



Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

ARSENIC

The behaviour of various arsenicals, particularly the inorganic and methylated forms, is a function of soil type, metal colloid content, redox potential/acidity, relative phosphate content, the chemical form of the arsenical, and microbiotic populations (Mushak 1985). In aerobic soils, arsenate is the major species, while in anaerobic soils, arsenite predominates. The biomethylation of inorganic arsenic yields monomethylarsonic and dimethylarsinic acids.

Arsenic adsorbs to and reacts with hydrous iron and aluminium oxides, and is, therefore, preferentially adsorbed in soils with a high clay content (Woolson 1983). Arsenic may accumulate as aluminium-arsenic or calcium-arsenic compounds. Arsenic can leach out if reactive iron, aluminium, and exchangeable calcium are low (Woolson et al. 1971).

Agricultural crops grown on arsenic-contaminated soils do not accumulate arsenic in their aboveground tissues (Leibig 1966). Edible portions of plants seldom accumulate arsenic since plant growth is retarded before this occurs. Plants sensitive to arsenic may suffer root damage and have little uptake. Plants tolerant to arsenic accumulate little due to mechanisms excluding arsenic.

For more information on the use, environmental concentrations, and chemical properties of arsenic, see the fact sheet on arsenic in Chapter 4 of *Canadian Environmental Quality Guidelines* and the technical supporting document (CCME 1997).

Water Quality Guideline Derivation

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

Irrigation Water

An interim water quality guideline for total arsenic of $100 \mu\text{g}\cdot\text{L}^{-1}$ in irrigation water is recommended for the protection of agricultural crop species.

Data on the toxicity of arsenic were available for 25 crop species. Beans, peas, and spinach seem to be the most sensitive, while cabbage was found to be the least sensitive (CCME 1997).

The LOECs ranged from $11.2 \text{ mg}\cdot\text{kg}^{-1}$ soil for reduced growth in green beans (*Phaseolus vulgaris*) and spinach (*Spinacia oleracea*) to $505 \text{ mg}\cdot\text{kg}^{-1}$ soil for reduced growth in cabbage (*Brassica oleracea*) (Woolson 1973). Other growth reduction LOECs include 13.5, 20, and $25 \text{ mg}\cdot\text{kg}^{-1}$ soil for radishes (*Arphanus sativus*) and lima beans (*Phaseolus limensis*), horse beans (*Vicia faba*), and peas (*Pisum sativum*), respectively (Jacobs et al. 1970; Woolson 1973; Kulich 1987).

There are sufficient data to develop an interim guideline. The most sensitive plant was the green bean (*P. vulgaris*) showing a 42% reduction in growth at arsenic level of $11.2 \text{ mg}\cdot\text{kg}^{-1}$ soil (Woolson 1973). The species maximum acceptable soil concentration (SMASC) was calculated as the geometric mean of the NOEC ($1.2 \text{ mg}\cdot\text{kg}^{-1}$ soil) and the LOEC ($11.2 \text{ mg}\cdot\text{kg}^{-1}$ soil) divided by an uncertainty factor of 10. The SMASC for green beans ($0.37 \text{ mg}\cdot\text{kg}^{-1}$ soil) was multiplied by the soil bulk density within 1 ha ($1300 \text{ kg}\cdot\text{m}^{-3}$) and soil bulk volume to a depth of 25 cm ($100 \times 100 \times 0.25 \text{ m}$) to calculate the allowable mass of arsenic (1.2 kg). The contaminant mass was then divided by the irrigation rate ($1.2 \times 10^7 \text{ L}\cdot\text{ha}^{-1}$), giving a SMATC of $100 \mu\text{g}\cdot\text{L}^{-1}$. This SMATC for green beans, being the lowest of all species, was adopted as the interim water quality guideline for irrigation (CCME 1997).

Livestock Water

The recommended water quality guideline for total arsenic for the protection of livestock is $25 \mu\text{g}\cdot\text{L}^{-1}$.

Table 1. Water quality guidelines for arsenic* for the protection of agricultural water uses (CCME 1997).

| Use | Guideline value ($\mu\text{g}\cdot\text{L}^{-1}$) |
|------------------|---|
| Irrigation water | 100 [†] |
| Livestock water | 25 [†] |

*For total arsenic.
[†]Interim guideline.

Data were available for 13 mammalian and 9 avian species. The most sensitive species was the beagle dog, which experienced reduced growth (18-month exposure) and lifespan (2-year exposure) after dosing with $2.2 \text{ mg}\cdot\text{kg}^{-1}$ of sodium arsenite (Byron et al. 1967).

Estimates of toxicity range from a LOEL for reduced growth and life span in beagles (*Canis domesticus*) of $2.2 \text{ mg}\cdot\text{kg}^{-1}$ per day to a single dose LD_{50} of $4989 \text{ mg}\cdot\text{kg}^{-1}$ for ring-necked pheasants (*Phasianus colchicus*) (Byron et al. 1967; Heath et al. 1972). Doses of arsenic trioxide from $4 \text{ mg}\cdot\text{kg}^{-1}$ per day resulted in histological changes in the skin, liver, kidneys, spleen, and testes of mice (*Mus musculus*) (Baronie et al. 1963; Bencko et al. 1968; Hattori et al. 1983). The California quail, *Lophortyx californicus*, has a single-dose LD_{50} of $47.6 \text{ mg}\cdot\text{kg}^{-1}$ (Hudson et al. 1984). Chickens (*Gallus gallus*) fed arsenic at $50 \text{ mg}\cdot\text{kg}^{-1}$ feed for 21 d showed low weight gain (Howell and Hill 1978). Arsenate at levels of $400 \text{ mg}\cdot\text{kg}^{-1}$ feed impaired weight gain, growth, and normal development in mallard ducklings (*Anas platyrhynchos*) (Camardese et al. 1990; Hoffman et al. 1992).

Sufficient information is available to derive of an interim water quality guideline for the protection of livestock watering (CCME 1993a). To develop the interim guideline, acceptable daily intake rates (ADIs) are first calculated. An ADI of $93 \mu\text{g}\cdot\text{kg}^{-1}$ per day for beagles was calculated by dividing the geometric mean of the LOEL ($2.2 \text{ mg}\cdot\text{kg}^{-1}$ per day) and NOEL (LOEL $\div 5.6$) by a safety factor of 10 (CCME 1993a, 1993b). An RC of $0.35 \text{ mg}\cdot\text{L}^{-1}$ was calculated by multiplying the ADI by the lowest body weight:water intake rate ratio (3.8 for white leghorn chickens). To account for exposure to arsenic from sources other than water, the lowest RC is multiplied by an apportionment factor of 0.2, to give an interim water quality guideline of $71 \mu\text{g}\cdot\text{L}^{-1}$ for the protection of livestock (CCME 1993a, 1993b). However, the protocol dictates that the lower of the interim livestock and the drinking water guidelines be adopted as the final interim guideline. The drinking water guideline is $25 \mu\text{g}\cdot\text{L}^{-1}$ and is, therefore, adopted as the interim guideline for the protection of livestock watering against the adverse effects of total arsenic (CCME 1997).

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