Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

ATRAZINE

Atrazine is a selective pre- and postemergence herbicide used for the control of annual broadleaf and grassy weeds in corn, sorghum, asparagus, turf, forestry applications, sugarcane, and pineapples (WSSA 1983).

Degradation of atrazine in soil is the result of microbial action, with dealkylation as the primary mechanism (Ghassemi et al. 1981). Biological dealkylation occurs simultaneously with chemical hydrolysis, which favours ring cleavage, and results in total microbial degradation (Goswami and Green 1971).

Chemical hydrolysis of atrazine to hydroxyatrazine is an important pathway of atrazine degradation in soil. The pH of the soil plays an important role in the rate of hydrolysis. Half-lives for atrazine of 95–165 d, 145–350 d, and 3–5 years were estimated for pHs of 4, 7, and 8, respectively (Armstrong et al. 1967). Studies of chemical hydrolysis of atrazine in aqueous fulvic acid, believed to be the major soluble organic fraction in soil solutions, have indicated that half-lives were influenced by the concentrations of fulvic acid, pH, and incubation temperature. A half-life of 742 d was found with a low fulvic acid concentration (0.5 $mg \cdot mL^{-1}$) at neutral pH incubated at 25ºC. In contrast, a half-life of 0.51 d was observed with 5.0 $mg \cdot mL^{-1}$ fulvic acid at pH 2.4 incubated at 60ºC (Khan 1978).

The rate of atrazine hydrolysis is also influenced by adsorption with a decrease in the half-life as adsorption increases (Burkhard and Guth 1981). Adsorption is affected by clay, organic matter, temperature, and pH. The K_d value (ratio of quantity adsorbed to quantity in equilibrium solution) for s-triazine and exchanger was reported to remain relatively constant over a concentration range of 2–20 $mg \cdot kg^{-1}$ (Talbert and Fletchall 1965). In addition, the adsorption reaction equilibrated within 1 h. Atrazine adsorption was reversed by increasing temperatures or elution with water. Higher temperature and pH resulted in lower adsorption of atrazine. Increased adsorption occurred with increased concentrations of organic matter or clay, with the organic matter being much more adsorptive. Harris and Warren (1964) also reported that organic matter adsorbed more atrazine residues than mineral materials. Desorption of atrazine was found to occur slowly and incompletely on organic soils.

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

Water Quality Guideline Derivation

The interim Canadian water quality guideline for atrazine in irrigation water was adopted from the U.S. Environmental Protection Agency's water quality guideline (USEPA 1977). The interim Canadian water quality guideline for atrazine in livestock water was developed according to the CCME protocol (CCME 1993).

Irrigation Water

A study in Saskatchewan showed that atrazine applied in dry irrigation ditches for weed control at 22.4 $kg \cdot ha^{-1}$ in September resulted in atrazine residues in the irrigation water the following summer. Initial water ponding in the ditches in June resulted in mean atrazine concentrations of 240 ± 100 $\mu g \cdot L^{-1}$. Additional water samples taken during the first irrigation of the season resulted in mean atrazine concentrations of 45 ± 20 $\mu g \cdot L^{-1}$. Two years later, atrazine was still present in irrigation ditch water at 19 ± 2 $\mu g \cdot L^{-1}$ (Smith et al. 1975). The authors concluded that irrigation water from the first two fillings of the ditches treated with atrazine should not be used for irrigation.

Table 1. Water quality guidelines for atrazine for the protection of agricultural water uses (USEPA 1977; CCME 1989).

Use	Guideline value ($\mu g \cdot L^{-1}$)
Irrigation water	10*
Livestock water	5*

*Interim guideline.

In the absence of sufficient information, an interim Canadian water quality guideline for atrazine in irrigation water of 10 $\mu g \cdot L^{-1}$ (CCME 1989) may be recommended by adopting the U.S. Environmental Protection Agency's guideline for atrazine in irrigation water (USEPA 1977).

Livestock Water

A review of avian toxicity data showed atrazine ingestion was not very toxic to birds and was reflected by LC_{50}s ranging from 700 $mg \cdot kg^{-1}$ bw for the mallard (Ghassemi et al. 1981) to 19 650 $mg \cdot kg^{-1}$ bw for bobwhite quail (WSSA 1983) for 5- to 8-d exposures. Although significant concentrations of atrazine remained in abdominal fat after cessation of exposure, chickens had the ability to metabolize atrazine by at least two separate pathways: N-dealkylation at the ethylamino group and hydrolysis of the ring-bound chlorine (Khan and Foster 1967).

The results of the available testing demonstrated low atrazine toxicity to mammals. Single acute oral dosages ranged from 1400 $mg \cdot kg^{-1}$ bw (Hayes 1982) to 5100 $mg \cdot kg^{-1}$ bw (Geigy Agricultural Chemicals 1971b) for rats and mice. Intraperitoneal injections produced much greater toxicity, with an LD_{50} of 125 $mg \cdot kg^{-1}$ (Hayes 1982). The lethal dose for atrazine ingestion by cattle was reported to be two doses of 250 $mg \cdot kg^{-1}$ within 24 h (Palmer and Radeleff 1964). Smaller doses produced reversible intoxication (Kobel et al. 1985).

Chronic oral intakes of 100 $mg \cdot kg^{-1}$ (21 d) and 760 $mg \cdot kg^{-1}$ (4 weeks) failed to induce significant adverse effects in cattle. Female sheep, however, were killed by daily dosages of 30 $mg \cdot kg^{-1}$ in 36–60 d (Binns and Johnson 1970). Other routes of exposure (i.e., dermal and inhalation) produced much less toxicity than oral intake (Geigy Agricultural Chemicals 1971a, 1971b).

The mutagenicity of atrazine has been studied with a wide variety of different microbial, animal, and plant systems. Generally, these studies showed atrazine to be nonmutagenic both with and without metabolic activation by animal systems (U.S. Department of Agriculture 1984).

The existing toxicity data for birds and mammals show that atrazine is not very toxic to livestock. It is significant that all the studies examined used atrazine-treated feed or oral doses (i.e., gavage) to expose the animals to atrazine via the gastrointestinal tract. None of the studies used atrazine-treated drinking water. In the absence of sufficient information, the CCME (1993) procedure of adopting the guideline value for human drinking water supplies (Health and Welfare Canada 1987, revised value published in Health Canada 1996) is followed to derive an interim Canadian water quality guideline for atrazine in livestock water of 5 $\mu g \cdot L^{-1}$ (CCME 1989; adoption updated 1998).

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