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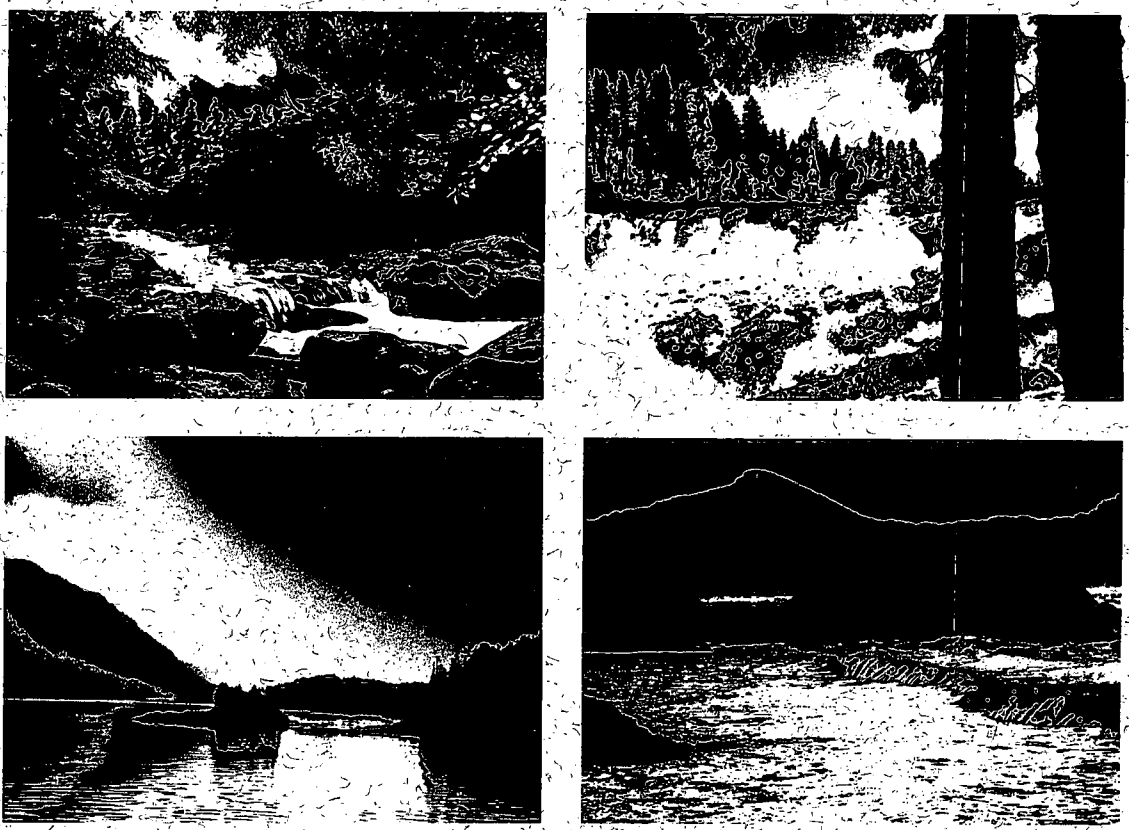
Canadian Water Quality Guidelines for Chlorinated Ethanes

D.R.J. Moore, S.L. Walker and D. Koniecki



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INLAND WATERS DIRECTORATE
WATER QUALITY BRANCH
OTTAWA, ONTARIO, 1991

(Disponible en français sur demande)

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Abstract

A literature review was conducted on the uses, fate, and effects of chlorinated ethanes on raw water for drinking water supply, freshwater aquatic life, agricultural uses, recreational water quality and aesthetics, and industrial water supplies. The information is summarized in this publication. From it, water quality guidelines for the protection of specific water uses are recommended.

Résumé

On a examiné la documentation relative aux utilisations, au devenir et aux effets des chloroéthanes sur l'eau naturelle utilisée comme eau potable non traitée, sur la vie aquatique en eau douce, sur l'utilisation de l'eau pour l'agriculture, sur la qualité de l'eau pour les loisirs et l'esthétique, ainsi que sur les approvisionnements en eau pour l'industrie. Ces renseignements sont résumés dans cette publication. À partir de cette étude, des lignes directrices sur la qualité de l'eau sont recommandées pour la protection d'utilisations particulières de l'eau.

Preface

The chlorinated ethanes are chlorinated aliphatic hydrocarbons not known to occur as natural products but found in many environmental compartments, including air, water, soil, sediments, food, and freshwater and marine biota (U.S. EPA, 1980). Toxicological and environmental concerns have led to the placement of several chlorinated ethanes on the Canadian Environmental Protection Act (CEPA) Priority Substances List (Canada Gazette, 1989). According to the Act, substances on this list must be assessed to determine whether they could have immediate or long-term adverse effects on the environment. The purpose of this report is to develop Canadian water quality guidelines for 1,2-dichloroethane (EDC), 1,1,1-trichloroethane (TCA), and 1,1,2,2-tetrachloroethane (TECA) that will ensure the protection and maintenance of freshwater and marine aquatic life and protect other important water uses, including drinking water, irrigation, livestock watering, and recreational and industrial use.

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INTRODUCTION

1,2-Dichloroethane (EDC)

The Chemical Abstracts Service (CAS) registry number for 1,2-dichloroethane, or CH_2ClCH_2Cl, is 107-06-02. Common synonyms include ethylene dichloride (EDC), 1,2-bichloroethane, dichloroethylene, ethylene chloride, glycoldichloride, sym-dichloroethane, and ethenedichloride (Archer, 1979; Konemann, 1981; Gossett et al., 1983; Verschueren, 1983). The structural formula of EDC is shown in Figure 1.

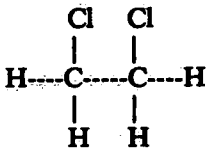


Figure 1. Structural formula for 1,2-dichloroethane (EDC).

EDC is manufactured either by catalytic chlorination of ethylene in the liquid phase or by oxychlorination of ethylene. Chlorination in the liquid phase is performed by mixing ethylene and chlorine in liquid ethylene dichloride with ferric chloride as a catalyst. The chlorination is carried out in the presence of air (5%) to prevent further chlorine substitution. The oxychlorination of ethylene is performed in the presence of oxygen and a cupric chloride catalyst. The latter process is primarily used in vinyl production plants in which a supply of hydrogen chloride is available as a by-product of other processes (Archer, 1979).

EDC has a high purity but may contain traces of 1,1,2-trichloroethane. Waste gases (e.g., nitrogen dioxide, carbon monoxide, small amounts of ethylene, and 1,1-dichloroethane) are formed only during oxychlorination (Konietzko, 1984).

Total production of EDC in Canada in 1988 was 763 000 t, of which 32 000 t were exported. Production is expected to increase to 880 000 t in 1992 (CPI, 1988a).

In Canada, 98% of EDC used in 1988 was for vinyl chloride production, with a small amount (0.4%) used as an antiknock additive in leaded fuel. Other minor applications include adhesives, coatings, solvent extractants, and cleaning solutions (ZENON, 1982).

1,1,1-Trichloroethane (TCA)

The CAS registry number for 1,1,1-trichloroethane (TCA), or CH_3CCl_3, is 71-55-6. Common synonyms include methylchloroform, chloroethene, and alpha-trichloroethane (Archer, 1979; Konemann, 1981; Verschueren, 1983). The structural formula of TCA is shown in Figure 2.

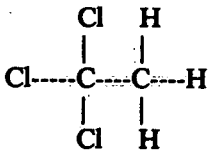


Figure 2. Structural formula for 1,1,1-trichloroethane (TCA).

The major TCA production process in Canada involves hydrochlorination of vinyl chloride to 1,1-dichloroethane, which is then thermally or photochemically chlorinated. A second process is based on 1,1-dichloroethylene hydrochlorination in the presence of a ferric chloride catalyst (Archer, 1979).

Because TCA is easily decomposed, it must be stabilized during production. The stabilizing system is made up of 1,4-dioxane, epoxide, alcohols, and nitro compounds (approximately 3%–7% by volume). The most common impurities found in 22 samples of technical TCA were 1,1-dichloroethylene (0.01%-0.6%), dichloroethane (0.01%), and 1,1,2-trichloroethane (0.01%) (Konietzko, 1984).

Total domestic production of TCA in 1988 was 10 000 t. An additional 6000 t were imported in 1988, predominantly from the United States and Europe (CPI, 1988b). TCA is widely used as an industrial solvent (Verschueren, 1983). In Canada, 85%–90% of the TCA produced is used in metal cleaning, particularly in armatures of electric motors, generators, and switchgear and in electronic equipment. The remaining 10%–15% is used in adhesives, as a propellant modifier in aerosols, in several textile finishing operations, as a constituent in various office supplies, as dry lubricants, and as a laboratory solvent (Environment Canada, 1988).

1,1,2,2-Tetrachloroethane (TECA)

The CAS registry number for 1,1,2,2-tetrachloroethane (TECA), or $CHCl_2CHCl_2$, is 79-34-5. A common synonym is acethylene tetrachloride (Archer, 1979; Konemann, 1981; Verschueren, 1983). The structural formula of TECA is shown in Figure 3.

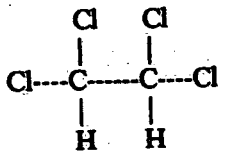


Figure 3. Structural formula for 1,1,2,2-tetrachloroethane (TECA).

TECA is produced by direct chlorination or oxychlorination of ethylene. TECA is not usually purified but instead is used as a feedstock to produce other chlorinated compounds (Archer, 1979). Until 1985, C.I.L. at Shawinigan (Quebec), the sole manufacturer of TECA in Canada, produced it for the manufacture of trichloroethylene and tetrachloroethylene. In 1985, C.I.L. closed its plant, and, at present, there is no Canadian manufacturer of TECA (CPI, 1988c).

Summary of Existing Guidelines

The U.S. Environmental Protection Agency (EPA) has proposed a maximum contaminant level of 5 $\mu g \cdot L^{-1}$ EDC in drinking water. The states of California and Florida have recommended drinking water guidelines of 1.0 $\mu g \cdot L^{-1}$ EDC (action level) and 3.0 $\mu g \cdot L^{-1}$ EDC (maximum contaminant level), respectively. The U.S. National Academy of Sciences recommended a suggested no-adverse-response level of 1.42 $\mu g \cdot L^{-1}$ for EDC in drinking water. A guideline value of 10 $\mu g \cdot L^{-1}$ was recommended by the World Health Organization (OMOE, 1989). A maximum contaminant level of 200 $\mu g \cdot L^{-1}$ was recommended by the U.S. EPA for TCA. California and Florida have recommended drinking water guidelines of 1 $mg \cdot L^{-1}$ (suggested no-adverse-effect level) and 200 $\mu g \cdot L^{-1}$ (maximum contaminant level), respectively, for TCA in drinking water (OMOE, 1989). Drinking water guidelines for TECA were not found.

The U.S. EPA (1980, 1986) prepared documents on ambient water quality for chlorinated ethanes, but, because the EPA's minimum data base requirements were not met, no numerical limits were set. However, on the basis of the available data, the U.S. EPA found that acute toxicity to freshwater biota occurred at concentrations as low as 118, 18.0, and 2.4 $mg \cdot L^{-1}$ for EDC, TCA, and TECA, respectively. During chronic exposures, the corresponding values found were 20.0 $mg \cdot L^{-1}$ EDC and 9.4 $mg \cdot L^{-1}$ TCA, with no value found for TECA. The only other agency that has proposed or set numerical limits for chlorinated ethanes is the state of Michigan, which set a guideline level of 0.117 $mg \cdot L^{-1}$ TCA; this concentration will theoretically produce no adverse effects on important freshwater aquatic organisms (and their progeny) exposed continuously for a lifetime (Zugger, 1989).

PHYSICAL AND CHEMICAL PROPERTIES

Properties

The physical and chemical properties of EDC, TCA, and TECA are listed in Tables 1, 2, and 3, respectively. In general, increasing chlorine content is positively correlated with boiling point temperature, density, and viscosity and inversely correlated with vapour pressure and solubility in water. Chlorinated ethanes are heavier than water and poorly adsorbed by soil particles (Konietzko, 1984).

Table 1. Physical and Chemical Properties of EDC

Parameter	Value
Physical state	Colourless liquid[1]
Odour/taste	Pleasant odour, sweet taste[1]
Boiling point	83.5°C[1]
Melting point	-35.0°C[2]
Density (20°C)	1.253 $g \cdot mL^{-1}$[3]
Viscosity (20°C)	0.84 $mPa \cdot s$[3]
Surface tension (20°C)	31.38 $mN \cdot m^{-1}$[3]
Vapour pressure (10°C)	5.3 kPa[3]
(20°C)	8.5 kPa[3]
(30°C)	13.3 kPa[3]
Aqueous solubility (20°C)	8690 $mg \cdot L^{-1}$[3]
Log K_{ow}	1.76[4]

[1] Sax and Lewis (1987)
[2] Konietzko (1984)
[3] Archer (1979)
[4] Konemann (1981)

Table 2. Physical and Chemical Properties of TCA

Parameter	Value
Physical state	Colourless liquid[1]
Odour/taste	Sweet, ether-like smell[1]
Boiling point	197.5°C[2]
Melting point	-33.0°C[1]
Density (20°C)	1.325 $g \cdot mL^{-1}$[3]
Viscosity (20°C)	0.86 $mPa \cdot s$[3]
Surface tension (25°C)	25.54 $mN \cdot m^{-1}$[3]
Vapour pressure (20°C)	13.3 kPa[3]
(40°C)	31.7 kPa[3]
Aqueous solubility (20°C)	4400 $mg \cdot L^{-1}$[4]
Log K_{ow}	2.49[5]

[1] Konietzko (1984)
[2] Sax and Lewis(1987)
[3] Archer (1979)
[4] Verschueren (1983)
[5] Konemann (1981)

Table 3. Physical and Chemical Properties of TECA

Parameter	Value
Physical state	Colourless liquid[1]
Boiling point	146.4°C[1]
Melting point	-42.5°C to -43.8°C[1]
Vapour pressure (20°C)	0.65 kPa[1]
Aqueous solubility (20°C)	2900 $mg \cdot L^{-1}$[1]
Log K_{ow}	3.01[2]

[1] Verschueren (1983)
[2] Konemann (1981)

EDC is highly volatile (vapour pressure = 8.5 kPa at 20°C), is soluble in water (8690 $mg \cdot L^{-1}$ at 20°C), and has a relatively low octanol/water partition coefficient (log K_{ow} = 1.76) compared with TCA and TECA. These properties suggest that volatilization will be the dominant process for the removal of EDC from the aquatic environment, whereas processes such as sediment adsorption and bioaccumulation are likely to be less important. TCA is also highly volatile (vapour pressure = 13.3 kPa at 20°C) and soluble in water (4400 $mg \cdot L^{-1}$ at 20°C), but it has a higher octanol/water partition coefficient than EDC (log K_{ow} = 2.49). Therefore, TCA and EDC should have similar environmental fate patterns, with the potential for bioaccumulation being higher for TCA. TECA is less volatile (vapour pressure = 0.65 kPa at 20°C) and less soluble in water (2900 $mg \cdot L^{-1}$ at 20°C) than EDC and TCA, and it has a higher octanol/water partition coefficient (log K_{ow} = 3.01). Thus, volatilization will be a less important removal process for TECA, whereas the potential for bioaccumulation is higher than for the other chlorinated ethanes.

Analytical Methodologies

The methods for analysis of EDC, TCA, and TECA are identical. The compounds are analyzed using batch purge-and-trap/capillary column gas chromatography (GC)/mass spectrometry (MS). Surface water (150 mL) is spiked with deuterated surrogate standards and internal standards, then purged with helium, and volatiles are adsorbed onto a Tenax GC trap. This is followed by thermal desorption and analysis using a 25-m DB-5 capillary column with MS detection. Scanning is performed using the relative retention time and relative abundances of two or more characteristic ions. Full identification of organics screened and quantified is performed using full reference spectra, multi-internal standards, and extracted areas of characteristic ions. Non-target compounds are tentatively identified using mass spectral libraries, the approximate concentration ranges of which are based on relative total ion counts. The detection limits for EDC, TCA, and TECA are 1.0, 0.2, and 5.0 $\mu g \cdot L^{-1}$ (NAQUADAT, 1988).

ENVIRONMENTAL CONCENTRATIONS

EDC

Sources

EDC can enter the environment during production, storage, disposal, and secondary

processing. In the production stage, EDC may be released to the environment via the atmosphere, wastewater releases, and land disposal. Total environmental release of EDC in the United States in 1979 was 12 238 t (Environment Canada, 1988). Atmospheric emissions of EDC accounted for 11 885 t, whereas waterway releases accounted for 252 t. Indirect environmental releases of EDC through dispersive uses such as lead scavenging, paints, coating, grain fumigation, and cleaning in the United States amounted to 4944 t in 1979. Other losses from EDC production and feedstock uses were estimated to be 6696 t during the same year (U.S. EPA, 1985). At present, EDC releases to the Canadian environment have not been determined.

Residues

Levels of EDC in Canadian waters are summarized in Table 4. Although the data are limited, it appears that EDC is rarely detected in Canadian surface waters. For instance, in the heavily industrialized Detroit, Niagara, St. Clair, and St. Lawrence river watersheds, EDC was not found above the detection limit of 0.08 $\mu g \cdot L^{-1}$ (Kaiser and Comba, 1983, 1986a, 1986b; Comba and Kaiser, 1985; Lum and Kaiser, 1986). Low levels were found in landfill leachates in Ontario (Lesage et al., 1989). However, high levels of EDC have been detected in groundwater samples at the Ville-Mercier landfill in Quebec (maximum concentration 7200 $\mu g \cdot L^{-1}$) (Pakdel et al., 1989). In groundwater, EDC is likely to be more persistent because volatilization cannot occur. Industrial discharges have also been found to contain high levels of EDC (maximum concentration 6000 $\mu g \cdot L^{-1}$).

Marine organisms collected near the discharge zone of the Los Angeles County wastewater treatment plant were analyzed to determine EDC levels (Gossett et al., 1983). EDC was not detected (detection limit 0.3 $\mu g \cdot kg^{-1}$ wet weight) in the livers from five fish species, crab digestive glands, shrimp muscles, and whole invertebrates. Further, EDC was not detected in the sediments (detection limit 0.5 $\mu g \cdot kg^{-1}$ dry weight), despite a mean effluent concentration of 44 $\mu g \cdot L^{-1}$ EDC. These results suggest that partitioning of EDC to sediments and biota is not an important fate process.

TCA

Sources

In the United States, total environmental releases of TCA in 1979 during its manufacture were estimated to be 483 t (U.S. EPA, 1982). Of this total, 81% (390 t) was released to water, 17% (80 t) to air, and 2% (9 t) to land.

During the consumption of TCA in degreasing operations, 2.2×10^5 t (68% of total production) of TCA were used. Approximately 1.7×10^5 t were released to the atmosphere, 2.7×10^4 t disposed to land, and 1.2×10^4 t released to water during these post-production processes. The remaining uses — including aerosol vapour depressants, adhesives, paints, film cleaners, and leather tanning — result almost entirely in atmospheric releases (U.S. EPA, 1982).

No information was found regarding environmental loadings of TCA in the Canadian environment.

Residues

TCA is a frequently found contaminant in Canadian waters, particularly near industrialized areas (Table 5). For example, in the St. Lawrence River, TCA was detected in the 0.01–0.05 $\mu g \cdot L^{-1}$ range. At several stations below Cornwall and in Lac-St-Louis, concentrations ranged from 0.5 to 18 $\mu g \cdot L^{-1}$ (Lum and Kaiser, 1986). In comparison, concentrations in the St. Clair River were in the 0.004–0.095 $\mu g \cdot L^{-1}$ range, and concentrations in Lake St. Clair ranged from 0.002 to 0.112 $\mu g \cdot L^{-1}$ (Kaiser and Comba, 1986a, 1986b). The concentrations of TCA in the Niagara River and in Lake Ontario ranged from below the detection limit (0.0005 $\mu g \cdot L^{-1}$) to 0.18 $\mu g \cdot L^{-1}$ (Kaiser et al., 1983; S. Lesage, 1989, National Water Research Institute, pers. com.).

Marine organisms collected near the discharge zone of the Los Angeles County wastewater treatment plant were analyzed to determine TCA levels (Gossett et al., 1983). Unlike EDC, TCA was detected in several fish species, including Pacific sanddab (*Citharichthys xanthostigna*), dover sole (*Microstomus pacificus*), and scorpionfish (*Scorpaena guttata*), and in whole invertebrates. TCA levels ranged from below the detection limit (0.3 $\mu g \cdot kg^{-1}$ dry weight) in several fish and invertebrate species to 7.0 $\mu g \cdot kg^{-1}$

Table 4. Environmental Concentrations of EDC in Canadian Waters*

Region	Year	Media	DL ($\mu g \cdot L^{-1}$)	No. of samples	Values >DL	Minimum Concentration ($\mu g \cdot L^{-1}$)	Maximum Concentration ($\mu g \cdot L^{-1}$)	Reference
Nova Scotia	1988	GW-NFD	1.0	9	0	—	—	S. Lesage, 1989 (National Water Research Institute, pers. com.)
Quebec	1988	GW-PS	1.0	2	2	102	105	Pakdel *et al.*, 1989
		GW-LF	1.0	3	3	4400	7200	
St. Lawrence R.	1985	SW	0.08	>200	0	—	—	Lum and Kaiser, 1986
Ontario	1985	SW	1.0	3	2	14.5	16	COARGLWQ, 1986
		BW	1.0	3	0			
	1988	GW-LF	1.0	37	11	3.9	58	Lesage *et al.*, 1990
	1988/89	LF	1.0	3	2	8	14	Lesage *et al.*, 1989
Welland R.	1980	SW	0.04	22	1	t	t	Kaiser and Comba, 1983
Niagara R.	1981	SW	0.08	17	0	—	—	Kaiser *et al.*, 1983
Lake Ontario	1981	SW	0.08	95	0	—	—	Kaiser *et al.*, 1983
Detroit R.	1982/83	SW	0.08	122	0	—	—	Comba and Kaiser, 1985
St. Clair R./ Lake St. Clair	1984	SW	0.08	67	0	—	—	Kaiser and Comba, 1986b
Alberta	1984	SW	1.0	1	0	—	—	AEC, 1989
	1985	SW	1.0	42	0	—	—	
		Sed.		1	0	—	—	
	1986	SW	1.0	16	0	—	—	
	1987	SW	1.0	35	0	—	—	
		WW	1.0	3	0	—	—	
	1988	SW	1.0	37	0	—	—	
		WW	1.0	12	0	—	—	

DL = detection limit
Sed. = sediment
SW = surface water
WW = wastewater
BW = bottom water
GW = groundwater
PS = pumping system
NFD = not for drinking
t = trace
LF = landfill

* No data were found for Newfoundland, Prince Edward Island, New Brunswick, Manitoba, Saskatchewan, British Columbia, Yukon, and Northwest Territories.

Table 5. Environmental Concentrations of TCA in Canadian Waters*

Region	Year	Media	DL ($\mu g \cdot L^{-1}$)	No. of samples	Values > DL	Minimum Concentration ($\mu g \cdot L^{-1}$)	Maximum Concentration ($\mu g \cdot L^{-1}$)	Reference
Nova Scotia	1988	GW-NFD	1.0	9	0	—	—	S. Lesage, 1989 (National Water Research Institute, pers. com.)
Quebec	1988	GW-PS	1.0	2	1	5.6	5.6	Pakdel *et al.*, 1989
		GW-LF	1.0	3	2	200	340	
St. Lawrence R.	1985	SW	0.001	>200	>33	NQ	18.0	Lum and Kaiser, 1986
Welland R.	1980/81	SW	0.001	32	30	0.01	0.30	Kaiser and Comba, 1983
Niagara R.	1981	SW	0.001	17	16	t	0.017	Kaiser *et al.*, 1983
Lake Ontario	1981	SW	0.0005	95	93	t	0.18	Kaiser *et al.*, 1983
Detroit R.	1982/83	SW	0.001	122	38	NQ	NQ	Comba and Kaiser, 1985
St. Clair R./ Lake St. Clair	1984	SW	0.001	67	66	0.002	0.112	Kaiser and Comba, 1986b
Ontario	1985	SW	1.0	8	4	5.0	21.0	COARGLWQ, 1986
		BW	1.0	8	3	2.0	4.0	
	1987	GW-LF	1.0	3	2	82.0	93.0	Jackson *et al.*, 1988
	1987	GW-LF	1.0	37	16	t	52.0	Lesage *et al.*, 1990
Alberta	1984	SW	0.2	1	0	—	—	AEC, 1989
	1985	SW	0.2	42	1	1.9	1.9	
		Sed.		1	0	—	—	
	1986	SW	0.2	16	2	t	t	
	1987	SW	1.0	35	0	—	—	
		WW	1.0	3	0	—	—	
	1988	SW	1.0	37	0	—	—	
		WW	1.0	12	0	—	—	

DL = detection limit
Sed. = sediment
SW = surface water
WW = wastewater

BW = bottom water
GW = groundwater
PS = pumping system
NFD = not for drinking

NQ = not quantified
t = trace
LF = landfill

* No data were found for Newfoundland, Prince Edward Island, New Brunswick, Manitoba, Saskatchewan, British Columbia, Yukon, and Northwest Territories.

dry weight in *C. xanthostigna*. TCA was not detected in the sediments (detection limit 0.5 $\mu g \cdot kg^{-1}$ dry weight), despite having a mean concentration of 31.0 $\mu g \cdot L^{-1}$ in the wastewater effluents.

TECA

Sources

There is little information available concerning sources of TECA entry into the environment. Because TECA is no longer produced in Canada and only negligible amounts are imported to Canada, it is likely that future releases of TECA to the Canadian environment will be small (CPI, 1988c; D. MacGregor, 1990, Environment Canada, pers. com.). The largest threat of release of TECA is to groundwater from existing landfills (Pakdel et al., 1989).

Residues

Surveys to determine TECA levels in Canadian waters have been conducted in Ontario and Alberta (Table 6). In Ontario, TECA has been detected in the Great Lakes (range, not detected to 4.0 $\mu g \cdot L^{-1}$; detection limit 1.0 $\mu g \cdot L^{-1}$) (COARGLWQ, 1986), the Welland River (range, not detected to 0.06 $\mu g \cdot L^{-1}$; detetection limit 0.005 $\mu g \cdot L^{-1}$) (Kaiser and Comba, 1983), and the St. Clair River (levels not quantified) (Kaiser and Comba, 1986a). In Alberta, surface water and wastewater samples collected between 1984 and 1988 contained no detectable levels of TECA (1984-86 detection limit 5.0 $\mu g \cdot L^{-1}$; 1987-88 detection limit 1.0 $\mu g \cdot L^{-1}$) (AEC, 1989).

ENVIRONMENTAL FATE AND PERSISTENCE

EDC

There is little information regarding the fate of EDC in the aquatic environment (Fig. 4). However, based upon the limited information available, volatilization appears to be the major process for the removal of EDC from the aquatic environment (Dilling et al., 1975). Dilling et al. (1975) determined the half-life of a 1 $mg \cdot L^{-1}$ EDC solution to be 29 min when stirred at 200 rpm in water in an open container. However, the authors commented that these data are not readily transferable to the environment, because natural concentrations of EDC are expected to be much lower, and because other factors such as wind speed and wave action are highly variable.

No studies were found that investigated photolysis, oxidation, or hydrolysis of EDC in water or sediment. Studies conducted on analogous compounds (e.g., dichloromethane, trichloroethane, dibromoethane), however, indicate that these processes are unlikely to be important in the removal of EDC from the aquatic environment (Dilling et al., 1975; Radding et al., 1977). Portier and Meyers (1984) found that aerobic biodegradation may also be an important removal process for EDC in the aquatic environment. In sediment/water microcosms, they found that EDC had a half-life of 48 h in fresh water. In saline conditions (10–24 $g \cdot L^{-1}$), the degradation rate was reduced by a factor of 4–5 times. Chitin amended to continuous-flow microcosms promoted either cometabolic or cooxidative biotransformation, resulting in 71% degradation of EDC after 48 h (Portier and Meyers, 1984). The products of biodegradation were not determined in this experiment.

Once EDC has volatilized to the atmosphere, the compound reacts with hydroxyl radicals to form chloracetyl chloride (Howard and Evenson, 1976; Radding et al., 1977). Radding et al. (1977) indicated an atmospheric half-life of 234 h for this photooxidation reaction; the U.S. EPA (1975) and Howard and Evenson (1976) predicted that EDC will have an atmospheric lifetime of 3–4 months and 1.7 months, respectively. Because this reaction is relatively rapid, little EDC is expected to reach the stratosphere from the troposphere. Similarly, chloracetyl chloride will be rapidly hydrolyzed to hydrochloric and carboxylic acids in the troposphere (Morrison and Boyd, 1973). Despite the relatively short residence time of EDC in the atmosphere, Pearson and McConnell (1975) suggested that EDC has the potential for long-range transport, and that this process accounts for its presence in upland waters.

TCA

As with EDC, volatilization is the major process for the removal of TCA from aquatic ecosystems (Fig. 5) (Dilling et al., 1975; Wakeham et al., 1983). Wakeham et al. (1983) investigated the volatilization behaviour of TCA in seawater microcosms under conditions simulating winter, spring, and summer in a moderately polluted estuary (2.7–4.3 $\mu g \cdot L^{-1}$ TCA). They found that TCA had a half-life that ranged from 11 d in winter to 24 d in spring. Subsequent experiments that compared TCA removal in microcosms poisoned with mercuric chloride to retard

Table 6. Environmental Concentrations of TECA in Canadian Waters*

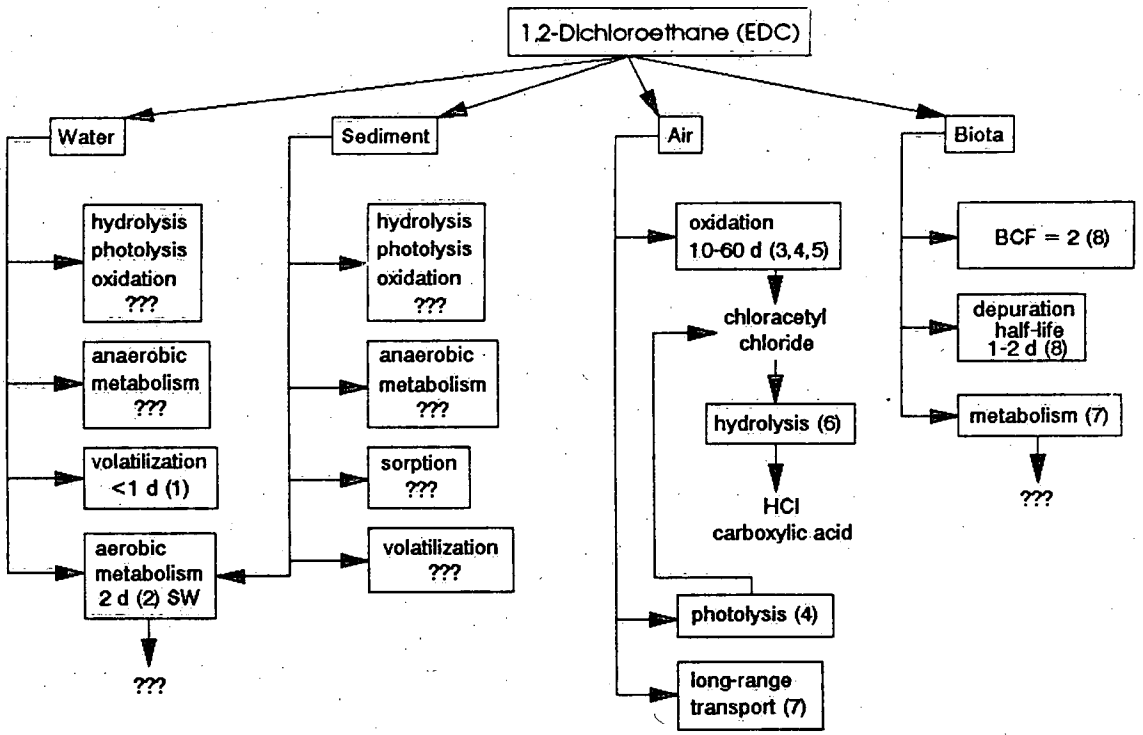
Region	Year	Media	DL ($\mu g \cdot L^{-1}$)	No. of samples	Values >DL	Minimum Concentration ($\mu g \cdot L^{-1}$)	Maximum Concentration ($\mu g \cdot L^{-1}$)	Reference
Quebec	1988	GW-Lf		4	3	760	1600	Pakdel *et al.*, 1989
Ontario	1985	SW	1.0	5	3	2.0	4.0	COARGLWQ, 1986
	1986	BW	1.0	4	1	2.0	2.0	
Niagara R.	1981	SW	0.0005	17	6	t	t	Kaiser *et al.*, 1983
Lake Ontario	1981	SW	0.0005	95	11	—	0.024	K.L.E. Kaiser, 1990 (National Water Research Institute, pers. com.)
	1982	SW	0.0005	92	7	—	0.001	
Alberta	1984	SW	5.0	1	0	—	—	AEC, 1989
	1985	SW	5.0	42	0	—	1.9	
		Sed.		1	0	—	—	
	1986	SW	5.0	16	0	—	t	
	1987	SW	1.0	35	0	—	—	
		WW	1.0	3	0	—	—	
	1988	SW	1.0	37	0	—	—	
		WW	1.0	12	0	—	—	

DL = detection limit
WW = wastewater
BW = bottom water

GW = groundwater
SW = surface water
Sed. = sediment

LF = landfill
t = trace

* No data were found for Newfoundland, Prince Edward Island, New Brunswick, Manitoba, Saskatchewan, British Columbia, Yukon, and Northwest Territories.



Note: Half-lives are given where known. Question marks indicate that the process (in box) or its metabolite (outside box) have not been studied.

References:
[1] Dilling et al. (1975)
[2] Portier and Meyers (1984)
[3] Radding et al. (1977)
[4] U.S. EPA (1975)
[5] Howard and Evenson (1976)
[6] Morrison and Boyd (1973)
[7] Pearson and McConnell (1975)
[8] Barrows et al. (1980)

Figure 4. Potential fate processes for EDC.

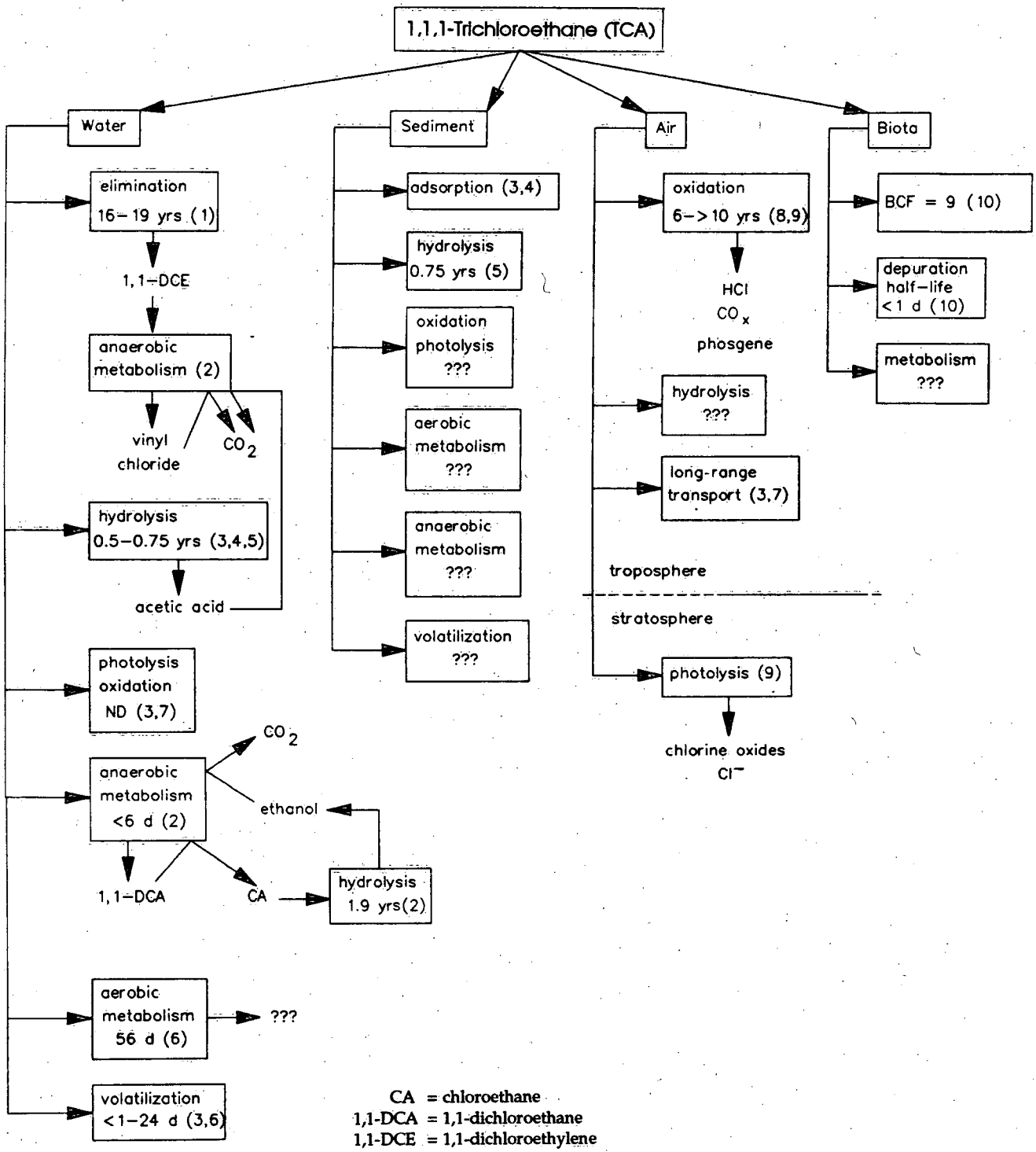
biological activity with that in non-poisoned microcosms indicated that 83.5% of TCA removal could be attributed to volatilization, whereas the remainder was due to microbial degradation. Other studies have indicated that photolysis, oxidation, and elimination reactions are not important in the removal of TCA from aquatic systems (Dilling et al., 1975; U.S. EPA, 1979; Vogel and McCarty, 1987b). Hydrolysis of TCA has been shown to occur in aquatic ecosystems; the half-life was 0.5–0.75 years (Dilling et al., 1975; Pearson and McConnell, 1975; Haag et al., 1986). Therefore, this process may be important in TCA removal from groundwater. However, in groundwater that is anaerobic and conducive to methanogenesis, TCA can also be biotransformed by reductive dehalogenation to 1,1-dichloroethane and chloroethene. The half-life for this process may be less than 6 d (Vogel and McCarty, 1987a). However, in Canadian groundwater, residues have been found more than 10 years after disposal (Lesage et al., 1990). These initial products then undergo hydrolysis to form ethanol.

At present, there is no clear evidence to suggest that TCA is selectively concentrated in sediments. Dilling et al. (1975) showed that bentonite clay, dolomitic limestone, and peat moss adsorbed TCA, but adsorption and desorption rates were approximately equal after 10–30 min.

TCA is long-lived in the atmosphere, with a photooxidative half-life of more than 6 years in the troposphere. Consequently, 12%–25% of TCA in the troposphere will reach the stratosphere (McConnell and Schiff, 1978; U.S. EPA, 1982). Chlorine atoms released during the photolysis of TCA in the stratosphere can attack and deplete ozone. As with EDC, the presence of TCA in upland waters is believed to be due to long-range transport (Pearson and McConnell, 1975).

TECA

Little is known of the environmental fate and behaviour of TECA (Fig. 6). Dilling et al. (1975) estimated the experimental half-life for volatilization of TECA initially present at 1 $mg \cdot L^{-1}$ to be 56 min when stirred at 200 rpm. However, the initial TECA concentration and experimental conditions are not likely to occur in the natural

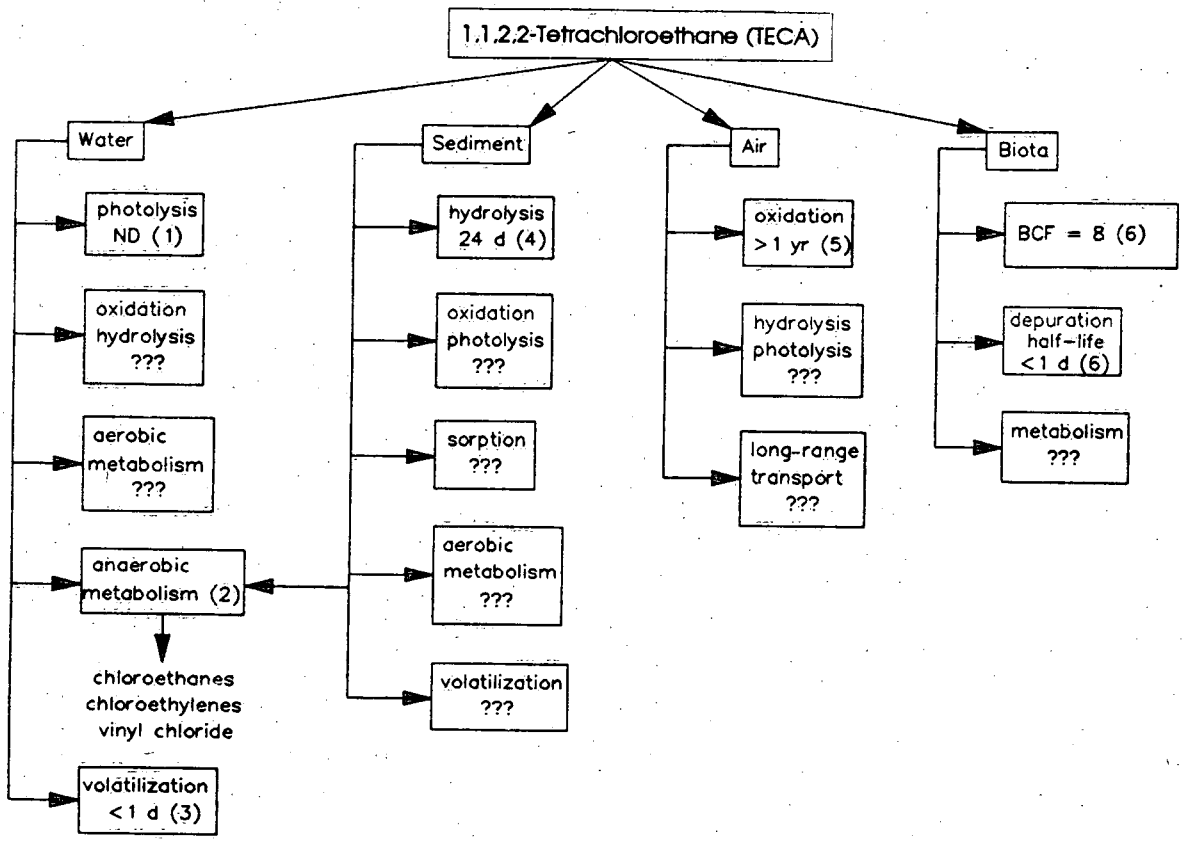


CA = chloroethane
1,1-DCA = 1,1-dichloroethane
1,1-DCE = 1,1-dichloroethylene

References: [1] Vogel and McCarthy (1987b)
[2] Vogel and McCarthy (1987a)
[3] Dilling et al. (1975)
[4] Pearson and McConnell (1975)
[5] Haag et al. (1986)
[6] Wakeham et al. (1983)
[7] U.S. EPA (1979)
[8] U.S. EPA (1982)
[9] McConnell and Schiff (1978)
[10] Barrows et al. (1980)

Note: Half-lives are given where known. Question marks indicate that the process (in box) or its products (outside box) have not been studied, whereas ND indicates that the process has been studied but was found not to occur at a detectable rate.

Figure 5. Potential fate processes for TCA.



Note: Half-lives are given where known. Question marks indicate that the process (in box) or its products (outside box) have not been studied, whereas ND indicates that the process has been studied but was found not to occur at a detectable rate.

References: [1] Jensen and Rosenberg (1975)
[2] Hallen et al. (1986)
[3] Dilling et al. (1975)
[4] Haag et al. (1986)
[5] Singh et al. (1982)
[6] Barrows et al. (1986)

Figure 6. Potential fate processes for TECA.

environment, and therefore the data can be used only as a rough approximation. No information was found regarding potential competing abiotic processes, except for photolysis, which was detected, but not quantified, in a study by Jensen and Rosenberg (1975).

Biotransformation of TECA to chlorinated ethylenes and ethanes and vinyl chloride has been demonstrated in conditions that simulated a landfill site (Hallen et al., 1986). Further anaerobic biotransformation and hydrolytic reactions would convert these products to carbon dioxide (Fig. 6). Hydrolysis of TECA in subsurface sediment has been demonstrated by Haag et al. (1986). The hydrolytic half-life was 24 d.

The tropospheric lifetime of TECA is estimated to be longer than 1160 d (Singh et al., 1982). The principal removal process in this estimate was photooxidation; however, competing processes have not yet been investigated.

BIOACCUMULATION

Freshwater Biota

Barrows et al. (1980) investigated the bioconcentration potential and persistence of chlorinated ethanes in juvenile bluegill (*Lepomis macrochirus*). The fish were continuously exposed to each of EDC, TCA, and TECA for a period of 14–28 d. The chlorinated ethanes were found to have a low potential for bioconcentration, with a bioconcentration factor (BCF) of 2 for EDC, 9 for TCA, and 8 for TECA (Table 7).

Immediately following exposure, fish were transferred to clean water to measure depuration rates. The biological half-lives of TCA and TECA were found to be less than 1 d; EDC had a half-life of 1–2 d. No other studies on the bioaccumulation potential of chlorinated ethanes in freshwater biota were found.

Table 7. Bioconcentration and Persistence of Chlorinated Ethanes in Bluegill *(Lepomis macrochirus)*

Compound	Exposure period (d)	Mean concentration ($mg \cdot L^{-1}$)	BCF	Depuration half-life (d)
EDC	14	0.095 ± 0.011	2	1–2
TCA	28	0.073 ± 0.014	9	<1
TECA	14	0.096 ± 0.001	8	<1

Source: Barrows et al., 1980.

Marine Biota

Pearson and McConnell (1975) found no evidence of EDC bioaccumulation at different trophic levels in marine biota of Liverpool Bay, Great Britain. No studies were found investigating the bioaccumulation potential of TCA and TECA in marine biota.

TOXICITY TO AQUATIC BIOTA

As standard protocols for toxicity testing may become outdated or are not always available or followed, a great deal of variability exists in the quality of published toxicity data. To ensure a consistent scientific evaluation for each chlorinated ethane compound, the data used in deriving a guideline must meet certain criteria as outlined in CCME (1991). These criteria include information on test conditions/design (e.g., flow-through, static), test concentrations, temperature, water hardness, pH, experimental design (controls, number of replicates), and a description of the statistics used in evaluating the data. Each study is evaluated based on the above information and ranked as primary, secondary, or unacceptable (see CCME,1991 for a detailed description of the ranking criteria). All data included in the minimum data set must be primary in order for full guideline derivation to proceed. For interim guideline derivation, primary or secondary data may be used. Toxicity data that do not meet the criteria of primary or secondary data are unacceptable and cannot be used in either derivation procedure.

Acute Toxicity

The acute toxic effects of the chlorinated ethanes on aquatic organisms are tabulated in Appendix A.

Fish

EDC

The effects of acute exposures to EDC have been examined for several fish species, particularly the fathead minnow (*Pimephales promelas*). Using a flow-through system, Walbridge et al. (1983) found that *P. promelas* had a 96-h LC_{50} of 116 $mg \cdot L^{-1}$ EDC (measured concentration). Using the same species and a similar experimental protocol, Geiger et al. (1985a) and Veith et al. (1983) determined 96-h LC_{50} values of 136 and 118 $mg \cdot L^{-1}$ EDC, respectively. All three studies were ranked as primary.

The response of rainbow trout (*Oncorhynchus mykiss*) to acute exposures to EDC has been examined in two studies that used static tests. Bartlett (1979) found that *O. mykiss* had a 96-h LC_{50} of 336 $mg \cdot L^{-1}$ EDC, whereas Mayer and Ellersieck (1986) obtained a 96-h LC_{50} of 225 $mg \cdot L^{-1}$ EDC. Both of these tests were ranked as secondary because EDC concentrations were not measured during the experiments.

Other reported LC_{50} values found under static conditions range from 106 $mg \cdot L^{-1}$ EDC with guppies (*Poecilia reticulata*) after a 7-d exposure (Konemann, 1981) to 550 $mg \cdot L^{-1}$ EDC for *L. macrochirus* after a 4-d exposure (Dawson et al., 1975/77).

The only acceptable study on a marine fish species (tidewater silverside, *Meridia beryllina*) reported a 96-h LC_{50} of 480 $mg \cdot L^{-1}$ in a static test ranked secondary because concentrations were not measured (Dawson et al., 1975/77).

A study conducted by Pearson and McConnell (1975) on dab (*Limanda limanda*), a

marine fish species, using a flow-through, measured test was deemed unacceptable because no information was provided concerning other test parameters (e.g., pH, water hardness, dissolved oxygen) and the experimental design used.

TCA

Three flow-through studies have been conducted to determine the effects of acute exposures of *P. promelas* to TCA. In a study ranked as primary, Geiger et al. (1985b) found that *P. promelas* had a 96-h LC_{50} of 42.3 $mg \cdot L^{-1}$ TCA and a 96-h EC_{50} (any of the following effect criteria: behavioural changes, increased respiration, loss of equilibrium) of 28.8 $mg \cdot L^{-1}$ TCA in flow-through tests. In a study ranked as secondary because TCA concentrations were not measured, Alexander et al. (1978) found that exposure to TCA in a static test resulted in a 96-h LC_{50} of 105.0 $mg \cdot L^{-1}$ TCA, almost 100% higher than the 96-h LC_{50} of 52.8 $mg \cdot L^{-1}$ TCA from a flow-through test that was ranked as primary. Using a flow-through test, Alexander et al. (1978) found that *P. promelas* had a 96-h EC_{50} (any of the following effect criteria: loss of equilibrium, melanization, narcosis, swollen, hemorrhaging gills) of 11.1 $mg \cdot L^{-1}$ TCA and a 96-h EC_{10} of 9.0 $mg \cdot L^{-1}$ TCA. The only other freshwater fish species examined was *L. macrochirus*, which was found to have an LC_{50} of 72 $mg \cdot L^{-1}$ TCA in a static test ranked as secondary because nominal (unmeasured) chemical concentrations were used (Buccafusco et al., 1981).

A study by the U.S. EPA (1978) on *L. macrochirus* was deemed unacceptable because insufficient information was provided regarding experimental design and test conditions.

Pearson and McConnell (1975) measured the short-term effects of TCA on the marine fish *L. limanda* in a flow-through, measured test. Another marine fish species, the sheepshead minnow (*Cyprinodon variegatus*), was exposed to TCA in a static, unmeasured test (Heitmuller et al., 1981). Both of these studies were, however, ranked as unacceptable because of insufficient information on experimental design and test conditions.

TECA

In a primary study, a 96-h flow-through test conducted with 2- to 4-month-old American flagfish (*Jordanella floridae*) yielded a measured LC_{50} of 18.5 $mg \cdot L^{-1}$ TECA (ATRG, 1988). When the study was repeated under static test conditions, based on nominal (unmeasured) chemical concentrations, the LC_{50} was 26.8 $mg \cdot L^{-1}$ TECA. Walbridge et al. (1983) investigated the acute effects of TECA using 30- to 35-d-old *P. promelas* in a flow-through test ranked as primary. The measured 96-h LC_{50} was 20.4 $mg \cdot L^{-1}$ TECA. In a static, unmeasured test ranked as secondary, Buccafusco et al. (1981) obtained a 96-h LC_{50} of 21 $mg \cdot L^{-1}$ TECA for young-of-year *L. macrochirus*.

The U.S. EPA (1978) and Heitmuller et al. (1981) obtained 96-h LC_{50} values for *L. macrochirus* and the marine *C. variegatus*, respectively. However, these two studies were deemed unacceptable because no information was provided regarding experimental design and test conditions.

Invertebrates

EDC

Richter et al. (1983) conducted 48-h static, measured tests ranked as primary on first instar *Daphnia magna*. The 48-h LC_{50} values for fed and unfed *D. magna* were 320 and 270 $mg \cdot L^{-1}$ EDC, respectively. The corresponding 48-h EC_{50} values based upon complete immobilization were 180 and 160 $mg \cdot L^{-1}$ EDC for fed and unfed *D. magna*, respectively. LeBlanc (1980), who examined first instar *D. magna* in static tests ranked as secondary because concentrations were not measured, found a 48-h LC_{50} value of 220 $mg \cdot L^{-1}$ EDC.

The only acceptable marine study found was on the brine shrimp (*Artemia salina*). This species was found to have a 24-h EC_{50} (immobilization) of 93.6 $mg \cdot L^{-1}$ EDC in a static, measured test ranked as primary (Foster and Tullis, 1985). In a similar experiment on this shrimp under salinity stress (25% artificial seawater), an EC_{50} of 36.4 $mg \cdot L^{-1}$ EDC was found (Foster and Tullis, 1985); this test was ranked as secondary.

A study by the U.S. EPA (1978) found a 48-h LC_{50} for *D. magna*; however, this study was deemed unacceptable because no information was provided regarding experimental design and test conditions.

A static test by Pearson and McConnell (1975), in which the barnacle (*Elminius modestus*) was exposed to seawater containing a known concentration of EDC, was deemed unacceptable because no information was provided concerning other test parameters.

TCA

The acute toxicity of TCA to freshwater invertebrates has been considered in only one study (LeBlanc, 1980). In this static test, ranked as secondary because concentrations were not measured, *D. magna* (<24 h old) did not suffer any mortality at 530 $mg \cdot L^{-1}$ TCA, the highest concentration tested.

Toxicity studies on *E. modestus* and mysid shrimp (*Mysidopsis bahia*) were conducted by Pearson and McConnell (1975) and the U.S. EPA (1978), respectively. Both of these studies, however, were deemed unacceptable because no information was provided on test conditions and experimental design.

TECA

Only two acute toxicological studies of TECA on freshwater invertebrate species were found, both of which used first instar *D. magna* (<24 h old). In a study ranked as primary, Richter et al. (1983) determined 48-h LC_{50} values of 62 and 57 $mg \cdot L^{-1}$ TECA for unfed and fed *D. magna*, respectively. When complete immobilization was used as the biological end point, the 48-h EC_{50} values were 23 and 25 $mg \cdot L^{-1}$ TECA for unfed and fed *D. magna*, respectively. In a static, unmeasured test ranked as secondary, LeBlanc (1980) found that *D. magna* had a 48-h LC_{50} of 9.3 $mg \cdot L^{-1}$ TECA.

The only study that considered the acute toxicity of TECA to the marine invertebrate myrid shrimp (*M. bahia*) (U.S. EPA, 1978) was deemed unacceptable because no information was provided regarding test conditions and experimental design.

Plants

EDC

The toxic effects of EDC on the green alga *Selenastrum capricornutum* were determined using the measured responses of chlorophyll-*a* level and cell number (U.S. EPA, 1978). However, this study was deemed unacceptable because no information was provided regarding experimental design and test conditions.

The only EDC toxicity study conducted on marine algae (*Phaeodactylum tricornutum*) (Pearson and McConnell, 1975) was also deemed unacceptable because no information was provided on other test parameters.

TCA

As with EDC, the only TCA toxicity study conducted on freshwater algae was performed by the U.S. EPA (1978) on *S. capricornutum*. However, this study was ranked as unacceptable because no information was provided on test conditions or experimental design.

Pearson and McConnell (1975) conducted an EC_{50} (carbon intake) toxicity study on the marine algae *P. tricornutum* in a static, measured test; however, this study was deemed unacceptable because insufficient information was provided on other test parameters.

TECA

A study by the U.S. EPA (1978) on the toxicity of TECA to freshwater *S. capricornutum* was deemed unacceptable because information was not provided on experimental design and test conditions. No studies on marine algae were found.

Chronic Toxicity

The effects of chlorinated ethanes on aquatic biota during chronic exposures are summarized in Appendix B.

Fish

EDC

In a study ranked as primary, Benoit et al. (1982) observed no effects on egg hatchability

and survival and no deformity of *P. promelas* at 59 $mg \cdot L^{-1}$ EDC, the highest concentration tested after a 28-d exposure. However, at the same concentration, juvenile weight gain was reduced by 62% (lowest-observed-effect level, or LOEL). At the second highest concentration tested (29 $mg \cdot L^{-1}$ EDC), no effect on weight gain was noted (no-observed-effect level, or NOEL).

Black et al. (1982), in a primary-ranked study, exposed fertilized eggs and larvae of *O. mykiss* to EDC in a flow-through test. The EC_{50} for hatchability and the LC_{50} for 4-d post-hatch survival were both 34 $mg \cdot L^{-1}$ EDC. Black et al. (1982) used the same experimental protocol to determine the effects of EDC on hatchability and 4-d post-hatch survival of two amphibians — the northwestern salamander (*Ambystoma gracile*) and the leopard frog (*Rana pipiens*). *Ambystoma gracile* had a hatchability EC_{50} of 6.53 $mg \cdot L^{-1}$, a 4-d post-hatch LC_{50} of 2.54 $mg \cdot L^{-1}$ EDC, and a 4-d post-hatch LOEL (23% reduction in survival) of 0.99 $mg \cdot L^{-1}$ EDC. The corresponding values for *R. pipiens* were 4.52, 4.40, and 1.07 $mg \cdot L^{-1}$ EDC (24% reduction in post-hatch survival), respectively.

In a freshwater study, coho salmon (*Oncorhynchus kisutch*) experienced 100% alevin mortality 9 d after hatching after exposure for 21 d to 73 $mg \cdot L^{-1}$ EDC in a static, measured test ranked as primary (Reid et al., 1982). In this study, 46% of eggs did not hatch after exposure to 124 $mg \cdot L^{-1}$ for 21 d.

During a 32-d exposure period, the chronic toxicity of EDC to the early life stages (embryo, larvae) of *P. promelas* was examined by the U.S. EPA (1978). However, this study was deemed unacceptable because insufficient information was provided on experimental design and test parameters.

TCA

Only one study on the chronic toxicity of TCA to freshwater fish was found. Thompson and Carmichael (1989) reported a 17-d LOEL of 30 $mg \cdot L^{-1}$ for effects of toxicity and weight gain for the mirror carp (*Cyprinus carpia*) in a flow-through measured test ranked primary. No studies were found regarding the chronic toxicity of TCA to marine fish.

TECA

The chronic toxicity of TECA to the early life stages of *J. floridae* was studied by ATRG (1988) using a flow-through, measured test ranked as a primary study. Egg hatchability was unaffected at 22.0 $mg \cdot L^{-1}$ TECA, the highest concentration tested. The LOEL for 10-d larval survival was 10.6 $mg \cdot L^{-1}$ TECA, and the LOEL for 28-d juvenile survival was 11.7 $mg \cdot L^{-1}$. Twenty-eight day fry growth was unaffected by the highest TECA concentration used (15.8 $mg \cdot L^{-1}$), due in part to the large variation found to be associated with fry growth.

D.L. DeFoe (U.S. EPA, unpubl. data) conducted early life stage toxicity studies of TECA using *P. promelas*. However, this study was deemed unacceptable because other test parameters were not reported.

No studies were found on the chronic toxicity of TECA to marine fish.

Invertebrates

EDC

Only one study has examined the chronic toxic effects of EDC on freshwater invertebrates. Richter et al. (1983) exposed *D. magna* to a range of EDC concentrations in a flow-through, measured test ranked as primary. The NOEL and LOEL values for reproductive success were 10.6 and 20.7 $mg \cdot L^{-1}$ EDC, respectively. The influence of EDC on growth was less severe, with NOEL and LOEL values of 41.6 and 71.7 $mg \cdot L^{-1}$ EDC, respectively.

In the only study found on the chronic toxic effects of EDC on a marine invertebrate, hatchability was reduced 90% in the polychaete *Ophryotrocha labronica* after exposure to 400 $mg \cdot L^{-1}$ EDC for 15 d (Rosenberg et al., 1975).

TCA

Only one chronic study on a freshwater invertebrate was found. Thompson and Carmichael (1989) reported a 17-d LC_{50} of 5.4 $mg \cdot L^{-1}$ in a static-renewal test ranked primary on *D. magna*. No studies were found regarding the chronic toxic effects of TCA on marine invertebrates.

TECA

As with EDC, only the study by Richter et al. (1983), ranked as primary, examined the chronic toxicity of TECA to a freshwater invertebrate. The NOEL and LOEL values for reproductive success

of *D. magna* were 6.9 and 14.4 $mg \cdot L^{-1}$, respectively, in a flow-through, measured test.

No studies were found on the chronic toxic effects of TECA on marine invertebrates.

Plants

No studies were found that examined the long-term toxic effects of EDC, TCA, or TECA on aquatic plants.

Carcinogenicity, Mutagenicity, and Teratogenicity

EDC

Direct reports of epidemiological studies on the carcinogenicity of EDC in humans are not available. However, several studies with laboratory animals have shown an increased incidence of benign and malignant tumours in mice and carcinomas in rats exposed to EDC. These results led the National Institute for Occupational Safety and Health in the United States to recommend that EDC be handled in the workplace as if it were a human carcinogen (U.S. EPA, 1985). Connor (1984) estimated that EDC presents a greater carcinogenic risk ($1.3–2.2 \times 10^{-6}$, the ratio of the excess lifetime cancer incidence in the human population based on 1.2–2.1 $\mu g \cdot L^{-1}$ EDC in groundwater) than does vinyl chloride, a known carcinogen (carcinogenic risk, $0.8–1.2 \times 10^{-6}$, based on 1.6–2.5 $mg \cdot L^{-1}$ vinyl chloride in groundwater). No information is available on the carcinogenic risk of EDC to aquatic biota.

Based on an extensive survey of the literature, Konietzko (1984) and the U.S. EPA (1985) concluded that EDC is a weak mutagen.

Several studies have indicated that EDC is teratogenic, both to laboratory rats (for a review, see Konietzko, 1984) and to *A. salina* (Kerster and Schaeffer, 1983).

TCA

Based on the available data, TCA does not appear to be carcinogenic, mutagenic, or teratogenic (U.S. EPA, 1982; Connor, 1984; Konietzko, 1984).

Table 8. Recommended Water Quality Guidelines for Chlorinated Ethanes

Water use	Guideline ($mg \cdot L^{-1}$)		
	EDC	TCA	TECA
Raw water for drinking water supply	0.005[1]	ID[2]	ID
Freshwater aquatic life	0.1[3]	ID	ID
Marine aquatic life	ID	ID	ID
Agricultural uses			
Livestock watering	0.005[4]	ID	ID
Irrigation	ID	ID	ID
Recreational water quality and aesthetics	ID	ID	ID
Industrial water supplies	ID	ID	ID

ID = insufficient data

(1) Interim maximum acceptable concentration (IMAC) proposed by Federal–Provincial Subcommittee on Drinking Water (Health and Welfare Canada, 1989).
(2) Awaiting review of Federal-Provincial Subcommittee on Drinking Water.
(3) Interim guideline.
(4) Canadian drinking water guideline (Health and Welfare Canada, 1989) adopted as interim Canadian livestock watering guideline

TECA

No information was found regarding possible carcinogenic, mutagenic, or teratogenic effects of TECA on humans, other mammals, or aquatic biota.

SUMMARY OF RECOMMENDED GUIDELINES

A review was conducted of the available information on the physical and chemical properties, environmental concentrations, environmental fate and behaviour, bioaccumulation potential, and toxic effects on aquatic biota of 1,2-dichloroethane (EDC), 1,1,1-trichloroethane (TCA), and 1,1,2,2-tetrachloroethane (TECA) (Appendix C). Table 8 summarizes the recommended guidelines for the protection and maintenance of the major water uses in Canada.

Raw Water for Drinking Water Supply

The Federal-Provincial Subcommittee on Drinking Water has proposed an interim guideline of 0.005 $mg \cdot L^{-1}$ EDC for this water use (Health and Welfare Canada, 1989). If, after 1 year, no evidence is presented that questions the suitability of the proposed value, it will be adopted as the guideline.

A drinking water guideline for TCA is under review for possible addition to the guidelines. Health and Welfare Canada (1989) has not prepared a maximum acceptable concentration for TECA in drinking water.

Freshwater Aquatic Life

The acute toxicity of the chlorinated ethanes to freshwater fish and invertebrates appears to increase with increasing chlorine content (Figs. 7, 8, and 9). For instance, *P. promelas* had LC_{50} values of 116–136 $mg \cdot L^{-1}$ for EDC, 42.3–105 $mg \cdot L^{-1}$ for TCA, and 20.3–20.4 $mg \cdot L^{-1}$ for TECA. The pattern of increasing toxic effects of chlorinated ethanes as chlorine content increases may also occur during chronic exposures (Fig. 10). However, there are insufficient data to accurately assess this trend. In particular, no chronic exposure tests have been conducted with TCA.

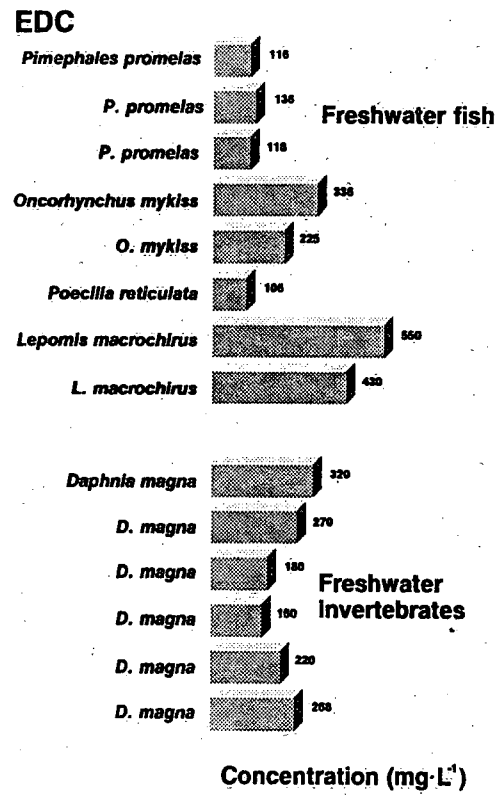


Figure 7. Observed LC_{50} and EC_{50} responses in aquatic biota after acute exposure to EDC.

EDC

An interim Canadian water quality guideline of 0.1 $mg \cdot L^{-1}$ EDC is recommended for the protection and maintenance of freshwater aquatic life. This level was derived by applying a safety factor of 10 to the lowest chronic value observed CCME, 1991), which was a 23% reduction in post-hatch survival (LOEL) of *A. gracile* exposed from the time of fertilization to 4 d post-hatch at a measured concentration of 0.99 $mg \cdot L^{-1}$ EDC in a flow-through test (Black et al., 1982).

Users of this guideline should note that development of Canadian aquatic guidelines is based on the most sensitive aquatic organism resident to Canada, irrespective of species range, location, and size. When site-specific objectives are developed, the most sensitive local species may be considered. The data base considered in this report (Appendices A and B) did not have the minimum number of acute and chronic toxicity data from studies on invertebrates and plants to proceed with full guideline

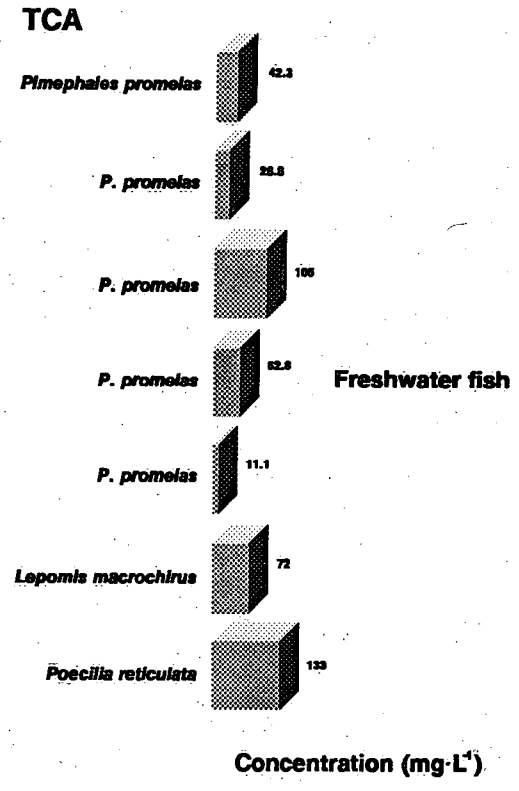


Figure 8. Observed LC_{50} and EC_{50} responses in aquatic biota after acute exposure to TCA.

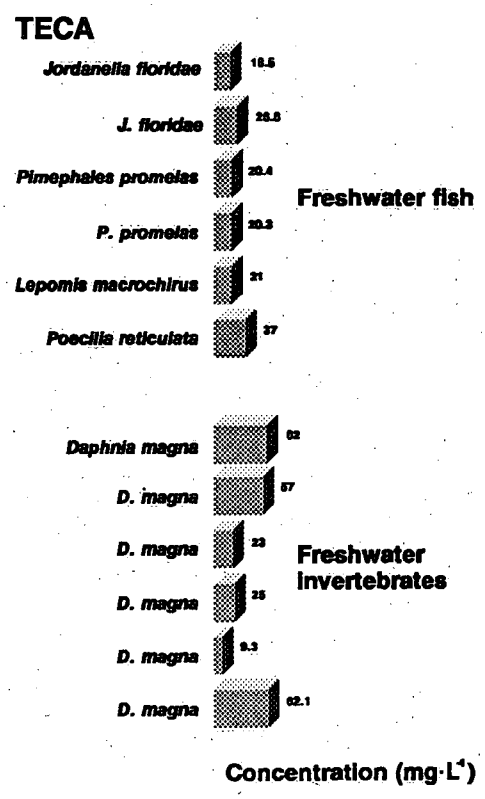


Figure 9. Observed LC_{50} and EC_{50} responses in aquatic biota after acute exposure to TECA.

development (Fig. D-1) (CCME, 1991). Further, there has been insufficient research to reliably determine the environmental fate and behaviour of EDC (see Fig. 4) (CCME, 1991). Therefore, 0.1 $mg \cdot L^{-1}$ EDC is recommended as an interim guideline.

TCA

No Canadian water quality guideline or interim water quality guideline for TCA is recommended for the protection and maintenance of freshwater aquatic life. The data considered in this report included only one fish and one invertebrate (Thompson and Carmichael, 1989) chronic exposure study and therefore did not meet the minimum data set requirements for developing a Canadian water quality guideline (Fig. D-2) (CCME, 1991). In addition, no toxicity studies were available for a cold-water fish species, nor were there any studies available for an invertebrate species other than *Daphnia*. Therefore, as specified in CCME (1991), there were insufficient data to develop a Canadian interim water quality guideline.

TECA

As with TCA, there are insufficient data available to recommend a Canadian water quality guideline or interim water quality guideline for TECA (Fig. D-3) (CCME, 1991). In particular, primary toxicity studies are required for a cold-water fish species and for an invertebrate species other than *Daphnia*. Further, little is known of the environmental fate and behaviour of TECA. Until the partitioning behaviour between environmental compartments and the kinds of biological and chemical reactions that affect its persistence are better understood, a water quality guideline cannot be derived (CCME, 1991). The derivation of an interim guideline requires primary or secondary toxicity studies on a cold-water fish species and on an invertebrate species other than *Daphnia*.

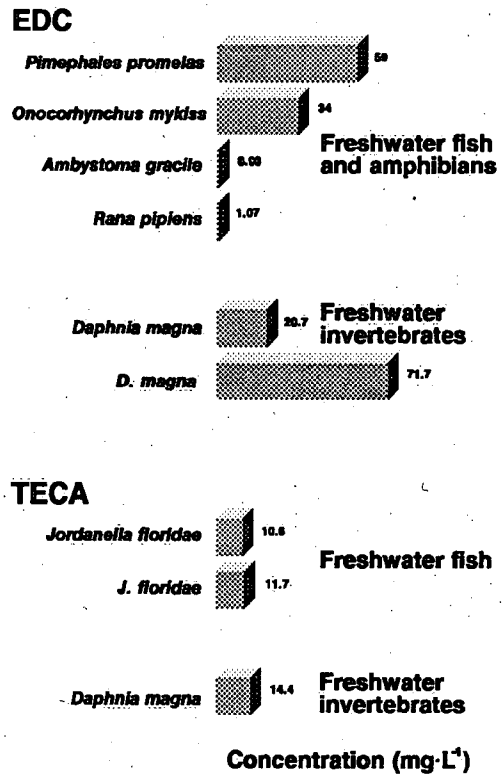


Figure 10. Observed significant LOEL responses in aquatic biota after chronic exposures to EDC and TECA.

Marine Aquatic Life

EDC

There are insufficient data to calculate a Canadian water quality guideline for EDC for the protection and maintenance of marine aquatic life (Fig. D-4). The only primary ranked data available were from an acute study (Foster and Tullis, 1984) for *A. salina* and from two secondary studies for the tidewater silverside *Meridia beryllina* and the polychaete *Ophryotrocha labronica*. Further, little is known of the environmental fate and behaviour of EDC. Before an interim guideline can be derived, at least one toxicity study on a temperate marine fish will have to be conducted.

TCA

There are insufficient data to recommend a Canadian water quality guideline for TCA for the protection and maintenance of marine aquatic life (Fig. D-5) (CCME, 1991). The studies by Heitmuller et al. (1981), Pearson and McConnell (1975), and the U.S. EPA (1978) did not report experimental conditions in sufficient detail to warrant inclusion in the minimum toxicological data set. As reported in Figure D-5, at least three primary toxicity stuidies on temperate marine fish species, two primary toxicity studies on temperate marine invertebrates from different classes, and one primary toxicity study on a temperate marine plant are required before a Canadian water quality guideline can be recommended. Four of these studies must be chronic exposure studies. To derive an initerim guideline, primary or secondary toxicity studies on a least two fish species and two invertebrate species from different classes are required. Further, each species must be a temperate marine species.

TECA

There are insufficient data to develop a Canadian water quality guideline for TECA that will protect and maintain marine aquatic life (Fig. D-6) (CCME, 1991). The only studies that considered the effects of TECA on marine biota were acute exposure studies on *M. bahia* and *Skeletonema costatum* by the U.S. EPA (1978) and *Cyprinodon variegatus* by Heitmuller et al. (1981). These studies did not report experimental conditions and cannot be included in the minimum toxicological data set. As reported in Figure D-6, at least three primary toxicity studies on temperate marine fish species, two primary toxicity studies on temperate marine invertebrates from different classes, and one primary toxicity study on a temperate marine plant are required before a Canadian water quiality guideline can be recommended. Four of these studies must be chronic exposure studies. Further, little is known of the environmental fate and behaviour to TECA. Derivation of an interim guideline requires that primary or secondary toxicity studies on a least two fish species and two invertebrate species from different classes be conducted. Each species must be a temperate marine species.

Agricultural Uses

Livestock Watering

No data could be found regarding the toxicity of chlorinated ethanes to domestic livestock and related biota. In the absence of such data for other chemicals, Canadian drinking water quality

guidelines are adopted as interim livestock water quality guidelines as a means of providing a margin of safety for livestock and preventing unacceptable residues in animal products. The EDC interim drinking water guideline of 0.005 $mg \cdot L^{-1}$ is recommended as the interim Canadian livestock watering guideline to protect this water use. As drinking water quality guidelines for TCA and TECA are not available, there is insufficient information to develop Canadian water quality guidelines for livestock water for these two chlorinated ethanes.

Irrigation

No data exist regarding the toxicity of chlorinated ethanes to terrestrial macrophytes. Therefore, there is insufficient information to develop Canadian water quality guidelines for irrigation water for the chlorinated ethanes.

Recreational Water Quality and Aesthetics

Recreational water quality can be aesthetically impaired by an offensive odour, taste, or colour. EDC, TCA, and TECA are colourless liquids with threshold odour concentrations in water of >20, 50, and 5 $mg \cdot L^{-1}$, respectively (Archer, 1979; Verschueren, 1983). The odour threshold for EDC is above the guideline level suggested above for freshwater aquatic life, and thus recreational water quality and aesthetics should be protected at levels that protect and maintain aquatic life. It is unknown if fish tainting and taste would be protected by the freshwater aquatic life guideline for EDC.

Although freshwater aquatic life guidelines could not be recommended for TCA and TECA, several studies have suggested that the threshold odour concentrations for these compounds would have deleterious effects on aquatic biota (TCA, Alexander et al., 1978; TECA, LeBlanc, 1980). As it is the aim of the CCME to protect the most sensitive water uses in preparing Canadian water quality guidelines, no recreational water quality guidelines are recommended for TCA and TECA.

Industrial Water Supplies

To date, there is no indication that chlorinated ethanes pose a threat to industrial water supplies. However, until a survey of industry requirements regarding water quality is conducted, development of Canadian water quality guidelines for industrial water supplies cannot be attempted. Such a survey is under way, and guideline development for this water use may be possible at a future date.

DATA GAPS

Numerous data gaps exist with regard to the occurrence, fate, and toxicity of the chlorinated ethanes in Canadian aquatic ecosystems. The toxicity information required to produce guidelines for each of the chlorinated ethanes for the protection and maintenance of freshwater and marine aquatic life was summarized above. As well, several other data gaps exist that need further investigation. At present, there is no monitoring information available for much of Atlantic Canada, Manitoba, Saskatchewan, British Columbia, the Yukon, or the Northwest Territories with regard to levels of EDC, TCA, and TECA in the aquatic environment. This is particularly evident with TECA, which has been quantified at only a few sites in Ontario and Alberta. Similarly, little is known of the environmental fate and behaviour of EDC and TECA in the aquatic environment. The major removal processes, degradation products, and environmental persistence of these chlorinated ethanes need to be either determined or better quantified. Finally, only one study has considered the bioaccumulation potential of EDC, TCA, and TECA (Barrows et al., 1980), and thus further investigation is desirable. Until the above environmental fate and behaviour and bioaccumulation data are acquired, particularly for EDC and TECA, aquatic life guidelines for these compounds cannot be recommended.

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Appendix A
Acute Toxicity of EDC, TCA, and TECA to Aquatic Organisms

Table A-1. Acute Toxicity of 1,2-Dichlorethane (EDC) to Aquatic Organisms

Organism	Methods	Test rank	Test conditions	LC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	EC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	Reference
FRESHWATER SPECIES										
Green algae (*Selenastrum capricornutum*)	S(U)	UN						>433		U.S. EPA, 1978
Water flea (*Daphnia magna*)	S(M)	PR	20 °C pH 7.1-7.7 (u) pH 7.0-7.5 (f) 44.7 (43.5-47.5) $mg \cdot L^{-1}$ $CaCO_3$ 7.9-9.9 $mg \cdot L^{-1}$ DO (u) 4.1-8.4 $mg \cdot L^{-1}$ DO (f)		270 (u) (250-190)* 320 (f) (270-410)			160 (u) (140-190) 180 (f) (150-230)		Richter *et al.*, 1983
Water flea (*Daphnia magna*)	S(U)	SE	22 °C ± 1 °C pH 6.6-8.1 72 $mg \cdot L^{-1}$ $CaCO_3$ 6.5-9.1 $mg \cdot L^{-1}$ DO	250 (190-320)	220 (160-280)					LeBlanc, 1980
Water flea (*Daphnia magna*)	S(U)	UN			218					U.S. EPA, 1978
Water flea (*Daphnia magna*)	S(M)	PR	20 °C pH 6.7-7.6 43-57 $mg \cdot L^{-1}$ $CaCO_3$ 7.0-9.6 $mg \cdot L^{-1}$ DO		268.0					Ahmad *et al.*, 1984
Amphipod (*Gammarus fasciatus*)	S(U)	SE	21 °C pH 7.1 44 $mg \cdot L^{-1}$ $CaCO_3$	>100		>100				Mayer and Ellersieck, 1986
Stonefly (*Pteronarcys californica*)	S(U)	SE	15 °C pH 7.1 44 $mg \cdot L^{-1}$ $CaCO_3$	>100		>100				Mayer and Ellersieck, 1986

* 95% confidence limits in parentheses.

S = static conditions
F = flow-through conditions
U = unmeasured concentrations
M = measured concentrations
PR = primary study, which may be included in minimum data set for Canadian water quality guidelines or interim guidelines
SE = secondary study, which may be included in minmimum data set for interim Canadian water quality guidelines
UN = unacceptable study, which cannot be included in minimum data set for Canadian water quality guidelines or interim guidelines

u = unfed
f = fed
DO = dissolved oxygen

Table A-1 Continued

Organism	Methods	Test rank	Test conditions	LC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	EC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	Reference
Rainbow trout (*Oncorhynchus mykiss*)	S(U)	SE	13 °C pH 7.1 44 $mg \cdot L^{-1}$ $CaCO_3$	>225		225				Mayer and Ellersieck, 1986
Rainbow trout (*Oncorhynchus mykiss*)	S(U)	SE	12 °C pH 8.0 110 $mg \cdot L^{-1}$ $CaCO_3$	362 (353–387)	340 (314–362)	336 (324–350)				Bartlett, 1979
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25 °C pH 7.41 44.8 $mg \cdot L^{-1}$ $CaCO_3$ 7.8 $mg \cdot L^{-1}$ DO			136 (129–144)				Geiger *et al.*, 1985a
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25 °C ± 1 °C mean pH = 7.5 45.5 $mg \cdot L^{-1}$ $CaCO_3$			118				Veith *et al.*, 1983
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25 °C ± 1 °C pH 6.7–7.6 45.1 $mg \cdot L^{-1}$ $CaCO_3$ 8.0 $mg \cdot L^{-1}$ DO	141 (131–153)	118 (111–125)	116 (110–123)				Walbridge *et al.*, 1983
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25 °C pH 6.7–7.6 43–57 $mg \cdot L^{-1}$ $CaCO_3$ 7.0–9.6 $mg \cdot L^{-1}$ DO			117.80				Ahmad *et al.*, 1984
Bluegill (*Lepomis macrochirus*)	S(U)	SE	22 °C ± 1 °C pH 6.7–7.8 32–48 $mg \cdot L^{-1}$ $CaCO_3$ 7.0–8.8 $mg \cdot L^{-1}$ DO	>600		430 (230–710)				Buccafusco *et al.*, 1981
Bluegill (*Lepomis macrochirus*)	S(U)	SE	23 °C pH 7.6–7.9 55 $mg \cdot L^{-1}$ $CaCO_3$			550				Dawson *et al.*, 1975/77
Guppy (*Poecilia reticulata*)	S(U)	SE	22 °C 25 $mg \cdot L^{-1}$ $CaCO_3$ > 5.0 $mg \cdot L^{-1}$ DO	[106 (168 h)]						Konemann, 1981

Table A-1. Continued

Organism	Methods	Test rank	Test conditions	LC_{50} (mg·L^{-1}) 24 h	48 h	96 h	EC_{50} (mg·L^{-1}) 24 h	48 h	96 h	Reference
MARINES SPECIES										
Marine algae (*Phaeodactylum tricornutum*)	S(M)	UN						340		Pearson and McConnell, 1975
Algae (*Skeletonema costatum*)	S(U)	UN						>433		U.S. EPA, 1978
Brine shrimp (*Artemia salina*)	S(M)	PR	19 °C pH 8.5–8.7 6.5–8.1 mg·L^{-1} DO				93.6			Foster and Tullis, 1984
Brine shrimp (*Artemia salina*)	S(M)	SE	19 °C salinity stress (25 % artificial seawater) pH 8.3–8.6 7.3–8.7 mg·L^{-1} DO				36.4			Foster and Tullis, 1985
Mysid shrimp (*Mysidopsis bahia*)	S(U)	UN				113				U.S. EPA, 1978
Shrimp (*Crangon crangon*)		UN	15 °C	75	65	65				Adema, 1976
Barnacle nauplii (*Elminius modestus*)	S(M)	UN			186					Pearson and McConnell, 1975
Sheepshead minnow (*Cyprinodon variegatus*)	S(U)	UN						>130	<230	Heitmuller *et al.*, 1981
Dab (*Limanda limanda*)	F(M)	UN				115				Pearson and McConnell, 1975
Tidewater silverside (*Menidia beryllina*)	S(U)	SE	20 °C pH 7.6–7.9 55 mg·L^{-1} $CaCO_3$			480				Dawson *et al.*, 1975/77

Table A-2. Toxicity of 1,1,1-Trichloroethane (TCA) to Aquatic Organisms

Organism	Methods	Test rank	Test conditions	LC_{50} (mg·L^{-1}) 24 h	48 h	96 h	EC_{50} (mg·L^{-1}) 24 h	48 h	96 h	Reference
FRESHWATER SPECIES										
Green algae (*Selenastrum capricornutum*)	S(U)	UN							>669	U.S. EPA, 1978
Water flea (*Daphnia magna*)	S(U)	SE	22 °C ± 1 °C pH 6.5–8.1 72 mg·L^{-1} $CaCO_3$ 6.5–9.1 mg·L^{-1} DO	>530	>530					LeBlanc, 1980
Fathead minnow (*Pimephales promelas*)	S(U)	SE	12 °C pH 7.8–8.0 >5.0 mg·L^{-1} DO		105 (91–126)*					Alexander *et al.*, 1978
	F(M)	PR	12 °C pH 7.8–8.0 27 mg·L^{-1} $CaCO_3$		52.8 (43.7–77.7)				11.1 (10–12.6)	
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25.0 °C pH 7.99 46.4 mg·L^{-1} $CaCO_3$ 65 mg·L^{-1} DO		42.3 (35.2–50.7)				28.8 (23–36.2)	Geiger *et al.*, 1985b
Bluegill (*Lepomis macrochirus*)	S(U)	UN			69.7					U.S. EPA, 1978
Bluegill (*Lepomis macrochirus*)	S(U)	SE	22 °C ± 1 °C pH 6.7–7.8 32–48 mg·L^{-1} $CaCO_3$ 7.0–8.8 mg·L^{-1} DO	110	72 (57–90)					Buccafusco *et al.*, 1981

* 95% confidence limits in parentheses.

S = static conditions
F = flow-through conditions
U = unmeasured concentrations
M = measured concentrations
DO = dissolved oxygen

PR = primary study, which may be included in minimum data set for Canadian water quality guidelines or interim guidelines
SE = secondary study, which may be included in minmimum data set for interim Canadian water quality guidelines
UN = unacceptable study, which cannot be included in minimum data set for Canadian water quality guidelines or interim guidelines

Table A-2. Continued

Organism Reference	Methods	Test rank	Test conditions	LC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	EC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	Reference
Guppy (*Poecilia reticulata*)	S(U)	SE	22 °C 25 $mg \cdot L^{-1}$ $CaCO_3$ >5.0 $mg \cdot L^{-1}$ DO	[133(168 h)]						Konemann, 1981
MARINES SPECIES										
Marine Algae (*Phaeodactylum tricornutum*)	S(M)	UN							5	Pearson and McConnell, 1975
Algae (*Skeletonema costatum*)	S(U)	UN							>669	U.S. EPA, 1978
Mysid shrimp (*Mysidopsis bahia*)	S(U)	UN				31.2				U.S. EPA, 1978
Barnacle naupili (*Elminius modestus*)	S(M)	UN			7.5					Pearson and McConnell, 1975
Dab (*Limanda limanda*)	F(M)	UN				33				Pearson and McConnell, 1975
Sheepshead minnow (*Cyprinodon variegatus*)	S(U)	UN		68 (57–79)	71 (60–81)	71 (60–81)				Heltmuller *et al.*, 1981

Table A-3. Acute Toxicity of 1,1,2,2-Tetrachloroethane (TECA) to Aquatic Organisms

Organism	Methods	Test rank	Test Conditions	LC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	EC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	Reference
FRESHWATER SPECIES										
Green algae (*Selenastrum capricornutum*)	S(U)	UN						136		U.S. EPA, 1978
Water flea (*Daphnia magna*)	S(M)	PR	20 °C pH 7.1–7.7 (u) pH 7.0–7.5 (f) 44.7 (43.5–42.5) $mg \cdot L^{-1}$ $CaCO_3$ 7.9–9.9 $mg \cdot L^{-1}$ DO (u) 4.1–8.4 $mg \cdot L^{-1}$ DO (f)		62(u) (56–71) 57 (f) (50–66)			23 (u) (16–35) 25 (f) (22–28)		Richter *et al.*, 1983
Water flea (*Daphnia magna*)	S(U)	SE	22 °C ±1 °C pH 7.4–9.4	18 (12–24)	9.3 (6.8–13)					LeBlanc, 1980
Water flea (*Daphnia magna*)	S(M)	PR	20 °C pH 6.7–7.6 43–57 $mg \cdot L^{-1}$ $CaCO_3$ 7.0–9.6 $mg \cdot L^{-1}$ DO		62.1					Ahmad *et al.*, 1984
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25 °C ± 1 °C mean pH = 7.5 45.5 $mg \cdot L^{-1}$ $CaCO_3$			20.3				Velth *et al.*, 1983
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25 °C ± 1 °C pH 6.7–7.6 45.1 $mg \cdot L^{-1}$ $CaCO_3$ 8.0 $mg \cdot L^{-1}$ DO	22.8 **(21.9–23.8)**	22.2 (21.2–23.1)	20.4 (20.0–20.9)				Walbridge *et al.*, 1983
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25.6 °C pH 7.3 45.2 $mg \cdot L^{-1}$ $CaCO_3$ 7.8 $mg \cdot L^{-1}$ DO			20.3 (19.9–20.7)				Geiger *et al.*, 1985c

*95% confidence limits in parentheses.

f = fed
u = unfed
S = static conditions
U = unmeasured concentrations

M = measured concentrations
DO = dissolved oxygen
F = flow-through conditions

PR = primary study, which may be included in minimum data set for Canadian water quality guidelines or interim guidelines
SE = secondary study, which may be included in minmimum data set for interim Canadian water quality guidelines
UN = unacceptable study, which cannot be included in minimum data set for Canadian water quality guidelines or interim guidelines

Table A-3. Continued

Organism	Methods	Test rank	Test Conditions	LC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	EC_{50} ($mg \cdot L^{-1}$) 24 h	48 h	96 h	Reference
Fathead minnow (*Pimephales promelas*)	F(M)	PR	25 °C pH 6.7–7.6 43–57 $mg \cdot L^{-1}$ $CaCO_3$ 7.0–9.6 $mg \cdot L^{-1}$ DO			20.3				Ahmad *et al.*, 1984
Bluegill (*Lepomis macrochirus*)	S(U)	SE	22 °C ± 1 °C pH 6.5–7.9 32–48 $mg \cdot L^{-1}$ $CaCO_3$ 7.0–8.8 $mg \cdot L^{-1}$ DO	21		21 (20–22)				Buccafusco *et al.*, 1981
Bluegill (*Lepomis macrochirus*)	S(U)	UN				21.3				U.S. EPA, 1978
American flagfish (*Jordanella floridae*)	S(U)	SE	25 °C ± 1 °C pH 6.95 48 $mg \cdot L^{-1}$ $CaCO_3$ ≥ 6.9 $mg \cdot L^{-1}$ DO			26.8 (21.3–33.7)				ATRG, 1988
American flagfish (*Jordanella floridae*)	F(M)	PR	25 °C ± 1 °C pH 6.95 48 $mg \cdot L^{-1}$ $CaCO_3$ ≥ 6.9 $mg \cdot L^{-1}$ DO			18.5 (16.4–20.8)				ATRG, 1988
Guppy (*Poecilia reticulata*)	S(U)	SE	22 °C 25 $mg \cdot L^{-1}$ $CaCO_3$ ≥ 5.0 $mg \cdot L^{-1}$ DO	[37.0 (168 h)]						Konemann, 1981
MARINES SPECIES										
Algae (*Skeletonema costatum*)	S(U)	UN						6.44		U.S. EPA, 1978
Mysid shrimp (*Mysidopsis bahia*)	S(U)	UN				9.02				U.S. EPA, 1978
Sheepshead minnow (*Cyprinodon variegatus*)	S(U)	UN		19 (14–120)	16 (12–20)	12 (4.7–32)				Heitmuller *et al.*, 1981

Appendix B
Chronic Toxicity of EDC, TCA, and TECA to Aquatic Organisms

Table B-1. Chronic Toxicity of EDC, TCA, and TECA to Aquatic Organisms*

Compound	Organisme	Effect measured	Concentration ($mg \cdot L^{-1}$)	Test rank	Reference
FRESHWATER SPECIES					
EDC	Water flea (*Daphnia magna*)	Reproduction—NOEL	10.6	PR	Richter *et al.*, 1983
		Growth—NOEL	41.6		
		Reproduction—LOEL	20.7		
		Growth—LOEL	71.7		
EDC	Fathead minnow (*Pimephales promelas*)	NOEL (29-d growth)	29	PR	Benoit *et al.*, 1980
		LOEL (28-d growth)	59		
EDC	Fathead minnow (*Pimephales promelas*)	Embryo—LOEL	14	UN	U.S. EPA, 1980
		Larvae—LEOL	29		
EDC	Rainbow trout (*Oncorhynchus mykiss*)	Hatchability—EC_{50}	34	PR	Black *et al.*, 1982
		Juvenile—LC_{50}	34		
		Juvenile— LOEL	3.49		
EDC	Coho salmon (*Oncorhynchus kisutch*)	Time to hatch delayed and 100 % alevin mortality 9 d after hatching	73	PR	Reid *et al.*, 1982
		Hatchability—EC_{46}	124		

* All studies used flow-through, measured tests.

NOEL = no-observed-effect level
LOEL = lowest-observed-effect level
PR = primary study, which may be included in minimum data set for Canadian water quality guidelines or interim guidelines
SE = secondary study, which may be included in minmimum data set for interim Canadian water quality guidelines
UN = unacceptable study, which cannot be included in minimum data set for Canadian water quality guidelines or interim guidelines

Table B-1. Continued

Compound	Organism	Effect measured	Concentration ($mg \cdot L^{-1}$)	Test rank	Reference
EDC	Leopard frog (*Rana pipiens*)	Hatchability—EC_{50} Juvenile—LC_{50} Juvenile—LOEL	4.52 4.40 1.07	PR	Black *et al.*, 1982
EDC	Northwestern Salamander (*Ambystoma gracile*)	Hatchability—$_{50}$ Juvenile—LC_{50} Juvenile—LOEL	6.53 2.54 0.99	PR	Black *et al.*, 1982
TCA	Mirror carp (*Cyprinus carpio*)	LOEL (17-d survival and weight gain) NOEL (17-d survival and weight gain)	30 7.7	PR	Thompson and Carmichael, 1989
TCA	Water flea (*Daphnia magna*)	LC_{50} (17-d) NOEL (survival)	5.4 1.3	PR	Thompson and Carmichael, 1989
TECA	Water flea (*Daphnia magna*)	Reproduction—NOEL Reproduction —LOEL	6.9 14.4	PR	Richter *et al.*, 1983
TECA	American flagfish (*Jordanella floridae*)	LOEL (10-d larval survival) LOEL (28-d fry survival) NOEL (estimated for egg hatchability)	10.6 11.7 >22.0	PR	ATRG, 1988
TECA	Fathead minnow (*Pimephales promelas*)	Embryo-larval — NOEL Embryo-larval — LOEL	1.4 4.0	UN	D.L. DeFoe, (U.S. EPA, unpubl. data)
MARINE SPECIES					
EDC	Polychaete (*Ophryotrocha labronica*)	Hatchability—EC_{50} (15 d)	400	SE	Rosenberg *et al.*, 1975

Appendix C
Literature Search

Appendix C

Literature Search

A literature search of the following data bases was conducted to retrieve any references that considered the effects of EDC, TCA, and TECA on major water uses in Canada.

	Data base	Coverage period
1.	AQUAREF (Canadian Water Resources References)	1970–Oct. 1988
2.	ASFA (Aquatic Sciences and Fisheries Abstracts)	1978–Nov. 1988
3.	BIOSIS	1979–Dec. 1988
4.	CAS Online (Chemical Abstracts Service)	1967–Dec. 1988
5.	CODOC	1970–Dec. 1988
6.	COMPENDEX	1970–Dec. 1988
7.	ELIAS (Environmental Libraries Automated System)	1976–Dec. 1988
8.	ENVIROLINE	1970–Oct. 1988
9.	EPB (Environmental Bibliography)	1974–April 1988
10.	FEDERAL REGISTER ABSTRACTS	1977–Dec. 1988
11.	GEOREF (Geological Reference File)	1985–Nov. 1988
12.	IRPTC (International Reference of Potentially Toxic Chemicals)	1976–Dec. 1988
13.	MICROLOG	1979–Sept. 1988
14.	NTIS (National Technical Information Service)	1964–Dec. 1988
15.	POLLUTION ABSTRACTS	1970–Sept. 1988
16.	SWRA (Selected Water Resources Abstracts)	1968–Jan. 1989
17.	TOXLIT	1981–Dec. 1988
18.	TOXICO	1974–Dec. 1988

Several studies were also obtained by consulting review papers.

Appendix D
Data Set Worksheets

Figure D-1. The minimum data set worksheet for the derivation of a Canadian water quality guideline for EDC to protect freshwater aquatic life.

Water Use : Protection of Freshwater Aquatic Life

Compound: 1,2-Dichloroethane, Ethylene dichloride (EDC)

Aquatic Biota	Number of Studies Required	Primary	Resident in North America	Additional Requirements *	Reference
Fish	1.	x	x	WARM, CHRONIC	Benoit *et al.*, 1982
	2.	x	x	COLD, CHRONIC	Black *et al.*, 1982
	3.	x	x	COLD, CHRONIC	Reid *et al.*, 1982
Invertebrates	1.	x	x	CHRONIC, CL 1, PLK	Richter *et al.*, 1983
	2.		x	CL 2	Mayer and Ellersieck, 1986
Plants	1.				

* Fish (i) at least on cold- and one warm-water species are required (COLD, WARM);
(ii) at least two chronic (partial or full life cycle) studies are required (CHRONIC).

Invertebrates: (i) at least two chronic (partial or full life cycle) studies are required (CHRONIC);
(ii) at least two invertebrate classes must be represented (CL 1, CL 2);
(iii) at least one species must be planktonic (PLK).

Scientifically Justified Exemptions to Above Requirements: Yes No *x* .

Minimum Toxicity Data Set Requirements Met: Yes No *x* . If no, go to interim guideline section.

Canadian Water Quality *Guideline* Requirements: Minimum *Environmental Fate* Data Set

(1) Are the mobility of the compound and the compartments of the aquatic environment in which it is likely to be found known? Yes No *x*

(2) Are the kinds of chemical and biological reactions that take place during transport and after deposition known? Yes No *x*

(3) Are the eventual chemical metabolites known? Yes No *x*

(4) Is the persistence of the compound in water, sediments, and biota known? Yes No *x*

If the answer is no to any of the above, go to interim guideline section.

Canadian Water Quality *Interim Guideline* Requirements:

(1) Are there at least two acute and/or chronic studies for fish and for invertebrates? Yes *x* No

(2) Is one fish species a cold-water species resident in North America? Yes *x* No

(3) Are the two invertebrate species from different classes, and is one species planktonic and resident in North America? Yes *x* No

If the answer is no to any of the above, then an interim guideline cannot be calculated. Primary or secondary studies may be used for the interim guideline data requirements.

Figure D-2. The minimum data set worksheet for the derivation of a Canadian water quality guideline for TCA to protect freshwater aquatic life.

Water Use: Protection of Freshwater Aquatic Life

Compound: 1,1,1-Trichloroethane (TCA)

Canadian Water Quality *Guideline* Requirements: Minimum *Toxicity* Data Sheet

Aquatic Biota	Number of Studies Required	Primary	Resident in North America	Additional Requirements *	Reference
Fish	1.	x	x	WARM	Geiger *et al.*, 1985b
	2.	x	x	WARM, CHRONIC	Thompson and Carmichael, 1989
	3.				
Invertebrates	1.	x	x	CHRONIC, CL 1, PLK	Thompson and Carmichael, 1989
	2.				
Plants	1.				

* Fish (i) at least on cold- and one warm-water species are required (COLD, WARM);
(ii) at least two chronic (partial or full life cycle) studies are required (CHRONIC).

Invertebrates: (i) at least two chronic (partial or full life cycle) studies are required (CHRONIC);
(ii) at least two invertebrate classes must be represented (CL 1, CL 2);
(iii) at least one species must be planktonic (PLK).

Scientifically Justified Exemptions to Above Requirements: Yes No *x*.

Minimum Toxicity Data Set Requirements Met: Yes No *x*. If no, go to interim guideline section.

Canadian Water Quality *Guideline* Requirements: Minimum *Environmental Fate* Data Set

(1) Are the mobility of the compound and the compartments of the aquatic environment in which it is likely to be found known? Yes *x* No

(2) Are the kinds of chemical and biological reactions that take place during transport and after deposition known? Yes *x* No

(3) Are the eventual chemical metabolites known? Yes *x* No

(4) Is the persistence of the compound in water, sediments, and biota known? Yes *x* No

If the answer is no to any of the above, go to interim guideline section.

Canadian Water Quality *Interim Guideline* Requirements:

(1) Are there at least two acute and/or chronic studies for fish and for invertebrates? Yes No *x*

(2) Is one fish species a cold-water species resident in North America? Yes No *x*

(3) Are the two invertebrate species from different classes, and is one species planktonic and resident in North America? Yes No *x*

If the answer is no to any of the above, then an interim guideline cannot be calculated. Primary or secondary studies may be used for the interim guideline data requirements.

Figure D-3. The minimum data set worksheet for the derivation of a Canadian water quality guideline for TECA to protect freshwater aquatic life.

Water Use: Protection of Freshwater Aquatic Life

Compound: 1,1,2,2-Tetrachloroethane (TECA)

Canadian Water Quality *Guideline* Requirements: Minimum *Toxicity* Data Sheet

Aquatic Biota	Number of Studies Required	Primary	Resident in North America	Additional Requirements*	Reference
Fish	1.	x	x	WARM, CHRONIC	ATRG, 1988
	2.	x	x	WARM, CHRONIC	Walbridge *et al.*, 1983
	3.				
Invertebrates	1.	x	x	CHRONIC, CL 1, PLK	Richter *et al.*, 1983
	2.				
Plants	1.				

*Fish (i) at least on cold- and one warm-water species are required (COLD, WARM);
(ii) at least two chronic (partial or full life cycle) studies are required (CHRONIC).

Invertebrates: (i) at least two chronic (partial or full life cycle) studies are required (CHRONIC);
(ii) at least two invertebrate classes must be represented (CL 1, CL 2);
(iii) at least one species must be planktonic (PLK).

Scientifically Justified Exemptions to Above Requirements : Yes No *x* .

Minimum Toxicity Data Set Requirements Met: Yes No *x* . if no, go to interim guideline section.

Canadian Water Quality *Guideline* Requirements: Minimum *Environmental Fate* Data Set

(1) Are the mobility of the compound and the compartments of the aquatic environment in which it is likely to be found known? Yes No *x*

(2) Are the kinds of chemical and biological reactions that take place during transport and after deposition known? Yes No *x*

(3) Are the eventual chemical metabolites known? Yes No *x*

(4) Is the persistence of the compound in water, sediments, and biota known? Yes No *x*

If the answer is no to any of the above, go to interim guideline section.

Canadian Water Quality *Interim Guideline* Requirements:

(1) Are there at least two acute and/or chronic studies for fish and for invertebrates? Yes No *x*

(2) Is one fish species a cold-water species resident in North America? Yes No *x*

(3) Are the two invertebrate species from different classes, and is one species planktonic and resident in North America? Yes No *x*

If the answer is no to any of the above, then an interim guideline cannot be calculated. Primary or secondary studies may be used for the interim guideline data requirements.

Figure D-4. The minimum data set worksheet for the derivation of a Canadian water quality guideline for EDC to protect marine aquatic life.

Water Use: Protection of Marine Aquatic Life

Compound: 1,2-Dichloroethane, Ethylene Dichloride (EDC)

Canadian Water Quality *Guideline* Requirements: Minimum *Toxicity* Data Set

Aquatic Biota	Number of Studies Required	Primary	Temperate Species	Chronic Study	Two Classes Represented	Reference
Fish	1. 2. 3.		x			Dawson *et al.*, 1975/77
Invertebrates	1. 2.	x	x x	x	x	Foster and Tullis, 1984 Rosenberg *et al.*, 1975
Plants	1.					

Scientifically Justified Exemptions to Above Requirements: Yes No *x* .

Minimum Toxicity Data Set Requirements Met: Yes No x. If no, go to interim guideline section.

Canadian Water Quality *Guideline* Requirements: Minimum *Environmental Fate* Data Sheet

(1) Are the mobility of the compound and the compartments of the aquatic environment in which it is likely to be found known? Yes No x

(2) Are the kinds of chemical and biological reactions that take place during transport and after deposition known? Yes No x

(3) Are the eventual chemical metabolites known? Yes No x

(4) Is the persistence of the compound in water, sediments, and biota known? Yes No x

If the answer is no to any of the above, go to interim guideline section.

Canadian Water Quality *Interim Guideline* Requirements:

(1) Are there at least two acute and/or chronic studies for marine fish and for marine invertebrates? Yes No x

(2) Is one fish species a temperate species? Yes x No

(3) Are the two invertebrate species from different classes, and is one of the species temperate? Yes No x

If the answer is no to any of the above, then an interim guideline cannot be calculated. Primary or secondary studies may be used for the interim guideline data requirements.

Figure D-5. The minimum data set worksheet for the derivation of a Canadian water quality guideline for TCA to protect freshwater aquatic life.

Water Use: Protection of Marine Aquatic Life

Compound: 1,1,1-Trichloroethane (TCA)

Canadian Water Quality *Guideline* Requirements: Minimum *Toxicity* Data Set

Aquatic Biota	Number of Studies Required	Primary	Temperate Species	Chronic Study	Two Classes Represented	Reference
Fish	1.					
	2.					
	3.					
Invertebrates	1.					
	2.					
Plants	1.					

Scientifically Justified Exemptions to Above Requirements: Yes No *x* .

Minimum Toxicity Data Set Requirements Met: Yes No x. If no, go to interim guideline section.

Canadian Water Quality *Guideline* Requirements: Minimum *Environmental Fate* Data Sheet

(1) Are the mobility of the compound and the compartments of the aquatic environment in which it is likely to be found known? **Yes No x**

(2) Are the kinds of chemical and biological reactions that take place during transport and after deposition known? Yes No x

(3) Are the eventual chemical metabolites known? **Yes No x**

(4) Is the persistence of the compound in water, sediments, and biota known? **Yes No x**

If the answer is no to any of the above, go to interim guideline section.

Canadian Water Quality *Interim Guideline* Requirements :

(1) Are there at least two acute and/or chronic studies for marine fish and for marine invertebrates? Yes No x

(2) Is one fish species a temperate species? Yes No x

(3) Are the two invertebrate species from different classes, and is one of the species temperate? Yes No x

If the answer is no to any of the above, then an interim guideline cannot be calculated. Primary or secondary studies may be used for the interim guideline data requirements.

Figure D-6. The minimum data set worksheet for the derivation of a Canadian water quality guideline for TECA to protect marine aquatic life.

Water Use: Protection of Marine Aquatic Life

Compound: 1,1,2,2-Tetrachloroethane (TECA)

Canadian Water Quality *Guideline* Requirements: Minimum *Toxicity* Data Set

Aquatic Biota	Number of Studies Required	Primary	Temperate Species	Chronic Study	Two Classes Represented	Reference
Fish	1. 2. 3.					
Inverebrates	1. 2.					
Plants	1.					

Scientifically Justified Exemptions to Above Requirements: Yes No *x* .

Minimum Toxicity Data Set Requirements Met: Yes No x. If no, go to interim guideline section.

Canadian Water Quality *Guideline* Requirements: Minimum *Environmental Fate* Data Sheet

(1) Are the mobility of the compound and the compartments of the aquatic environment in which it is likely to be found known? Yes No x

(2) Are the kinds of chemical and biological reactions that take place during transport and after deposition known? Yes No x

(3) Are the eventual chemical metabolites known? Yes No x

(4) Is the persistence of the compound in water, sediments, and biota known? Yes No x

If the answer is no to any of the above, go to interim guideline section.

Canadian Water Quality *Interim Guideline* Requirements:

(1) Are there at least two acute and/or chronic studies for marine fish and for marine invertebrates? Yes No x

(2) Is one fish species a temperate species? Yes No x

(3) Are the two invertebrate species from different classes, and is one of the species temperate? Yes No x

If the answer is no to any of the above, then an interim guideline cannot be calculated. Primary or secondary studies may be used for the interim guideline data requirements.