Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

DIMETHOATE

Dimethoate ($C_5H_{12}NO_3PS_2$) is a broad spectrum organophosphorus pesticide that is used in a wide variety of agricultural applications in Canada. In Canada, dimethoate is registered under a variety of trade names, including Cygon (Cyanamid), Lagon (U.A.P.), Hopper Stopper (Peacock Industries), and Sys-Tem (Chipman) (CCME 1993a).

Dimethoate is an insecticide and acaricide that exhibits both contact and systemic activity. Agricultural uses of dimethoate in Canada include pest control in barley, canola, oats, pastures, rye, wheat, alfalfa, beans, clovers, corn, flax, mushrooms, peas, potatoes, sugar beets, and sunflowers (Ali et al. 1989). Dimethoate is also used to control pests on ornamental plants in field and greenhouse applications (Agriculture Canada 1991). Target pests in agricultural applications include aphids, grasshoppers, leafhoppers, lygus bugs, mites, plant bugs, say stink bugs, sweet clover weevils, tarnished plant bugs, and thrips (Ali et al. 1989). Dimethoate is also effective as a residual spray on the walls of farm buildings for fly control. In forestry applications, dimethoate is used as a foliar spray to control spruce budworm, pine shoot moth, and seed and cone insects (Adams 1988). Dimethoate has also been used as a systemic insecticide in livestock, however, it is no longer registered for this use in Canada.

The low log K_{oc} of dimethoate (0.96–1.44 $mg \cdot L^{-1}$) and high water solubility (25 $g \cdot L^{-1}$) indicate that dimethoate has a low affinity for most soil types and therefore a relatively high potential for movement through agricultural soils. McRae (1991) classified dimethoate as having a moderate potential for leaching, and it has only been detected in two water quality monitoring programs in Canada

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

Water Quality Guideline Derivation

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

Irrigation Water

Only a single acceptable study was found on the toxicity of dimethoate to nontarget crops. Zaki and Reynolds (1961) treated cotton seeds with dimethoate (equivalent to 1.14 $kg \cdot ha^{-1}$) and planted them in four soil types in a greenhouse. Phytotoxicity has been observed in other studies, however, application rates were not reported.

Insufficient data were found to derive a water quality guideline or interim water quality guideline for irrigation.

Livestock Water

Nontarget mammals and birds may be exposed to dimethoate via the inhalatory, dermal, and oral routes through which uptake is rapid (Carman et al. 1982). Following uptake, dimethoate is distributed throughout the tissues of mammals. In a study of its metabolic fate, Dauterman et al. (1959) detected most of the dimethoate in the liver, kidneys, and skin (either as the parent compound or as metabolites). Significant residues were also found in the heart, brain, fat, blood, and bones within 24 h of dosing.

Studies show that vertebrates have a well-developed ability to detoxify dimethoate. While a number of degradation pathways have been identified, hydrolysis is the most important. The hydrolytic reaction catalyzed by carboxy amidase is believed to be particularly important since it cleaves the C–N bonds of dimethoate (and dimethoxon), producing nontoxic metabolites (Hassan et al. 1969).

Studies on the acute toxicity of dimethoate were found for 12 species of North American mammals and showed that

Table 1. Water quality guidelines for dimethoate for the protection of agricultural water uses (CCME 1993a).

Use	Guideline value ($\mu g \cdot L^{-1}$)
Irrigation water	NRG[*]
Livestock water	3[†]

[*] No recommended guideline.
[†] Interim guideline.

dimethoate was moderately toxic. Acute toxicity ranged from 28 to 680 $mg \cdot kg^{-1}$ (CCME 1993a). Cattle were the most sensitive of the three ungulates tested, with an LD_{100} of 80 $mg \cdot kg^{-1}$ (Hewitt et al. 1958). These results indicated that technical grade dimethoate was more toxic than either the laboratory grade or pure forms (Sanderson and Edson 1964).

Data on the chronic oral toxicity of dimethoate were found for six mammals resident in North America. The studies showed that cattle were particularly sensitive to dimethoate exposures. A 78-d exposure of heifers to 0.6 $mg \cdot kg^{-1}$ resulted in a 91% decrease in blood acetyl-cholinesterase (AChE) activity. Shorter-term (9-d) exposure of these cattle to 3 $mg \cdot kg^{-1}$ also resulted in significant (78%) reduction in blood AChE activity. No AChE inhibition was observed at 0.22 $mg \cdot kg^{-1}$ per day for 28 d in bulls and 42 d in cows (Beck et al. 1968).

The reproductive and developmental toxicity of dimethoate to four mammals showed that these endpoints were not as sensitive as inhibition of AChE and growth rates. While teratogenesis has been reported in mice, other reproductive effects were more sensitive endpoints (CCME 1993a).

Studies indicated that birds were more sensitive than mammals to acute exposures. The acute LD_{50} values of dimethoate (1-d exposures) ranged from 6.6 to 17.8 $mg \cdot kg^{-1}$ in the red-winged blackbird *(Agelaius phoeniceus)* (Schafer et al. 1983) to 63.5 $mg \cdot kg^{-1}$ in female mallard ducks *(Anas platyrhynchos)* (Hudson et al. 1984). In a single chronic study (Francis et al. 1985), 100% mortality was observed in three white leghorn pullets (species unknown) dosed at 5.4–6.6 $mg \cdot kg^{-1}$ per day in their diet for 28 or 31 d.

The existing toxicity studies for mammals and birds indicated that dimethoate was toxic to various organisms. The acute oral toxicity of dimethoate to mammals was similar across taxonomic groups, with cattle showing the most sensitive acute and chronic endpoints. A 91% decrease in blood AChE activity was observed in heifers exposed to 0.6 $mg \cdot kg^{-1}$ per day for 78 d (Beck et al. 1968). The no-observed-effect dose (NOED) in this study was 0.22 $mg \cdot kg^{-1}$ per day. In rats, inhibition of plasma and erythrocyte AChE activity was correlated with reduced growth rates (West et al. 1961); a 24% reduction in growth rate was associated with a 67% reduction in blood AChE activity. For this reason, inhibition of blood AChE activity was considered an acceptable endpoint for the development of a generic mammalian acceptable daily intake (ADI.) This was used as the scientific basis for the water quality guideline developed for livestock watering.

An ADI for cattle was calculated using the results of Beck et al. (1968) on the chronic effects of dimethoate. The NOED and lowest-observed-effect dose (LOED) were 0.22 and 0.6 $mg \cdot kg^{-1}$ per day, respectively. The ADI was calculated by dividing the geometric mean of the NOED and LOED values by an uncertainty factor of 100 (CCME 1993b). This uncertainty factor was recommended to account for uncertainty in the estimate of the safe dose of the pesticide. Sources of uncertainty in the estimate of the ADI are due to differences in sensitivity associated with species, sex, life stage, duration of exposure, nature and severity of effect measured, exposure route, and a number of other factors. This calculation resulted in a mammalian ADI of 0.004 $mg \cdot kg^{-1}$ per day or 4 $\mu g \cdot kg^{-1}$ per day.

The calculated ADI was then used, in conjunction with a livestock body weight (bw = 2.3 kg for white leghorn chickens) and daily water intake rate (WIR = 0.61 $L \cdot d^{-1}$ for white leghorn chickens), to calculate an RC for dimethoate.

In livestock species, water consumption varies considerably with ambient air temperature, humidity, activity levels, and, where applicable, milk production of the animals. A comparison of the bw and WIR ranges for various livestock animals found that white leghorn chickens had the most sensitive bw/WIR ratio, which should be used to simulate a worst-case scenario (CCME 1993b). The RC of dimethoate in water sources that may be used for livestock watering was calculated to be approximately 15 $\mu g \cdot L^{-1}$ using the data for chickens. This calculation assumed that 100% of the daily exposure to dimethoate resulted from the consumption of drinking water.

Livestock may also be exposed to dimethoate through spray drift (e.g., dermal and/or inhalation exposure) and contamination of their food source. Water quality guidelines, therefore, should account for other exposure routes and be modified appropriately. Unfortunately, no information was available on the relative exposure to dimethoate through drinking water, food, and dermal exposures. In the absence of specific information, the presumed percentage drinking water contribution (PDWC = 20%) (USEPA 1988a), was used in the calculation of the water quality guideline.

The interim water quality guideline for dimethoate for livestock watering is therefore 3 $\mu g \cdot L^{-1}$. The guideline

was developed to protect the most sensitive livestock watering use (i.e., chickens) and is therefore considered appropriate for other livestock watering uses.

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