



Thallium (Tl) is an inorganic element found in the earth's crust at concentrations ranging from 0.3 to 0.6 mg·kg<sup>-1</sup> (NRCC 1982). Thallium is rarely present as large ore deposits, but can be recovered from sulphide ores of lead, copper, and zinc and may also be associated with cadmium, iron, and potassium minerals such as feldspars and micas. Thallium minerals such as crookesite, hutchinsonite, lorandite, and avicennite occur naturally but are rare. Most of the thallium used in Canada is imported from the United States and is used in alloys, electrodes, low-melting and highly refractive glass, cardiac imaging, electroplating, and as a high-temperature super-conducting compound (ATSDR 1991; Gregotti et al. 1992; Sager 1992). Thallium compounds are also used in photocells, infrared detectors, catalysts, dyes, imitation jewellery, electrical equipment, photographic and ceramic formulations, ozone measurement, and pyrotechnical applications (McNeely et al. 1979; Chandler and Scott 1986; ATSDR 1991). The estimated yearly world production of thallium was 30 t for 1985 (Emsley 1991).

Natural inputs of thallium to aquatic environments occur by weathering processes and are not considered toxicologically significant. However, anthropogenic point sources, which include potash, effluents from the roasting of pyrite during the production of sulphuric acid, and the mining and smelting of copper, gold, zinc, lead, and cadmium, are of potential concern (McNeely et al. 1979). Combustion of coal and oil also release thallium as a component of fly ash emissions from power plants and is a potential source of aerial deposition to surface waters (NRCC 1982).

Thallium exists in aquatic systems in oxidation states of +1 and +3. The thallos ion, Tl(I), does not complex readily, whereas the thallic ion, Tl(III), is present in several organometallic compounds (Cotton and Wilkinson 1980). Thallium may be removed from the water column through adsorption to sediments and suspended particulate, remain in solution as soluble complexes, or be absorbed and bioaccumulated by organisms (USEPA 1979). In natural aerobic waters, the predominant form is the thallos ion. In reducing environments, thallium may be precipitated in the presence of sulphur as the insoluble sulphide (Lee 1971; Magorian et al. 1974). Soluble thallic compounds may also be precipitated when hydrolyzed to form colloidal oxides. Thallium does not readily complex

with humic acids, and the interactions of ligands and thallium are affected by pH. O'Shea and Mancy (1978) found that significant binding with humates occurred only above pH 7.2. Thallium adsorbed strongly to montmorillonite clay at pH 8.1, but sorption was not extensive at pH 4 (Magorian et al. 1974). Biomethylation has been demonstrated in anaerobic bacterial cultures, where Tl (III) was methylated to form (CH<sub>3</sub>)<sub>2</sub>Tl<sup>+</sup> (Huber et al. 1978), but the extent to which this occurs under natural conditions is unknown (NRCC 1982).

Concentrations of total thallium in Canadian freshwaters range from 1 (Zitko et al. 1975) to 100 µg·L<sup>-1</sup> (NAQUADAT 1985). Concentrations of dissolved thallium in the Great Lakes range from 0.09 to 12 ng·L<sup>-1</sup> (Cheam et al. 1995). Sediment concentrations of 5 mg·kg<sup>-1</sup> have been reported downstream from copper and zinc industries (Calspun Corporation 1977).

Bluegill sunfish (*Lepomis macrochirus*) acclimated for 30 d to thallos sulphate (Tl<sub>2</sub>SO<sub>4</sub>) and exposed to 80 µg·L<sup>-1</sup> thallium for 28 d had a BCF of 34 (Barrows et al. 1980). Laboratory exposures up to 0.2 mg·L<sup>-1</sup> over 12 d resulted in BCFs of 114–130 in muscle, 80–235 in liver, and 27–1430 in gill, respectively (Zitko et al. 1975). The BCFs exceeded 1000 only in gill tissue, and then only at the lowest exposure concentration of 18 ng·L<sup>-1</sup>. Molluscs continuously exposed to thallium for 88 d at 50 and 100 µg·L<sup>-1</sup> accumulated 3.7 and 10.78 µg·kg<sup>-1</sup> dw, respectively, and 40-d exposures resulted in 2.17 and 5.29 µg·kg<sup>-1</sup> dw, indicating a BCF of <1 (Oehme 1979). Kwan and Smith (1988) reported that thallium was highly bioaccumulative in duckweed (*Lemna minor*). BCFs ranged from 6000 to 88 000, depending on water concentrations.

**Table 1. Water quality guidelines for thallium for the protection of aquatic life (Stephenson et al. 1996).**

Aquatic life	Guideline value (µg·L <sup>-1</sup> )
Freshwater	0.8
Marine	NRG*

\*No recommended guideline.

**Water Quality Guideline Derivation**

The Canadian water quality guideline for thallium for the protection of freshwater life was developed in 1998 based on the CCME protocol (CCME 1991). For more information, see Stephenson et al. (1996). A literature search covering January 1992 to February 1998 was undertaken to complement the data presented in Stephenson et al. (1996), however, no relevant additional data were found.

**Freshwater Life**

Acute 96-h LC<sub>50</sub> values for vertebrates ranged from 0.86 mg·L<sup>-1</sup> for fathead minnows (*Pimephales promelas*) (Leblanc and Dean 1984) to 132 mg·L<sup>-1</sup> for bluegill sunfish (*Lepomis macrochirus*) (Dawson 1977). For invertebrates, acute values ranged from a 96-h LC<sub>50</sub> of 0.68 mg·L<sup>-1</sup> for *Daphnia magna* (Kimball n.d.) to a 48-h LC<sub>100</sub> of 4 mg·L<sup>-1</sup> for *Gammarus* sp. (Nehring 1962). For the aquatic plant *Elodea canadensis*, the 24-h IC<sub>50</sub> and IC<sub>90</sub> values were 1.43 and 2.75 mg·L<sup>-1</sup>, respectively (Brown and Rattigan 1979).

Fertilized eggs and larvae of *P. promelas* exposed to thallium sulphate resulted in a 30-d LC<sub>100</sub> and a LOEL

(survival) of 350 and 40 µg·L<sup>-1</sup>, respectively (LeBlanc and Dean 1984). Similarly, the 28-d LC<sub>55</sub> and LOEC (growth) for *P. promelas* were 292 and 81 µg·L<sup>-1</sup>, respectively (Kimball n.d.). For embryos of the toad (*Gastrophryne carolinensis*), the 7-d LC<sub>50</sub> value was 110 µg·L<sup>-1</sup>. For rainbow trout (*Oncorhynchus mykiss*), the 28-d LC<sub>50</sub> was 170 µg·L<sup>-1</sup> (Birge 1978). For juvenile Atlantic salmon (*Salmo salar*), a 108-d incipient lethal level (ILL) of 30 µg·L<sup>-1</sup> was interpolated from the toxicity curve (LT<sub>50</sub> versus the log thallium concentration) even though there was no clear threshold (Zitko et al. 1975). For invertebrates, the 28-d LC<sub>50</sub> and LOEC (reproduction) for *D. magna* were 393 and 181 µg·L<sup>-1</sup>, respectively (Kimball n.d.).

Chronic toxicity values for plants include 10-d EC<sub>50</sub>s for *Lemna minor* of 33, 41.8, and 48 µg·L<sup>-1</sup> (0.16, 0.2, and 0.23 nmol·cm<sup>-3</sup>) and LOELs of 8.4, 14.6, and 16.7 µg·L<sup>-1</sup> (0.04, 0.07, and 0.08 nmol·cm<sup>-3</sup>) for decreases in frond area, frond weight, and frond number, respectively (Kwan and Smith 1988). The LOEL of 8.4 µg·L<sup>-1</sup> is supported by a 14-d EC<sub>50</sub> (whole plant damage) of 8 µg·L<sup>-1</sup> for *L. minor* (Brown and Rattigan 1979).

The water quality guideline for thallium for the protection of freshwater life is 0.8 µg·L<sup>-1</sup>. It was derived by multiplying the 14-d EC<sub>50</sub> of 8 µg·L<sup>-1</sup> for *L. minor* (Brown and Rattigan 1979) by a safety factor of 0.1 (CCME 1991).

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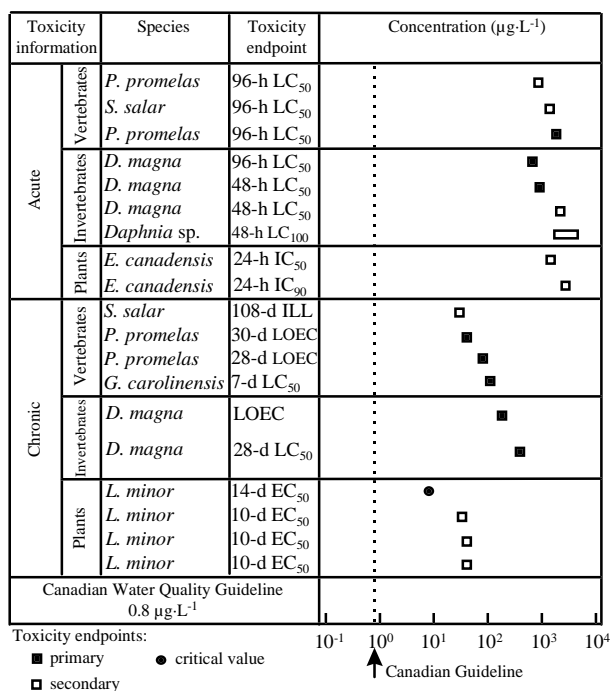
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**Figure 1. Select freshwater toxicity data for thallium.**

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