



Canadian Water Quality Guidelines for the Protection of Aquatic Life

GLYPHOSATE

Glyphosate ($C_3H_8NO_5P$) has a CAS name and number of *N*-(phosphonomethyl)glycine and 1071-83-6, respectively. The isopropylamine salt of glyphosate (CAS 38641-94-0) is the active ingredient in a number of herbicides including Roundup, Vision, Clear-it, and Sidekick. Roundup and Vision contain the equivalent of $356 \text{ g}\cdot\text{L}^{-1}$ of glyphosate ($480 \text{ g}\cdot\text{L}^{-1}$ of the isopropylamine salt) (Worthing and Walker 1983; WSSA 1983; Monsanto Company 1987).

Glyphosate, introduced in 1971, was registered in Canada in 1976 as a nonselective systemic herbicide. It acts on various enzyme systems to interfere with the formation of amino acids and other important endogenous chemicals (Tomlin 1994). Glyphosate is registered to control annual and perennial grasses, sedges, broadleaf weeds, and woody brush and trees in fruit and nut orchards, wheat, barley, canola, flax, peas, lentils, dry beans, legumes, and in forestry, nursery, and noncrop areas such as rights-of-way and industrial sites (Agriculture and Agri-Food Canada 1997).

Glyphosate may be introduced into the aquatic environment through spillage, accidental discharge, or waste disposal during production, packaging, storage, and use. When applied according to label instructions, the likelihood of aquatic contamination is remote (Brønstad and Friestad 1985). Glyphosate can, however, enter freshwater by direct use near aquatic environments, runoff or leaching from terrestrial applications, or drift during agricultural or silviculture applications (Tooby 1985; Beck 1987). Concentrations found in Canadian freshwater range from $1.5 \mu\text{g}\cdot\text{L}^{-1}$, due to direct overspray, to $5153 \mu\text{g}\cdot\text{L}^{-1}$ in runoff water where two to four times the recommended application rate of glyphosate was applied (Edwards et al. 1980; Feng et al. 1986). Concentrations found in sediments range from 0.05 to $0.4 \text{ mg}\cdot\text{kg}^{-1}$ (Newton et al. 1984; Wan 1986).

Glyphosate dissipation in water follows two major pathways: microbial breakdown to the inactive glyphosate metabolite aminomethylphosphonic acid (AMPA) and CO_2 and adsorption to sediments with subsequent microbial breakdown of bound residues under anaerobic conditions (Tooby 1985). The half-life values for the dissipation of glyphosate range from 1.5 d to 10 weeks (Ghassemi et al. 1981; Goldsborough and Beck 1989).

The photodegradation half-lives were reported as 4 d and 3–4 weeks for concentrations of 1.0 and $2000 \text{ mg}\cdot\text{L}^{-1}$, respectively (Lund-Høie and Friestad 1986).

Reports indicate that particulate matter has a high adsorptive capacity for glyphosate (Hance 1976; Hensley et al. 1978; Newton et al. 1984; Lund-Høie and Friestad 1986; Wan 1986). The adsorption coefficient of glyphosate increases as the ratio of soil to water decreases (Damanakis 1976).

Glyphosate has a low potential for accumulation in aquatic organisms. Reported BCFs range from 0.03 for rainbow trout (*Oncorhynchus mykiss*) to 1.6 for bluegill sunfish (*Lepomis macrochirus*) (Sacher 1978).

Water Quality Guideline Derivation

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

Freshwater Life

The available toxicity data for the effects of glyphosate on vertebrates include data for glyphosate, technical glyphosate, the isopropylamine salt, Roundup, and the surfactant (MONO818) found in Roundup. The 96-h LC_{50} s for glyphosate range from $86 \text{ mg}\cdot\text{L}^{-1}$ for rainbow trout (USDA 1984) to $150 \text{ mg}\cdot\text{L}^{-1}$ for bluegill sunfish (Folmar et al. 1979). The 96-h LC_{50} s for technical glyphosate range from $16 \text{ mg}\cdot\text{L}^{-1}$ for bleak (*Alburnus alburnus*) (Linden et al. 1979) to $168 \text{ mg}\cdot\text{L}^{-1}$ for harlequin fish (*Rasbora heteromorpha*) (Monsanto Company

Table 1. Water quality guidelines for glyphosate for the protection of aquatic life (CCME 1989).

Aquatic life	Guideline value ($\mu\text{g}\cdot\text{L}^{-1}$)
Freshwater	65*
Marine	NRG†

* Interim guideline.

† No recommended guideline.

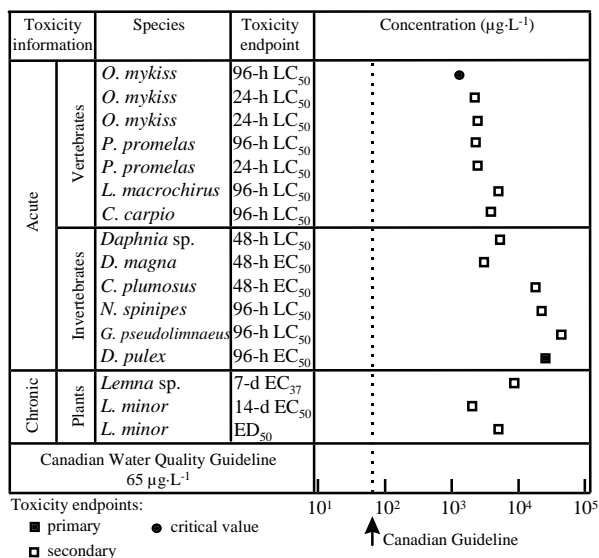


Figure 1. Select freshwater toxicity data for glyphosate.

1982a). The isopropylamine salt and Roundup were more toxic, with 96-h LC₅₀s for rainbow trout ranging from 7.4 to 12 mg·L⁻¹ (Mitchell et al. 1987b) and from 1.3 to 48 mg·L⁻¹, respectively (Folmar et al. 1979; USDA 1981). The surfactant was much more toxic than glyphosate, with a 96-h LC₅₀ of 1.0 mg·L⁻¹ for fathead minnows (*Pimephales promelas*) and a 24-h LC₅₀ of 18 mg·L⁻¹ for channel catfish (*Ictalurus punctatus*) (USDA 1984).

The previous data show that the acute toxicity of glyphosate is an order of magnitude lower than either the surfactant or the commercial formulation. A study by Servizi et al. (1987) using natural lake water suggested that antagonistic reactions between the surfactant and glyphosate exist. However, similar analyses of toxicity tests conducted in reconstituted water suggested the combined effects of glyphosate and the surfactant were synergistic.

The acute toxicity data for invertebrates for glyphosate ranged from a 48-h EC₅₀ of 55 mg·L⁻¹ for midge larvae (*Chironomus plumosus*) (Folmar et al. 1979) to a 96-h LC₅₀ of 934 mg·L⁻¹ for fiddle crabs (USDA 1981; Monsanto Company 1982a). For Roundup, the toxicity values ranged from a 48-h EC₅₀ of 3.0 mg·L⁻¹ for *Daphnia magna* (Folmar et al. 1979) to a 96-h LC₅₀ >1000 mg·L⁻¹ for crayfish (Monsanto Company 1982b).

The toxicity of glyphosate for algal species ranged from 1 mg·L⁻¹, based on the inhibition of oxygen evolution, to 203 mg·L⁻¹, based on reduction of cell numbers in *Euglena gracilis* (Richardson et al. 1979; Christy et al.

1981). Glyphosate toxicities for the vascular plant duckweed ranged from a 14-d EC₅₀ of 2.0 mg·L⁻¹ for *Lemna minor* (Hartman and Martin 1985) to an effect on enzyme activities at 169.1 mg·L⁻¹ for *L. gibba* (Hoagland 1978; Hoagland and Paul 1978).

Given the fact that residues of Roundup in the Canadian aquatic environment will continue to be monitored by the presence of glyphosate, it is appropriate that the guideline for the active ingredient (glyphosate) be set using toxicity data for the formulated product (Roundup). The interim water quality guideline for glyphosate for the protection of freshwater life is 65 $\mu\text{g}\cdot\text{L}^{-1}$ (CCME 1989). It was derived by multiplying the lowest acceptable 96-h LC₅₀ value for Roundup of 1300 $\mu\text{g}\cdot\text{L}^{-1}$ for the most sensitive organism, *O. mykiss* (Folmar et al. 1979), by a safety factor of 0.05 (acute toxicity study, nonpersistent substance) (CCME 1991).

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.

Beck, A.E. 1987. Glyphosate residues in surface water following 1985 Manfor Ltd. field trials. Water Standards and Studies Report No. 87-4. Manitoba Environment and Workplace Safety and Health, Winnipeg.

Brønstad, J.O., and H.O. Friestad. 1985. Behaviour of glyphosate in the aquatic environment. In: The herbicide glyphosate, E. Grossbard and D. Atkinson, eds. Butterworth and Co. Publishers Ltd., London.

CCME (Canadian Council of Ministers of the Environment). 1989. Appendix V—Canadian water quality guidelines: Updates (September 1989), carbofuran, glyphosate, and atrazine. In: Canadian water quality guidelines, Canadian Council of Resource and Environment Ministers. 1987. Prepared by the Task Force on Water Quality Guidelines.

———. 1991. Appendix IX—A protocol for the derivation of water quality guidelines for the protection of aquatic life (April 1991). 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 4, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]

Christy, S.L., E.P. Karlander, and J.V. Parochetti. 1981. Effects of glyphosate on the growth rate of *Chlorella*. *Weed Sci.* 29:5–7.

Damanakis, M.E. 1976. Behaviour of glyphosate in the soil (adsorption, leaching, degradation). *Ann. Inst. Phytopathol. Benaki* 11:153–167.

Edwards, W.M., G.B. Triplett, Jr., and R.M. Kramer. 1980. A watershed study of glyphosate transport in runoff. *J. Environ. Qual.* 9:661–665.

Environment Canada/Agriculture Canada. 1987. Pesticide registrant survey 1986 report. Prepared by Environment Canada, Commercial Chemicals Branch.

Feng, J.C., P.E. Reynolds, and H.D. Klassen. 1986. Persistence of glyphosate in streamwater following aerial application with a microfoil boom at Carnation Creek, British Columbia, 1984. File

- Report No. 73. Canadian Forestry Service, Forest Pest Management Institute, Sault Ste. Marie, ON.
- Folmar, L.C., H.O. Sanders, and A.M. Julin. 1979. Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. *Arch. Environ. Contam. Toxicol.* 8:269–278.
- Ghassemi, M., L. Fargo, P. Painter, S. Quinlivan, R. Scofield, and A. Takata. 1981. Environmental fates and impacts of major forest use pesticides. EPA Contract No. 68-02-3174. U.S. Environmental Protection Agency, Washington, DC.
- Goldsborough, L.G., and A.E. Beck. 1989. Rapid dissipation of glyphosate in small forest ponds. *Arch. Environ. Contam. Toxicol.* 18(4):537–544.
- Hance, R.J. 1976. Adsorption of glyphosate by soils. *Pestic. Sci.* 7:363–366.
- Hartman, W.A., and D.B. Martin. 1985. Effects of four agricultural pesticides on *Daphnia pulex*, *Lemna minor*, and *Potamogeton pectinatus*. *Bull. Environ. Contam. Toxicol.* 35:646–651.
- Hensley, D.L., D.S.N. Buerman, and P.L. Carpenter. 1978. The inactivation of glyphosate by various soils and metal salts. *Weed Res.* 18:287–291.
- Hoagland, R.E. 1978. The effects of N-(phosphonomethyl)glycine on selected enzymes in *Lemna gibba* (L.). *Proc. South. Weed Sci. Soc.* 31:285.
- Hoagland, R.E., and R. Paul. 1978. Ultrastructural effects of glyphosate on *Lemna gibba* (L.). *Weed Sci. Soc. Am.*, 1978 Meet. Abstract No. 170.
- Linden, E., B.E. Bengtsson, O. Svanberg, and G. Sunstrom. 1979. The acute toxicity of 78 chemicals and pesticide formulations against two brackish water organisms, the bleak (*Alburnus alburnus*) and the harpacticoid (*Nitocra spinipes*). *Chemosphere* 8:843–851.
- Lund-Høie, K., and H.O. Friestad. 1986. Photodegradation of the herbicide glyphosate in water. *Bull. Environ. Contam. Toxicol.* 36:723–729.
- Mitchell, D.G., P.M. Chapman, and T.J. Long. 1987. Seawater challenge testing of coho salmon smolts following exposure to Roundup[®] herbicide. *Environ. Toxicol. Chem.* 6:875–878.
- Monsanto Company. 1982a. Monsanto material safety data: Glyphosate technical. Monsanto Company, St. Louis, MO.
- . 1982b. Monsanto material safety data: Roundup herbicide. Monsanto Company, St. Louis, MO.
- . 1987. Monsanto material safety data: Vision herbicide. Monsanto Company, St. Louis, MO.
- Newton, M., K.M. Howard, B.R. Kelpas, R. Danhaus, C.M. Lottman, and S. Duebelman. 1984. Fate of glyphosate in an Oregon forest ecosystem. *J. Agric. Food Chem.* 32:1144–1151.
- Richardson, J.T., R.E. Frans, and R.E. Talbert. 1979. Reactions of *Euglena gracilis* to fluometuron, MSMA, metribuzin and glyphosate. *Weed Sci.* 27:619–624.
- Sacher, R.M. 1978. Safety of Roundup in the aquatic environment. In: *Proc. Eur. Weed Res. Soc.*, 5th Symp. on Aquatic Weeds, Amsterdam.
- Servizi, J.A., R.W. Gordon, and D.W. Martens. 1987. Acute toxicity of Garlon 4 and Roundup herbicides to salmon, *Daphnia*, and trout. *Bull. Environ. Contam. Toxicol.* 39:15–22.
- Tomlin, C. (ed.). 1994. The pesticide manual: A world compendium. 10th ed. (Incorporating the Agrochemicals handbook.) British Crop Protection Council and Royal Society of Chemistry, Thornton Heath, UK.
- Tooby, T.E. 1985. Fate and biological consequences of glyphosate in the aquatic environment. In: *The herbicide glyphosate*. E. Grossbard and D. Atkinson, eds. Butterworth and Co. Publishers Ltd., London.
- USDA (U.S. Department of Agriculture). 1981. Herbicide background statements. Pacific Northwest Region, Forest Service, Portland, OR. (Cited in USDA 1984.)
- . 1984. Herbicide background statement: Glyphosate. In: *Pesticide background statements, Vol. 1. Herbicides, Agricultural Handbook No. 633*. Portland, OR.
- Wan, M.T.K. 1986. The persistence of glyphosate and its metabolite aminomethylphosphonic acid in some coastal British Columbia streams. Regional Program Report 85-01. Environment Canada, Environmental Protection Service, Pacific and Yukon Region, Vancouver.
- Worthing, C.R., and S.B. Walker (eds.). 1983. The pesticide manual: A world compendium. 7th ed. The British Crop Protection Council, Croydon, UK.
- WSSA (Weed Science Society of America). 1983. Herbicide handbook. 5th ed. WSSA, Champaign, IL.

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Glyphosate. 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: spcme@chc.gov.mb.ca