Canadian Water Quality Guidelines for the Protection of Aquatic Life

BROMACIL

Bromacil ($C_9H_{13}BrN_2O_2$) is a substituted uracil herbicide. It is a colourless, odourless, crystalline solid that may be formulated alone or with either 2,4-D (Calmix) or diuron (Krovar). Bromacil has a CAS name and number of 5-bromo-6-methyl-3-(1-methylpropyl)-2,4(1*H*,3*H*)-pyrimidinedione and 314-40-9, respectively. Available as wettable powder, soluble concentrate, or granules, bromacil has a relatively high water solubility of 807 $mg \cdot L^{-1}$ at pH 5 and 25°C, but is soluble in various organic solvents.

Bromacil acts as a nonselective herbicide effective against most annual and perennial broadleaved weeds and grasses as well as some brush species by inhibiting photosynthesis at the electron transport chain (OMAF 1994; Agriculture and Agri-Food Canada 1997). In Canada, bromacil is registered for broadcast and spot ground application to control weeds and brush on noncropland such as industrial sites, storage areas, parking lots, airports, dry ditches, fence lines, and railroads (Agriculture Canada and Environment Canada 1990). In western Canada, bromacil is used to control weed growth in irrigation ditches (Environment Canada 1990).

In 1990, 2100 and 36 000 kg of bromacil were sold in Canada for domestic and commercial uses, respectively. Most of this was sold in Alberta (12 300 kg), Manitoba (9600 kg), and Ontario (9500 kg) (Agriculture Canada and Environment Canada 1990).

Surface waters may become contaminated by bromacil through spray drift, accidental spills, equipment-washing operations, and dumping of tank residues. Bromacil has a low log organic carbon partition coefficient (1.66 to 2.10) indicating that it adsorbs only slightly to soil organic carbon and is, therefore, mobile in soil (Montgomery 1993). The contamination of groundwater can thereby occur via leaching from treated areas and/or improper use and handling procedures (e.g., back-siphoning into wells). Occasionally, groundwater recharge by contaminated surface water contributes to groundwater contamination (Frank et al. 1987).

Bromacil does not absorb sunlight; therefore, photolysis in aquatic systems is minimal unless naturally occurring sensitizers such as humic acids, chlorophyll, and riboflavin are abundant (Acher and Salzman 1980; Acher 1984;). Volatilization of bromacil is also a minor route for environmental dissipation owing to its low vapour pressure (41 µPa at 25ºC) (Tomlin 1994). Bromacil is slowly debrominated by microflora under anaerobic, methanogenic conditions but is not degraded under denitrifying or sulphate-reducing conditions (Adrian and Sulfita 1990). Smith et al. (1975) measured bromacil residues (1 $\mu g \cdot L^{-1}$) in irrigation ditch water one year after application (31 $\mu g \cdot L^{-1}$), suggesting that bromacil is relatively persistent in water.

Bromacil has a low log octanol–water partition coefficient (log K_{ow}) of 1.87 at pH 7 and therefore is not likely to bioaccumulate in biota (Tomlin 1994). For example, the bioconcentration factors for 30-d old fathead minnows (*Pimephales promelas*) exposed for 17 d to 4.25 $\mu g \cdot L^{-1}$ or 35.11 $\mu g \cdot L^{-1}$ of ^{14}C-labelled bromacil were 2.8 and 3.5, respectively (Call et al. 1983).

Water Quality Guideline Derivation

The interim Canadian water quality guideline for bromacil for the protection of freshwater life was developed based on the CCME protocol (CCME 1991).

Freshwater Life

Toxicity data indicate that bromacil is relatively nontoxic to fish. For example, acute (24- to 168-h LC_{50}) toxicity concentrations range from 71 to 186 $mg \cdot L^{-1}$ for four species of fish native to Canada. The most sensitive fish species are bluegill sunfish (*Lepomis macrochirus*) and rainbow trout (*Oncorhynchus mykiss*), with 48-h LC_{50}s of 71 and 75 $mg \cdot L^{-1}$, respectively (Sherman and Kaplan 1975). Fathead minnows *(Pimephales promelas)* are the most tolerant fish, with an LC_{50} of approximately 184 $mg \cdot L^{-1}$ for both 96-h static and 24-h flow-through tests (Call et al. 1987; Geiger et al. 1988). The 168-h

Table 1. Water quality guidelines for bromacil for the protection of aquatic life (CCME 1997).

Aquatic life	Guideline value ($\mu g \cdot L^{-1}$)
Freshwater	5.0*
Marine	NRG†

*Interim guideline.
†No recommended guideline.

flow-through LC_{50} value for this fish is slightly lower at 167 mg·L^{-1} (Call et al. 1987). Carp *(Cyprinus carpio)* showed similar tolerance to bromacil with a 48-h LC_{50} of 164 mg·L^{-1} (Sherman and Kaplan 1975). In a chronic test, fathead minnows exposed to bromacil concentrations from 1.0 to 29.0 mg·L^{-1} during hatching and for 60 d thereafter did not have reduced hatching success, reduced survival rate to 60 d, or increased number of abnormal fry compared to controls. However, wet weight and length of fry measured at 60 d were significantly reduced at all exposures, except 1.9 mg·L^{-1} (Call et al. 1983).

From the limited data found, bromacil appears to be relatively nontoxic to freshwater invertebrates. For example, third-instar *Chironomus tentans* larvae have a 96-h static LC_{50} value of 210 mg·L^{-1}. *Daphnia magna* neonates have 48-h static EC_{50} and LC_{50} values of 313 mg·L^{-1} and 363 mg·L^{-1}, respectively (Environment Canada 1996).

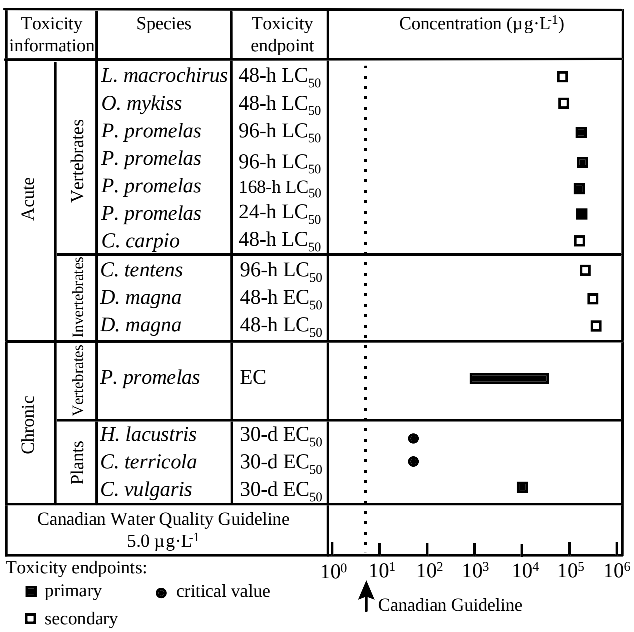

Figure 1. Select freshwater toxicity data for bromacil.

Aquatic plant toxicity data are only available for green algae. Algae growing in media containing 0.01–10 mg·L^{-1} of bromacil have EC_{50} values for growth inhibition from 0.05 mg·L^{-1} for *Haematococcus lacustris* 34-1j and *Chlamydomonas terricola* to 10 mg·L^{-1} for *Chlorella vulgaris*. Two species, *Chlorella ellipsoidea* and *Coccomyxa subellipsoidea*, were unaffected by all concentrations tested (Cullimore 1975). *Chlorella pyrenoidosa* suffered growth inhibition of approximately 50% when exposed to 1 and 10 mg·L^{-1} bromacil for 18 to 36 h (Kratky and Warren 1971).

The interim water quality guideline for bromacil for the protection of freshwater life is 5.0 µg·L^{-1}. It was derived by multiplying the 30-d LC_{50}s of 0.05 mg·L^{-1} (Cullimore 1975) for the most sensitive organisms to bromacil, the green algae *Chlamydomonas terricola* and *Haematococcus lacustris* 34-1j, by a safety factor of 0.1 (CCME 1997).

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