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

CADMIUM
1999

This fact sheet provides Canadian soil quality guidelines for cadmium (Cd) for the protection of environmental and human health (Table 1). Supporting scientific documents are also available (Environment Canada 1996; Health Canada 1996).

Background Information

Cadmium (CAS 7440-43-9), a soft-white, blue-tinged, lustrous metal, seldom found as a pure mineral, occurs in nature as a divalent cation (Cd^{2+}). Cadmium has an atomic weight of 112.40 and a vapour pressure of 1.4 mm Hg. With a boiling point of 765°C, cadmium is unlikely to volatilize, except under extreme conditions (e.g., volcanoes and forest fires) (Eisler 1985). The elemental form of cadmium is insoluble in water, whereas the solubility of cadmium salts varies from 0.00013 to 140 $g \cdot 100\ mL^{-1}$ (Lide 1992).

Cadmium is recovered from the fumes produced during the roasting of zinc ores and concentrates and from the precipitates obtained during the purification of zinc sulphate (Brown 1977). Global production of refined cadmium metal for 1990 was estimated at 21 800 t, which represents an increase of approximately 5% over 1989

Table 1. Soil quality guidelines for cadmium ($mg \cdot kg^{-1}$).

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline	**1.4**[a]	**10**[a, b]	**22**[a]	**22**[a]
SQG_{HH}	1.4	14	49	192
Limiting pathway for SQG_{HH}	Soil ingestion	Soil ingestion	Soil ingestion	Off-site migration
Provisional SQG_{HH}	NC[c]	NC[c]	NC[c]	NC[c]
Limiting pathway for provisional SQG_{HH}	ND	ND	ND	ND
SQG_E	3.8	10	22	22
Limiting pathway for SQG_E	Soil contact	Soil contact	Soil contact	Soil contact
Provisional SQG_E	NC[d]	NC[d]	NC[d]	NC[d]
Limiting pathway for provisional SQG_E	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	3	5	20	20

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

[a] Data are sufficient and adequate to calculate an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully integrated de novo guideline for this land use, derived in accordance with the soil protocol (CCME 1996a). The corresponding interim soil quality criterion (CCME 1991) is superseded by the soil quality guideline.

[b] The soil–plant–human pathway is not considered in this guideline. If produce gardens are present or planned, a site-specific objective must be derived to take into account the bioaccumulation potential (e.g., adopt the agricultural guideline as objective). The off-site migration check should be recalculated accordingly.

[c] Because data are sufficient and adequate to calculate an SQG_{HH} guideline for this land use, a provisional SQG_{HH} is not calculated.

[d] Because data are sufficient and adequate to calculate an SQG_E for this land use, a provisional SQG_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.

(Hoskin 1991). Canada is the fourth largest producer of cadmium in the world, with an output of approximately 1865 t in 1991 (Koren 1992). The annual production of cadmium in Canada has been relatively stable since 1984, with the mean level for this period near 1570 t annually (Koren 1992). An estimated 75% of the Canadian production of cadmium was exported in 1990, mainly to the United States, Japan, and France (Hoskin 1991). Imports of cadmium into Canada in 1991 have been estimated at 116.3 t (Koren 1992). It may be conservatively estimated that the total amount of cadmium metal "entering" Canada in the form of nonexported domestic production and imported products in 1990 was approximately 700 t.

There are five main industrial uses of cadmium: nickel/cadmium batteries, coatings, pigments, stabilizers in plastics and synthetic products, and alloys (Hoskin 1991). Domestic industrial consumption in Canada has been increasing steadily in recent years: from 18.9 t in 1987 to 35.2 t in 1990 (Hoskins 1991; Koren 1992). Cadmium compounds are used in the production of polyvinyl chloride (PVC) and picture tubes for television sets. Cadmium is also present in cadmium–silver solders, telephone and trolley wires, metal sheets for automobile radiators, control rods and shields for nuclear reactors, motor oils, and curing agents for rubber (CCREM 1987). In Canada, electroplating accounted for 61–77% of the total consumption, with soldering, alloys, chemicals, and pigments making up the remainder (Hoskin 1991).

Cadmium is registered under the Pesticide Control Act for use as a fungicide in turf grass production. Three pesticide products that contain cadmium as the active ingredient are currently marketed in Canada (Agriculture Canada 1992).

The available data indicate that background concentrations of cadmium in Canada range from not detectable (Whitby et al. 1978) to as high as 8.1 $mg \cdot kg^{-1}$ (Frank et al. 1986). In surface soil samples from areas not impacted by local point sources of pollution throughout Ontario, the 98th percentiles of cadmium concentration measurements are 0.71 and 0.84 $mg \cdot kg^{-1}$ for rural parkland and old urban parkland soils, respectively (OMEE 1993).

The available Canadian data also emphasize the potential effects of anthropogenic activities on cadmium levels in soil. While the highest concentrations have been reported in the vicinity of lead–zinc smelters, elevated levels of cadmium have also been observed as the result of the disposal of sewage sludge, combustion of fossil fuels, and weathering of galvanized metals. In British Columbia, elevated levels of cadmium have been reported in soils from the Columbia River valley in the vicinity of the Cominco lead–zinc smelter. Average cadmium concentrations in surface litter within 10 km of the smelter were 17.1 $mg \cdot kg^{-1}$ (John 1975). Data collected in the vicinity of a copper smelter in Flin Flon, Manitoba, indicate significant contamination with cadmium. The mean concentration in garden soils in this area was 5.19 $mg \cdot kg^{-1}$ and ranged from 3.2 to 13 $mg \cdot kg^{-1}$ (Pip 1991). Whereas background concentrations of cadmium in Ontario soils are fairly low, higher levels have been reported near known sources of cadmium, such as power transmission towers (Jones et al. 1988), sewage sludge application sites (Frank et al. 1976; Webber and Shamess 1987), and urban roads (Van Loon et al. 1973). Data collected in the vicinity of the smelter at Rouyn-Noranda in Quebec indicate that soils are highly contaminated with cadmium. Within 1–3.7 km of the smelter, cadmium levels ranged from 54 to 66 $mg \cdot kg^{-1}$ in the top 15 cm of soil.

Environmental Fate and Behaviour in Soil

A variety of factors influence the mobility of cadmium in soils, with pH and soil type (including particle size; content of metal oxides, hydroxides, and oxyhydroxides; and organic matter content) probably being the most important. Numerous studies have identified soil pH as an important factor in influencing the mobility of cadmium in soil (Chanmugathas and Bollag 1987; Christensen 1989b; Eriksson 1989; Lodenius and Autio 1989), and most studies indicate that significant movement of cadmium within the soil matrix and into other media is likely to occur under acidic conditions. A number of processes also have the potential to affect the fate of cadmium in soils, including aeolian transport (wind erosion), fluvial transport, leaching, and uptake by terrestrial organisms.

Soils are particularly important in the attenuation of cadmium since they have both mineral and organic constituents involved in metal retention (Evans 1989). Many studies have shown that clay minerals (McBride et al. 1981; Inskeep and Baham 1983; Christensen 1984a, 1984b), metal oxides, hydroxides, oxyhydroxides (Benjamin and Leckie 1981a, 1981b; Bruemmer et al. 1988; Fu et al. 1991), and organic matter (Blume and Brummer 1991) are involved in the immobilization of cadmium in soils. However, the presence of high concentrations of dissolved organic matter in soil leachates can also enhance cadmium mobility and, as such, pose a risk to groundwater quality (Bollag and Czaban 1989; Christensen 1989a; Singh 1990).

Microorganisms may have either an inhibitory or a stimulatory effect on the mobility of cadmium in soil. Organic substances produced by some soil microorganisms may chelate and effectively immobilize cadmium (Bollag and Czaban 1989). In addition, microbial production of hydrogen sulphide can result in the formation of insoluble cadmium sulphides, which are very stable (Bollag and Czaban 1989). However, microbial decomposition of organic matter or metal sulphides may result in the release of cadmium from stable complexes and, as such, increase its overall mobility (Cole 1979). The degree of mobilization is dependent on soil type, aeration, and moisture content.

Under certain circumstances, lateral transport, including aeolian and fluvial transport, has been shown to be an important environmental process affecting the fate of cadmium in soils. Bell et al. (1991) reported significant losses of cadmium within 1 year from soils treated with sewage sludge or metal salts and suggested that the mixing of surficial soils with subsurface soils and lateral transport were the most important factors contributing to these losses. McGrath and Lane (1989) also suggested that lateral transport due to mechanical cultivation and erosion can significantly affect the fate of cadmium in soils. Nriagu and Pacyna (1988) calculated that wind erosion of soils constituted one of the largest natural cadmium fluxes to the atmosphere.

Behaviour and Effects in Biota

Soil Microbial Processes

Populations of bacteria and fungi have been reduced in size in soils containing as little as 2.9 mg $Cd\cdot kg^{-1}$ (Naidu and Reddy 1988; Kobus and Kurek 1990). Nitrogen mineralization has been reduced by 17–39% at 5 mg $Cd\cdot kg^{-1}$ soil (Liang and Tabatabai 1977). A 60% reduction in nitrification has been observed at 1000 $mg\cdot kg^{-1}$, and carbon dioxide evolution in soil has been reduced 17–47% by concentrations ranging from 10 to 8000 $mg\cdot kg^{-1}$ (Cornfield 1977; Bewley and Stotzky 1983; Lighthart et al. 1983; Doelman and Haanstra 1984).

Terrestrial Plants

Uptake rates of cadmium by terrestrial plants are variable and depend on the plant species (Kuboi et al. 1986; Kim et al. 1988), cadmium concentration in soil, and other factors influencing the bioavailability of cadmium in soils. Translocation of cadmium is not universal among plants, and research has shown accumulation of cadmium in the roots of some plants (Carlson and Ragsdale 1988; Mench et al. 1989) and in the leaves of others (Kim et al. 1988; Boon and Soltanpour 1992).

Environment Canada has calculated soil-to-plant BCFs for different plant tissues and gave BCFs values of 1.81, 1.07, and 15.22 for leaves, shoots, and roots, respectively, using the results of many studies (Kelly et al. 1979; Burton and Morgan 1984; Wadge and Hutton 1986; Kim et al. 1988; Bache and Lisk 1990). However, using the geometric mean of all the BCFs for those plant tissues, an overall BCF value of 2.65 can be calculated (Environment Canada 1996).

The lowest soil cadmium concentrations at which phytotoxic effects have been observed are 2.5 and 4 $mg\cdot kg^{-1}$, which resulted in a 21% yield reduction of wheat (Haghiri 1973), a 14% yield reduction in soy beans (Haghiri 1973), a 25% reduction of shoot yield in spinach (Bingham et al. 1975), and a 28% reduction in corn shoot growth (Miller et al. 1977). The literature shows that a variety of growth endpoints are reduced by 25% at concentrations ranging from 4 to >640 $mg\cdot kg^{-1}$. Fifty percent reductions in growth endpoints occurred at concentrations ranging from 16 to 205 $mg\cdot kg^{-1}$.

Terrestrial Invertebrates

Many studies have indicated that uptake and accumulation of cadmium by earthworms occurs in contaminated soils (Hartenstein et al. 1981; Simmers et al. 1983; Pietz et al. 1984; Kruse and Barrett 1985). In a field study, Ma (1982) demonstrated that soil pH and cation exchange capacity (CEC) both affected cadmium uptake in earthworms. A significant negative correlation was found between the concentration factor and soil pH, as lowering of pH leads to increased desorption of metal cations. A second significant negative correlation was found between the concentration factor and soil CEC, indicating the general importance of metal availability rather than the total concentration in soils.

LD_{50} values for earthworms *(Eisenia foetida)* range from 253 to 1843 $mg\cdot kg^{-1}$ (Neuhauser et al. 1985; van Gestel et al. 1991). For collenbolan, the LD_{50} values range from 778 to 893 $mg\cdot kg^{-1}$ (Crommentuijn et al. 1993). The more sensitive endpoints of cocoon production, growth, and sexual development of earthworms are reduced by 50% at 46, 33, and 27 $mg\cdot kg^{-1}$, respectively (van Gestel et al. 1991; Spurgeon et al. 1994).

Livestock and Wildlife

Under most circumstances, the most important exposure route is probably through ingestion. In mammals and birds, upon ingestion, the absorption of cadmium is influenced by many factors including dose, age, diet, and the presence of other substances, such as calcium (USEPA 1988). Adverse effects of cadmium ingestion have been observed in various mammals and bird species at levels ranging from 15 to 1350 $mg\cdot kg^{-1}$ bw (Environment Canada 1996). Effects observed included reduction of food intake and growth rate, impaired reproduction, and mortality. Cadmium has been shown to distribute throughout the body and accumulate primarily in the liver and renal cortex. Animals have a limited capability to eliminate assimilated cadmium (Health and Welfare Canada 1978).

Effects in livestock range from a 21% decrease in the body weight gain of lambs at 4.56 $mg \cdot kg^{-1}$ per day to a 96% decrease in body weight gain in pigs at 140 $mg \cdot kg^{-1}$ per day (Cousins et al. 1973; Doyle et al. 1974).

Human and Experimental Animal Health Effects

Cadmium is absorbed via the lungs, gastrointestinal tract, and skin in both humans and experimental animals. Short-term exposure to cadmium has been associated with a wide range of sublethal adverse effects on mammalian receptors. The symptoms of cadmium toxicity following acute exposure include nausea, vomiting, diarrhea, muscular cramps, and salivation (USEPA 1988). Acute gastroenteritis has been reported following dietary exposure to doses as low as 0.25–0.50 $mg \cdot kg^{-1}$ bw (Health and Welfare Canada 1978). The acute oral dose of cadmium in humans has been estimated to be in the order of 5–500 $mg \cdot kg^{-1}$ bw (USEPA 1988). After the renal cortex and liver, the pancreas, thyroid, gallbladder, and testes accumulate relatively high concentrations of cadmium (WHO 1974).

Most foodstuffs consumed in Canada contain cadmium. In the most detailed study, the cadmium content of 218 food composites was determined under the Total Diet Program of Health Canada. Mean concentrations exceeded 20 $ng \cdot g^{-1}$ fresh weight (fw) in many of the foods analyzed, and some contained >90 $ng \cdot g^{-1}$ fw (Dabeka and McKenzie 1992, 1995). Adverse effects on the nervous system, kidney, liver, bones, hematopoietic, cardiovascular, and immune systems, as well as growth, reproduction, and development, have been observed in various mammals and birds following chronic, low-level oral exposure to cadmium (USEPA 1988). In addition, long-term exposure to higher doses of cadmium has been associated with teratogenicity, mutagenicity, and carcinogenicity (WHO 1984). Renal dysfunction appears to be a relatively sensitive indicator of cadmium toxicity, and proteinuria was evident in rats exposed to cadmium at doses as low as 2.15 $mg \cdot kg^{-1}$ bw per day in drinking water (Kotsonis and Klassen 1978). Toxic effects of cadmium probably result when the amount of metallothionein present in the liver is insufficient to bind with absorbed cadmium (Piscator 1964).

Another major source of exposure of the general population to cadmium is tobacco smoking. Body burdens of cadmium are higher in smokers (Health Canada 1996).

Reported oral LD_{50} values in rats for cadmium chloride, cadmium oxide, and cadmium sulphate range from 88 to 357 $mg \cdot kg^{-1}$ bw. By the inhalation route, LC_{50}s for 15-min exposures to cadmium oxide were about 29 mg $Cd \cdot m^{-3}$ for rats.

In the majority of limited studies of populations exposed to cadmium in the environment, there has been no consistent evidence in an increased risk of cancer in general or of specific types of cancer, including cancer of the kidney, urinary tract, bladder, stomach, liver, breast, lung, gastrointestinal tract, or prostate. The limitations of the studies (mostly ecological) conducted to date preclude assessment of the carcinogenicity of cadmium in populations exposed in the general environment. Evidence of other effects in populations exposed to cadmium in the general environment is limited.

The genotoxicity of cadmium compounds has been examined in a large number of studies. Cadmium chloride has been genotoxic in vitro, most consistently manifested as cytogenetic alteration or DNA damage in mammalian cells, including those of humans (USEPA 1985). In most available studies, the fertility of male or female rats or mice was not affected by gestational or subchronic exposure by the oral route to between 1.5 and 10 mg $Cd \cdot kg^{-1}$ bw per day, most often as cadmium chloride (Health Canada 1996). Neurobehavioural development was affected in offspring of female rats following oral administration of as little as 0.04 mg $Cd \cdot kg^{-1}$ bw per day as cadmium chloride (Baranski et al. 1983). There is no convincing evidence of reproductive and developmental effects associated with exposure to cadmium in the workplace (ATSDR 1993).

In humans, the half-life for elimination of cadmium has been estimated to be between 10 and 33 years (Friberg et al. 1974; Shaikh and Smith 1980). Only small proportions of absorbed cadmium is eliminated, mainly in the urine and feces. Negligible amounts are eliminated through hair, nails, and sweat.

Cadmium has been shown to accumulate in organisms. Soil-to-plant BCFs ranging from 1.07 to 15.22 have been calculated for different plant tissues. A soil-to-invertebrate BCF of 8.30 has been calculated for a variety of earthworm species and soil types (Environment Canada 1996).

On the basis principally of results from inhalation studies in animals and supporting documentation on genotoxicity, Government of Canada (1994) classified inorganic cadmium compounds in Group II as "probably carcinogenic to humans", i.e., as substances for which there is believed to be some chance of adverse health effects at any level of exposure. However, there is no evidence that inorganic cadmium compounds are carcinogenic following oral administration and no clear evidence for the genotoxicity of cadmium (Environment Canada 1996).

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 cadmium soil quality guidelines are provided in Environment Canada (1996) and Health Canada (1996).

Soil Quality Guidelines for Environmental Health

Environmental soil quality guidelines (SQG_Es) are based on soil contact using 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. For the soil contact pathway, sufficient data are available to allow use of the preferred weight-of-evidence procedure. 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.

In the case of cadmium, the SQG_E for agricultural land use is based on the soil and food ingestion guideline; for all other land uses it is based on the soil contact guidelines (Table 2).

Soil Quality Guidelines for Human Health

Human health soil quality guidelines (SQG_{HH}s) for threshold contaminants are derived using a TDI for the most sensitive receptor designated for a land use.

The CCME recommends the application of various check mechanisms, when relevant, in order to provide a broader scope of protection. The lowest of the soil ingestion guideline, the inhalation of indoor air check, the off-site migration check, and groundwater for drinking water check is recommended as the SQG_{HH} (Table 2).

Therefore, the SQG_{HH}s for cadmium for agricultural, residential/parkland, and commercial land uses are based on the soil ingestion guidelines. For industrial land use, the SQG_{HH} is based on the off-site migration check (Table 2).

The soil protocol (CCME 1996a) does not explicitly address the uptake of metal contaminants into produce. However, a large body of literature exists to show that cadmium is among the most easily mobilized and assimilated metal contaminants in soil. Dabeka (1995) reported that vegetables, bakery goods, and cereals are the main sources of dietary cadmium exposure for Canadians. Leafy vegetables in particular are known cadmium accumulators. Uptake of cadmium by leafy vegetables as a function of soil pH was summarized by C.C. Ferguson (1994, Nottingham-Trent University, U.K., pers. com.). His analysis indicates that BCFs for these plants may exceed 10 in soils below pH 5.5. Thus, cadmium uptake into produce and subsequent human exposure cannot be ignored in the agricultural guideline. For this reason, a safety factor of 10 was applied to the SQG_{HH} for agricultural land use.

Soil Quality Guidelines for Cadmium

The soil quality guidelines are the lower of the SQG_{HH} and the SQG_E. For agricultural land use, the soil quality guideline for cadmium is the soil concentration for the SQG_{HH}, which is based on soil ingestion. For all other land uses the soil quality guideline is the soil concentration calculated for the SQG_E, which is based on the soil contact guideline (Table 1).

Because there are sufficient data to derive an SQG_{HH} and an SQG_E, for each land use, the soil quality guidelines represent fully integrated de novo guidelines, derived

Table 2. Soil quality guidelines and check values for cadmium (mg·kg^{-1}).

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline	**1.4**[a]	**10**[a, b]	**22**[a]	**22**[a]
Human health guidelines/check values				
SQG_{HH}	1.4[c, d]	14[c]	49[c]	192[c]
Soil ingestion guideline	1.4[d]	14	49	2090
Inhalation of indoor air check	NC[e]	NC[e]	NC[e]	NC[e]
Off-site migration check	—	—	—	192
Groundwater check (drinking water)	NC[f]	NC[f]	NC[f]	NC[f]
Produce, meat, and milk check	NC[g]	NC[g]	—	—
Provisional SQG_{HH}	NC[h]	NC[h]	NC[h]	NC[h]
Limiting pathway for provisional SQG_{HH}	ND	ND	ND	ND
Environmental health guidelines/check values				
SQG_E	3.8[i]	10[j]	22[j]	22[j]
Soil contact guideline	10	10	22	22
Soil and food ingestion guideline	3.8	—	—	—
Nutrient and energy cycling check	54	54	195	195
Off-site migration check	—	—	—	132
Groundwater check (aquatic life)	NC[f]	NC[f]	NC[f]	NC[f]
Provisional SQG_E	NC[k]	NC[k]	NC[k]	NC[k]
Limiting pathway for provisional SQG_E	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	3	5	20	20

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 a guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.

[a]Data are sufficient and adequate to calculate an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully integrated de novo guideline for this land use, derived in accordance with the soil protocol (CCME 1996a). The corresponding interim soil quality criterion (CCME 1991) is superseded by the soil quality guideline.

[b]The soil–plant–human pathway is not considered in this guideline. If produce gardens are present or planned, a site-specific objective must be derived to take into account the bioaccumulation potential (e.g., adopt the agricultural guideline as objective). The off-site migration check should be recalculated accordingly.

[c]The SQG_{HH} is the lowest of the human health guidelines and check values.

[d]The soil–plant–human pathway is considered in this guideline.

[e]Applies only to volatile organic compounds and is not calculated for metal contaminants.

[f]Applies to organic compounds and is not calculated for metal contaminants. Concerns about metal contaminants should be addressed on a site-specific basis.

[g]Applies to nonpolar organic compounds and is not calculated for metal contaminants. Concerns about metal contaminants should be addressed on a site-specific basis.

[h]Because data are sufficient and adequate to calculate an SQG_{HH} for this land use, a provisional SQG_{HH} is not calculated.

[i]The SQG_E is based on the soil and food ingestion guideline.

[j]The SQG_E is based on the soil contact guideline.

[k]Because data are sufficient and adequate to calculate an SQG_E for this land use, a provisional SQG_E is not calculated.

according to the soil protocol (CCME 1996b). The interim soil quality criteria (CCME 1991) for cadmium are superseded by the soil quality guidelines.

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

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