Canadian Water Quality Guidelines for the Protection of Aquatic Life

TOLUENE

Toluene (C_7H_8) is a volatile and flammable aromatic hydrocarbon with a CAS registry number of 108-88-3. Toluene is less dense than water (0.867 g·cm^3), has a water solubility of 515 mg·L^{-1}, a vapour pressure of 2933 Pa, and a Henry's Law constant of 648 Pa·m^3·mol^{-1} (Verschueren 1983; Howard 1990). Synonyms for toluene include toluol, methylbenzene, and phenylmethane. Trade names are Antisal 1a and Methacide (Government of Canada 1993).

Toluene occurs naturally in coal and crude oil (Nielson and Howe 1991; Government of Canada 1993). It is also a by-product of the petroleum refining process, formed by catalytic dehydrogenation of methylcyclohexane. Toluene is present in many consumer products including gasoline, cosmetics, and cleaners (OMOEE 1994). It is used as a solvent in paints, lacquers, inks, adhesives, cleaning agents, pesticides, and for chemical extractions (Government of Canada 1993; CIS 1994). Other uses include the synthesis of organic chemicals, dyes, and pharmaceuticals (Government of Canada, 1993). The largest use of toluene in Canada is the production of benzene. Toluene is used as an octane enhancer in gasoline instead of lead and other compounds (CIS 1994). However, all toluene present in Canadian gasoline occurs from refining and none is added when blended (Government of Canada 1993).

Toluene can enter the environment during production, use, storage, transportation, and accidental spillage. It is nonpersistent in the environment and is rapidly biodegraded. Mackay's fugacity model predicts that 99.53% of toluene will partition into the air, 0.43% into water, and 0.02% into soil and sediment (ASTER 1995). Atmospheric photooxidation is the predominant removal process with a half-life of <2 d (ATSDR 1989; Howard 1990).

When released into water, toluene will remain there for days and sometimes weeks (Howard 1990). Toluene is removed from water by volatilization and biodegradation at a rate dependent on temperature, mixing conditions, and the existence of acclimated microorganisms.

Toluene does not tend to hydrolyze or adsorb to sediments. It will not bioconcentrate in aquatic organisms, which is indicated by its log octanol–water partition coefficient (K_{ow}) of 2.7 (Lyman et al. 1982; Hawker and Connell 1988). Veith et al. (1980) calculated BCFs ranging from 15 to 70 in fish. The BCF for the alga *Chlorella fusca* was found to be 380 (Geyer et al. 1984).

When released into soil, toluene will evaporate into the atmosphere or it may leach into groundwater. Leaching into groundwater may occur in soils with a low organic carbon content (Howard 1990). It is persistent in groundwater because it is not very susceptible to anaerobic biodegradation. Although biodegradation of toluene in soil and groundwater can occur, the rate and magnitude will depend on the type of microbes, the concentration of toluene, the presence of other compounds, and the amount of oxygen present (Nielson and Howe 1991).

Toluene has been detected in the environment throughout North America. Sites include effluents from municipal sewage treatment plants and industries, industrialized river basins, groundwater, sediments, soil, and air (Fishbein 1985; ATSDR 1989; Howard 1990). There is little tendency for accumulation, and ambient levels remain low due to physical, chemical, and biological processes.

Water Quality Guideline Derivation

The interim Canadian water quality guidelines for toluene for the protection of aquatic life were developed based on the CCME protocol (CCME 1991). The freshwater guideline was modified from OMOEE (1994).

Freshwater Life

Estimates of acute toxicity for fish range from 5.46 mg·L^{-1} (96-h LC_{50}) for coho salmon *(Oncorhynchus*

Table 1. Water quality guidelines for toluene for the protection of aquatic life (CCME 1996).

Aquatic life	Guideline value (µg·L^{-1})
Freshwater	2.0*
Marine	215*

*Interim guideline.

kisutch) (Moles 1981) to 1340 mg·L^{-1} (24-h TL_m) for mosquito fish *(Gambusia affinis)* (Wallen et al. 1957), thereby exceeding the water solubility limit. The only invertebrate studied was *Daphnia magna*, with EC_{50}s (immobilization) ranging from 7 mg·L^{-1} (24-h) (Galassi et al. 1988) to 310 mg·L^{-1} (48-h) (LeBlanc 1980). Acute effect concentrations (72-h EC_{50}; reduction in growth) for plants and bacteria range from 12.5 mg·L^{-1} for *Selenastrum capricornutum* (Galassi et al. 1988) to >456 mg·L^{-1} for *Entosiphon sulcatum* (Bringmann and Kühn 1980). The study by Bringmann and Kühn (1980) is unacceptable, however, because the experimental protocol and data reporting are insufficient.

Estimates of chronic toxicity to fish range from 0.02 mg·L^{-1} (27-d LC_{50}) for rainbow trout *(O. mykiss)* (Black et al. 1982) to 68.3 mg·L^{-1} (14-d LC_{50}) for guppies *(Poecilia reticulata)* (Könemann 1981). For amphibians, chronic data for the leopard frog *(Rana pipiens)* and the salamander *Ambystoma gracile* were 0.39 mg·L^{-1} (9-d LC_{50}) and 1.1 mg·L^{-1} (5.5-d LC_{50}), respectively (Black et al. 1982). Chronic invertebrate studies report toxicities ranging from 3.75 mg·L^{-1} (16-d LC_{50} from QSAR extrapolation) for *Daphnia magna* (Hermens et al. 1984) to 173 mg·L^{-1} (6-d EC_{40}) for the rotifer *Dicranophorus forcipatus* (reduction in growth) (Erben 1978).

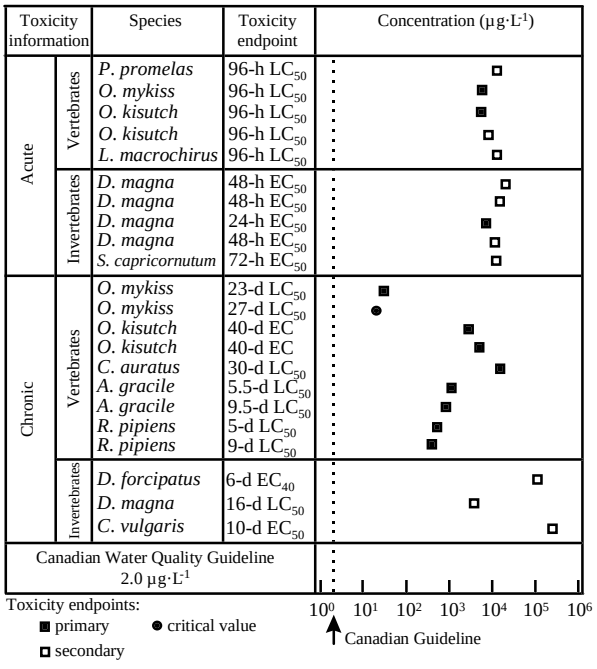

Figure 1. Select freshwater toxicity data for toluene.

The interim water quality guideline for toluene for the protection of freshwater life is 2.0 µg·L^{-1} (CCME 1996). It was derived by multiplying the 27-d LC_{50} of 20 µg·L^{-1} (Black et al. 1982) for the most sensitive organism, the rainbow trout, by a safety factor of 0.1 (CCME 1991).

Marine Life

Estimates of acute toxicity (LC_{50}s) to fish range from 5.4 mg·L^{-1} (24 h) for pink salmon *(O. gorbuscha)* (Thomas and Rice 1979) to 480 mg·L^{-1} (96 h) for sheepshead minnows *(Cyprinodon variegatus)* (Heitmuller et al. 1981). Acute data for invertebrates range from 2.35 mg·L^{-1} (80-min EC_{50}; reduction in feeding rate) for the mussel *Mytilus edulis* (Donkin et al. 1989) to 552.6 mg·L^{-1} (24-h LC_{50}) for the rotifer *Branchionus spinipes* (Ferrando and Andreu-Moliner 1992).

Chronic toxicity values for fish range from 3.2 to 7.7 mg·L^{-1}, based on a reduction in hatching success and increased mortality in sheepshead minnows *(C. variegatus)* (Ward and Parrish 1981). Chronic toxicities for invertebrates range from 23.5 to 52.7 mg·L^{-1} for shore crabs *(Hemigrapsus nudus)* (8-d LC_{50}) (Gharett and Rice 1987).

Estimates of toxicity for plants range from a 10 mg·L^{-1} LOEC for a phytoplankton mixture consisting of three strains of *Dunaliella biocula* (Dunstan et al. 1975; Jensen et al. 1984) to 342 mg·L^{-1} for both the 12-h EC_{33} and 12-h EC_{70} (inhibition of respiration) for *Chlorella* sp. (Potera 1975).

The most sensitive, nonlethal effect concentration is 1.4 mg·L^{-1}, based on behavioural changes in coho salmon *(O. kisutch)* (Maynard and Weber 1981). This study was not considered, however, as behaviour is not an accepted endpoint in guideline derivation (CCME 1991). The interim water quality guideline for toluene for the protection of marine life is 215 µg·L^{-1} (CCME 1996). It was derived by multiplying the 96-h LC_{50} of 4300 µg·L^{-1} for the bay shrimp *(Crago franciscorum)* (Benville and Korn 1977) by a safety factor of 0.05 (acute study involving a nonpersistent chemical) (CCME 1991). It is recognized that the guideline for the protection of marine life is two orders of magnitude above the guideline for the protection of freshwater life. While that may be due in part to differences in sensitivities between marine and freshwater organisms, it is largely a reflection of the paucity of available marine data.

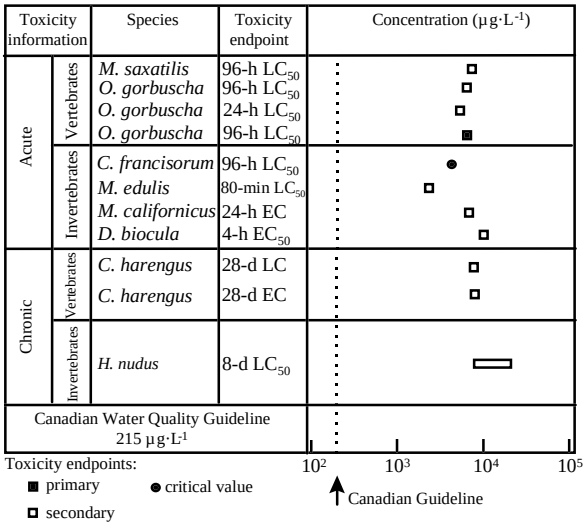

Figure 2. Select marine toxicity data for toluene.

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