaminated by sewage effluent and municipal and industrial wastes near Boston, Massachusetts (Barber, 1988; Barber et al., 1988). The plume of sewage contamination containing 1,2-dichlorobenzene extended more than 3500 m from the sewage disposal bed and the authors established that the 1,2-dichlorobenzene had entered the aquifer some 20 to 30 years previously. The persistence of 1,2-dichlorobenzene in the aquifer was attributed to redox conditions and nutrient limitations (carbon and oxygen) that were unfavorable for microbial degradation (Barber, 1988).

Biodegradation of 332 and 163  $\mu\text{g/L}$  of 1,2-dichlorobenzene under aerobic conditions in an experimental plume in an unconfined aquifer near Borden, Ontario was reported by Wilson et al. (1987). After 58 weeks, approximately 4% of 1,2-dichlorobenzene remained in the aquifer. Biodegradation of 1,2-dichlorobenzene occurred during field measurements simulating infiltration of river water to groundwater and only in the presence of 1,4-dichlorobenzene and xylenes (Kuhn et al., 1985). 1,2-Dichlorobenzene was transformed only under aerobic conditions and did not fall below 25% of the initial concentration (0.5  $\mu\text{M}$ ). These processes ceased under anaerobic conditions (Kuhn et al., 1985). Zoeteman et al. (1980) estimated that the half-life in groundwater for 1,2-dichlorobenzene ranged between 30 and 300 days.

### Soil

1,2-Dichlorobenzene has been shown to biodegrade in soil under aerobic conditions. Transformation of 1,2-dichlorobenzene (influent concentration: 25  $\mu\text{g/L}$ ) by the bacteria Pseudomonas testosteroni strain P51 in an aerobic soil percolation column occurred after an adaptation period of 80 days, resulting in an effluent concentration of 0.1  $\mu\text{g/L}$  after a period of 500 days (Schraa and van der Meer, 1987). Inoculation of Pseudomonas testosteroni with influent concentrations of 20, 200 and 1000  $\mu\text{g/L}$  of 1,2-dichlorobenzene, resulted in effluent concentrations of 5 - 10  $\mu\text{g/L}$  for all three experiments. The authors confirmed the ability of the bacteria Pseudomonas testosteroni to biodegrade 1,2-dichlorobenzene.

van der Meer (1987) reported aerobic biodegradation of 1,2-dichlorobenzene in Rhine River sediments and in percolation columns containing sediments inoculated with Pseudomonas sp. strain P51. In the noninoculated sediment columns the native microbial population, were able to degrade 1,2-dichlorobenzene after a long lag phase (100 days) and an influent solution of 25  $\mu\text{g/L}$ . The

study was operated for 200 days, and resulted in an effluent concentration of 0.1  $\mu\text{g/L}$ . Upon inoculation with cells of strain P51 into a sediment column with concentrations of 1 000  $\mu\text{g/L}$  1,2-dichlorobenzene, more than 99% degradation of 1,2-dichlorobenzene was observed. In two additional inoculation experiments with influent concentrations of 200 and 40  $\mu\text{g/L}$  1,2-dichlorobenzene, rapid degradation was again observed with removal of 90% and 50%, respectively. Biodegradation was not observed below the threshold concentration of  $6 \pm 4 \mu\text{g/L}$  in all three inoculation experiments (van der Meer et al., 1987). The results indicated that the biodegradation was concentration dependent, i.e., a low substrate level resulted in a loss of the degradation ability.

1,2-Dichlorobenzene was degraded by the bacteria *Pseudomonas* strain GJ60 in unsterilized soil slurries utilizing chlorobenzene and 1,2-dichlorobenzene as sole carbon sources (Oldenhuis et al., 1989). Doubling times of 5.5 hours and 3.0 hours were reported in mineral salts medium and a soil slurry, respectively, supplemented with 1 mM 1,2-dichlorobenzene as sole energy and carbon source. Without inoculation with GJ60, only partial degradation of 1,2-dichlorobenzene occurred. Upon addition of activated sludge (5 mg cell dry mass per liter) to an initial concentration of 50 mg/L of 1,2-dichlorobenzene at 30°C, 1,2-dichlorobenzene was completely degraded within 50 hours.

A microcosm was constructed by Piwoni et al. (1986) to study the behaviour of 1,2-dichlorobenzene during rapid infiltration of municipal wastewater and spring water into a fine sandy soil. Three weeks after monitoring began, a mass balance evaluation indicated that  $21\% \pm 12\%$  was volatilized,  $<1\%$  was detected in the effluent and  $79 \pm 12\%$  was not accounted for. Approximately 10% (10.3 - 20.6  $\mu\text{g/L}$ ) of the applied concentration of 1,2-dichlorobenzene was detected in the effluent that received spring water. The compound was not found in the effluent from the soil that received wastewater.

Based on a review of available literature, Mackay et al. (1992) selected a half-life of approximately 8 months for 1,2-dichlorobenzene in soil, while Howard (1991), reported the half-life to range from 4 weeks to 6 months.

### Sediments

Based on a review of the literature, Mackay et al. (1992) selected a half-life of approximately 2 years for 1,2-dichlorobenzene in the first 1 cm of sediment.

However, Oliver and Nicol (1982), 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.

### Sludge

The behaviour of 1,2-dichlorobenzene in a mixed primary sewage sludge incubated anaerobically with and without azide addition to arrest biological activity was reported by Kirk et al. (1989). The authors attributed the removal of 66% of 1,2-dichlorobenzene over the 32 day study period to a chemical conversion or physical removal process other than sorption. Haigler et al. (1988) demonstrated that Pseudomonas sp. (strain JS100) isolated by selective enrichment from activated sludge, was capable of growing on 1,2-dichlorobenzene as the sole source of energy and carbon under aerobic conditions. The minimum doubling time for the Pseudomonas sp. with 1,2-dichlorobenzene was 5.5 hours.

The fate of 1,2-dichlorobenzene in a complete-mix, continuous-flow activated sludge system over a 60 day period was examined by Kincannon et al. (1983). Greater than 99.9% 1,2-dichlorobenzene was removed in the activated sludge. Biodegradation was the major removal mechanism (78%) with the remaining 22% removed by stripping.

#### **4.2.2     Abiotic Degradation**

##### Hydrolysis

Under the range of conditions found in the Canadian environment and in view of the difficulty with which aryl halides undergo nucleophilic substitution, hydrolysis of 1,2-dichlorobenzene in ambient water is unlikely to occur (Morrison and Boyd, 1987; Callahan et al., 1979). Ellington et al. (1988) estimated a half-life due to hydrolysis to be greater than 879 years in groundwater beneath land disposal sites.

##### Photolysis

The ozone layer limits the wavelengths available for photolysis at the earth's surface to the 290 to 750 nm range. 1,2-Dichlorobenzene absorbs very weakly at wavelengths greater than 300 nm, hence direct photolysis of 1,2-dichlorobenzene is not expected to be a significant transformation mechanism (Bunce et al. 1987). 1,2-Dichlorobenzene was photolyzed in the vapour phase under an atmosphere of nitrogen and a wavelength of 254 nm (Bunce et al. (1987). Photolyzation of 1,2-dichlorobenzene yielded trace amounts of monochlorobenzene, trichlorobenzenes, phenols, biphenyls and chlorobiphenyls. However, direct photolysis of 1,2-dichlorobenzene in water, on soil or in the atmosphere is not expected to play an important role in the environmental fate of 1,2-dichlorobenzene (U.S. EPA, 1987).

## Photooxidation

The primary mechanism for 1,2-dichlorobenzene transformation in the atmosphere is through reaction with hydroxyl radicals (OH) (Atkinson et al., 1985). 1,2-Dichlorobenzene will react with photochemically produced hydroxyl radicals in the atmosphere with an estimated photooxidation half-life of 24 days (Howard et al., 1989). Mackay et al. (1992) estimated a mean half-life in the atmosphere for photooxidation and advection processes of approximately three weeks. Based on rate constants published in the literature (Atkinson et al., 1985; Wahner and Zetzch, 1983), Howard et al. (1991) estimated the photooxidation half-lives to range from 6 to 64 days, respectively. Singh et al. (1983) reported a 2.6% loss of 1,2-dichlorobenzene in one 12 hour sunlit day by reaction with the hydroxy radical. A residence time of 38.6 days was calculated by Singh et al. (1981) based on an estimated average daily (24-h) OH abundance of  $10^6$  molecule  $\text{cm}^3$ .

### 4.3 Environmental Concentration

1,2-Dichlorobenzene has been detected in surface water, sediments and biota in the Great Lakes region. It has also been detected, albeit infrequently, in ambient air, groundwater, and soil in Canada.

#### 4.3.1 Air

The mean concentration of 1,2-dichlorobenzene measured in extensive (24 hour) samples of ambient air from 22 sites from five provinces throughout Canada during the period October, 1988 through December 1990 was less than the detection limit of 0.05 to 0.1  $\mu\text{g}/\text{m}^3$  (Table 4-1) (Environment Canada, 1991, unpubl.). Median concentrations for the urban and industrial sites were also below the detection limit. Daily maximum concentrations of 1,2-dichlorobenzene in ambient air ranged from 0.06  $\mu\text{g}/\text{m}^3$  (Vancouver, British Columbia) to 0.61  $\mu\text{g}/\text{m}^3$  (Toronto, Ontario); 96% of the measurements were below the detection limit. Between August 1984 and August 1985, Dann (1985) reported maximum concentrations of 0.1  $\mu\text{g}/\text{m}^3$  in ambient air in both Toronto, Ontario and Montreal, Quebec (Table 4-1).

1,2-Dichlorobenzene was reported in the rain-dissolved phase and the atmospheric gas phase for seven rain events in Portland, Oregon during February to April, 1984. Concentrations ranged from 3.3 to 10.0  $\text{ng}/\text{m}^3$  in the gas phase and from 0.13 to 0.62  $\text{ng}/\text{L}$  in the dissolved phase (Ligocki et al., 1985).

In heavily industrialized areas of New Jersey in the United States, maximum concentrations of 1,2-dichlorobenzene are an order of magnitude higher than in Canada (Table 4-1). 1,2-Dichlorobenzene was detected in ambient air at six abandoned

hazardous waste sites and one sanitary landfill in New Jersey in a three to five day study in 1983 and 1984 (Harkov et al., 1985). Arithmetic mean values for 1,2-dichlorobenzene ranged from 0.24 to 5.16  $\mu\text{g}/\text{m}^3$ , with a maximum concentration at the six sites of 50.5  $\mu\text{g}/\text{m}^3$ .

#### 4.3.2 Water

##### Fresh Surface Water

1,2-Dichlorobenzene was measured in the Great Lakes and associated rivers in Canada between 1980 and 1989 at concentrations ranging from 0.007 to 240 ng/L (Table 4-2). Concentrations of 1,2-dichlorobenzene were at their highest in the early 1980s and have decreased in recent years. Stevens and Neilson (1989) reported a mean concentration of 1,2-dichlorobenzene in Lake Ontario in 1986 of 0.79 ng/L and a maximum level of 3.7 ng/L in samples of whole water. Lower mean concentrations were found for Lakes Erie, Huron and Superior in 1986, ranging between 0.10 and 0.20 ng/L 1,2-dichlorobenzene (Stevens and Neilson, 1989). Mean concentrations of 1,2-dichlorobenzene found in 51 samples of ambient water from April 1988 to March 1989 at the head (Fort Erie) and mouth (Niagara-on-the-Lake) of the Niagara River were 0.27 and 2.05 ng/L, respectively (NRDIG, 1990). 1,2-Dichlorobenzene was detected in ambient water at Fort Erie and Niagara-on-the-Lake for the period April 1986 to March 1987, at mean concentrations from 44 samples of 0.35 and 1.74 ng/L, respectively (NRDIG, 1988). From 1981 to 1983, Oliver and Nicol (1984) reported a mean of 23 ng/L 1,2-dichlorobenzene (range 4 to 240 ng/L) in whole water samples collected weekly from the Niagara River, at Niagara-on-the-Lake, Ontario.

Levels of 1,2-dichlorobenzene along the St. Clair River in 1985 were comparable to those in the Niagara River in recent years. Forty-litre water samples were collected at locations upstream and downstream of a petrochemical industrial site at Sarnia along the St. Clair River between August and October of 1985 (Chan and Kohli, 1987). Levels of 1,2-dichlorobenzene ranged from 0.007 to 2.98 ng/L. The concentrations of 1,2-dichlorobenzene were generally higher downstream of Sarnia at Port Lambton than upstream from the petrochemical site.

1,2-Dichlorobenzene was measured in 1981 in Niagara River water and suspended solids near Niagara-on-the-Lake and in western Lake Ontario sediments and benthic fauna (Fox et al., 1983). Concentrations of 1,2-dichlorobenzenes in the Niagara-on-the-Lake suspended material increased as the size fractions increased, ranging from 38 ng/g (<75  $\mu\text{m}$ ) (dry weight) to 350 ng/g (>700  $\mu\text{m}$ ) (dry weight). Niagara River water contained a mean concentration of 5.5 ng/L (or about 0.006 ng/g) 1,2-dichlorobenzene indicating that partitioning onto the solids had occurred. 1,2-

Dichlorobenzene was not detectable in the Fort Erie water and suspended solids ( $>700\ \mu\text{m}$ ).

#### Marine and Estuarine Water

No information was found on 1,2-dichlorobenzene levels in marine or estuarine water in Canada.

#### Industrial and Municipal Wastewater

Concentrations of 1,2-dichlorobenzene in industrial and municipal wastewater are presented in Table 3-3 and discussed in Section 3.2.5.

#### Runoff

Marsalek and Schroeter (1988) reported concentrations of 1,2-dichlorobenzene in urban runoff from 12 urban centres in the Canadian Great Lakes basin (Lakes Erie, Huron, Ontario, St. Clair and Superior). Mean concentrations of 39 ng/L and 120 ng/g 1,2-dichlorobenzene were measured in stormwater and street sediments, respectively (Tables 4-2 and 4-5).

#### Groundwater

In Canada, elevated levels of 1,2-dichlorobenzene have been measured in groundwater near waste disposal and landfill sites (Table 4-3). 1,2-Dichlorobenzene was detected in groundwater at a former disposal site for waste oils and solvents near Ville Mercier, Quebec (Martel and Ayotte, 1989). Analysis of 146 samples of groundwater from the Ville Mercier area for the period May 1988 to August 1989 revealed concentrations of 1,2-dichlorobenzene ranging from 3 300 to 46 000 ng/L in samples in contact with oil deposits (detection limit: 50 ng/L) (Martel and Ayotte, 1989) (Table 4-3). Characterization studies of a chemical production site near Napierville, Quebec in 1987 were conducted after municipal wells were found to contain chlorobenzenes and naphthalene (Foratek International Inc., 1987; Foratek Inc., 1989; ADS associ  s lt  e, 1990). Highest levels of 1,2-dichlorobenzene were found near the warehouse of the plant site. Concentrations of 1,2-dichlorobenzene in groundwater at the plant site ranged from non detectable (detection limit of 2  $\mu\text{g/l}$ ) to 58 400  $\mu\text{g/L}$ , and up to 692 000  $\mu\text{g/L}$  in the oil phase (Foratek International Inc., 1987; Foratek Inc., 1989). The site is targeted for remediation.

1,2-Dichlorobenzene was found in groundwater near a municipal landfill near North Bay, Ontario, in 1981 (Reinhard et al., 1984). Concentrations of 1,2-dichlorobenzene were detected in groundwater under the landfill (13 000 ng/L) and 800 m away where the leachate-contaminated groundwater emerged in springs (2 800 ng/L). Pankow et al. (1985) reported a mean concentration of 38 ng/L 1,2-

dichlorobenzene in groundwater at an inactive landfill near Burlington, Ontario. A total of 32 piezometers were sampled in duplicate from October to November, 1983 using the adsorption/thermal desorption (ATD) analysis method.

Groundwater from well sites containing organic compounds were sampled in Cape Cod, Massachusetts, northern New Jersey and southern New Jersey. Sampling wells from the Cape Cod, Massachusetts and northern New Jersey sites showed levels below the detection limit ( $<1 \mu\text{g/L}$ ). Groundwater from the southern New Jersey well, which was contaminated by a chemical waste recycling facility, contained concentrations of 1,2-dichlorobenzene ranging from 14 000 to 15 000 ng/L (Imbrigiotta et al., 1988).

#### 4.3.3 Soil

Characterization studies of a chemical production site near Napierville, Quebec in 1987, 1989 and 1990 were conducted after municipal wells were found to contain chlorobenzenes and naphthalene (Foratek International Inc., 1987; Foratek Inc., 1989; ADS associés Itée, 1990) (Table 4-5). A total of 28 samples were taken to determine the limits of the contaminated soil. Highest levels of 1,2-dichlorobenzene were found near the distillation unit and the warehouse of the plant site. Levels of 1,2-dichlorobenzene in soil ranged from non detectable ( $<2.0 \mu\text{g/g}$ ) to  $7\,980 \mu\text{g/g}$  (dry weight). In the 1990 study, concentrations of 1,2-dichlorobenzene in a drainage ditch on the plant site ranged from non detectable ( $<0.1 \mu\text{g/g}$ ) to  $36.9 \mu\text{g/g}$ . The site is targeted for remediation.

#### 4.3.4 Bottom Sediment

Levels of 1,2-dichlorobenzene in sediments in Canada are restricted mainly to concentrations in samples collected in the late 1970s to mid 1980s (Table 4-5). 1,2-Dichlorobenzene concentrations were reported in surficial sediment in the Niagara and St. Clair Rivers, Lake Ontario, and two rivers and a harbour in Nova Scotia.

1,2-Dichlorobenzene was not detected in bottom sediments near a municipal sewage outfall at Victoria, British Columbia. In the 1992 study, 1,2-dichlorobenzene was below the limit of detection of  $1 \mu\text{g/kg}$  (dry weight) (EVS Consultants, 1992).

Elevated concentrations of 1,2-dichlorobenzene were measured in bottom sediments along a 7 km stretch of the St. Clair River. Oliver and Pugsley (1986) reported maximum concentrations of  $34\,000 \text{ ng/g}$  (dry weight) (average  $5\,500 \text{ ng/g}$ ) total dichlorobenzene (1,2-, 1,3-, and 1,4-dichlorobenzenes) in the St. Clair River sediment between 1984 and 1985. Based on levels reported for the dichlorobenzene isomers in the same area by Oliver (pers. comm., 1992), it was estimated that the relative composition of 1,3-

dichlorobenzene, 1,2-dichlorobenzene, and 1,4-dichlorobenzene was approximately 58, 32 and 10%, respectively. Therefore, using the average value of 5 500 ng/g reported by Oliver and Pugsley (1986), it was estimated that the concentration of 1,2-dichlorobenzene in the St. Clair River sediments was 1 700 ng/g.

Examination of the vertical distribution of 1,2-dichlorobenzene in bottom sediments in Lake Ontario in 1981 near the mouth of the Niagara River, provides insight into the history of chlorobenzene production and loading to the Niagara River. U.S. production of chlorobenzenes was greatest from 1960 to 1970 as is evident from cores at the 7 to 10 cm depth (69 to 87 ng/g) (Durham and Oliver, 1983). Concentrations of 1,2-dichlorobenzene at the 0 to 3 cm depth ranged from 13 to 25 ng/g and increased to 87 ng/g at a depth of 8 to 9 cm. Samples containing 1,2-dichlorobenzene were collected from the top 2 cm of sediment from five sites in western Lake Ontario from April to July 1981 (Fox et al., 1983). Concentrations decreased from 22 to 54 ng/g in April to 7 to 23 ng/g (dry weight) in July. Mean concentrations of 1,2-dichlorobenzene in bottom sediment taken from three Great Lakes locations were highest in Lake Ontario (11 ng/g) and decreased in Lakes Huron (8 ng/g dry weight), Lake Erie (2 ng/g) and Superior (1 ng/g) from 1980 to 1981 (Oliver and Nicol, 1982). In 1981, ten stations sampled for concentration and distribution of 1,2-dichlorobenzene in bottom sediments along the St. Lawrence River were comparable to levels measured in the Great Lakes (Merriman, 1987). Concentrations of 1,2-dichlorobenzene in bottom sediments ranged from 2 ng/g near Cape Vincent, New York to a maximum of 15 ng/g across the river at Kingston, Ontario. Upriver, near Cornwall, Ontario, levels of 1,2-dichlorobenzene ranged from 3 to 5 ng/g.

In a 1979 study of chlorobenzenes in bottom sediments near a coking oven, a chlor-alkali chemical plant and a textile plant, MacLaren Marex Ltd. (1979) only reported levels above the detection limit of 2 ng/g of 1,2-dichlorobenzene in sediment in the vicinity of the chlor-alkali plant. Nine samples containing levels of 1,2-dichlorobenzene ranging from <2 to 47 ng/g were detected near the chlor-alkali plant in Pictou Harbour, Nova Scotia.

#### 4.3.5 Suspended Sediments

In suspended sediments in Canada, highest concentrations were reported in the Niagara River in the early to mid 1980s (Table 4-5). Niagara River water samples collected between August 1985 and August 1986 were analyzed for 1,2-dichlorobenzene in suspended solids and extracts of water under acidic and basic conditions (Maguire et al., 1989). 1,2-Dichlorobenzene was detected in suspended solids at a concentration of 41 ng/L, but not in the Niagara River water acidic or basic extracts. Fox et al. (1983) measured 1,2-dichlorobenzene in suspended sediments at two sites

along the Niagara River at Niagara-on-the-Lake (NOTL) and Fort Erie, in 1981. High concentrations (35 to 350 ng/g dry weight) of 1,2-dichlorobenzene were observed in the suspended sediment samples collected at NOTL, but no 1,2-dichlorobenzene was detected at Fort Erie, indicating sources of this contaminant along the Niagara River. 1,2-Dichlorobenzene concentrations measured in suspended sediments in earlier studies at Niagara-on-the-Lake support the levels reported by Fox et al. (1983). Kuntz and Wary (1983) reported a mean value of 148 ng/g (dry weight) in suspended sediments in the lower Niagara River from April 1979 to December 1981. Oliver and Charlton (1984) collected settling particles from sediment traps suspended at 20 to 68 m depth in the water column from September to October, 1982 in the Niagara Basin of Lake Ontario. Concentrations of 1,2-dichlorobenzene in the traps ranged from non detectable to 47 ng/g (dry weight).

Sylvestre (1987) reported the presence of 1,2-dichlorobenzene in suspended sediments near Wolfe Island in the St. Lawrence River from April 1982 to June 1984. Levels of 1,2-dichlorobenzene were below the detection limit (50 ng/g) in the first year of the sampling program but during the period July 1983 to May 1984, 1,2-dichlorobenzene was found in 40% of the samples with a maximum concentration of 660 ng/g (dry weight). However, the author questions the accuracy of these values, attributing the results to possible solvent interference in the analysis. In 1981, ten stations were sampled for the concentration and distribution of contaminants in the suspended sediments along the St. Lawrence River (Merriman, 1987). Concentrations of 1,2-dichlorobenzene were consistent along the river, ranging from 29 to 36 ng/g at Kingston, Ontario and Cape Vincent, New York, respectively, to 31 ng/g in the Cornwall, Ontario region. Between 1981 and 1987, Germain and Langlois (1988) collected dissolved and particulate samples from the St. Lawrence River, from Cornwall, Ontario to l'île d'Orléans, Québec. The authors did not detect 1,2-dichlorobenzene in the particulate phase, however, the compound was detected in the dissolved phase at a concentration of 1.03 ng/L.

#### 4.3.6 Effluent and Sludge

Sludges from 15 municipalities across Canada were analysed for organic contamination from 1980 to 1985 (Webber and Lesage, 1989). 1,2-Dichlorobenzene was detected in only one of the sludges. Maximum and median concentrations of 1 600 ng/g and 550 ng/g (dry weight) 1,2-dichlorobenzene, respectively, were detected in digested sludge samples from Winnipeg, Manitoba (Table 4-5). A field monitoring program of influent, final effluent and raw and treated sludges from 37 municipal water pollution control plants (WPCP) across Ontario was carried out from January 1987 to July 1987. 1,2-Dichlorobenzene was found in one of 274 samples of raw sewage tested at a concentration of 42 000 ng/L (OME, 1988).

In the United States, 1,2-dichlorobenzene was detected at 2 depths in soil samples after 5, 122 and 241 days, following application of 448 343 kg/ha sludge (Demirjian, et al., 1987). The sludge contained 580 µg/kg of 1,2-Dichlorobenzene. Elevated concentrations (816 µg/kg) were present in the first sample depth (0 to 15.2 cm) after 5 days but were not detected at the second core depth (22.9 to 38.1 cm). After 122 and 241 days, levels had decreased at the first depth (113 and 115 µg/kg, respectively), and were now present at the lower sample depth (45 and 23 µg/kg, respectively), indicating that leaching had occurred.

#### 4.3.7 Biota

1,2-Dichlorobenzene was detected in amphipods, oligochaetes, clams and fish in studies conducted in the early 1980s. No studies were available on levels of 1,2-dichlorobenzene in wild mammals, reptiles, amphibians or birds in Canada. In a study conducted near a sewage treatment plant outfall at Clover Point, near Victoria, BC, 1,2-dichlorobenzene was not detected in mussel (Modiolus sp.) tissue (detection limit 5 µg/kg) (EVS Consultants, 1992).

Based on studies conducted in the Great Lakes in the early 1980s, the concentrations of 1,2-dichlorobenzene in lake trout (Salvelinus namaycush) and rainbow trout (Oncorhynchus mykiss) ranged between 0.3 and 1 ng/g (wet weight) (Oliver and Nicol, 1982; Oliver and Niimi, 1983). Higher concentrations of 1,2-dichlorobenzene were reported in sediment-dwelling organisms collected from five sites in western Lake Ontario in April and July, 1981 (Fox et al., 1983). Levels of 1,2-dichlorobenzene ranged from non detected to 18 ng/g (dry weight) in amphipods, and non detected to 100 ng/g (dry weight) in oligochaetes. 1,2-Dichlorobenzene was not detected in mysids and lake trout. Worms (Tubifex tubifex and Limnodrilus hoffmeisteri) exposed to contaminated sediments from Toronto Harbour in Lake Ontario were found to rapidly accumulate 1,2-dichlorobenzene over a 79 day exposure period (Oliver, 1987b). Worms were analyzed after 4, 11, 39 and 79 days. A mean concentration of 260 ng/g (dry weight) 1,2-dichlorobenzene was measured in the worms after 4 days and decreased to 40 ng/g after 79 days. 1,2-Dichlorobenzene was found in clams collected in the area of a outfall from a chlor-alkali chemical plant near Pictou, Nova Scotia. Concentrations ranged up to 40 ng/g (dry weight) in clams (MacLaren Marex Inc., 1979).

## **5.0 POPULATION EXPOSURE**

### **5.1 Exposure of Wildlife Populations**

In general, three routes of exposure may be of concern for wildlife: oral, inhalation and dermal. Oral exposures might occur via ingestion of contaminated food (e.g. aquatic prey), or water or incidental ingestion of contaminated media (e.g. soils, sediment). Inhalation of vapours or particulates might be a significant route of exposure for animals active near point sources. Dermal exposures are likely to be most significant for burrowing mammals (i.e. via contact with contaminated soils) and animals that spend considerable amounts of time partially submerged in contaminated surface waters. Wildlife can also be affected indirectly by removal of their food resources if levels in the environment are sufficiently high to be toxic to plants or invertebrates.

### **6.0 TOXICOKINETICS**

(Refer to supporting documentation from Health Canada)

### **7.0 MAMMALIAN TOXICOLOGY**

(Refer to supporting documentation from Health Canada)

### **8.0 EFFECTS ON HUMANS**

(Refer to supporting documentation from Health Canada)

### **9.0 EFFECTS ON THE ECOSYSTEM**

The effects-related information for 1,2-dichlorobenzene includes acute and chronic data from a number of aquatic species. The results of aquatic toxicity tests of 1,2-dichlorobenzene are presented in Tables 9-1 to 9-7. An estimation of effects on sediment biota is presented in Table 9-8. 1,2-Dichlorobenzene is a volatile compound, and therefore, aquatic tests conducted under closed, static or continuous flow conditions were considered reliable. Information on toxicity to terrestrial organisms is very limited. However, the toxicity of 1,2-dichlorobenzene to terrestrial organisms can be assessed by extrapolation from the results of toxicity studies conducted with laboratory mammals.

The mode of toxic action of 1,2-dichlorobenzene is not well understood. The mechanism has been described as a non-specific narcotic or anaesthetic action, controlled by the organism/water partitioning properties of the chemical (Abernethy et al., 1988). It appears that the effect occurs when a target site (thought to be the lipid membrane) accumulates a sufficient volume of chemical to interfere with normal structure and function.

## 9.1 Aquatic Systems and Components

### 9.1.1 Bacteria and Primary Producers

Studies on the effects of 1,2-dichlorobenzene on bacteria and primary producers are presented in Table 9-1.

A 16-h toxicity threshold (inhibition of cell multiplication) at 15 mg/L for the bacteria Pseudomonas putida, was reported by Bringmann and Kuhn, 1980. The response of Photobacterium phosphoreum to 1,2-dichlorobenzene in a 30 min Microtox test was measured by Ribo and Kaiser (1983). The reduction of light emitted by Photobacterium phosphoreum when exposed to 1,2-dichlorobenzene was 4.4 mg/L.

The effect of 1,2-dichlorobenzene on the diatom Cyclotella meneghiniana using percent reduction of DNA was reported by Figueroa and Simmons (1991). The use of biochemical parameters such as nucleic acids measurement is an alternative method of determining the effects of contaminants on cellular components related to growth, biosynthesis and reproduction. Algal DNA reduction occurred after 48 h exposure of Cyclotella meneghiniana to 23.33 mg/L 1,2-dichlorobenzene.

Reduction of growth and photosynthesis was observed in the alga Selenastrum capricornutum, at concentrations of 2.2 (96-h EC50) and 10.0 mg/L (3-h EC50) 1,2-dichlorobenzene, respectively (Calamari et al., 1983). The primary productivity of the freshwater green alga Ankistrodesmus falcatus exposed to 1,2-dichlorobenzene was monitored by measuring the uptake of <sup>14</sup>C-carbonate by cells over a 4-h period (Wong et al., 1984). A 4-h EC50 value of 19.9 mg/L was reported.

### 9.1.2 Invertebrates

#### 9.1.2.1 Acute Toxicity

A comparison of aquatic invertebrate sensitivities to 1,2-dichlorobenzene indicated that the freshwater invertebrate Daphnia magna was the most sensitive invertebrate species reported in the literature (Table 9-2). Results of acute toxicity tests using the most acceptable laboratory procedures for the Daphnia ranged from a 24-h immobilization concentration of 0.78 mg/L in a closed static system (Calamari et al., 1983) to a 48-h EC50 result of 2.35 mg/L under static, closed conditions (Abernethy et al., 1986).

In studies with saltwater invertebrates, toxicity values were higher, with LC50 values ranging from 9.4 mg/L (96-h LC50) (Curtis et al., 1979) for the grass shrimp (Palaemonetes pugio) to 14.9 mg/L (24-h LC50) for the Artemia nauplii (Abernethy et al., 1986).

In an acute toxicity study with the midge (Tanytarsus dissimilis), Call et al. (1983) reported an LC50 value (48-h) for exposure to 1,2-dichlorobenzene under static, measured conditions of 12.0 mg/L.

#### 9.1.2.2 Chronic Toxicity

Impairment of reproduction was the most sensitive endpoint reported in the literature on the chronic toxicity of 1,2-dichlorobenzene to aquatic invertebrates (Table 9-3). Under closed, static conditions, Calamari et al. (1983) reported a 14-d EC50 (reduced fertility) of 0.55 mg/L in Daphnia magna. Kuhn et al. (1989) determined the chronic toxicity of 1,2-dichlorobenzene to Daphnia magna under nominal, static conditions. In a 21 d reproduction test, a no observed effect concentration (NOEC) of 0.63 mg/L was reported.

Using calculated quantitative structure activity relationships (QSARs), a number of authors determined chronic responses of Daphnia magna to 1,2-dichlorobenzene (Hermens et al., 1984; Hermens et al., 1985; De Wolf et al., 1985). The highest concentration of 1,2-dichlorobenzene which did not produce a significant effect (16-day NOEC) on reproduction of Daphnia magna was 0.58 mg/L. Hermens et al. (1984) determined reproductive effects (16-d EC50) at 0.47 mg/L and lethal effects (16-day LC50) in Daphnia magna at 1.5 mg/L. However, it should be noted that chemical analysis showed that for 1,2-dichlorobenzene, between 80 and 110% was present in the test solutions and the NOEC value was not corrected for these measured concentrations. When corrected for the actual dose, the 16-d NOEC (reproduction) is 0.46 to 0.64 mg/L, respectively.

#### 9.1.3 Fish and Amphibians

##### 9.1.3.1 Acute Toxicity

In acute toxicity tests with fish, the most sensitive species to exposure to 1,2-dichlorobenzene was rainbow trout (Oncorhynchus mykiss). 96-h LC50 results for the rainbow trout ranged from 1.58 mg/L (U.S. EPA, 1980) to 1.61 mg/L (Ahmad et al., 1984) in closed, flow through systems (Table 9-4). Abnormal swimming and loss of equilibrium for the rainbow trout (Oncorhynchus mykiss) were observed at 1.55 mg/L (96-h EC50) (Ahmad et al., 1984). The freshwater bluegill sunfish (Lepomis macrochirus) and zebra fish (Brachydanio rerio) exhibited lower sensitivity to 1,2-dichlorobenzene under static, closed conditions, with LC50 values of 5.59 mg/L (96-h) (U.S. EPA, 1977) and 6.8 mg/L (48-h) (Calamari et al. 1983), respectively. A no-effect concentration at 96-h of 3.2 mg/L for bluegill sunfish was reported by the U.S. EPA (1977). No methodology was given for this study.

The acute toxicities of the marine tidewater silverside (Menidia beryllina) (Dawson et al., 1975/77) and sheepshead minnow

(Cyprinodon variegatus) (Heitmuller et al., 1981) were determined under static, nominal conditions (Table 9-4). 96-H LC50 values of 7.3 and 9.7 mg/L for 1,2-dichlorobenzene, respectively, were reported.

Injection of rainbow trout (Oncorhynchus mykiss) was investigated by Smith and Craig (1981) and Hodson et al. (1988) to determine the effects of pure compounds on the organism. 1,2-Dichlorobenzene was dissolved in cod liver oil and injected into the peritoneal cavity of the rainbow trout (Oncorhynchus mykiss) (Smith and Craig, 1981). The authors reported a LD50 of 8 012 mg/kg (54.5 mM/kg) 1,2-dichlorobenzene with the majority of the mortalities (97%) occurring within 72 h. Hodson et al. (1988) reported a lower LD50 value (96-h LD50) of 1095 mg/kg upon intraperitoneal injection in oil base of 1,2-dichlorobenzene in rainbow trout.

#### 9.1.3.2 Chronic Toxicity

Effects of 1,2-dichlorobenzene on embryo-larval stages of fish and amphibians were studied by Black et al. (1982) (Table 9-5 and 9-6). The organisms were exposed from 20 to 30 minutes following fertilization of the egg to 4 days after hatching of the larva. The authors reported LC50s of 3.01 mg/L for the rainbow trout (Oncorhynchus mykiss) and 5.56 mg/L for the leopard frog (Rana pipiens), following total exposure times of 27 and 9 days, respectively. Following chronic exposure (14-day LC50) to 1,2-dichlorobenzene under closed, static-renewal conditions, a toxic concentration of 5.8 mg/L was reported for the guppy (Poecilia reticulata) (Konemann, 1981).

#### 9.2 Birds and Mammals

No data are available on wild mammals, thus results from laboratory studies were extrapolated to determine effects on wild mammals.

In inhalation studies conducted by Bonnet et al. (1979, 1982), the LC50s (6 hour exposure period) for Sprague-Dawley rats and SPF-OF1 female mice were 9192 mg/m<sup>3</sup> and 7416 mg/m<sup>3</sup>, respectively. Hollingsworth et al. (1958) reported an LC50 in rats following exposure by inhalation for 7 hours of 5862 mg/m<sup>3</sup> 1,2-dichlorobenzene. In Sprague-Dawley rats exposed for four hours to levels of 1,2-dichlorobenzene greater than 1830 mg/m<sup>3</sup>, increases in circulating hepatic enzymes were reported after 24 hours (Brondeau et al., 1983). In a subchronic study by the inhalation route (6 to 7 months exposure), the NOEL in rats, guinea pigs, rabbits and monkeys was determined to be 560 mg/m<sup>3</sup> (Hollingsworth et al., 1958).

No deaths were observed in guinea pigs following ingestion of 800 mg/kg-bw, whereas 2000 mg/kg-bw was lethal to 100% of the

animals (Hollingsworth et al., 1958). In subchronic oral studies with rats and mice, the lowest NOEL was 25 mg/kg-bw per day (NTP, 1983; Robinson et al., 1991).

No empirical data were available regarding adverse effects of 1,2-dichlorobenzene on wildlife due to decreased prey availability or quality. Potentially, toxic effects at low trophic levels of foodchains could affect the availability or nutritional quality of food items available to wildlife consumers, in turn affecting the distribution and abundance of some wild mammalian or avian species. The possible extent of food chain perturbation by 1,2-dichlorobenzene may be indicated by the relative sensitivities or various prey groups (aquatic invertebrates, fish) to 1,2-dichlorobenzene.

No data are available to measure the effects on terrestrial or aquatic vascular plants.

### **9.3 Terrestrial Systems and Components**

The effects of 1,2-dichlorobenzene on microbial respiration in two soils (silt loam - 1.49% organic carbon content and sandy loam - 0.66% organic carbon content) were reported by Walton et al. (1989). CO<sub>2</sub> efflux over a 6 day period was used as the index of respiration after addition of 1 000 µg/g soil (dry weight). A higher microbial respiration rate was observed for the soil with the higher organic content (silt loam) although depression of CO<sub>2</sub> efflux was reported initially in both soils. However, by the final day of the experiment (day 6), no effect on respiration was observed.

The sole acute toxicity study pertaining to terrestrial organisms, involved exposing earthworms (*Eisenia fetida*) to direct contact with filter papers soaked in graduated concentrations of 1,2-dichlorobenzene (Neuhauser et al., 1986). Acute lethality (24-h LC50) was reported at a concentration of 0.021 mg/cm<sup>2</sup>. Although the test attempts to simulate soil conditions by providing close contact between the worm and a chemical, the contact test does not provide an accurate representation of a soil and worm ecosystem; it serves only to indicate the substances likely to be toxic to earthworms.

### **9.4 Sediment Toxicity**

No empirical data were available on the toxicity of 1,2-dichlorobenzene to benthic biota in freshwater, estuarine or marine sediments in Canada.

#### **Marine**

Barrick et al. (1988) reported effect thresholds for 1,2-

dichlorobenzene in marine sediment using the Apparent Effects Threshold (AET) approach. This method involves the comparison of field data on chemical concentrations in sediments and indicators of bioavailability (benthic infaunal analysis, toxicity tests) to estimate the concentration of a chemical above which statistically significant biological effects (relative to reference sediments) are always expected (Barrick et al., 1988). Specifically, this approach was used to estimate the concentration of contaminants in sediment collected in a contaminated area in Puget Sound, Washington State, above which significant ( $p < 0.05$ ) biological effects to marine benthic infauna (Mollusca, Polychaeta, Crustacea) are consistently observed. The marine sediment AET for benthic organisms for 1,2-dichlorobenzene was reported to be 23 ng/g (normalized to 1% total organic carbon). However, as noted by U.S. EPA (1989), the AET approach is not recommended for the development of sediment quality criteria to be applied widely due to its site-specific nature, and its inability to describe cause and effect relationships.

### Freshwater

Although no empirical freshwater sediment toxicity data were available for 1,2-dichlorobenzene, results from the equilibrium partitioning approach were used to establish effect threshold levels. These values represent concentrations of chemicals in sediment that are expected to be associated with adverse biological effects (Di Toro et al., 1991). This method involves converting toxic threshold concentrations for pelagic organisms to toxic threshold concentrations in sediment which are then compared to sediment concentrations measured in the environment. Water column and benthic species are assumed to be similarly sensitive to 1,2-dichlorobenzene (Di Toro et al., 1991). Additional assumptions built into this approach are that: 1) nonionic organic chemicals such as 1,2-dichlorobenzene are associated with sediment organic carbon, 2) partitioning of chemicals between the organic carbon and sediment pore water is at equilibrium, and 3) ingestion is not a route of exposure.

The effect threshold in sediment ( $C_s$ ) was calculated based on the equilibrium relationship:

$$C_{s,oc} = C_d / f_{oc} = K_{oc} \times C_d$$

formulated by Di Toro et al. (1991).  $C_{s,oc}$  is the organic carbon-normalized sediment concentration, and  $C_d$  is the dissolved concentration of 1,2-dichlorobenzene that caused effects in the most sensitive organism tested. The organic carbon fraction ( $f_{oc}$ ) of the sediment was set at 0.035, corresponding to levels measured in the most severely contaminated areas of western Lake Ontario. An estimated effect level of 20  $\mu\text{g/g}$  (the level which could adversely effect sensitive benthic species) was calculated for  $C_d$ .

using a chronic effect level (NOEL) for dissolved 1,2-dichlorobenzene for freshwater organisms of 550  $\mu\text{g/L}$  (14-d EC50 reduced fertility in Daphnia magna) (Calamari et al., 1983) and a  $K_{oc}$  of 1 030 (Mackay et al., 1992).

van Leeuwen et al. (1992) used quantitative structure-activity relationships and equilibrium partitioning modelling to predict the concentration of 1,2-dichlorobenzene at which 95% of the species in marine or freshwater benthic communities are unlikely to be affected. The authors calculated an effect threshold level of 5336 ng/g (d.w.) for sediments with an organic carbon content of 5%, or 1067 ng/g for sediments with an organic carbon content of 1%.

Although use of equilibrium partitioning is becoming increasingly common in sediment quality assessment (Di Toro et al., 1991), the method has undergone only preliminary field validation (Chapman, 1989; Adams et al., 1992), and thus is of limited use in a regulatory context.

## **10.0 OTHER PERTINENT DATA**

### **10.1 Greenhouse Effects**

Like other trace gasses that are known to contribute to global warming (Ramanathan et al., 1985), 1,2-dichlorobenzene is volatile at tropospheric temperatures and absorbs infrared radiation in the 7 to 13  $\mu\text{m}$  wavelength region (Ramanathan et al., 1985). However, because 1,2-dichlorobenzene is removed from the atmosphere by photooxidation (mean half-life of approximately 3 weeks), and steady state concentrations in the atmosphere are low (mean  $<0.1 \mu\text{g/m}^3$ ), 1,2-dichlorobenzene is not expected to have a significant direct effect on global warming (Hengeveld, pers. comm., 1992). However, the degradation of 1,2-dichlorobenzene through reactions with the OH radical can contribute to lower concentrations of OH which is an important sink for other greenhouse gases, particularly methane (IPCC, 1990). Therefore, its release into the atmosphere can indirectly contribute to increased global warming. The magnitude of this effect is difficult to estimate because of the complexity of the chemistry, however, it is believed to be small (Hengeveld, pers. commun. 1992).

### **10.2 Ozone formation/Depletion**

Because of the low concentrations found in the atmosphere in Canada, the contribution of 1,2-dichlorobenzene to the ground-level ozone-forming potential of volatile organic compounds (VOCs) mixtures is insignificant (Dann, pers. comm., 1992).

Substances involved in the depletion of stratospheric ozone are generally halogenated, insoluble in water, and persistent in the atmosphere allowing movement to the stratosphere where they

are degraded by high energy, short wavelength ultraviolet radiation (Firor, 1990). 1,2-Dichlorobenzene has a short residence time in the atmosphere due to the combined action of photooxidation and atmospheric washout and is therefore not associated with the depletion of stratospheric ozone.

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**Table 2-1 Physical and Chemical Properties of 1,2-Dichlorobenzene**

PROPERTY		REFERENCE
Molecular Weight	147.01	Mackay et al., 1992
Melting Point (°C)	-17.0	Mackay et al., 1992
Boiling Point (°C)	180.5	Mackay et al., 1992
Density (g/m <sup>3</sup> @ 20°C)	1.3048	Mackay et al., 1992
Solubility in Water (g/m <sup>3</sup> @ 25°C)	118	Mackay et al., 1992
Vapour Pressure (Pa)	196	Mackay et al., 1992
Octanol-water Partition Coefficient (Log K <sub>ow</sub> )	3.40	Mackay et al., 1992
Henry's Law (Pa m <sup>3</sup> /mol)	244	Mackay et al., 1992
Soil Organic Distribution Coefficient (Log K <sub>om</sub> )	2.54	Chiou et al. 1979
Sorption Partition Coefficient (Log K <sub>oc</sub> )	3.01 (soil)	Mackay et al. (1992)
Bioconcentration Factor, (Log BCF)	1.95-4.46	Barrows et al., 1980; Pereira et al., 1988

**Table 3-1 Use Pattern of Dichlorobenzenes in Canada (tonnes)<sup>1</sup>**

Year	1984	1985	1986	1987	1988	1989	1990	1995f <sup>2</sup>
Domestic production	4000	4500	3600	2500	2100	1900	1900	2500
Imports	1712	1102	1922	3334	3919	3540	3900	3500
Total supply	5712	5602	5522	5834	6019	5440	5800	6000

<sup>1</sup> Camford Information Services, 1991; both the 1,2- and 1,4-dichlorobenzene isomer are included

<sup>2</sup> forecasted

**Table 3-2 Imports of 1,2-Dichlorobenzene into Canada<sup>1</sup>**

Year	Amount (tonne)
1990	926.4
1989	567.8
1988	1,006.3
1987	59.3
1986	257.7
1985	109.0
1984	79.0
1983	235.0
1982	180.0
1981	187.0
1980	219.0

<sup>1</sup> Data from Statistics Canada - International Trade Division

**Table 3-3 Levels of 1,2-Dichlorobenzene in Industrial and Municipal Wastewater in Canada**

Location	Year	Concentration (ng/L)		Reference
		Mean	Range min. max.	
<u>Waste water plants</u>				
Ontario	1980	13	(6-22)	Oliver & Nicol (1982)
WPCP Ontario	1986	ND		OME (1988)
Vancouver, BC	1987		(<10-290)	Fanning et al. (1989)
<u>Pulp and Paper Mills</u>				
Fort Francis, ON	1986	ND		Merriman (1988)
Thorold, ON	1990 6	90	(0-530)	OME (1991a)
Marathon, ON	1990 6	2600	(0-15600)	OME (1991a)
Kenora, ON	1990 6	70	(0-420)	OME (1991b)
Trenton, ON	1990 6	140	(0-840)	OME (1991b)
<u>Textile Plants</u>				
Carpet mill	1985/86	95000		Environment Canada (1989)
Truro, NS	1979	ND		Maclaren Marex Inc. (1979)
<u>Organic Chemical Plant</u>				
Sarnia, ON				
landfill leachate	1985		(10-780)	King & Sherbin (1986)
Maitland, ON	1989/90	300		OME (1992 unpubl.)
Sarnia, ON	1989/90	400		OME (1991 unpubl.)
Sarnia, ON	1990/91	60500		OME (1992 unpubl.)
Corunna, ON	1989/90	6900		OME (1992 unpubl.)
<u>Inorganic Chemical Plant</u>				
Niagara Falls, ON	1989/90		(0.0-1.5)	OME (1992b)

**Table 3-4 Air Emission Factors for 1,2-Dichlorobenzene from Chemical Production Plants <sup>1</sup>**

Emission	1,2-Dichlorobenzene emitted in kg/t Category of product produced		
	DCB	dye synthesis	3,4-dichloro- aniline
Process	2.32	0.40	1.05
Storage	0.47	0.05	0.15
Fugitive	0.76	0.05	0.30
Total	3.55	0.50	1.50

<sup>1</sup> The above emission factors are only general estimates (U.S. EPA, 1986).

**Table 3-5 Total Release (tonnes/yr) of 1,2-Dichlorobenzene into Air, Land and Water in the United States in 1989<sup>1</sup>**

substance	air	water	injection	land	POTW	offsite	fugitive	total
1,2-DCB	36.4	7	8.2	34.3	12	1074	89.5	1261

<sup>1</sup> Toxic Release Inventory (Marcos, 1989)

**Table 4-1 Levels of 1,2-Dichlorobenzene in Air in Canada and the United States**

Location	Year	Concentration ( $\mu\text{g}/\text{m}^3$ )		Reference
		Mean	Range min. max.	
Halifax	1989/90	<0.1	(<0.1-0.16)	Environment Canada (1991, unpubl.)
Montreal				
Pte. Trembles	1989/90	<0.1	(<0.1-0.14)	Environment Canada (1991, unpubl.)
Ontario St.	1989/90	<0.1	(<0.1-0.29)	Environment Canada (1991, unpubl.)
Ottawa	1989/90	<0.1	(<0.1-0.41)	Environment Canada (1991, unpubl.)
Toronto				
Edgar Ave.	1988/90	<0.1	(<0.1-0.10)	Environment Canada (1991, unpubl.)
Perth/Ruskin	1988/90	<0.1	(<0.1-0.12)	Environment Canada (1991, unpubl.)
Stouffville	1988/90	<0.1	(<0.1-0.61)	Environment Canada (1991, unpubl.)
Hamilton	1989/90	<0.1	(<0.1-0.17)	Environment Canada (1991, unpubl.)
Sarnia	1989/90	<0.1	(<0.1-0.14)	Environment Canada (1991, unpubl.)
Windsor				
Univ. Ave.	1988/90	<0.1	(<0.1-0.18)	Environment Canada (1991, unpubl.)
College	1990	<0.05	(<0.05-0.06)	Environment Canada (1991, unpubl.)
Walpole Is.	1989/90	<0.1	(<0.1-0.29)	Environment Canada (1991, unpubl.)
Vancouver				
Kensington P.	1988/90	<0.05	(<0.05-0.07)	Environment Canada (1991, unpubl.)
Rocky Pt. P.	1988/90	<0.1	(<0.1-0.30)	Environment Canada (1991, unpubl.)
Burnaby Mtn.	1990	<0.1	(<0.1-<0.1)	Environment Canada (1991, unpubl.)
Toronto				
Jnct Triangle	1984/85		(ND-0.1)	Dann (1985)
Montreal	1984/85		(ND-0.1)	Dann (1985)

Table 4-1 cont'd      Levels of 1,2-Dichlorobenzene in Air in Canada and the United States

Location	Year	Concentration ( $\mu\text{g}/\text{m}^3$ )		Reference
		Mean	Range min. max.	
Bound Brook, New Jersey		18	0.66 0.39 0.89 0.10 0.14 0.09	Krost et al. (1982)
New Jersey	1983/84	0.18 5.16 0.72 0.30 0.42 0.24		Harkov et al. (1985)
Newark, New Jersey	1981/82	0.18		Harkov et al. (1983)
Elizabeth New Jersey	1981/82	0.12		Harkov et al. (1983)
Camden New Jersey	1981/82	0.06		Harkov et al. (1983)
Portland, Oregon (dissolved in rain $\mu\text{g}/\text{L}$ )	1984		0.13 0.62	Ligocki et al. (1985)
Portland, Oregon (atmospheric gas, $\text{ng}/\text{m}^3$ )	1984		3.3 10.0	Ligocki et al. (1985)

**Table 4-2 Levels of 1,2-Dichlorobenzene in Canadian Surface Water.**

Location	No. of Samples	Concentration (ng/L)		Reference
		Mean	Range min. max.	
<b>Surface Water (ng/L)</b>				
Great L. Basin				
urban runoff	1979/83	39		Marsalek & Schroeter (1988)
Rainy R., ON	1983	ND		Merriman (1988)
L. Superior	1986	0.141	(0.064-0.369)	Stevens & Neilson (1989)
L. Huron	1980	ND		Oliver & Nicol (1982)
	1986	0.141	(0.068-0.238)	Stevens and Neilson (1989)
Georgian Bay	1986	0.108	(0.062-0.202)	Stevens and Neilson (1989)
St. Clair R.	1985		(0.007-2.975))	Chan and Kohli (1987)
L. Erie	1986	0.214	(0.035-1.168)	Stevens and Neilson (1989)
Niagara R.				
Ft. Erie	1981	ND		Fox et al. (1983)
	1986/87	0.353		NRDIG (1988)
	1988/89	0.277		NRDIG (1989)
Niagara-on-the-Lake	1982	20		Oliver & Charlton (1984)
	1981/83	23	(3.9-240)	Oliver & Nicol (1984)
	1981	5.5		Fox et al. (1983)
	1986/87	1.744		NRDIG (1988)
	1988/89	2.049		NRDIG (1989)
L. Ontario	1980	5	(2-7)	Oliver & Nicol 1982)
	1986	0.78	(0.143-3.73)	Stevens and Neilson (1989)
Grand R.	1980	6	(ND-31)	Oliver & Nicol (1982)

**Table 4-3 Levels of 1,2-Dichlorobenzene in Canadian Groundwater, and Leachates**

Location	Year Samples	Concentration (ng/L)		Reference
		Mean	Range min. max.	
<hr/> <b>Ground water (ng/L)</b>				
<u>Municipal Landfill Sites</u>				
North Bay, ON	1981		(2,800-13,000)	Reinhard et al. (1984)
Burlington, ON	1983	38		Pankow et al. (1985)
<u>Hazardous Waste Sites</u>				
Napierville, QC	1987		(2.0- 7290 µg/L)	Foratek Inc. (1989)
Napierville, QC	1987		(692,000 µg/L in oil phase)	Foratek Inc. (1989)
Napierville, QC	1987		(2.0-58,400 µg/L)	Foratek Intern. Inc. (1987)
Ville Mercier, QC	1988/89		(3,300-46,000)	Martel and Ayotte (1989)

**Table 4-4 Levels of 1,2-Dichlorobenzene in Water in Countries Other Than Canada**

Location	Media	Concentration ( $\mu\text{g/L}$ )		Reference
		Mean	Range	
United States	wastewater	352.8		Piwoni et al. (1986)
United States	wastewater	2.96		Bouwer et al. (1984)
Netherlands	surface water		0.9-1.9	Zoeteman et al. (1980)

**Table 4-5 Levels of 1,2-Dichlorobenzene in Soils, Sediment and Sludge in Canada and the United States**

Location	Year	Concentration (ng/L)		Reference
		Mean	Range	
		min.	max.	
<hr/>				
<b>Soil</b>				
Napierville, QC	1987/89	(<2-7980 µg/g)		Foratek Intern. Inc. (1987)
Napierville, QC	1990	(<0.1-36.9µg/g)		Foratek Inc. (1989) ADS ass. Itée (1990)
<b>Bottom (B) and Suspended (S) sediments (ng/g)</b>				
St. Clair R. ON	1984/85	1700		Oliver and Pugsley (1986)
Niagara-on-the-Lake (S)	Suspended solids size (ng/g)	June	July	Sept
	<75µm	38	NS	54
	75-175µm	36	35	110
	175-300µm	65	64	106
	300-500µm	69	66	77
	500-700µm	72	53	110
	>700 µm	82	350	100
Fort Erie	>700 µm	NS	ND	NS
Victoria, BC (B)	1991		(<1)	EVS Consultants (1992)
Niagara River (S)	1985/86	41		Maguire et al. (1989)
Great L. Basin urban runoff (S)	1979/83	120		Marsalek and Schroeter (1988)
Rainy R. ON (S)	1983	ND		Merriman (1988)
L. Superior (B)	1980	1	(ND-1)	Oliver and Nicol (1982)

**Table 4-5 cont'd      Levels of 1,2-Dichlorobenzene in Soils, Sediment and Sludge in Canada and the United States**

Location	Year	Concentration Mean Range min. max.		Reference
<b>Bottom (B) and Suspended (S) sediments (ng/g)</b>				
L. Huron (B)	1980	8	(ND-56)	Oliver and Nicol (1982)
L. Erie (B)	1980	2	(1-4)	Oliver and Nicol (1982)
Niagara River Niagara-on-the-Lake, ON (S)	1979/81	148		Kuntz and Wary (1983)
<b>L. Ontario</b>				
Niagara plume				
(S)	1982		(ND-47)	Oliver and Charlton (1984)
(B)	1982	10		Oliver and Charlton (1984)
(B)	1981		(7-54)	Fox et al. (1983)
(B)	1981		(ND-87)	Durham and Oliver (1983)
various sites				
(B)	1980	11	(4-27)	Oliver and Nicol (1982)
<b>St. Lawrence R</b>				
(S)	1981		(<1-36)	Merriman (1987)
(B)	1981		(2-15)	Merriman (1987)
(S)	1982/83/84		(ND-660)	Sylvestre (1987)
<b>Economy R., NS</b>				
(B)	1979	ND		MacLaren Marex Inc. (1979)

**Table 4-5 cont'd      Levels of 1,2-Dichlorobenzene in Soil, Sediment and Sludge in Canada and the United States**

Location	Year	Concentration ( $\mu\text{g}/\text{m}^3$ ) Mean Range min. max.	Reference
<b>Bottom (B) and Suspended (S) sediments (ng/g)</b>			
Salmon R, NS (B) (Ind. outfall)	1979	ND	MacLaren Marex Inc. (1979)
Pictou Harbour, NS (B) (Ind. outfall)	1979	(ND-47)	MacLaren Marex Inc. (1979)
<b>Sewage Sludge (ng/g)</b>			
Canadian sludges	1980/85	(ND-1600)	Webber & Lesage (1989)
WPCP Ontario Waterloo, ON	1987	(<40000-42000)	OME (1988)

-----  
NS - Not sampled

Table 4-6 Levels of 1,2-Dichlorobenzene in Biota in Canada

Media/Location	Year	Concentration Mean (Range) min. max.	Reference
<b>Biota</b>			
<u>Oligochaete</u> (ng/g dw)			
		260	Oliver (1987b)
		220	
		140	
		40	
L. Ontario/ Niagara plume	1981	(ND-100)	Fox et al. (1983)
<u>Amphipods</u> (ng/g dw)			
L. Ontario/ Niagara plume	1981	(ND-18)	Fox et al. (1983)
Blue Mussels Pictou Harbour, NS	1979	(ND-40)	MacLaren Marex Ltd. (1979)
<u>Fish</u> (ng/g ww)			
Lake Trout ( <u>Salvelinus namaycush</u> )			
L. Superior	1980	0.3 <sup>1</sup>	Oliver and Nicol (1982)
L. Huron	1980	1 <sup>1</sup>	Oliver and Nicol (1982)
L. Ontario	1980	1 (1)	Oliver and Nicol (1982)
	1981	ND	Fox et al. (1983)

Table 4-6 cont'd      Levels of 1,2-Dichlorobenzene in Biota in Canada

Media/Location	Year	Concentration Mean (Range) min. max.	Reference
<b>Biota (ng/g ww)</b>			
Rainbow Trout ( <u>Oncorhynchus mykiss</u> )			
L. Erie	1980	1 <sup>1</sup>	Oliver and Nicol (1982)
L. Ontario	1981	ND	Oliver and Niimi (1983)

<sup>1</sup> only one sample analysed

**Table 9-1 Acute Toxicity Studies of 1,2-Dichlorobenzene to Bacteria and Primary Producers**

Species	Concentration Criterion	Concentration	Comments	References
<u>Photobacterium phosphoreum</u>	30 min. EC50 Microtox test	4.4 mg/L	50% light reduction	Ribo & Kaiser (1983)
<u>Tetrahymena pyriformis</u>	24-h EC50	51 mg/L	Growth inhibition	Yoshioka (1985)
<u>Bacillus cereus</u>	EC50	400 mg/L	Stimulation/ inhibition of dehydrogenase activity	Thomsom et al. (1986)
<u>Pseudomonas putida</u>	16-h EC50	15 mg/L	Inhibition of cell multiplication	Bringmann & Kuhn (1980)
<u>Ankistrodesmus falcatus</u>	4-h EC50	19.9 mg/L (0.13 mmol)	Primary production Static, unmeasured	Wong et al. (1984)
<u>Cyclotella meneghiniana</u>	48-h EC50	23.33 mg/L	DNA reduction Static	Figuerola & Simmons (1991)
<u>Selenastrum capricornutum</u>	96-h EC50	2.2 mg/L	Growth inhibition Static, measured	Calamari et al. (1983)
<u>Selenastrum capricornutum</u>	3-h EC50	10.0 mg/L	Photosynthesis Static, measured	Calamari et al. (1983)
<u>Selenastrum capricornutum</u>	96-h EC50	2.2 mg/L	Growth inhibition Static, unmeasured	Galassi & Vighi (1981)

Table 9-1 cont'd      Acute Toxicity Studies of 1,2-Dichlorobenzene to  
Bacteria and Primary Producers

Species	Concentration Criterion	Concentration	Comments	References
<u>Selenastrum</u> <u>capricornutum</u>	96-h LC50	91.6 mg/L	Static unmeasured	LeBlanc (1984)
<u>Selenastrum</u> <u>capricornutum</u>	96-h LC50	76.1 mg/L	Static Cell count	U . S .      E P A (1978)
<u>Skeletonema</u> <u>costatum</u>	96-h EC50	34.2 mg/L	Static Cell count	U.S. EPA (1978)
<u>Scenedesmus</u> <u>subspicatus</u>	48-h EC50	13.5 mg/L	Static Unmeasured inhibition of growth	Kuhn & Pattard ( 1 9 9 0 )

**Table 9-2 Acute Toxicity Studies of 1,2-Dichlorobenzene to Aquatic Invertebrates**

Species	Concentration Criterion	Concentration	Comments	References
<u>Daphnia magna</u>	48-h EC50	2.35 mg/L (16 mmol/m <sup>3</sup> )	Static, closed Unmeasured	Bobra et al. (1985)
<u>Daphnia magna</u>	48-h LC50	<6.46 mg/L (<44 mmol/m <sup>3</sup> )	Static, closed Unmeasured	Bobra et al. (1983)
<u>Daphnia magna</u>	24-h IC50	0.78 mg/L	Immobilization Static, measured	Calamari et al. (1983)
<u>Daphnia magna</u>	24-h EC50	1.7 mg/L	Static, closed measured	Kuhn et al. (1989)
<u>Daphnia magna</u>	48-h LC50	2.35 mg/L (16 mmol/m <sup>3</sup> )	Static, closed Unmeasured	Abernethy et al. (1986)
<u>Daphnia magna</u>	24-h LC50	2.4 mg/L	Static Unmeasured	LeBlanc (1980)
<u>Daphnia magna</u>	48-h LC50	2.4 mg/L	Static Unmeasured	LeBlanc (1980)
<u>Daphnia magna</u>	48-h LC50	2.44 mg/L	Static Unmeasured	LeBlanc (1984)
<u>Daphnia magna</u>	48-h-IC50	3.77 mg/L	Static Unmeasured	Hermens et al. (1984)

**Table 9-2 cont'd      Acute Toxicity Studies of 1,2-Dichlorobenzene to Aquatic Invertebrates**

Species	Concentration Criterion	Concentration	Comments	References
<u>Mysidopsis bahia</u>	96-h LC50	71.1 mg/L	Static Unmeasured	U.S. EPA (1978)
<u>Artemia nauplii</u>	24-h LC50	14.9 mg/L (102 mmol/m <sup>3</sup> )	Static, closed Unmeasured	Abernethy et al. (1986)
Grass shrimp ( <u>Palaemonetes pugio</u> )	48-h LC50	10.3 mg/L	Static Measured	Ortis et al. (1979)
Grass shrimp ( <u>Palaemonetes pugio</u> )	96-h LC50	10.0 mg/L	Static Unmeasured	Curtis and Ward (1981)
Grass shrimp ( <u>Palaemonetes pugio</u> )	96-h LC50	9.4 mg/L	Static Unmeasured	Ortis et al. (1979)
Midge ( <u>Tanytarsus dissimilis</u> )	48-h LC50	12.0 mg/L	Static Measured	Call et al. (1985)

**Table 9-3 Chronic Toxicity Studies of 1,2-Dichlorobenzene to Aquatic Invertebrates**

Species	Concentration Criterion	Concentration	Comments	References
<u>Daphnia magna</u>	16-day LC50	1.5 mg/L (log 1.01)	Mortality Calculated <sup>1</sup>	Hermens et al. (1984)
<u>Daphnia magna</u>	16-day EC50	0.47 mg/L (log 0.51)	Reproduction Calculated <sup>2</sup>	Hermens et al. (1984)
<u>Daphnia magna</u>	16-day NOEC	0.58 mg/L (log 0.60)	Growth Calculated <sup>3</sup>	Hermens et al. (1985)
<u>Daphnia magna</u>	16-day EC50	0.68 mg/L (log 0.67)	Reproduction Calculated <sup>3</sup>	De Wolf et al. (1985)
<u>Daphnia magna</u>	14-day EC50	0.55 mg/L (log 0.60)	Fertility Static, measured	Calamari et al. (1983)
<u>Daphnia magna</u>	21-day NOEC	0.63 mg/L	Reproduction Static, measured	Kuhn et al. (1989)

**Table 9-4 Acute Toxicity Studies of 1,2-Dichlorobenzene to Fish**

Species	Concentration Criterion	Concentration	Comments	References
Rainbow trout ( <u>Oncorhynchus mykiss</u> )	96-h LC50	1.58 mg/L	Flow through measured	U.S. EPA (1980)
Rainbow trout ( <u>Oncorhynchus mykiss</u> )	48-h LC50	1.58 mg/L	Flow through measured	Call et al. (1983)
Rainbow trout ( <u>Oncorhynchus mykiss</u> )	96-h LC50	1.58 mg/L	Flow through measured	Call et al. (1983)
Rainbow trout ( <u>Oncorhynchus mykiss</u> )	96-h LC50	1.61 mg/L	Flow through measured	Ahmad et al (1984)
Rainbow trout ( <u>Oncorhynchus mykiss</u> )	48-h LC50	2.3 mg/L	Static, measured	Calamari et al. (1983)
Rainbow trout ( <u>Oncorhynchus mykiss</u> )	72-h LD50	8012 mg/kg (54.5 mM/kg)	Static, measured	Smith and Craig (1981)
Rainbow trout ( <u>Oncorhynchus mykiss</u> )	96-h LD50	1095 mg/kg (7.45 mM/kg)	Static, Measured	Hodson et al. (1988)
Sheepshead minnows ( <u>Cyprinodon variegatus</u> )	48-h LC50 72-h LC50 96-h LC50	9.3 mg/L 9.7 mg/L 9.7 mg/L	Static, unmeasured Marine	Heitmüller et al. (1981)
Sheepshead minnows ( <u>Cyprinodon variegatus</u> )	96-h LC50	9.11 mg/L	Static, unmeasured	LeBlanc (1984)

Table 9-4 cont'd Acute Toxicity Studies of 1,2-Dichlorobenzene to Fish

Species	Concentration Criterion	Concentration	Comments	References
Sheepshead minnows ( <u>Cyprinodon</u> <u>variegatus</u> )	48-h LC50 96-h LC50	9.3 mg/L 9.7 mg/L	Static Unmeasured	Heitmuller et al. (1981)
Tidewater silversides ( <u>Menidia beryllina</u> )	96-h LC50	7.3 mg/L	Static Unmeasured	Dawson et al. (1975/77)
Bluegill sunfish ( <u>Lepomis</u> <u>macrochirus</u> )	96-h LC50	27.0 mg/L	Static unmeasured	Dawson et al. (1975/77)
Bluegill sunfish ( <u>Lepomis</u> <u>macrochirus</u> )	24-h LC50 96-h LC50	6.3 mg/L 5.6	Static unmeasured	Buccafusco et al. (1981)
Bluegill sunfish ( <u>Lepomis macrochirus</u> )	96-h LC50	27.0 mg/L	Static Unmeasured	Dawson et al. (1975/77)
Bluegill sunfish ( <u>Lepomis macrochirus</u> )	48-h LC50	6.06 mg/L	Static Unmeasured	U.S. EPA (1977)
Bluegill sunfish ( <u>Lepomis macrochirus</u> )	96-h LC50	5.59 mg/L	Static Unmeasured	U.S. EPA (1977)
Zebra fish ( <u>Brachydanio rerio</u> )	48-h LC50	6.8 mg/L	Static Measured	Calamari et al. (1983)
Zebra fish ( <u>Brachydanio rerio</u> )	48-h LC50	10.0 mg/L	Flowthrough Measured	Sloof (1979)

Table 9-4 cont'd      Acute Toxicity Studies of 1,2-Dichlorobenzene to Fish

Species	Concentration Criterion	Concentration	Comments	References
Fathead minnows ( <u>Pimephales</u> <u>promelas</u> )	96-h LC50	57.0 mg/L	Flow through Unmeasured	Curtis et al. (1979)
Fathead minnows ( <u>Pimephales</u> <u>promelas</u> )	96-h LC50	57.0 mg/L	Flow through Unmeasured	Curtis et al. (1979)

**Table 9-5      Chronic Toxicity Studies of 1,2-Dichlorobenzene to Amphibians**

Species	Concentration Criterion	Concentration	Comments	References
Leopard frog eggs ( <u>Rana pipiens</u> )	0 days after hatching LC50 4 days after hatching LC50	12.07 (mg/L) 5.56 (mg/L)	Flow through Measured	Black et al. (1982)

**Table 9-6 Chronic Toxicity Studies of 1,2-Dichlorobenzene to Fish**

Species	Concentration Criterion	Concentration	Comments	References
Rainbow trout eggs ( <u>Oncorhynchus</u> <u>mykiss</u> )	0 days after hatching LC50 4 days after hatching LC50	3.01 (mg/L) 3.01 (mg/L)	Flow through measured	Black et al. (1982)
Guppy ( <u>Poecilia reticulata</u> )	14 day LC50	5.85 mg/L (log 1.60)	Static Unmeasured	Konemann (1981)

**Table 9-7 Acute Toxicity Studies of 1,2-Dichlorobenzene to Terrestrial Invertebrates**

Species	Concentration Criterion	Concentration	Comments	References
Earthworm ( <i>Eisenia fetida</i> )	48-h LC50	0.021 mg/cm <sup>2</sup> 21 µg/cm <sup>2</sup>	Contact test	Neuhauser et al. (1986)

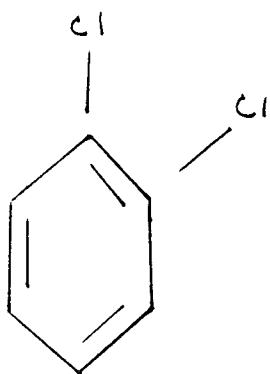


Figure 1 Structural formula of 1,2-dichlorobenzene