Canadian Water Quality Guidelines for the Protection of Aquatic Life

ARSENIC

Arsenic (elemental) is a silver-grey crystalline metallic material that melts at 817°C, sublimes at 613°C, and has a density of 5.72 $g \cdot cm^{-3}$ at room temperature (Eisler 1988; Hazardous Substances Data Bank 1989). Arsenic has an atomic number of 33 and an atomic weight of 74.92 atomic mass units (amu). Although arsenic is odourless, tasteless, and insoluble in water, its inorganic salts and organic compounds vary in their physical and chemical properties (Hazardous Substances Data Bank 1989). The solubility of the arsenic ion depends on the nature of the counter ions (Slooff et al. 1990).

Arsenic is produced as arsenic trioxide (As_2O_3) through the roasting of arsenious gold ores. Demand for arsenic has fallen since the 1980s because of its ecotoxicity (Government of Canada 1993).

Arsenic is used in metallurgical applications and in manufacturing wood preservatives. Arsenic compounds are also used in herbicide, pharmaceutical, and glass manufacturing (Government of Canada 1993).

The largest natural source of arsenic entering surface waters is that from weathered rocks and soils (Nriagu 1989). Smelting and refining industries are anthropogenic sources (MacLatchy 1992).

Levels of total arsenic in uncontaminated surface waters are generally less than 2 $\mu g \cdot L^{-1}$ (Government of Canada 1993). All lake and estuary samples (683 samples) showed arsenic concentrations below 50 $\mu g \cdot L^{-1}$ (Leger 1991).

Arsenic undergoes chemical and microbiological oxidation, reduction, and methylation (Eisler 1988). In rivers, approximately two thirds of the total arsenic is soluble and one third is adsorbed to suspended solids (Reuther 1986). Arsenic is sorbed by colloidal humic material under conditions of high organic content, low pH, low phosphorus, and low mineral content (Thanabalasingam and Pickering 1986). Arsenic is affected by biotic uptake, sorption to iron or clay particles, or, less frequently, by precipitation or co-precipitation (Government of Canada 1993).

There is no indication that arsenic biomagnifies in freshwater food chains (National Academy of Sciences 1977; National Research Council of Canada 1978; Jenkins 1980; Phillips 1980, 1990; Eisler 1988). The degree and rate of uptake depends on phosphorus, which interacts with arsenic and competes for sorption sites, thus reducing the surfaces available for arsenic (Reuther 1992).

Water Quality Guideline Derivation

The Canadian water quality guidelines for arsenic for the protection of aquatic life were developed based on the CCME protocol (CCME 1991). For more information, see the supporting documents (CCME 1997; Fletcher et al. 1998).

Freshwater Life

Data on the toxicity of arsenic to freshwater biota were available for 21 species of fish, 14 species of invertebrates, and 14 species of plants. Rainbow trout *(Oncorhynchus mykiss)* and climbing perch *(Anabas testudineus)*, the most sensitive fish, seem to be equally as sensitive as invertebrates such as copepods *(Cyclops vernalis)* and daphnids *(Daphnia magna)*. Some aquatic plants, however, are an order of magnitude more sensitive (CCME 1997).

The lowest estimates of toxicity for fish ranged from a 28-d LC_{50} of 550 $\mu g \cdot L^{-1}$ for rainbow trout *(O. mykiss)* (Birge et al. 1979), a 7-d LOEC of 500 $\mu g \cdot L^{-1}$ and a 72-h LOEC (survival) of 970 $\mu g \cdot L^{-1}$ for climbing perch *(A. testudineus)* (Jana and Sahana 1989), to a 7-d LOEC of 970 $\mu g \cdot L^{-1}$ for catfish *(Clarias batrachus)* (Jana and Sahana 1989).

The lowest estimates of toxicity for invertebrates ranged from a 14-d EC_{20} (sublethal concentration causing 20%

Table 1. Water quality guidelines for arsenic* for the protection of aquatic life (CCME 1997).

Aquatic life	Guideline value ($\mu g \cdot L^{-1}$)
Freshwater	5.0
Marine	12.5†

*For total arsenic.
†Interim guideline.

reduction in growth) of 320 µg·L^{-1} for the copepod *C. vernalis* (Borgmann et al. 1980), a 21-d EC_{16} (reproduction) of 520 µg·L^{-1} for *D. magna* (Biesinger and Christensen 1972), a 96-h EC_{50} (immobility) of 850 µg·L^{-1} for *Bosmina longirostris* (Passino and Novak 1984), and a 7-d LC_{80} of 960 µg·L^{-1} for *Gammarus pseudolimnaeus* (Spehar et al. 1980), to a 7-d LOEC (immobilization) of 1000 µg·L^{-1} for *Ceriodaphnia dubia* (Spehar and Fiant 1986).

The lowest estimates of toxicity for plants ranged from a 14-d EC_{50} (growth) of 50 µg·L^{-1} for *Scenedesmus obliquus* (Vocke et al. 1980), two EC_{50}s (growth) of 75 µg·L^{-1} for *Melosira granulata* and *Ochromonas vallesiaca* (Planas and Healey 1978), to a 20-d VSUE (very severe unfavourable effect) of 960 µg·L^{-1} for *S. quadricus* (Fargasova 1993).

The water quality guideline for arsenic for the protection of freshwater life is 5.0. It was derived by multiplying the 14-d EC_{50} (growth) of 50 µg·L^{-1} (Vocke et al. 1980) for the most sensitive organism to arsenic, the alga *S. obliquus*, by a safety factor of 0.1 (CCME 1991).

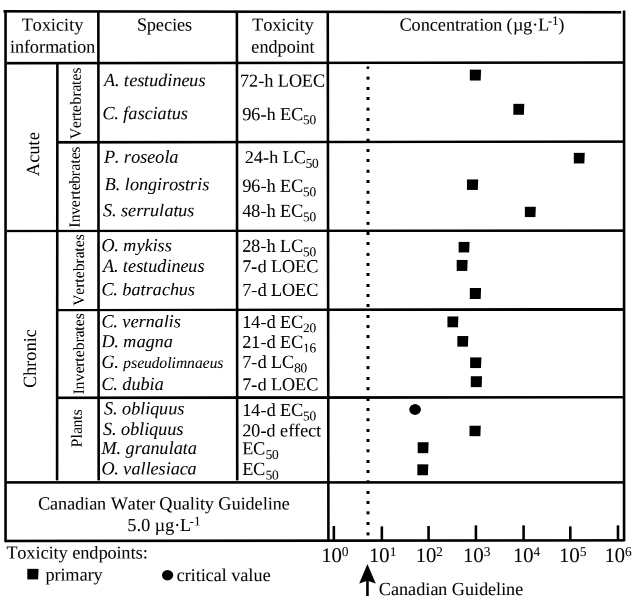

Figure 1. Select freshwater toxicity data for arsenic.

Marine Life

Data on toxicity of arsenic to marine biota were available for 8 species of fish, 21 species of invertebrates, and 4 species of plants. Fish seem to be more tolerant than either invertebrates or aquatic plants. The most sensitive fish studied, pink salmon *(O. gorbuscha)* and striped bass *(Morone saxatilis)*, were over an order of magnitude less sensitive than the most sensitive invertebrates studied, Dungeness crabs *(Cancer magister)*, zooplankters *(Eurythemora affinis)*, Pacific oysters *(Crassostrea edulis)*, and sea urchins *(Paracentrotus lividus)*. Aquatic plants, especially the red alga *Champia parvula* and *Skeletonema costatum*, seem to be four to eight times more sensitive than invertebrates (CCME 1997).

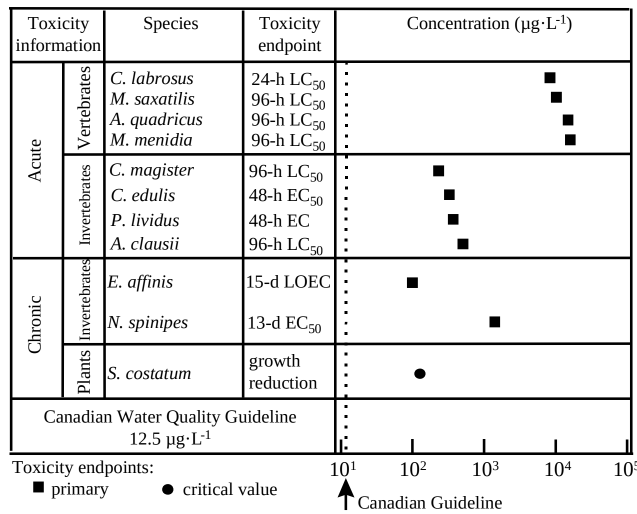

Figure 2. Select marine toxicity data for arsenic.

The lowest estimates of toxicity for marine fish ranged from a 10-d LC_{54} of 3790 µg·L^{-1} for pink salmon *(O. gorbuscha)* (Holland et al. 1964), a 96-h LC_{50} of 10 300 µg·L^{-1} for striped bass *(M. saxatilis)* (Dwyer et al. 1992), to a 96-h LC_{50} of 14 900 µg·L^{-1} for the fourspine stickleback *(Apeltes quadracus)* (USEPA 1980).

The lowest estimates of toxicity for invertebrates ranged from a 96-h LC_{50} of 230 µg·L^{-1} for Dungeness crabs *(C. magister)* (Martin et al. 1981), a 15-d LOEC (survival) of 100 µg·L^{-1} for the zooplankter *E. affinis* (Sanders 1986), a 48-h EC_{50} (development) of 326 µg·L^{-1} for Pacific oysters *(Crassostrea edulis)* (Martin et al. 1981), developmental effects at 370 µg·L^{-1} for sea urchins *(P. lividus)* ([48-h exposure] Pegano et al. 1982), to a 96-h LC_{50} of 510 µg·L^{-1} for *Acartia clausii* (USEPA 1980).

The lowest estimates of toxicity for plants ranged from the 14-d decrease in reproductive success of 60 µg·L^{-1} for the red alga *C. parvula* (Thursby and Steel 1984), to growth reductions in *S. costatum* after exposure to 125 µg·L^{-1} (Sanders 1979).
The interim water quality guideline for arsenic for the protection of marine and estuarine life is 12.5 µg·L^{-1}. It

was derived by multiplying the LOEC of 125 μg·L^{-1} (Sanders 1979) for the most sensitive organism to arsenic, the diatom *S. costatum*, by a safety factor of 0.1 (CCME 1991).

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