Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

BROMACIL

Bromacil ($C_9H_{13}BrN_2O_2$) is a substituted uracil herbicide. It 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. Bromacil is a colourless, odourless, crystalline solid that is available as wettable powder (WP), soluble concentrate, or granules. It may be formulated alone or with either 2,4-D (Calmix) or diuron (Krovar). Bromacil is soluble in various organic solvents even though it has a relatively high water solubility of 807 $mg \cdot L^{-1}$ at pH 5 and 25ºC.

By inhibiting photosynthesis at the electron transport chain, bromacil acts as a nonselective herbicide effective against most annual and perennial broad-leaved weeds and grasses as well as some brush species (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 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).

Spray drift, accidental spills, equipment-washing operations, and dumping of tank residues may contaminate surface waters. Irrigation and livestock water drawn from contaminated surface waters may threaten sensitive crop and animal species.

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

Water Quality Guideline Derivation

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

Irrigation Water

Bromacil is toxic to a variety of nontarget crop species. Sorghum *(Sorghum vulgare)* seedlings placed in nutrient solution containing bromacil at concentrations from 0.128 to 26.1 $mg \cdot L^{-1}$ died after 11 d of exposure (Hilton and Nomura 1964). Chromosomal abnormalities in root tips of young dry barley plants *(Hordeum vulgare)*, which as seeds were soaked in solutions of Hyvar X (80% WP), increased with increasing exposure periods (6–24 h), but not with increasing concentrations (50–1500 $mg \cdot L^{-1}$ of bromacil) (Wuu and Grant 1966). The number of root cells with chromosomal abnormalities averaged 9.12% for treated plants in contrast to 0.68% for control plants. Bromacil residues (0.4 $kg \cdot ha^{-1}$ a.i.) in fields that received four annual applications of 2.24 $kg \cdot ha^{-1}$ a.i. did not impede emergence and early growth of barley seedlings or reduce grain size of mature plants grown 1 year later, but did reduce crop yield (Wiseman and Lawson 1970). By the third year neither germination counts, yield, or weight of grains of growth differed significantly between treated and control plants. Root growth of oat *(Avena sativa)* and radish *(Raphanus sativus)* seedlings was negatively correlated with bromacil concentrations of 0.26–261 $mg \cdot L^{-1}$ (Ashton et al. 1969). Also, development of chloroplast grana and fret systems in oat seedling leaves was inhibited at 2.6 $mg \cdot L^{-1}$ of bromacil (Ashton et al. 1969). Oats sown in sandy clay loam soil containing 0.2 $mg \cdot kg^{-1}$ of bromacil showed no signs of injury 4 weeks after planting (Sharma 1989). At 0.8 and 2.0 $mg \cdot kg^{-1}$, however, oats suffered severe chlorosis, necrosis, and wilting, with symptoms first appearing 7 d after sowing and fully developed within 3 weeks. Bromacil is more phytotoxic to oats sown in sand than soil because it absorbs to clay and organic particles (Sharma 1989).

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

Use	Guideline value ($\mu g \cdot L^{-1}$)
Irrigation water	0.2*
Livestock water	1100*

*Interim guideline.

The effects of bromacil treatment on fruits and vegetables vary from beneficial, to tolerant, to harmful. For example, low levels of bromacil (22.5 g·kg^{-1}) improved nutrient accumulation and utilization in young soybeans *(Glycine max)* by 15.5% dw and 15.6% dw for nitrogen and phosphorus, respectively (Hiranpradit et al. 1972). Young plum trees *(Prunus cerasifera)* sprayed with 4.48 and 6.73 kg·ha^{-1} bromacil showed no adverse affects, while young apple trees *(Malus sylvestris)* suffered 33 and ~100% mortality, respectively (Holloway 1968). Fresh weight of stems and roots of treated apple trees were also reduced by bromacil (Price and Fisher 1966; Holloway 1968). The plant most sensitive to bromacil treatment is the cucumber *(Cucumis sativus)*. Cucumber radicles submerged in 0.1 mg·L^{-1} of bromacil produced shoots weighing 30% less than control plants. Cucumber seedlings submersed in a bromacil solution for 11 d have a minimum lethal concentration of 0.05 mg·L^{-1} (Hilton and Nomura 1964).

A SMATC was calculated according to the protocol (CCME 1993) for each crop for which proper data were available. An uncertainty factor of 100 was used in the SMATC calculations because bromacil is very persistent in soils (Jury et al. 1984) and the protocol requires a higher uncertainty factor to be used for persistent substances (CCME 1993). The lowest SMATC in each crop group is adopted as the interim guideline for that group (CCME 1993). The recommended interim guidelines, therefore, are 0.6 µg·L^{-1} for cereals, tame hays, and pastures based on the lowest SMATC for sorghum, and 0.2 µg·L^{-1} for other crops based on the lowest SMATC for cucumbers. The lower of these two values, 0.2 µg·L^{-1}, is adopted as the interim Canadian water quality guideline for irrigation water (CCME 1997).

The guideline value may be modified for areas that do not grow the most sensitive species (upon which the guideline was derived) or for areas with sources of the contaminant other than irrigation water (e.g., natural background levels, fertilizer, atmospheric inputs). In these cases, the SMATC value listed in CCME (1997) may be used as a site-specific objective for that crop only.

Livestock Water

Acute toxicity tests indicate that bromacil is most toxic to mammals when administered orally. A sheep dosed for 10 d with Hyvar X (80%WP) at 250 mg·kg^{-1} showed signs of poisoning after eight doses, while a second dosed for 5 d at 250 mg·kg^{-1} experienced poisoning after 3 d. A third sheep given 10 daily doses at 25 mg·kg^{-1} showed no adverse effect (Palmer and Radeleff 1969). Signs of poisoning included anorexia, depression, stomach distension, and uncoordinated gait. In the same study, two cattle given 10 daily doses of 100 mg·kg^{-1} showed no adverse effects, but a third given 10 daily doses of 250 mg ·kg^{-1} showed signs of poisoning after just one dose. Acute oral LD_{50}s of technical grade bromacil for adult male, adult female, and male weanling rats are 791, 1641 and 1737 mg·kg^{-1}, respectively (Gaines and Linder 1986). Sherman and Kaplan (1975) reported a higher oral LD_{50} of 5200 mg·kg^{-1} for male rats administered Hyvar X (80% WP). Rats given doses of 25, 50, or 250 mg·kg^{-1} of bromacil for 14 d exhibited behaviour modifications that were consistent neurotoxic effects. While the highest dose significantly decreased the number of rearing events and time spent near cage walls, the lowest dose caused the opposite effect (Lakoski et al. 1993). As little as 100 mg·kg^{-1} bromacil administered orally to mongrel dogs induced vomiting (Sherman and Kaplan 1975).

Similar toxicity thresholds are found in birds. For example, white leghorn chickens from a commercial hatchery dosed with 500 mg·kg^{-1} a.i. per day of Hyvar X (80% WP) in gelatin capsules for 10 d gained 24% less weight than the controls (Palmer and Radeleff 1969). The 8-d dietary LC_{50} for both the mallard duck and the bobwhite quail is >10 000 mg·kg^{-1} (Sherman and Kaplan 1975). Assuming average food consumption rates of 10% body weight per day and that body weight ranges from 1.6 to 2.3 kg, this value represents an LD_{50} value of >1000 mg·kg^{-1} per day (Caux et al. 1993).

Bromacil is less toxic when applied dermally. The dermal LD_{50} for both male and female rats is >2500 mg·kg^{-1} (Gaines and Linder 1986). Sherman and Kaplan (1975) reported a dermal LD_{50} >5000 mg·kg^{-1} for rabbits exposed for 24 h to a paste made from WP (80% a.i.). WP (50% a.i.) applied directly or in a mineral oil suspension to the eyes of adult male rabbits caused mild, temporary conjunctivitis but no corneal injury (Sherman and Kaplan 1975). A 50% aqueous suspension of WP (80% a.i.) irritated the skin of albino guinea pigs (Sherman and Kaplan 1975).

Limited data exist on the chronic toxicity of bromacil to mammals. Female rats fed bromacil as WP (80% a.i.) at 62.5 mg·kg^{-1} per day for 2 years experienced significantly reduced body weight gains, consumed less food, and used food less efficiently than the control group (Sherman and Kaplan 1975). Both males and females also had slightly higher incidences of focal light cell hyperplasia and focal follicular cell hyperplasia than control animals. Rats that inhaled 1.83 or 3.75 mg·kg^{-1} per day of bromacil during days 7 to 14 of gestation showed no increase in fetal abnormalities, while those that inhaled 7.92 mg·kg^{-1} per day experienced a decrease in fetal weight and caudal ossification and an increase in fetal re-sorption rate (Newell and Dilley 1978).

Sufficient data are available to derive an interim Canadian water quality guideline for the protection of livestock water. A TDI was calculated for each species for which suitable toxicological data were available. The TDI is the geometric mean of the LOEL and the NOEL divided by an uncertainty factor. A TDI of 1.4 $mg \cdot kg^{-1}$ per day was calculated for beagle dogs having a LOEL and NOEL of 13.25 and 6.25 $mg \cdot kg^{-1}$ per day, respectively, for body weight loss (Sherman and Kaplan 1975). An RC was derived by multiplying the lowest TDI, in this case that of beagle dogs, by the lowest ratio of body weight to water intake rate, that of leghorn chickens (3.8). To account for exposure to bromacil from sources other than water, the lowest RC (5.3 $mg \cdot L^{-1}$) is multiplied by an apportionment factor of 0.2 to give an interim water quality guideline of 1100 $\mu g \cdot L^{-1}$ for the protection of livestock (CCME 1996).

References

Agriculture and Agri-Food Canada. 1997. Regulatory Information on Pesticide Products (RIPP) Database (CCINFODISK). Issue 97-3. Produced by Agriculture and Agri-Food Canada and distributed by the Canadian Centre for Occupational Health and Safety. CD-ROM.

Agriculture Canada and Environment Canada. 1990. Pesticide registrant survey 1990 report. Agriculture Canada, Pesticides Directorate, and Environment Canada, Commercial Chemicals Branch. Ottawa.

Ashton, F.M., E.G. Cutter, and D. Huffstutter. 1969. Growth and structural modifications of oats induced by bromacil. Weed Res. 9:198–204.

CCME (Canadian Council of Ministers of the Environment). 1993. Appendix XV—Protocols for deriving water quality guidelines for the protection of agricultural water uses (October 1993). In: Canadian water quality guidelines, Canadian Council of Resource and Environment Ministers. 1987. Prepared by the Task Force on Water Quality Guidelines. [Updated and reprinted with minor revisions and editorial changes in Canadian environmental quality guidelines, Chapter 5, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]

———. 1997. Appendix XXIII—Canadian water quality guidelines: Updates (June 1997), arsenic, bromacil, carbaryl, chlorpyrifos, deltamethrin, and glycols. In: Canadian water quality guidelines, Canadian Council of Resource and Environment Ministers. 1987. Prepared by the Task Force on Water Quality Guidelines.

Caux, P-Y, R.A. Kent, M. Taché, C. Grande, G.T. Fan, and D.D. MacDonald. 1993. Environmental fate and effects of dicamba: A Canadian perspective. Rev. Environ. Contam. Toxicol. 133:1–58.

Gaines, T.B., and R.E. Linder. 1986. Acute toxicity of pesticides in adult and weanling rats. Fundam. Appl. Toxicol. 7:299–308.

Hilton, H.W., and N. Nomura. 1964. Phytotoxicity of herbicides as measured by root absorption. Weed Res. 4:216–222.

Hiranpradit, H., C.L. Foy, and G.M. Shear. 1972. Effects of low levels of bromacil on some mineral constituents and forms of nitrogen in *Glycine max* (L.) Merrill. Agron. J. 64(3):274–276.

Holloway, R.I.C. 1968. The response of potted apple and plum plants to bromacil and chlorthiamid. Rep. E. Malling Res. Stn. for 1967.

Jury, WA, W.F. Spencer, and W.J. Farmer. 1984. Behavior assessment model for trace organics in soil: III. Application of screening model. J. Environ. Qual. 13(4):573–579.

Lakoski, J.M., M.I. Arentsen, N.L. Kneisley, W.W. Au, and M.S. Legator. 1993. Evaluation of toxic and genotoxic effects of bromacil: Part II. Open-field behavioural assessment of locomotor effects in the rat. J. Occup. Med. Toxicol. 2(2):173–187.

Newell, G.W., and J.V. Dilley. 1978. Teratology and acute toxicology of selected chemical pesticides administered by inhalation. EPA-600/1-78-003, U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC.

OMAF (Ontario Ministry of Agriculture and Food). 1994. 1994 Guide to weed control. Publication No. 75. Queen's Printer for Ontario, Toronto.

Palmer, J.S., and R.D. Radeleff. 1969. The toxicity of some organic herbicides to cattle, sheep and chickens. Prod Res. Report 106. U.S. Department of Agriculture, U.S. Government Printing Office, Washington, DC.

Price, H.C., and J. Fisher. 1966. Comparison of several substituted uracil herbicides for control of weeds around young peach and apple trees. Proc. Northeast. Weed Control Conf. 20:174–180.

Sharma, M.P. 1989. Efficiency of activated charcoal for inactivation of bromacil and tebuthiuron residues in soil. Prepared for The Oil and Gas Reclamation Research Program, Alberta Land Conservation and Reclamation Council, Vegreville, AB.

Sherman, H., and A.M. Kaplan. 1975. Toxicity studies with 5-bromo-3-sec-butyl-6-methyluracil. Toxicol. Appl. Pharmacol. 34:189–196.

Wiseman, J.S., and H.M. Lawson. 1970. Effects on subsequent cereal crops of residual herbicides used in raspberry experiments. In: Proceedings 10th Br. Weed Control Conf. 10:768–774.

Wuu, K.D., and W.F. Grant. 1966. Morphological and somatic chromosomal aberrations induced by pesticides in barley *(Hordeum vulgare)*. Can. J. Genet. Cytol. VIII(3):481–501.

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of agricultural water uses: Bromacil. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

For further scientific information, contact:

Environment Canada
Guidelines and Standards Division
351 St. Joseph Blvd.
Hull, QC K1A 0H3
Phone: (819) 953-1550
Facsimile: (819) 953-0461
E-mail: ceqg-rcqe@ec.gc.ca
Internet: http://www.ec.gc.ca

For additional copies, contact:

CCME Documents
c/o Manitoba Statutory Publications
200 Vaughan St.
Winnipeg, MB R3C 1T5
Phone: (204) 945-4664
Facsimile: (204) 945-7172
E-mail: spccme@chc.gov.mb.ca

Excerpt from Publication No. 1299; ISBN 1-896997-34-1

Aussi disponible en français.