Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

LINURON

Linuron ($C_9H_{10}Cl_2N_2O_2$) is a substituted phenyl urea herbicide with a CAS name and number of N-(3, 4-dichlorophenyl)-N-methoxy-N-methylurea and 41205-21-4, respectively. Pure linuron is a colourless crystalline solid with a water solubility of 81 mg·L^{-1} at 24°C and an organic partition coefficient (K_{oc}) of 2.83. Trade names for linuron include Afolan and Lorox, or when formulated with metolachlor, Dulain.

Linuron is registered to control a variety of annual weeds on field and garden crops such as corn, carrots, potatoes, fruit trees, wheat, oats, and barley (Du Pont, 1991; Tomlin 1994). Linuron is also registered for noncrop use to control broadleaf weeds, triazine-resistant weeds, and annual grasses on turf grass, shelter belts, and rights-of-way (WSSA 1989). In 1990, 272 t of linuron were sold in Canada, with 80% being sold in Ontario for application on fruits and vegetables (Agriculture Canada and Environment Canada 1990).

Contamination of aquatic environments occurs from direct application or indirectly through spray drift, leaching, runoff events, and dry/wet deposition events. Extreme pollution may result from spills, dumping of tank residues, or equipment-washing operations. The moderate water solubility and K_{oc} of linuron also raise concern about its potential to leach through soil and contaminate groundwater (McRae 1991). Within 1 month, 94% of linuron sprayed on a soil surface 1 d after crop sowing evanesced through leaching, runoff, and photodegradation (Abraham et al. 1987). Other studies, however, demonstrate that linuron readily adsorbs to soils rich in organic matter and dissipates primarily through microbial degradation (Grover 1975; Heinonen-Tanski 1989). Data are limited, but contamination of well water seems rare in Canada.

Linuron is absorbed by plant roots and transported passively, via the xylem, to leaves where it inhibits photosynthesis by disrupting Photosystem II (photosynthetic electron transport) (USEPA 1984). Linuron is usually most effective when applied to soil because absorption and translocation through leaves is poor (Bayer and Yamaguchi 1965). The selective phytotoxicity of linuron results from differential uptake, translocation, and metabolism (OMAF 1989). Resistant plants degrade or metabolize linuron via *N*-dealkylation, deamination, decarboxylation, and/or liberation of 3,4-dichloroaniline (McEwen and Stephenson 1979). Soybeans, corn, and potatoes virtually eliminate linuron and its metabolites within 83, 31, and 98 d, respectively (Du Pont 1988a, 1988b, 1988c). Asparagus *(Asparagus officinalis* L.*)* treated either pre- or post-emergence for 2 years with 2.2 kg·ha^{-1} linuron accumulated 10 and 400 µg·kg^{-1}, respectively, the first year and 10 and 60 µg·kg^{-1}, respectively, by the second year (Cessna 1990).

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

Water Quality Guideline Derivation

The interim Canadian water quality guideline for linuron for the protection of irrigation water was developed based on the CCME protocol (CCME 1993).

Irrigation Water

The effect of linuron on nontarget plants depends on soil moisture, time of application, and lifestage of the plant (Hogue 1976; Bishnoi and Pancholi 1987). Toxicity thresholds among cereal, tame hay, and pasture crops are similar. Oats *(Avena sativas)* subjected to two seasons of pre-emergence linuron treatment have a 65-d NOEAR and LOEAR for decreased leaf area of 0.5 and 0.75 kg·ha^{-1}, respectively (Sinha and Singh 1987).

Table 1. Water quality guidelines for linuron for the protection of agricultural water uses (CCME 1995).

Use	Guideline value (µg·L^{-1})
Irrigation water	0.071*
Livestock water	NRG†

*Interim guideline.
†No recommended guideline.

Triticale *(X Triticosecale* Wittmarck*)* and rye *(Secale cereale)* have LOEARs of 0.84 and 1.12 $kg \cdot ha^{-1}$, respectively, while those of wheat *(Triticum aestivum)* and corn *(Zea mays)* are >1.14 and >2.24 $kg \cdot ha^{-1}$, the highest concentrations tested (Ludwig 1973; Abdel Halim et al. 1987; Bishnoi and Pancholi 1987). Isolated chloroplasts from corn have a 7-d EC_{50} for electron transport inhibition of 0.85 $kg \cdot ha^{-1}$ when pre-emergence treated with a wettable powder formulation (50% a.i.) (Muschinek et al. 1979).

Toxic concentrations of linuron are more variable in other crops. LOEARs for reduced fresh weight range from 0.018 to 2.26 $kg \cdot ha^{-1}$ for tomatoes *(Lycopersicum esculentum)* and parsnips *(Pastinaca sativa)*, respectively (Hogue and Warren 1968). Pre-emergent application rates of 1.12 and 2.8 $kg \cdot ha^{-1}$ linuron have no effect on soybeans *(Gylcine max)* (Johnson 1971; Stoller et al. 1973). Linuron concentrations as high as 39.8 $mg \cdot L^{-1}$ do not affect lupin *(Lupinus albus)* germination, however, when applied post-emergence, 3 $mg \cdot L^{-1}$ is sufficient to significantly reduce growth within 30 d (Fernandez-Pascual et al. 1988). Shoots of lettuce *(Lactuca sativa* L.*)* and turnips *(Brassica rapa* L.*)* have LOECs of 0.06 and 0.04 $\mu g \cdot mL^{-1}$, respectively (Walker and Schmidt 1974).

Toxicity data for linuron are sufficient to develop a full water quality guideline for irrigation water for cereal, tame hay, and pasture crops and an interim guideline for other crops (CCME 1993). To derive guideline values, acceptable application rates (AAR) for each nontarget crop are calculated first by multiplying the geometric mean of the LOEAR and the NOEAR by an uncertainty factor of 0.1. The AARs for triticale and tomato are 3.96×10^{-2} $kg \cdot ha^{-1}$ and 8.5×10^{-4} $kg \cdot ha^{-1}$, respectively. The AARs are then divided by the maximum irrigation rate used in Canada (i.e., 1.2×10^{7} $L \cdot ha^{-1}$) to calculate the SMATC (3.3 and 7.1×10^{-2} $\mu g \cdot L^{-1}$ for triticale and tomato, respectively). The lowest SMATC for each crop group is adopted as the guideline for that group, namely 3.3 $\mu g \cdot L^{-1}$ for cereals (triticale), tame hays and pastures and 0.071 $\mu g \cdot L^{-1}$ for other crops (tomato) (CCME 1995). The lowest of these values, 0.071 $\mu g \cdot L^{-1}$, becomes the interim guideline for linuron in irrigation water for all crops.

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