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

CADMIUM

20XX

This fact sheet provides Canadian soil quality guidelines (CSoQGs) for cadmium for the protection of environmental and human health (Table 1). A supporting scientific document is also available (Canadian Council of Ministers of the Environment [CCME] 20XX).

Background Information

Cadmium (CAS 7440-43-9) is a silver-white, blue-tinged, lustrous metal. It is a relatively rare element, seldom found as a pure mineral in nature, where it occurs as a divalent cation (Cd^{2+}). Cadmium has an atomic weight of 112.40 g/mol and 1.4 mmHg vapour pressure. With a boiling point of 765°C, it is unlikely to volatilize, except under extreme conditions (e.g., volcanoes, forest fires) (Eisler 1985). Elemental cadmium is insoluble in water, whereas the solubilities of cadmium salts vary from insoluble to ≥1000 mg/L (Lide *et al*. 1992).

Cadmium is a by-product of the metal industry, where it 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 and the production of other metals, such as lead and copper (Brown 1977). Some 10 to 25% of the western world's cadmium production now comes from recycled batteries and from residues or intermediate products (Natural Resources Canada [NRCan] 2009; United States Geological Survey [USGS] 2013). Canada ranks among the top five producers of refined cadmium in the world, with an estimated output of approximately 55 metric tonnes in 2016 (NRCan 2016).

Cadmium has a low melting point, excellent electrical conductivity, and no definite odour or taste. Compounds containing cadmium exhibit excellent resistance to chemicals and to high temperatures (International Cadmium Association [ICdA] 2004). Cadmium pigments produce intense colourings such as yellow, orange and red.

About 86% of total consumption of cadmium in 2013 was for batteries, 9% for pigments, 4% for coatings and plating, and 1% for other uses, including alloys, stabilizers and solar cells (USGS 2015). Domestic industrial consumption in Canada increased steadily between 1990 and 2001 and remained relatively stable thereafter (207.9 and 204.5 tonnes in 2006 and 2007, respectively) (NRCan 2009). Cadmium may also be present in fertilizers as the result of the recycling of by-products and waste materials into soil amendments for land application as fertilizers and supplements. Agriculture and Agri-Food Canada has set a Maximum Acceptable Cumulative Metal Addition to Soil for cadmium at 4 kg/ha over a 45-year period (Agriculture and Agri-Food Canada 2017). In the past, cadmium was a registered ingredient in some turf fungicides

(International Veterinary Information Service [IVIS] 1999); however, a search of Pesticides Management Regulatory Agency (PMRA)-controlled products did not identify any products containing cadmium or cadmium compounds (Health Canada [HC] 2015).

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

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline (SoQG)[a]	**3.8**	**10**	**20**	**22**
$SoQG_{HH}$[b]	13	13	20	180
$SoQG_{E}$[c]	3.8	10	22	22

Notes: $SoQG_{HH}$ = soil quality guideline for human health; $SoQG_{E}$ = soil quality guideline for environmental health. Soil guidelines and the data used to calculate them are, by convention, always expressed on a dry weight basis to allow the data to be standardized. In case of doubt and if the scientific criteria document does not specify whether wet or dry weight is used, readers are advised to check the references provided.

[a] The soil quality guideline (SoQG) is the lower of the 2023 $SoQG_{HH}$ and the 1999 $SoQG_{E}$ for the given land use.

[b] Data are sufficient and adequate to calculate an $SoQG_{HH}$.

The $SoQG_{E}$ is the 1999 value (CCME 1999). The $SoQG_{E}$ is not updated in this current revision.

While no single soil concentration can adequately represent the variance across Canada, it is essential to define a reasonable value for the purpose of generic guideline development. Using an extensive dataset of soil samples (<63 µm size fraction from till; n = 14,812) collected from across Canada (Grunsky 2010a; b; c), a mean background cadmium concentration of 0.24 mg/kg in Canadian soils was identified (HC 2011). Much higher concentrations of cadmium in soils have been reported near industrial plants and urban areas, especially near copper and zinc production facilities, smelters and sewage sludge disposal areas, and as the result of the combustion of fossil fuels and the weathering of galvanized metals (Environment Canada [EC]/HC 2001).

National Atmospheric Pollutant Surveillance Program (NAPS) data from 2003 to 2009 (5.73×10^{-7} - 1.85×10^{-2} µg/m^3; arithmetic mean = 0.15 ± 0.42 ng/m^3) (EC 2010) were used to develop the ambient air inhalation component of the estimated daily intakes (EDIs) for cadmium for the Canadian population (HC 2011). This data set represented the best and most comprehensive data available for Canada at that time.

The overall mean cadmium concentration in Canadian drinking water supplies was estimated to be 0.165 ± 1.6 µg/L (arithmetic mean, n = 15,546) based on data obtained from the Ontario Ministry of Environment (1998–2007), Saskatchewan Ministry of Environment (2000–2009) and Department of Environment and Conservation, Government of Newfoundland and Labrador (2000–2009) (HC 2011).

Results of the Total Diet Study (TDS) (2000–2007) indicate that most foodstuffs consumed in Canada contain cadmium (Dabeka *et al*. 2010). Cadmium intake via food represents the highest contributing source to total cadmium exposure in Canada (HC 2011). Mean estimated daily intakes (EDI) of cadmium from food ranged from 0.18 to 0.49 µg/kg/day (HC 2011).

CCME (20XX) provides data on additional environmental media that are not included in CSoQG derivation (e.g., groundwater, dust, sediment).

Environmental Fate and Behaviour in Soil

Cadmium exists in two oxidation states in nature (0 and 2^+); however, the 0, or metallic state, is rare (National Research Council of Canada [NRCC] 1979). A variety of factors influence the mobility of cadmium in soils, with pH and soil type among the most influential. Processes including eolian transport (wind erosion), fluvial transport, leaching and uptake by terrestrial organisms also have the potential to affect the fate of cadmium in soils.

As with most metals, cadmium mobility decreases linearly as pH increases and cadmium is adsorbed or forms complexes (Agency for Toxic Substances and Disease Registry [ATSDR] 2008; Suen-Zone *et al*. 1996). Soil type—including particle size, organic matter content and the presence of metal oxides, hydroxides and oxyhydroxides—also contributes to cadmium partitioning between the dissolved and bound phases in soil. Generally, soil concentrations increase as particle size decreases (Rasmussen 2004; Rasmussen and Hughes 2002). Manganese and iron oxides play a role in reducing cadmium mobility (Benjamin and Leckie 1981; Bruemmer *et al.* 1988; Fu *et al.* 1991; Rieuwerts *et al.* 1998).

Organic matter in soils can immobilize cadmium in soils (Blume and Brummer 1991; Liu *et al.* 2007; Suen-Zone *et al*. 1996) due to its higher sorption characteristics than clay minerals (Prokop *et al.* 2003). However, cadmium can form soluble complexes with inorganic ions (in particular with chloride ions) and organic ligands. These complexes tend to increase cadmium mobility in soils and pose a risk to groundwater (Bollag and Czaban 1989; Christensen 1989; McLean and Bledsoe 1992; Singh 1990).

Microorganisms may have either an inhibitory or a stimulatory effect on the mobility of cadmium in soil depending on whether they degrade metal sulphides or chelate them (Bollag and Czaban 1989; Cole 1979).

Behaviour and Effects in Biota

This section is based on the information presented by CCME (1999), as the CSoQGs for the protection of ecological health were not updated.

Soil Microbial Processes

Reduced population sizes of bacteria and fungi were observed in soils containing as little as 2.9 mg Cd/kg (Kobus and Kurek 1990; Naidu and Reddy 1988). At 5 mg Cd/kg soil, nitrogen mineralization was reduced by 17 to 39% (Liang and Tabatabai 1977). A 60% reduction in nitrification was observed at 1,000 mg/kg, and carbon dioxide evolution in was reduced by 17 to 47% at soil cadmium concentrations ranging from 10 to 8,000 mg/kg (Bewley and Stotzky 1983; Cornfield 1977; Doelman and Haanstra 1984; Lighthart *et al*. 1983).

Terrestrial Plants

In general, plant uptake of cadmium from soils relies partly on soil characteristics such as soil type (Liu *et al*. 2007; Shentu *et al*. 2008), pH, organic matter content, cation exchange capacity (Liu *et al*. 2007), and nutrient status of the soil (Podar and Ramsey 2005; Sun *et al*. 2007). Translocation of cadmium is not universal among plants, and research has shown cadmium accumulation in the roots of some plants (Carlson and Ragsdale 1988; Mench *et al*. 1989) and in the leaves of others (Boon and Soltanpour 1992; Kim *et al*. 1988).

Environment Canada has calculated soil-to-plant bioconcentration factors (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 (Bache and Lisk 1990; Burton and Morgan 1984; Kelly *et al.* 1979; Kim *et al.* 1988; Wadge and Hutton 1986). However, using the geometric mean of all the BCFs for those plant tissues, an overall BCF value of 2.65 can be calculated (EC 1999).

The lowest soil cadmium concentrations at which phytotoxic effects were observed are 2.5 and 4 mg/kg, which resulted in a 21 and 14% yield reduction of wheat and soybeans, respectively (Haghiri 1973), a 25% yield reduction in spinach (Bingham *et al*. 1975) and a 28% growth reduction in corn (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/kg. Fifty percent reductions in growth endpoints occurred at concentrations ranging from 16 to 205 mg/kg.

Terrestrial Invertebrates

Lethal dose 50% (LD_{50}) values for earthworms (*Eisenia foetida*) range from 253 to 1,843 mg/kg (Neuhauser *et al*. 1985; van Gestel *et al*. 1991). For collembolans, the LD_{50} values range from 778 to 893 mg/kg (Crommentuijn *et al*. 1993). The more sensitive endpoints of earthworm cocoon production, growth and sexual development were reduced by 50% at 46, 33 and 27 mg/kg respectively (Spurgeon *et al*. 1994; van Gestel *et al*. 1991).

Livestock and Wildlife

Under most circumstances, ingestion is the most important exposure route. Adverse effects of cadmium ingestion have been observed in various mammals and bird species at levels ranging from 15 to 1350 mg/kg body weight (bw) (EC 1996). Observed effects include the reduction of food intake and growth rate, impaired reproduction and mortality. Effects in livestock range from a 21% decrease in weight gain in lambs at 4.56 mg/kg/day to a 96% decrease in weight gain in pigs at 140 mg/kg/day (Cousins *et al*. 1973; Doyle *et al*. 1974).

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Bioaccumulation and Bioconcentration

Plant uptake of cadmium from soils relies partly on soil characteristics such as soil type, pH, organic matter content, cation exchange capacity and soil nutrient status (Liu *et al*. 2007; Millennium 2013; Podar and Ramsey 2005; Shentu *et al*. 2008; Sun *et al*. 2007). Evidence suggests that plant uptake of cadmium decreases with increasing pH from acid to neutral (pH 1–7) in soils but is unchanged or increases in alkaline soils (pH >7) (Bolan *et al*. 2003; Podar and Ramsey 2005) in the presence of increased cadmium in soil solution (Tyler and Olsson 2001).

The soil quality guidelines protocol (CCME 2006) 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. There is considerable variation in accumulation across plant species and tissue types. For plants with low moisture content at harvest, such as grains and seeds, cadmium concentrations were increased relative to the wet weight correction of other foods (Millennium 2013). Young, leafy plants with high transpiration rates tend to have higher cadmium uptake values than other plant tissues with high available moisture (Millennium 2013).

Many studies have indicated that earthworms in contaminated soils take up and accumulate cadmium in their tissues (Hartenstein *et al*. 1981; Kruse and Barrett 1985; Pietz *et al*. 1984; Simmers *et al*. 1983). 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.

In mammals and birds, cadmium absorption after oral exposure is influenced by many factors including dose, age, diet and the presence of other substances, such as calcium (United States Environmental Protection Agency [US EPA] 1988). Long-lived ungulates can accumulate significant levels of cadmium, generally increasing in concentration with animal age, especially in the liver and kidneys (Danielsson and Frank 2008; Frøslie *et al*. 1986). Animals have a limited capability to eliminate assimilated cadmium (Health and Welfare Canada [HWC] 1986). Millennium (2013) identified BCF values for domestic animals (i.e., cows, sheep and chickens). Dairy products had lower biotransfer factors than meat (organs) and plants, with milk having lower biotransfer factors than cream, butter and buttermilk (Hayashi *et al*. 1982; Mehennaoui *et al*. 1999). Caution should be used when applying meat transfer coefficients to kidney and liver tissue estimates as they were shown to under-predict tissue concentrations (California Environmental Protection Agency's Office of Environmental and Health Hazard Assessment [OEHHA] 2012; Waegeneers *et al*. 2011).

Health Effects in Humans and Experimental Animals

Results from investigations into non-cancer effects conducted in experimental animals indicate that exposure to cadmium is associated with a variety of effects including kidney, bone and liver injury as well as effects on reproduction and development. Pulmonary inflammation and tissue degeneration have been observed in inhalation experiments. Investigations conducted in occupationally or environmentally exposed humans have extensively documented effects in the renal and skeletal tissues, with some recent studies suggestive of adverse health effects on other organ systems as well (CCME 20XX).

Experimental animal studies have identified cadmium as a multi-route (oral, inhalation, parenteral), multi-site and multi-species (mice, hamster, rats) carcinogen. In addition, occupational studies indicate that cadmium is carcinogenic to humans by inhalation (HC 2020). The intracellular mechanisms thought to be involved in cadmium-induced toxicity are both broad and complex and have been the subject of several literature reviews (Cuypers *et al*. 2010; Moulis 2010; Thévenod 2010; Van Kerkhove *et al*. 2010).

Diet is the main source of exposure to cadmium within the general (non-smoking) population (ATSDR 2012; Olsson *et al.* 2002). Absorption is influenced by several physiological factors (e.g., age, nutritional status) and diet (e.g., fibre level, type of food) (Ruoff *et al*. 1994). Gastrointestinal absorption of soil-adsorbed cadmium is lower than for cadmium in solution (Schilderman *et al*. 1997). Age decreases apparent absorption (Eklund *et al*. 2001; Horiguchi *et al*. 2004), with absorption rates higher in neonates or young rodents than in adults (Nordberg *et al*. 1985; Sasser and Jarboe 1980). Particle size governs the fate and disposition of inhaled cadmium; larger particles (>10 µm in diameter) are deposited in the upper airways whereas smaller particles (~0.1 µm) can penetrate into alveoli, where the majority of absorption occurs (ATSDR 2012). Dermal absorption is a slow process and would be of concern only in situations where concentrated solutions would be in contact with the skin for prolonged periods of time (ATSDR 2012).

Once absorbed, cadmium is transported by red blood cells and plasma. Cadmium is usually bound to metallothionein (MT) (in the liver) or to other sulfhydryl-rich proteins, peptides or amino acids (Goyer 1991; Zalups and Ahmad 2003). Higher concentrations can initially be found in the liver but redistribution to the kidneys occurs over time (HC 2020; Massányi *et al.* 1995a; b) and was detected in virtually all tissues in post-mortem (Joint Food and Agriculture Organization [FAO]/World Health Organization [WHO] Expert Committee on Food Additives [JECFA] 2011). A human milk-to-plasma ratio of 3:4 indicates an apparent absence of a transfer barrier (Kippler *et al.* 2009).

Cadmium is not metabolized in the human body (HC 2020). Absorbed cadmium is excreted in very small amounts equally in feces and urine (ATSDR 2008; Nordberg *et al*. 2007). The biological half-life of cadmium ranges from several months to years in experimental animals and 10 to 30 years in humans (Kjellström and Nordberg 1978; Nordberg *et al*. 2007).

Numerous subchronic and some chronic studies have examined the systemic, immunological, neurological, reproductive and developmental effects of subchronic cadmium oral exposure in experimental animals (ATSDR 2012; JECFA 2001; WHO 1992). The most sensitive targets of cadmium toxicity appear to be the kidneys and skeletal system, while pulmonary effects from subchronic inhalation exposures at higher doses include immunological responses, tissue damage and increased relative lung weight (ATSDR 2012; Glaser *et al.* 1986; Kutzman *et al*. 1986; National Toxicology Program [NTP] 1995; Prigge 1978).

Cadmium-induced kidney and skeletal toxicity have also been documented in numerous epidemiological studies, which are thoroughly reviewed and summarized by ATSDR (2012), European Food Safety Authority (EFSA) (2009), JECFA (2001; 2004a; b; 2011) and Nordberg *et al*. (2008).

Several studies have also evaluated the possible association between occupational exposure and carcinogenicity (Huff *et al.* 2007; International Agency for Research on Cancer [IARC] 2012; 1993; Lemen *et al.* 1976; Stayner *et al.* 1992a; b; Thun *et al.* 1985). In spite of confounding factors, there is some evidence that prolonged inhalation exposure increased lung and prostate cancer-related mortality (IARC 1993; 2012; Stayner *et al.* 1993).

Several agencies have developed toxicological reference values (TRV). The oral tolerable daily intake (TDI) of 0.8 µg/kg bw/day, as proposed by HC (2020; 2021), was selected for the development of soil quality guidelines for the protection of human health (SQG_{HH}) for oral, inhalation and dermal exposures. This chronic TDI is based on JECFA (2011) for threshold effects from oral exposure. For non-threshold effects, the inhalation unit risk (0.0042 $(\mu g/m^3)^{-1}$) proposed by HC (2021) and the California Environmental Protection Agency (CalEPA) (2009) for inhalation exposures only was adopted.

Guideline Derivation

CSoQGs for different land uses are derived following the process outlined in CCME (2006). Different receptors and exposure scenarios are defined for each land use (CCME 2006). Detailed derivations for the soil quality guidelines for cadmium are provided in the scientific criteria document (CCME 20XX).

Soil Quality Guidelines for Environmental Health

The following information is extracted from CCME (1999).

Soil quality guidelines for the protection of environmental health ($SoQG_E$) are based on soil contact using data from toxicity studies in 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 the use of the preferred weight-of-evidence procedure. To provide a broader scope of protection, a nutrient and energy cycling check is calculated where data permit. 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 adopted as the SoQG 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 SoQG 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 $SoQG_{E}$.

For residential/parkland and commercial land uses, the soil quality guideline for soil contact is recommended as the $SoQG_{E}$.

For industrial land use, the lower of the soil quality guideline for soil contact and the off-site migration check is recommended as the $SoQG_{E}$.

In the case of cadmium, the $SoQG_{E}$ 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

The human-health-based soil quality guidelines for direct contact ($SoQG_{DH}$) (threshold effects) for cadmium in agricultural, residential/parkland, commercial and industrial land uses are based on three combined exposure pathways (ingestion, inhalation and dermal). Guidelines for non-threshold effects are derived for the inhalation pathway only. A toddler receptor was used in the calculation of the $SoQG_{DH}$ for agricultural, residential/parkland and commercial land uses for threshold effects. An adult receptor was used to derive the $SoQG_{DH}$ for industrial land use for threshold effects and for all land uses for non-threshold effects.

For the purpose of deriving the soil quality guidelines for the protection of human health ($SoQG_{HH}$), oral and inhalation relative bioavailability (RBA) were conservatively set at one (1), while the dermal relative absorption factor (RAF) was set at 0.01, based on OMOE (2009).

For the purpose of derivation of soil quality guidelines for the general Canadian population, a background soil concentration of cadmium of 0.24 mg/kg was considered a reasonable value based on available data. Although localized areas within Canada may have different background concentrations of cadmium, the SQG_{HH} developed for cadmium should be protective in most circumstances. For specific locations with unusually high natural background concentrations the development of site-specific guidelines or comparison to regional background may be considered.

A mathematical rearrangement of the CCME (2006) equation for estimation of soil quality guidelines for non-threshold effects, when the cancer potency factor is expressed as an inhalation unit risk factor, was used to calculate the soil quality guideline for direct contact for particulate inhalation ($SoQG_{DH\text{-}PI}$).

CCME recommends the application of various check mechanisms (i.e., SoQGs for indirect exposure or check values), when relevant, in order to provide a broader scope of protection. The lowest of the $SoQG_{DH}$ or applicable check mechanism values (SoQG for the protection of inhalation of indoor air, SoQG for the protection of groundwater used for drinking, off-site migration check, and produce meat and milk check) is recommended as the soil quality guideline for the protection of human health ($SoQG_{HH}$).

No inhalation of indoor air value was derived as cadmium is not considered volatile. No guideline for the protection of groundwater used as a source of raw water for drinking was derived for inorganic cadmium compounds due to constraints on the mathematical model when applied to inorganic compounds (CCME 2006). Transfers of contaminated soil from one property to another are possible by means of wind and water erosion (CCME 2006). An off-site migration check was carried out to estimate the transfer of soil from one property to another. No produce, meat and milk check was considered due to high variability in many of the modelled parameters, which resulted in unrealistically low values with high uncertainty.

The $SoQG_{HH}$ for cadmium in agricultural, residential/parkland and commercial land uses is based on the $SoQG_{DH}$ (threshold effects). For industrial land use, the $SoQG_{HH}$ is based on the soil quality guideline for off-site migration (SQG_{OM-HH}).

Background concentrations of cadmium in drinking water, air, dust and soil contribute relatively small amounts to the cadmium EDI, such that variations in the assumed average Canadian concentrations will typically only have a minor impact on the EDI and SQG_{HH}. Cadmium intake via food represents the highest contributing source to total cadmium exposure in Canada. At sites where appreciable amounts of garden produce are consumed, a lower SQG_{HH} may be required for consideration. Drinking water consumption was not evaluated in the development of the SQG_{HH}. It may be necessary to consider alternative limits to daily intake at sites where drinking water is sourced from nearby wells.

Soil Quality Guidelines for Cadmium

The SoQGs are intended to be protective of both environmental and human health and are taken as the lower of the $SoQG_{HH}$ and the $SoQG_{E}$.

The $SoQG_{HH}$s represent fully integrated *de novo* guidelines, derived according to the soil protocol (CCME 2006). The interim soil quality criteria (CCME 1991) for cadmium for the protection of human health are superseded by these soil quality guidelines.

The $SoQG_{E}$s from CCME (1999) have not been updated and are therefore adopted herein.

CCME (2006) provides guidance on potential modifications to the final recommended soil quality guidelines when setting site-specific objectives.

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

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline (SoQG)	**3.8**	**10**	**20**	**22**
Human health guidelines or check values				
$SoQG_{HH}$[a,b,c]	13	13	20	180
Direct contact $SoQG_{DH}$ (threshold)	13	13	20	630
Direct contact $SoQG_{DH}$ (non-threshold):				
Incremental target risk level = 10^{-5}	3000	3000	3000	3000
Incremental target risk level = 10^{-6}	300	300	300	300
Inhalation of indoor air check[d]	NC	NC	NC	NC
Off-site migration check	NC	NC	NC	180
Groundwater check (drinking water)[e]	NC	NC	NC	NC
Produce, meat and milk check[f]	NC	NC	NC	NC
1999 environmental health guidelines or check values (CCME 1999)				
$SoQG_E$[a]	3.8[g]	10[h]	22[h]	22[h]
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[e]	NC[e]	NC[e]	NC[e]

Notes: NC = not calculated. The dash indicates a guideline or check value that is not part of the exposure scenario for this land use and therefore is not calculated. Soil guidelines and the data used to calculate them are, by convention, always expressed on a dry weight basis to allow the data to be standardized. In case of doubt and if the scientific criteria document does not specify whether wet or dry weight is used, readers are advised to check the references provided.

[a] Data are sufficient and adequate to calculate an updated $SoQG_{HH}$. Data were sufficient and adequate to calculate an $SoQG_E$ (CCME 1999), which is included here to allow for the selection of final SoQGs for each land use.

[b] The $SoQG_{HH}$ is the lowest of the human health guidelines and check values.

[c] The $SoQG_{HH}$ is based on direct exposure to soil ingestion, dermal contact and particulate inhalation (agricultural, residential/park and commercial land uses) and the off-site migration check value (industrial land uses).

[d] The "inhalation of indoor air" check applies to volatile organic compounds and is not calculated for non-volatile contaminants.

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

[f] This check is intended to protect against chemicals that may biomagnify in human food. Variability in model parameters was high and resulting check values were excessively low (µg/kg) and therefore unreasonable and unworkable, as required for application as SoQGs. This pathway should be assessed on a site-specific basis, as applicable.

[g] The $SoQG_E$ is based on the soil and food ingestion guideline.

[h] The $SoQG_E$ is based on the soil contact guideline.

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