Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

CADMIUM

Cadmium may be present in natural waters as hydrated ions, chloride salts, complexed with inorganic ligands, or chelated to form complexes with organic ligands. Soils may contain various components, such as mixed hydroxides, oxides, silicates, and sulphides, that can complex with cadmium and influence its fate in water. Adsorption and ion exchange can occur with clay, silica, or organic matter, as cadmium has a high affinity for negatively charged particle surfaces. Consequently, cadmium tends to be removed rapidly from solution and accumulate in soils or sediments. Changes in environmental conditions, however, such as reduced pH, changes in redox status (e.g., due to spring and fall turnover), and biological and chemical oxidation of organic matter, have the potential to remobilize and transport cadmium to other compartments of the ecosystem.

For more information on the use, environmental concentrations, and chemical properties of cadmium, see the fact sheet on cadmium in Chapter 4 of *Canadian Environmental Quality Guidelines*.

Water Quality Guideline Derivation

The Canadian water quality guidelines for cadmium for the protection of agricultural water uses were developed based on the CCME protocol (CCME 1993).

Irrigation Water

A water quality guideline for cadmium of 5.1 $\mu g{\cdot}L^{-1}$ in irrigation water is recommended for the protection of agricultural crop species (CCME 1996). Data on the toxicity of cadmium to agricultural crops were available for 11 species from five plant families ranging from 1.8 to 16 $mg{\cdot}kg^{-1}$ (Environment Canada 1994). Chronic data on four crop species within the grain family (Graminae) indicate that this group of plants is very sensitive to cadmium.

The acceptable soil concentration (ASC) is calculated as the geometric mean of the lowest quantifiable LOEL for crop plants (2.0 $mg{\cdot}kg^{-1}$) resulting in a significantly reduced yield (20%) in rye *(Lolium perenne)* (Coppola et al. 1988) and the estimated corresponding NOEL of 0.44 $mg{\cdot}kg^{-1}$ (NOEL = LOEL ÷ 4.5), and dividing by an uncertainty factor of 10 (CCME 1993). This ASC of 0.094 $mg{\cdot}kg^{-1}$ was then multiplied by the soil mass within 1 ha (soil bulk density 1300 $kg{\cdot}m^{3}$) × (soil bulk volume to a depth of 5 cm [i.e., 100 × 100 × 0.05 m]) to calculate the allowable mass of cadmium in soil. A depth of 5 cm was chosen, since most of the cadmium (>95%) remains in surface soils for several years with only minor leaching occurring. The contaminant mass was then divided by the maximum irrigation rate (1.2×10^{7} $L{\cdot}ha^{-1}$ per year) to give the SMATC of 0.0051 $mg{\cdot}L^{-1}$ (i.e., 5.1 $\mu g{\cdot}L^{-1}$) in irrigation water (CCME 1996).

Livestock Water

The recommended water quality guideline for cadmium for the protection of livestock is 80 $\mu g{\cdot}L^{-1}$ (CCME 1996). Data were available for five avian species, including two livestock species (Environment Canada 1994). Egg production, the most sensitive endpoint, was significantly reduced by 39% in domestic chickens after receiving a cadmium dose of 2.19 $mg{\cdot}kg^{-1}$ bw per day (Leach et al. 1979). Similar reductions in egg production by domestic chickens were reported at cadmium doses of 2.28–2.4 $mg{\cdot}kg^{-1}$ bw per day (Anke et al. 1970; Sell 1975). Data were available for 10 mammalian species, including four livestock species (Environment Canada 1994). The most sensitive livestock mammal was the sheep. Reduced body weight gain (20%) in sheep, the most sensitive endpoint, was reported after an oral cadmium dose of 1.87 $mg{\cdot}kg^{-1}$ bw per day (Doyle et al. 1974). Similar reductions (30%) were reported for Holstein and Jersey cattle at a dose of 2.88 $mg{\cdot}kg^{-1}$ bw per day (Powell et al. 1964).

Table 1. Water quality guidelines for cadmium for the protection of agricultural water uses (CCME 1996).

Use	Guideline value ($\mu g{\cdot}L^{-1}$)
Irrigation water	5.1*
Livestock water	80

*Crop-specific based on sensitivity.

The TDI for each species is calculated as the geometric mean of the NOAEL and LOAEL divided by an uncertainty factor of 10. The most sensitive avian TDI was 0.11 $mg·kg^{-1}$ per day based on the white leghorn chicken (NOAEL of 0.55 $mg·kg^{-1}$ bw per day, LOAEL of 2.19 $mg·kg^{-1}$ per day). The most sensitive mammalian TDI was 0.13 $mg·kg^{-1}$ per day, based on sheep (NOAEL of 0.92 $mg·kg^{-1}$ bw per day, LOAEL of 1.87 $mg·kg^{-1}$ bw per day). Multiplying these TDIs by the ratio of the animal body weight to water intake yielded the respective RCs. The lowest RC was calculated to be 0.41 $mg·L^{-1}$ from the TDI for the white leghorn chicken (body weight of 2.3 kg, water intake of 0.61 $L·d^{-1}$). To account for exposure to cadmium from sources other than water, the lowest RC is multiplied by an apportionment factor of 0.2, to give a water quality guideline of 80 $\mu g·L^{-1}$ for the protection of livestock.

References

Anke, M., A. Hennig, H.J. Schneider, H. Leudke, W. Von Gagern, and G. Schlegel. 1970. The interrelations between cadmium, zinc, copper and iron in metabolism of hens, ruminants and man. In: Trace element metabolism in animals, C.F. Millsand and S. Livingstone, eds. Proc. WAAP/IBP International Symposium, Aberdeen, Scotland, July 1969. Livingston, Edinburgh.

CCME (Canadian Council of Ministers of the Environment). 1993. Appendix XV—Protocols for deriving water quality guidelines for the protection of agricultural water uses (October 1993). In: Canadian water quality guidelines, Canadian Council of Resource and Environment Ministers. 1987. Prepared by the Task Force on Water Quality Guidelines. [Updated and reprinted with minor revisions and editorial changes in Canadian environmental quality guidelines, Chapter 5, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]

———. 1996. Appendix XXI—Canadian water quality guidelines: Updates (May 1996), cadmium. In: Canadian water quality guidelines, Canadian Council of Resource and Environment Ministers. 1987. Prepared by the Task Force on Water Quality Guidelines.

CCREM 1987 (Canadian Council of Resource and Environment Ministers). 1987. Canadian water quality guidelines. Prepared by the Task Force on Water Quality Guidelines.

Coppola, S., S. Dumontet, M. Pontonio, G. Basile, and P. Marino. 1988. Effect of cadmium-bearing sewage sludge on crop plants and microorganisms in two different soils. Agric. Ecosyst. Environ. 20:181–194.

Doyle, J.J., W.H. Pfander, S.E. Grebing, and J.O. Pierce II. 1974. Effect of dietary cadmium on growth, cadmium absorption and cadmium tissue levels in growing lambs. J. Nutr. 104:160–164.

Environment Canada. 1994. Cadmium and its compounds. Canadian Environmental Protection Act Priority Substances List Supporting Document. Ecosystem Sciences and Evaluation Directorate, Ottawa.

Leach, R.M., K.W. Wang, and D.E. Baker. 1979. Cadmium and the food chain: The effect of dietary cadmium on tissue composition in chicks and laying hens. J. Nutr. 109:437–443.

Powell, G.W., W.J. Miller, J.D. Morton, and F.M. Clifton. 1964. Influence of dietary cadmium level and supplemental zinc and cadmium toxicity in the bovine. J. Nutr. 84:205–214.

Sell, J.L. 1975. Cadmium and the laying hen: Apparent absorption, tissue distribution, and virtual absence of transfer to eggs. Poult. Sci. 54:1674–1678.

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of agricultural water uses: Cadmium. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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