



# Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health

## THALLIUM 1999

This fact sheet provides Canadian soil quality guidelines for thallium (Tl) for the protection of environmental and human health (Table 1). Supporting scientific documents are also available (Health Canada 1995; Environment Canada 1998).

### Background Information

Thallium (atomic number 81; CAS 7440-28-0) is a widely distributed, naturally occurring element in the earth's crust. Pure thallium is a tasteless and odourless, greyish-white, soft and malleable heavy metal with a metallic lustre when freshly cut that quickly dulls to a bluish grey. Thallium exists in two main oxidation states: Tl(I) (thallous) and Tl(III) (thallic), the former being more

common and more stable. A rare and very unstable bivalent form (Tl(II)) is also known. Thallium is recovered commercially as a by-product from sulphuric acid plants, cadmium refineries, and copper, zinc, and lead smelters. Thallium and its compounds are highly toxic and, thus, have limited industrial, agricultural, and medical uses. Thallium is no longer produced commercially in North America, but world production of thallium has been estimated in the range of about 10–15 t per year (Kemper and Bertram 1991). Less than 23 kg of thallium and thallium compounds was imported into Canada between January 1991 and February 1993 (O. Soucy 1993, Statistics Canada, Ottawa, pers. com.).

In the past, thallium sulphate was extensively employed as a rodenticide and an insecticide, but accidental poisonings

**Table 1. Soil quality guidelines for thallium (mg·kg<sup>-1</sup>).**

	Land use			
	Agricultural	Residential/ parkland	Commercial	Industrial
<b>Guideline</b>	<b>1<sup>a</sup></b>	<b>1<sup>b</sup></b>	<b>1<sup>b</sup></b>	<b>1<sup>b</sup></b>
SQG <sub>HH</sub>	NC <sup>c</sup>	NC <sup>c</sup>	NC <sup>c</sup>	NC <sup>c</sup>
Limiting pathway for SQG <sub>HH</sub>	ND	ND	ND	ND
Provisional SQG <sub>HH</sub>	1	1	1	1
Limiting pathway for provisional SQG <sub>HH</sub>	Soil ingestion	Soil ingestion	Soil ingestion	Soil ingestion
SQG <sub>E</sub>	1	1.4	3.6	3.6
Limiting pathway for SQG <sub>E</sub>	Soil and food ingestion	Soil contact	Soil contact	Soil contact
Provisional SQG <sub>E</sub>	NC <sup>d</sup>	NC <sup>d</sup>	NC <sup>d</sup>	NC <sup>d</sup>
Limiting pathway for provisional SQG <sub>E</sub>	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	1	No value	No value	No value

**Notes:** NC = not calculated; ND = not determined; SQG<sub>E</sub> = soil quality guideline for environmental health; SQG<sub>HH</sub> = soil quality guideline for human health.

<sup>a</sup>Data are sufficient and adequate to calculate a provisional SQG<sub>HH</sub> and an SQG<sub>E</sub>. The provisional SQG<sub>HH</sub> is equal to the SQG<sub>E</sub> and to the existing interim soil quality criterion (CCME 1991) and thus becomes the soil quality guideline, which supersedes the interim soil quality criterion for this land use.

<sup>b</sup>Data are sufficient and adequate to calculate a provisional SQG<sub>HH</sub> and an SQG<sub>E</sub>. The provisional SQG<sub>HH</sub> is less than the SQG<sub>E</sub> and thus becomes the soil quality guideline for this land use.

<sup>c</sup>Data are insufficient/inadequate to calculate an SQG<sub>HH</sub> for this land use. However, data are sufficient and adequate to calculate a provisional SQG<sub>HH</sub>.

<sup>d</sup>Because data are sufficient and adequate to calculate an SQG<sub>E</sub> for this land use, a provisional SQG<sub>E</sub> is not calculated.

The guidelines in this fact sheet are for general guidance only. Site-specific conditions should be considered in the application of these values. The values may be applied differently in various jurisdictions. The reader should consult the appropriate jurisdiction before application of the values.

and the misuse of these preparations for suicidal and homicidal purposes have led to the ban or restriction of all thallium-based pesticides in most countries. In Canada, TL<sub>SO</sub><sub>4</sub>-based insecticidal baits for ant traps were the only registered agricultural use for thallium until discontinued in 1974 (L. Lang 1993, Agriculture Canada, Ottawa, pers. com.). Thallium-containing rodenticides and insecticides were banned in 1972 in the United States (ATSDR 1992). Thallium salts were once extensively prescribed to treat syphilis, gonorrhoea, and tuberculosis and as a depilatory in the treatment of ringworm infections in children. However, the practice was discontinued because of highly toxic and often lethal side effects (Smith and Carson 1977).

At present, alloys of thallium are used in anode plates, low-temperature switches and seals, bearings, and contact points (Hui 1983; Marcus 1985; Hammond 1990). Thallium salts are used in semiconductor switches and closures, low-range thermometers, optical systems, infrared detectors, and photoelectric cells, and as a chemical intermediate for other thallium compounds and thallium metal (Hammond 1990; ATSDR 1992). Various thallium compounds are also used in the manufacture of spectrophotometers, photoelectric cells, high refractory lenses, low-melting glass, artificial gems, ceramic lenses, photographic and xerographic formulations, and fireworks (Hammond 1990; ATSDR 1992). Organothallium compounds are important reagents in organic chemical synthesis (Smith and Carson 1977; Hui 1983). Radioactive thallium (<sup>201</sup>Tl) is currently used for diagnostic purposes such as for myocardial scintigraphy (Kemper and Bertram 1991; ATSDR 1992). Thallium is finding new applications in experimental high-temperature superconductors (Waldrop 1988).

As a result of natural weathering, an estimated 2400 t of thallium enter the global environment annually (Bowen 1979), as thallium is readily mobilized along with alkaline metals (Kabata-Pendias and Pendias 1992). However, as a result of human activities, an additional 2000–7000 t of thallium are mobilized globally each year (Ewers 1988; Nriagu and Pacyna 1988). The major environmental releases of thallium are emissions and waste materials from the combustion of fossil fuels, ferrous and nonferrous smelting, metal processing, and cement production. No significant releases are expected from industries using thallium (Schoer 1984; ATSDR 1992).

Traces of thallium in the range of 0.010–0.020 µg·L<sup>-1</sup> have been measured in unpolluted seawater (Smith and Carson 1977; Bruland 1983; Flegal and Patterson 1985). Higher concentrations were reported in unpolluted freshwater (0.01–14 µg·L<sup>-1</sup>) (Kazantzis 1986; Kemper and Bertram 1991). Korkisch and Steffan (1979) reported low levels in European hydrothermal waters (<0.6 µg Tl·L<sup>-1</sup>)

and much higher levels in U.S. oil field waters (12.9–672.0 µg Tl·L<sup>-1</sup>). No Canadian data on thallium levels in groundwater were available.

Traces of thallium have been measured in surface and subsurface sediments, ranging from 0.13 to 0.27 µg·g<sup>-1</sup> dw and from 0.14 to 0.30 µg·g<sup>-1</sup> dw, respectively, at four remote Rocky Mountain National Park lakes (Heit et al. 1984). Higher thallium concentrations were determined in surface (range: 5.8–10.0 µg·g<sup>-1</sup> dw) and subsurface sediments (range: 5.7–11.0 µg·g<sup>-1</sup> dw) of two Adirondack lakes (Heit et al. 1981).

There is a paucity of information on the status of thallium in Canadian soils. In Ontario, soil samples from old urban and rural parkland sites were analyzed to determine the Ontario typical range background concentration. This concentration, taken as the 98th percentile of the measured concentrations, was equal to 0.81 mg·kg<sup>-1</sup> for rural parkland and 0.77 mg·kg<sup>-1</sup> for old urban parkland (OMEE 1993). Similar background concentrations of thallium were determined in some British soils in eight out of nine sampled locations ranging from 0.03 to 0.35 mg HNO<sub>3</sub>-extractable Tl·kg<sup>-1</sup> soil and with one anomaly at Shipham (range: 0.42–0.99 HNO<sub>3</sub>-extractable Tl·kg<sup>-1</sup> soil) (Alloway 1990). Ure et al. (1979) reported a mean value of 0.3 mg Tl·kg<sup>-1</sup> for Scottish soils (range: 0.1–0.8 mg Tl·kg<sup>-1</sup>) and Tremel et al. (1997) reported a mean value of 1.51 mg Tl·kg<sup>-1</sup> for French soils (median = 0.29 mg Tl·kg<sup>-1</sup>; 90th percentile = 1.54 mg Tl·kg<sup>-1</sup>).

CCME (1993) recommends USEPA Method 6010, Revision 0, entitled “Inductively Coupled Plasma-Atomic Emission Spectroscopy”, for the analysis of thallium in groundwater, soil, sludge, sediment, and other solid waste samples. The detection limit of this last method is 40 µg·L<sup>-1</sup>. Thus, assuming that a 1-g sample of soil is digested in 100 mL, the detection limit in soil would be 4 mg Tl·kg<sup>-1</sup> soil. As is the case for most metals in soil samples, the amount of total thallium available for analysis varies depending on the extraction treatment of the samples prior to analysis. Care should be taken to indicate the extraction treatment used when reporting analytical results.

## Environmental Fate and Behaviour

The behaviour of thallium in the atmosphere has been reviewed by USEPA (1988) and ATSDR (1992). Thallium compounds released to the atmosphere as a result of human activities are not volatile and are removed by precipitation, atmospheric dispersion, and gravitational settling (ATSDR 1992). Although some thallium compounds, such as TlCl, are photosensitive, there is no evidence that photochemical reactions play a significant

role in determining the atmospheric fate of thallium (ATSDR 1992).

The fate of thallium in the aquatic environment has been reviewed by Callahan et al. (1979), CCREM (1987), and ATSDR (1992). In most aerated natural waters, Tl(I) (thallous ion) is the predominant and the most stable valence of ionic thallium; in highly oxygenated water, Tl(III) (thallic ion) may be present (Callahan et al. 1979). In reducing environments, Tl(I) may be precipitated as the metal or, in the presence of sulphur, as the insoluble sulphide Tl<sub>2</sub>S. Under oxidizing conditions, Tl(III) may be removed from solution by the formation of Tl(OH)<sub>3</sub>, which precipitates.

Thallium may partition from water to sediments (ATSDR 1992) and sorb onto some clay minerals and hydrous metal oxides (Zitko et al. 1975; Callahan et al. 1979; Frantz and Carlson 1987). Thus, it has been implied that sediments may act as an active sink for thallium in the aquatic environment (Callahan et al. 1979).

The fate of thallium in soils was reviewed by Alloway (1990) and Kabata-Pendias and Pendias (1992). In geochemical formations, thallium is known to occur in three oxidation states: Tl(I), Tl(II), and Tl(III). The cation Tl(I), mainly incorporated in sulphide, is highly associated with potassium and rubidium, and its geochemical behaviour is analogous to that of potassium (Kabata-Pendias and Pendias 1992). However, not much is known about the chemical form taken by the element in soils. Nevertheless, it is generally believed that thallium is present as Tl(I) in soils and is transferred to solution in this form (Alloway 1990). Thallium is most often fixed in situ by clays and gels (colloids) of manganese and iron oxides, but the sorption of thallium by organic matter, especially under reducing conditions, is also known (Kabata-Pendias and Pendias 1992). Thallous sulphate was found to be strongly bound in the upper 10 cm of various soil types and to strongly resist leaching to lower horizons (Alloway 1990). Anthropogenic thallium in soils appears to be very soluble and, thus, readily available to plants (Kabata-Pendias and Pendias 1992).

## **Behaviour and Effects in Biota**

### *Soil Microbial Processes*

The effects of thallium on microorganisms vary strongly between species. Acheloplasmataceae are inhibited at low thallium levels, whereas growth of mycoplasmataceae is hardly influenced (Kunze 1973). Other microorganisms, such as *Proteus mirabilis*, *Streptococcus pyogenes* A., *Listeria monocytogenes*, *Escherichia coli*, *Klebsiella*, *Salmonella typhimurium*, *Micrococcus lysodeicticus*,

*Aeromonas hydrophila*, *Bacterium subtilis*, and *Pseudomonas aeruginosa*, are strongly inhibited (Kunze 1972).

Thallium can be actively and/or passively taken up by microorganisms. In most cases, the toxicity of thallium declines with increasing potassium concentrations (Sager 1994).

Thallium sulphate applied at 1943 mg·kg<sup>-1</sup> to loam soil retarded nitrate formation by 5.8% (McCool 1933), whereas nitrification by *Nitrobacter agilis* was inhibited at concentrations between 0.8 and 8 ppm (Tandon and Mishra 1968).

### *Terrestrial Plants*

To a certain extent, the thallium content of plants is a function of thallium concentrations in soils where they are grown (Kabata-Pendias and Pendias 1992). Thallium is readily absorbed by the roots of most plants, probably due to the similarity in behaviour between potassium and thallium (Sherlock and Smart 1986). Studies by Logan et al. (1983) have shown that Tl(I) salts are absorbed more rapidly than Tl(III) salts. Lehn and Bopp (1987) observed that thallium from anthropogenic sources is more available to plants than thallium from geological origins. Thallium is also absorbed via foliage (Schoer 1984). Green vegetables and particularly cruciferous and umbelliferous vegetables appear to concentrate much higher thallium levels (Tooze 1980; Sherlock and Smart 1986). During the lifetime of a plant, concentrations of thallium are always highest in the seedling (Lehn and Bopp 1987).

Sprinkling thallium sulphate onto leaves causes pale round chlorotic spots distributed over the entire leaf. In contrast, thallium uptake by roots causes discoloration, due to chlorophyll degradation, beginning at the base of the leaf vein, progressing along the vein, reaching the tip, and spreading over the whole blade until it is totally covered with intercostal chlorosis (Schoer 1984). Effects may also include necroses and litterfall at every season since scar material identical to that developing before normal autumnal litterfall forms at the end of the stem (Prinz et al. 1979).

In sandy loam, 2 ppm of thallium sulphate (1.6 mg Tl·kg<sup>-1</sup> soil) retard corn top and root growth, causing a 19% reduction in plant height (McCool 1933, Lachover et al. 1958). In the same conditions, tomato plant height is reduced by 13% (Lachover et al. 1958). In silt loam, 2 ppm of thallium sulphate reduce buckwheat yield by 32% (McCool 1933), and in clay loam, this same concentration reduces bean plant height by 24%

(Lachover et al. 1958). In sandy loam, 1.7 ppm of thallium sulphate ( $1.4 \text{ mg Tl}\cdot\text{kg}^{-1}$  soil) were sufficient to injure soybeans, wheat, buckwheat, alfalfa, and rye grass (McCool 1933). Wax beans grown in sandy loam seem to be more resistant to thallium toxicity, showing no significant reduction in plant height at 6 ppm of thallium sulphate ( $4.8 \text{ mg Tl}\cdot\text{kg}^{-1}$  soil). Retarded root and top development were observed at 8.5 ppm thallium sulphate ( $6.9 \text{ mg Tl}\cdot\text{kg}^{-1}$  soil) (Lachover et al. 1958; McCool 1933).

### *Terrestrial Invertebrates*

Very little information is available on the effects of thallium on terrestrial invertebrates. Popenoe (1926) observed that thallium, when offered to small red ants (*Monomorium pharaonis*) in a sweet syrup, destroyed entire colonies over a period of 3 weeks to a month. Environment Canada (1996) reports that in a 14-d toxicity test using artificial soil, no earthworm mortality was observed at  $12 \text{ mg Tl}\cdot\text{kg}^{-1}$  soil. In that experiment, the LOEC for mortality was  $27 \text{ mg Tl}\cdot\text{kg}^{-1}$  soil and the  $\text{LC}_{50}$  was  $30 \text{ mg Tl}\cdot\text{kg}^{-1}$  soil.

### *Livestock and Wildlife*

Thallium has been used extensively as a rodenticide and as an insecticide. It has also been used, in more moderate ways, for the control of other species. The number of wild and domestic animals that have been accidentally poisoned by thallium is large (Environment Canada, 1998).

For mammals and birds, the  $\text{LD}_{50}$  generally lies between 5 and  $70 \text{ mg}\cdot\text{kg}^{-1}$  bw. Mammals exhibit no marked differences in their susceptibility to thallium poisoning (Schoer 1984). In rats, thallium is readily adsorbed and quickly distributed in the whole body, including extensive placental transfer resulting in similar thallium levels in maternal and fetal organs. Subacute poisoning leads to loss of hair or fur, molting of feathers, bloody lesions of the skin, tremor, and paralysis of the muscles (Landauer 1931a; Pile 1956; Mather and Low 1960; Lennox 1966; Sager 1994). In female mice, chronic intoxication with thallium leads to total atrophy of the genital tract (Champy et al. 1958), whereas in birds, chicks fathered by cocks chronically poisoned by thallium suffer higher mortality during the first 3 weeks after hatching than chicks fathered by normal cocks (Landauer 1931b). For chicken embryos, thallium is highly teratogenic in ovo (Ridgway and Karnofsky 1952; Hall 1972; Sager 1994). When given in trace amounts, thallium is principally excreted via the

feces (80%), while total excretion via the kidneys amounts to only about 16%. Thallium is also excreted in the milk (Potter et al. 1971).

### **Human and Experimental Animal Health Effects**

Canadians are likely exposed to small quantities of thallium via food, ambient air, drinking water, and soil. Food (mainly green vegetables) is the major route of intake. TDI estimates for Canadians were 0.15, 0.21, 0.15, 0.09, and  $0.08 \mu\text{g Tl}\cdot\text{kg}^{-1}$  bw per day for infants, toddlers, school-age children, teenagers, and adults, respectively. These estimates of thallium exposure are similar to those estimated in other industrialized countries. Cigarette smoke may be a source of thallium for smokers. In Germany, populations living near certain cement factories were exposed to significant amounts of thallium, mainly through the consumption of contaminated garden fruits and vegetables home-grown in thallium-contaminated soils and not by inhalation of thallium-contaminated air.

Thallium is a slow but persistent systemic poison that is rapidly and almost completely absorbed through the gastrointestinal tract. It is also readily absorbed following inhalation or skin contact (Kanzantis 1986). Thallium levels have been measured in various human tissues and bodily fluids such as blood, urine, hair, and nails (Singh et al. 1975; Brockhaus et al. 1981; Apostoli et al. 1988; Ewers, 1988). Studies have shown that thallium determinations in urine are the most reliable indicator of thallium absorption and a useful tool in the screening of environmental or occupational low-level exposures (Singh et al. 1975; Apostoli et al. 1988; Ewers 1988). No data on thallium levels in tissues and bodily fluids of North American people were identified. Studies from Europe have shown that average urinary thallium levels in subjects exposed to naturally occurring thallium concentrations to be generally  $<1 \mu\text{g}\cdot\text{L}^{-1}$ , with an upper normal limit of  $0.8 \mu\text{g}\cdot\text{L}^{-1}$  (Brockhaus et al. 1981). Although thallium and  $^{201}\text{Tl}$  are secreted in human milk (ICRP 1975; Murphy et al. 1989), actual concentrations have not been reported.

Thallium crosses the placental barrier as well as the blood-brain barrier (Stokinger 1981; Formigli et al. 1983). The two main routes of elimination of thallium are the gastrointestinal tract and the kidneys (Lund 1956). Lie et al. (1960) found that the excretion pattern remained the same regardless of the route of administration. In rats that were given  $10 \text{ mg Tl}\cdot\text{kg}^{-1}$  as thallium sulphate by gavage, 32% of the administered dose was eliminated in the feces and 21% in the urine after 8 d (Lehman and Favari 1985).

The minimum lethal dose for humans ranges from 0.2 to 1 g thallium. The body burden in humans has been estimated at 0.002 mg Tl·kg<sup>-1</sup>, corresponding to 0.14 mg thallium for a 70-kg adult. Acute thallium poisoning effects in humans following ingestion involve mainly the central nervous system, the gastrointestinal tract, kidneys, lungs, heart, and liver. Damages to skin, mucous membranes, hair, and nails were also observed (Kemper and Bertram 1991). Chronic thallosis may involve symptoms such as temporary hair loss (alopecia), general ill health, and paraesthesia. No studies were found concerning the carcinogenicity of thallium in humans or animals after any route of exposure. Hence, thallium is classified in Group VIb (unclassifiable as to human carcinogenicity).

In a 90-d gavage study in rats at doses of 8.1, 40.5, or 202.4 µg Tl·kg<sup>-1</sup> bw per day, Stoltz et al. (1986) suggested a NOAEL of 0.20 mg Tl·kg<sup>-1</sup> per day. An apparent dose-related increase in the shedding of hair was observed along with moderate dose-related changes in some of the blood chemistry parameters (i.e., serum glutamic-oxaloacetic transaminase, lactate dehydrogenase, sodium levels, and sugar levels). Only alopecia was observed at necropsy, and microscopic evaluations did not show any histological alterations. The U.S. Environmental Protection Agency derived a reference dose of 0.07 µg Tl·kg<sup>-1</sup> bw per day, using the lowest NOAEL reported in the literature, 0.20 mg Tl·kg<sup>-1</sup> bw per day, from the study by Stoltz et al. (1986), and applying an uncertainty factor of 3000 (10 for intraspecific and 10 for interspecific effects, 10 for less-than lifetime study, and an additional uncertainty factor of 3 for the lack of carcinogenicity studies, the potential teratogenic and reproductive effects, and the potential to cross the placental barrier). The U.S. reference dose is adopted here as a provisional TDI for derivation of health-based soil quality guidelines for thallium at contaminated sites in Canada.

## **Guideline Derivation**

Canadian soil quality guidelines are derived for different land uses following the process outlined in CCME (1996a) using different receptors and exposure scenarios for each land use (Table 1). Detailed derivations for thallium soil quality guidelines are provided in Environment Canada (1998) and Health Canada (1995).

### *Soil Quality Guidelines for Environmental Health*

Environmental soil quality guidelines (SQG<sub>E</sub>) are based on soil contact using data from toxicity studies on plants and invertebrates. In the case of agricultural land, soil and

food ingestion toxicity data for mammalian and avian species are included. To provide a broader scope of protection, a nutrient and energy cycling check is calculated. For industrial land use, an off-site migration check is also calculated.

For all land uses, the preliminary soil contact value (also called the threshold effects concentration [TEC] or effects concentration low [ECL], depending on the land use) is compared to the nutrient and energy cycling check. If the nutrient and energy cycling check is lower, the geometric mean of the preliminary soil contact value and the nutrient and energy cycling check is calculated as the soil quality guideline for soil contact. If the nutrient and energy cycling check is greater than the preliminary soil contact value, the preliminary soil contact value becomes the soil quality guideline for soil contact.

For agricultural land use, the lower of the soil quality guideline for soil contact and the soil and food ingestion guideline is recommended as the SQG<sub>E</sub>.

For residential/parkland and commercial land uses, the soil quality guideline for soil contact is recommended as the SQG<sub>E</sub>.

For industrial land use, the lower of the soil quality guideline for soil contact and the off-site migration check is recommended as the SQG<sub>E</sub>.

In the case of thallium, the recommended SQG<sub>E</sub> for agricultural land is based on the soil and food ingestion guideline. The calculated preliminary soil and food ingestion value was lower than typical background concentrations. As a result, no SQG<sub>I</sub> above background could be derived. Therefore, the SQG<sub>I</sub> for thallium is set to 1 mg·kg<sup>-1</sup> soil dw. This value corresponds to the upper 98th percentile value of the range of typical concentrations of this element in Ontario soils. For all other land use categories, the recommended SQG<sub>E</sub> is based on the soil contact guideline (Table 2).

### *Soil Quality Guidelines for Human Health*

Human health soil quality guidelines (SQG<sub>HHs</sub>) for threshold contaminants are derived using a TDI for the most sensitive receptor designated for a land use. For thallium, a provisional TDI is used in place of a conventional TDI.

The estimated TDI of thallium exceeds the provisional TDI for all Canadians, regardless of age. As a result, no acceptable concentration of thallium in soil above typical background can be derived. Therefore, a provisional soil

Table 2. Soil quality guidelines and check values for thallium ( $\text{mg}\cdot\text{kg}^{-1}$ ).

Guideline	Land use			
	Agricultural 1 <sup>a</sup>	Residential/ parkland 1 <sup>b</sup>	Commercial 1 <sup>b</sup>	Industrial 1 <sup>b</sup>
Human health guidelines/check values				
$\text{SQG}_{\text{HH}}$	NC <sup>c</sup>	NC <sup>c</sup>	NC <sup>c</sup>	NC <sup>c</sup>
Soil ingestion guideline	NC	NC	NC	NC
Inhalation of indoor air check	NC <sup>d</sup>	NC <sup>d</sup>	NC <sup>d</sup>	NC <sup>d</sup>
Off-site migration check	—	—	—	NC
Groundwater check (drinking water)	NC <sup>e</sup>	NC <sup>e</sup>	NC <sup>e</sup>	NC <sup>e</sup>
Produce, meat, and milk check	NC <sup>f</sup>	NC <sup>f</sup>	—	—
Provisional $\text{SQG}_{\text{HH}}$	1	1	1	1
Limiting pathway for provisional $\text{SQG}_{\text{HH}}$	Soil ingestion	Soil ingestion	Soil ingestion	Soil ingestion
Environmental health guidelines/check values				
$\text{SQG}_{\text{E}}$	1 <sup>g</sup>	1.4 <sup>h</sup>	3.6 <sup>h</sup>	3.6 <sup>h</sup>
Soil contact guideline	1.4	1.4	3.6	3.6
Soil and food ingestion guideline	1 <sup>i</sup>	—	—	—
Nutrient and energy cycling check	NC <sup>j</sup>	NC <sup>j</sup>	NC <sup>j</sup>	NC <sup>j</sup>
Off-site migration check	—	—	—	140
Groundwater check (aquatic life)	NC <sup>e</sup>	NC <sup>e</sup>	NC <sup>e</sup>	NC <sup>e</sup>
Provisional $\text{SQG}_{\text{E}}$	NC <sup>k</sup>	NC <sup>k</sup>	NC <sup>k</sup>	NC <sup>k</sup>
Limiting pathway for provisional $\text{SQG}_{\text{E}}$	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	1	No value	No value	No value

**Notes:** NC = not calculated; ND = not determined;  $\text{SQG}_{\text{E}}$  = soil quality guideline for environmental health;  $\text{SQG}_{\text{HH}}$  = soil quality guideline for human health. The dash indicates guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.

<sup>a</sup>Data are sufficient and adequate to calculate a provisional  $\text{SQG}_{\text{HH}}$  and an  $\text{SQG}_{\text{E}}$ . The provisional  $\text{SQG}_{\text{HH}}$  is equal to the  $\text{SQG}_{\text{E}}$  and to the existing interim soil quality criterion (CCME 1991) and thus becomes the soil quality guideline, which supersedes the interim soil quality criterion for this land use.

<sup>b</sup>Data are sufficient and adequate to calculate a provisional  $\text{SQG}_{\text{HH}}$  and an  $\text{SQG}_{\text{E}}$ . The provisional  $\text{SQG}_{\text{HH}}$  is less than  $\text{SQG}_{\text{E}}$  and thus becomes the soil quality guideline for this land use.

<sup>c</sup>Data are insufficient/inadequate to calculate an  $\text{SQG}_{\text{HH}}$  for this land use. However, data are sufficient and adequate to calculate a provisional  $\text{SQG}_{\text{HH}}$ .

<sup>d</sup>Applies only to volatile organic compounds and is not calculated for metal contaminants.

<sup>e</sup>Applies to organic compounds and is not calculated for metal contaminants. Concerns about metal contaminants should be addressed on a site-specific basis.

<sup>f</sup>Applies to nonpolar organic compounds and is not calculated for metal contaminants. Concerns about metal contaminants should be addressed on a site-specific basis.

<sup>g</sup>Based on the soil and food ingestion guideline value.

<sup>h</sup>Based on the soil contact guideline value.

<sup>i</sup>The calculated preliminary soil and food ingestion value was lower than typical background concentrations. As a result, no  $\text{SQG}_{\text{I}}$  above background could be derived. Therefore, the  $\text{SQG}_{\text{I}}$  for thallium is set to  $1 \text{ mg}\cdot\text{kg}^{-1}$ . This value corresponds to the upper 98th percentile value of the range of typical concentrations of this element in Ontario soils.

<sup>j</sup>Data are insufficient/inadequate to calculate the nutrient and energy cycling check for this land use.

<sup>k</sup>Because data are sufficient and adequate to calculate an  $\text{SQG}_{\text{E}}$  for this land use, a provisional  $\text{SQG}_{\text{E}}$  is not calculated.

quality guideline for thallium of 1 mg·kg<sup>-1</sup> soil dw is proposed for all land uses. This value corresponds to the upper 98th percentile value of the range of typical concentrations of this element in Ontario soils. Thus, the proposed human health-based soil quality guidelines for thallium (total) for all land uses are set at the typical background soil concentration (Table 2).

### Soil Quality Guidelines for Thallium

The soil quality guidelines are intended to be protective of both environmental and human health. Where sufficient and adequate data exist for both, the interim soil quality criteria (CCME 1991) can be superseded.

Data are sufficient and adequate to calculate provisional SQG<sub>HHS</sub> and SQG<sub>ES</sub> for all land uses. The provisional SQG<sub>HHS</sub> are less than the SQG<sub>ES</sub> and equal to the interim soil quality criterion for agricultural land use (CCME 1991) and thus become the recommended guidelines. The recommended soil quality guideline for agricultural land use supersedes the interim soil quality criterion for that land use.

CCME (1996b) provides guidance on potential modifications to the recommended soil quality guideline when setting site-specific objectives.

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