



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

**ZINC
1999**

This fact sheet provides Canadian soil quality guidelines for total zinc (Zn) for the protection of environmental health (Table 1). A supporting scientific document is also available (Environment Canada 1996).

Background Information

Zinc (CAS 7440-66-6) is a transition metal; it has an atomic number of 30 and an atomic weight of 65.38. In its pure state, zinc has a relatively low melting point of 419°C and a boiling point of 907°C. Zinc is divalent and tends to strongly react with organic and inorganic compounds. Zinc forms stable combinations with many

organic substances including humic and fulvic acids and a wide range of biochemical compounds. Metallic zinc is insoluble while the solubilities of different zinc compounds range from insoluble (oxides, carbonates, phosphates, and silicates) to extremely soluble (sulphates and chlorides) (Environment Canada 1996).

The primary and fastest growing use of zinc is for galvanizing. It is anticipated that zinc demand will continue to increase due to increasing demand for galvanized products for automobiles and for structural components in the construction industry. The second most important use of zinc is in the manufacture of brass and bronze for plumbing components and for heating and cooling system components. The balance of zinc use is for

Table 1. Soil quality guidelines for zinc (mg·kg⁻¹).

Guideline	Land use			
	Agricultural	Residential/ parkland	Commercial	Industrial
Guideline	200 ^a	200 ^a	360 ^a	360 ^a
SQ _{HH}	NC ^b	NC ^b	NC ^b	NC ^b
Limiting pathway for SQ _{HH}	ND	ND	ND	ND
Provisional SQ _{HH}	NC ^c	NC ^c	NC ^c	NC ^c
Limiting pathway for provisional SQ _{HH}	ND	ND	ND	ND
SQ _E	200	200	360 ^d	360 ^d
Limiting pathway for SQ _E	Soil contact	Soil contact	Nutrient and energy cycling check	Nutrient and energy cycling check
Provisional SQ _E	NC ^e	NC ^e	NC ^e	NC ^e
Limiting pathway for provisional SQ _E	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	600	500	1500	1500

Notes: NC = not calculated; ND = not determined; SQ_E = soil quality guideline for environmental health; SQ_{HH} = soil quality guideline for human health.

^aData are sufficient and adequate to calculate only an SQ_E. It is less than the existing interim soil quality criterion (CCME 1991) for this land use. Therefore, the soil quality guideline supersedes the interim soil quality criterion for this land use.

^bThere is no SQ_{HH} for this land use at this time.

^cThere is no provisional SQ_{HH} for this land use at this time.

^dThe SQ_E for this land use is the geometric mean of the effects concentration low (ECL) and the nutrient and energy cycling check.

^eBecause data are sufficient and adequate to calculate an SQ_E for this land use, a provisional SQ_E 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.

the production of zinc semi-manufactures, oxides, chemicals, and zinc dust. Zinc oxide is important in the manufacture of tires and other rubber products. In addition, there has been increased research on the use of zinc in batteries with a zinc-air battery recently developed for personal computers, which lasts three times longer than nickel-cadmium batteries and is easily recyclable. Zinc powder is used in the production of mercury-free batteries (Environment Canada 1996).

A total of 1.18 million t of zinc is released to the Canadian environment each year, with 65% (768 500 t) originating from natural sources and the balance of 414 000 t contributed by anthropogenic sources. Natural weathering of materials is the single largest source of zinc released to the environment at 725 000 t annually (Taylor and Demayo 1980). Sources of anthropogenic zinc in the environment include electroplaters, smelting and ore processors, mine drainage, domestic and industrial sewage, combustion of solid wastes and fossil fuels, road surface runoff, corrosion of zinc alloy and galvanized surfaces, and erosion of agricultural soils (Environment Canada 1996).

McKeague and Wolynetz (1980) reported a mean of 74 mg Zn·kg⁻¹ in Canadian soils. By region, the concentration of zinc in soil from the Canadian Shield is 54 mg·kg⁻¹; from the Interior Plains, 64 mg·kg⁻¹; from the Cordilleran Region is 73 mg·kg⁻¹; from the St. Lawrence Lowlands, 80 mg·kg⁻¹; and from the Appalachians, 81 mg·kg⁻¹.

Zinc in the surface horizons of northwest Alberta agricultural soils was measured at 55 mg·kg⁻¹ and 94 mg·kg⁻¹ and at 81 mg·kg⁻¹ in the subsurface soil (Soon and Abboud 1990; Soon 1994). Chernozemic and Luvisolic soils supporting native vegetation in southeast and central Alberta ranged in concentration from 29 to 235 mg Zn·kg⁻¹ soil. The Chernozemic Ah horizons were enriched with zinc in comparison to their respective C horizons, and the LFH layers of the Luvisolic soils had elevated zinc levels (Dudas and Pawluk 1980).

Whitby et al. (1978) sampled 26 agricultural soils from southwestern Ontario for total zinc content. Average zinc concentrations were 88, 87, and 71 mg·kg⁻¹ for the Ap, B, and C horizons, respectively. Webber and Shames (1987) reported an average zinc concentration of 126 mg·kg⁻¹ in the plough layers of cultivated soil in southwestern Ontario. Frank et al. (1976) measured an average of 56.7 mg Zn·kg⁻¹ in soils collected from all agricultural areas of Ontario. Organic soils contained the highest average concentration of 66.3 mg Zn·kg⁻¹, while sandy soils contained the lowest average concentration of 39.9 mg Zn·kg⁻¹.

In surface soil samples from areas not impacted by local point sources of pollution throughout Ontario, the 98th percentiles of zinc concentration measurements are 120 and 140 mg·kg⁻¹ for rural parkland and old urban parkland soils, respectively (OMEE 1993).

Inductively coupled plasma-atomic emission spectroscopy (USEPA Method 6010) is the recommended analytical method for the measurement of zinc in soils (CCME 1993).

Environmental Fate and Behaviour in Soil

Zinc is highly reactive in soils, so that in addition to inorganic Zn⁺², zinc is present as part of both soluble and insoluble organic compounds. Zinc can also be adsorbed to clay minerals or metallic oxides and may be present within primary minerals of the soil parent material (Sachdev et al. 1992). In general, total zinc was found to be evenly distributed throughout soil profiles. However, EDTA-extractable zinc was reported to decrease with depth in the profile (Lindsay 1972).

The concentration of zinc in soil solution is dependent on the amount of zinc present in the soil, solubility of the particular zinc compound, and the extent of adsorption. Zinc compounds vary significantly in solubility. Zinc sulphate is readily soluble in soil solution, while zinc oxide is relatively insoluble. Zinc may be adsorbed to clay minerals and may also form stable compounds with soil organic matter, hydroxides, oxides, and carbonates. Soil pH has been identified in many studies as one of the main factors affecting zinc mobility and sorption in soils (Shuman 1975; Evans 1989; Duquette and Hendershot 1990; Davis-Carter and Shuman 1993). Zinc becomes more soluble as pH decreases, therefore zinc is more mobile and increasingly available to organisms in low pH environments, especially below pH 5 (Duquette and Hendershot 1990). At pH <7.7, zinc occurs as Zn⁺² in soil solution, whereas at pH >7.7, the dominant form is Zn(OH)₂ (Giordano and Mortvedt 1980). Leaching of zinc occurs more readily from acid soils.

The amount of bioavailable zinc will be determined by the amount of zinc present that is soluble or may be solubilized. Within a given soil, an equilibrium exists between the different forms of zinc (adsorbed, exchangeable, secondary minerals, insoluble complexes) in the liquid and solid phases of the soil. Plant uptake, losses by leaching, input of zinc in various forms, changes in moisture content of the soil, pH changes, mineralization of organic matter, and changing redox potential of the soil will influence the equilibrium. Due to the complexity of zinc interactions in soil, zinc transport

behaviour in soil cannot be predicted accurately (Hinz and Selim 1994), and soil adsorption effects cannot be separated from solution effects such as precipitation.

Behaviour and Effects in Biota

Zinc is an essential element required for good health and proper functioning of biological processes in plants and animals and is a known constituent of over 200 metalloenzymes and other metabolic compounds (Vallee 1959).

Microbial Processes

Microbial processes are sensitive to zinc concentrations. Cornfield (1977) noted a 21% reduction in CO₂ respiration after exposure to 10 mg Zn·kg⁻¹ in soil for 8 weeks. Nitrification appears to be less sensitive to zinc; Liang and Tabatabai (1978) determined that 327 mg Zn·kg⁻¹ resulted in a 24% inhibition of nitrification.

Terrestrial Plants

The lowest zinc concentration at which phytotoxic effects have been observed is 50 mg·kg⁻¹ dry soil, which resulted in a 50% reduction in seed yield in turnips (*Brassica rapa*) at pH 6.3 (Sheppard et al. 1993).

Chlorosis, mainly in new leaves, and depressed plant growth are common symptoms of zinc toxicity (Kabata-Pendias and Pendias 1992). Zinc interacts with other chemicals in soil. Iron levels in plant tissue tend to be markedly reduced when an excess of zinc is present in the soil, and excess phosphorous in soil is known to induce zinc deficiency in plants (Kabata-Pendias and Pendias 1992).

Terrestrial Invertebrates

An LC₅₀ of 80 mg Zn·kg⁻¹ dry soil was reported for the earthworm *Eisenia foetida* (Sheppard et al. 1993). Soil characteristics play a significant role in the uptake of zinc by worms. Ma (1982) found that the level of zinc in the earthworm *Lumbricus rubellus* was generally related to zinc concentrations in the soil and highly correlated with zinc concentrations in low pH soils. At lower pH, the soil adsorbs less zinc, rendering zinc more bioavailable to earthworms.

Wildlife and Livestock

Zinc is an essential nutrient required for proper growth, development, and function in mammals and birds. Zinc requirements for young domestic animals and fowl range from about 40 to 100 mg Zn·kg⁻¹ in the diet. Puls (1988) indicates there is a strong relationship between zinc and calcium in the dietary requirements of cattle. The recommended dietary requirement for cattle is 45 mg Zn·kg⁻¹ dry matter intake with 0.3% calcium. For each additional 0.1% calcium, 16 mg Zn·kg⁻¹ should be added to the diet. In a review by NRC (1980), the following values for zinc content in various animal feeds were reported: pasture, 17–60 Zn·kg⁻¹; cereal grains, 20–30 Zn·kg⁻¹; and soybean meal, 50–70 Zn·kg⁻¹ dw. Clinical signs of zinc toxicity include loss of appetite, decreased water consumption and dehydration, increased mineral consumption, loss of condition (decrease in weight gain or loss of weight), weakness, jaundice, diarrhea, and paralysis of the legs in birds (Environment Canada 1996). Wildlife and livestock are sensitive to high concentrations of zinc in their diet.

The lowest effect reported was 64% reduction in the number of viable offspring in Cheviot sheep exposed to 750 mg Zn·kg⁻¹ in their diet (Campbell and Mills 1979). The required amount of zinc for proper growth and development ranges markedly depending upon the organism and the surrounding environment.

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 zinc soil quality guidelines are provided in Environment Canada (1996).

Soil Quality Guidelines for Environmental Health

The environmental soil quality guidelines (SQG_{ES}) are based on soil contact data from toxicity studies on plants and invertebrates. In the case of agricultural land use, 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 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_E.

For residential/parkland and commercial land uses, the soil quality guideline for soil contact is recommended as the SQG_E.

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_E.

For zinc there are insufficient data to calculate the off-site migration check.

Soil Quality Guidelines for Human Health

There are no human health guidelines or check values available at this time (Table 2).

Soil Quality Guidelines for Zinc

The soil quality guidelines are the lower of the SQG_{ES} and the interim soil quality criteria (CCME 1991).

For all land uses the SQG_{ES} are less than the existing interim soil quality criteria. Therefore the soil quality guidelines supersede the interim soil quality criteria.

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

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

Guideline	Land use			
	Agricultural	Residential/ parkland	Commercial	Industrial
	200 ^a	200 ^a	360 ^a	360 ^a
Human health guidelines/check values ^b				
SQG _{HH}	NC	NC	NC	NC
Soil ingestion guideline	NC	NC	NC	NC
Inhalation of indoor air check	NC	NC	NC	NC
Off-site migration check	—	—	—	NC
Goundwater check (drinking water)	NC	NC	NC	NC
Produce, meat, and milk check	NC	NC	—	—
Provisional SQG _{HH}	NC	NC	NC	NC
Limiting pathway for provisional SQG _{HH}	ND	ND	ND	ND
Environmental health guidelines/check values				
SQG _E	200 ^c	200 ^c	360 ^d	360 ^d
Soil contact guideline	200	200	360	360
Soil and food ingestion guideline	640	—	—	—
Nutrient and energy cycling check	200	200	320	320
Off-site migration check	—	—	—	1000
Groundwater check (aquatic life)	NC ^e	NC ^e	NC ^e	NC ^e
Provisional SQG _E	NC ^f	NC ^f	NC ^f	NC ^f
Limiting pathway for provisional SQG _E	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	600	500	1500	1500

Notes: NC = not calculated; ND = not determined; SQG_E = soil quality guideline for environmental health; SQG_{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.

^aData are sufficient and adequate to calculate only an SQG_E. It is less than the existing interim soil quality criterion (CCME 1991) for this land use. Therefore the soil quality guideline supersedes the interim soil quality criterion for this land use.

^bThere are no values for the human health guidelines/check values at this time.

^cThe SQG_E for this land use is based on the soil contact guideline.

^dThe SQG_E for this land use is the geometric mean of the effects concentration low (ECL) ($410 \text{ mg}\cdot\text{kg}^{-1}$) and the nutrient and energy cycling check.

^eThe environmental groundwater check (aquatic life) applies to organic compounds and is not calculated for metal contaminants. Concerns about metal contaminants should be addressed on a site-specific basis.

^fBecause data are sufficient and adequate to calculate an SQG_E for this land use, a provisional SQG_E is not calculated.

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This fact sheet was originally published in the working document entitled “Recommended Canadian Soil Quality Guidelines” (Canadian Council of Ministers of the Environment, March 1997, Winnipeg). A revised and edited version is presented here.

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian soil quality guidelines for the protection of environmental and human health: Zinc (1999). In: *Canadian environmental quality guidelines, 1999*, Canadian Council of Ministers of the Environment, Winnipeg.

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