Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

CHROMIUM

hexavalent chromium
trivalent chromium

Canada has large chromite ($FeCr_2O_4$) ore deposits in Quebec, Ontario, British Columbia, and Newfoundland. However, they are of low and medium grade, and Canada is not a chromite-producing country (Nriagu 1988).

Natural content of chromium in Canadian soils ranges between 10 and 100 $mg \cdot kg^{-1}$. The Cordilleran region has soils with an average concentration of 78 $mg \cdot kg^{-1}$; the St. Lawrence Lowlands, 51 $mg \cdot kg^{-1}$; the Interior Plains, 38 $mg \cdot kg^{-1}$; the Appalachian, 30 $mg \cdot kg^{-1}$; and the Canadian Shield, 19 $mg \cdot kg^{-1}$ (McKeague and Wolynetz 1980). Anthropogenic emissions can increase these background concentrations considerably, e.g., to 5000 $mg \cdot kg^{-1}$ in Atlantic Canada, to 1000 $mg \cdot kg^{-1}$ in Newfoundland, and to 718 $mg \cdot kg^{-1}$ (background approximately 30 $mg \cdot kg^{-1}$) and 243 $mg \cdot kg^{-1}$ (background approximately 10 $mg \cdot kg^{-1}$) in Manitoba (Pawlisz et al. 1997).

Concentrations of chromium in plants grown on uncontaminated soils are usually below 1.0 $mg \cdot kg^{-1}$ (Lepp 1992). Concentrations depend on the plant species and the soil type. Plants grown on soils derived from ultramafic rocks have 2–36 times more chromium than plants grown on silicic or calcareous soils (Dowdy and Larson 1975). Vegetation in polluted areas can experience elevated levels of chromium. For example, near a coal generating station in Battle River, Alberta, vegetation contained 2–16 $mg \cdot kg^{-1}$ of chromium, while the surface soil contained 24–32 $mg \cdot kg^{-1}$ (Van Voris et al. 1985). Chromium does not seem to accumulate in fish, and chromium body burdens remain low even in contaminated water (0.03–1.6 $mg \cdot kg^{-1}$ dw) (Pawlisz et al. 1997).

For more information on the use, environmental concentrations, and chemical properties of chromium, see the fact sheet on chromium in Chapter 4 of *Canadian Environmental Quality Guidelines*, the supporting document (Environment Canada 1997), and a recent review article by Pawlisz et al. (1997).

Water Quality Guideline Derivation

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

Irrigation Water

Hexavalent Chromium

A water quality guideline for hexavalent chromium of 8.0 $\mu g \cdot L^{-1}$ in irrigation water is recommended for the protection of agricultural crop species.

Toxicity data for several plant species, including lettuce *(Lactuca sativa)*, sage *(Salvia sclarea)*, peas *(Pisum sativum)*, turnips *(Brassica rapa)*, oats *(Avena sativa)*, maize *(Zea mays)*, wheat *(Triticum aestivum)*, barley *(Hordeum vulgare)*, onions *(Allium cepa)*, and rye grass *(Lolium perenne)* are available. The toxic effects include those on growth at 0.16 $mg \cdot L^{-1}$ (lettuce), germination at 1.0 $mg \cdot L^{-1}$ (lettuce), photosynthesis at 2.5 $mg \cdot L^{-1}$ (peas), and survival at 10 $mg \cdot L^{-1}$ (rye grass) (Pawlisz et al. 1997).

There were sufficient data to derive a full irrigation guideline for hexavalent chromium. The SMATC (the geometric average of the LOEC and the NOEC divided by the uncertainty factor of 10) was calculated for each crop species for which adequate data were available (CCME 1993). The most sensitive plant is lettuce *(L. sativa)*, with a 2-week EC_{50} (reduction in growth) of 0.16 $mg \cdot L^{-1}$ and a NOEC of 0.04 $mg \cdot L^{-1}$ (Adema and Henzen 1989). The resulting SMATC of 8.0 $\mu g \cdot L^{-1}$ (0.0080 $mg \cdot L^{-1}$) is recommended as the guideline for the protection of water used for irrigation of crops against the adverse effects of hexavalent chromium.

Trivalent Chromium

An interim water quality guideline for trivalent chromium of 4.9 $\mu g \cdot L^{-1}$ in irrigation water is recommended for the protection of agricultural crop species.

Table 1. Water quality guidelines for chromium for the protection of agricultural water uses (Environment Canada 1997).

Use		Guideline value ($\mu g \cdot L^{-1}$)
Irrigation water	Cr(VI)	8.0
	Cr(III)	4.9*
Livestock water	Cr(VI)	50*
	Cr(III)	50*

*Interim guideline.

Toxicity data for several crop species, including oats *(A. sativa)*, wheat *(T. aestivum)*, corn *(Z. mays)*, rye grass *(L. perenne)*, and tomatoes *(Lycopersicon esculentum)* are available. The toxic effects include reduced growth at 0.104 mg·L^{-1} (oats) and 1.25 mg·L^{-1} (wheat), and mortality at 10 mg·L^{-1} (rye grass) (Pawlisz et al. 1997).

There were sufficient data to derive an interim guideline. The most sensitive plant was oats, with a LOEL of 0.104 mg·L^{-1} (McGrath 1982). Following the protocol (CCME 1993), the NOEL (LOEC ÷ 4.5) and the SMATC were calculated. The SMATC of 4.9 µg·L^{-1} (0.0049 mg·L^{-1}) is recommended as the interim guideline for the protection of water used for irrigation of crops against the adverse effects of trivalent chromium.

Livestock Water

Hexavalent Chromium

An interim water quality guideline for hexavalent chromium of 50 µg·L^{-1} is recommended for the protection of livestock.

Hexavalent chromium is most toxic to dogs, where levels of 62.7 mg·L^{-1} (LOAEL) caused adverse effects such as reduced growth, food and water intake rates, and hepatotoxicity. Rodents are less sensitive. Adverse effects such as reduced growth, hepatotoxicity, changes in blood chemistry, and increased mortality begin to show at 70 mg·L^{-1} (LOAEL in rats) and 100 mg·L^{-1} (LOAEL in mice) (Pawlisz et al. 1997).

There were sufficient data to develop an interim guideline for hexavalent chromium. The effect level of 62.7 mg·L^{-1} for a dog (LOAEL) (Anwar et al. 1961) was selected as the critical study. The TDI was calculated as the geometric mean of the NOAEL (LOAEL÷5.6) and LOAEL, divided by an uncertainty factor of 10. Multiplying the TDI by the most conservative ratio of an animal body weight to water intake (i.e., chicken) yielded an RC of 10.07 mg·L^{-1}. To account for exposure to hexavalent chromium from sources other than water, the lowest RC is multiplied by an apportionment factor of 0.2 to give a water quality guideline value (CCME 1993). This value of 2.01 mg·L^{-1}, however, is higher than the human drinking water quality guideline value of 0.05 mg·L^{-1} (50 µg·L^{-1}) (Health Canada 1996). The human drinking water quality guideline value, therefore, was adopted as the interim guideline for the protection of waters used for livestock watering against the adverse effects of hexavalent chromium.

Trivalent Chromium

An interim water quality guideline for trivalent chromium of 50 µg·L^{-1} is recommended for the protection of livestock.

Trivalent chromium is most toxic to mice and rats, where levels in drinking water exceeding 5–28 mg·L^{-1} (LOAEL) showed reduced growth and increased mortality, respectively. Cattle were observed to experience hepatotoxicity when body burdens of trivalent chromium exceed 9.6 mg·kg^{-1} (Pawlisz et al. 1997).

Sufficient data were available to develop an interim guideline. The effect level of 28.0 mg·L^{-1} for a rat (NOAEL) (Schroeder et al. 1965) was selected as the critical study. However, because the guideline number of 0.9 mg·L^{-1} calculated following the protocol is higher than the drinking water guideline of 0.05 mg·L^{-1} (50 µg·L^{-1}), the latter value was set as the guideline for trivalent chromium for the protection of waters used for livestock water (CCME 1993).

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