Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

MCPA

MCPA ($C_9H_9ClO_3$) is a systemic phenoxyacetic acid herbicide used to control a suite of broadleaf weeds in agricultural and noncropland applications (Agriculture and Agri-Food Canada 1997). MCPA has a CAS name and number of (4-chloro-2-methylphenoxy) acetic acid and 94-74-6, respectively.

MCPA is a plant growth regulator and is exceptionally effective because uptake occurs through roots and foliage, and translocation to all tissues is rapid (WSSA 1989; Tomlin 1994). MCPA has selective herbicidal properties with differences in absorption, translocation, and metabolic degradation rates among species (Frear 1976). Many plants degrade MCPA to less toxic metabolites or conjugates through decarboxylation reactions or by complexing with plant proteins (WSSA 1989).

In mammals, phenoxy herbicides are readily absorbed from the stomach and gut, bound reversibly to plasma cells, and eliminated through urine, primarily as the parent compound (Loos 1979; Tyynela et al. 1990). Elo (1976) reported that within 24 h of administration to rats, 92.3 and 6.7% of radiolabeled MCPA is excreted through urine and feces, respectively. Milk and cream samples collected from cows dosed with 0.15–15 $mg·kg^{-1}$ MCPA per day in their feed for 2–3 weeks, contained residues <0.07 $mg·L^{-1}$ (Bjerke et al. 1972)

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

Water Quality Guideline Derivation

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

Irrigation Water

Cereals, pasture and rangeland crops, and turf grass are relatively tolerant to MCPA, though yield reductions and mortality may occur. Although grain yields of spring wheat *(Triticum aestivum)* and barley *(Hordeum vulgare)* are not affected by MCPA amine concentrations up to 1.7 $kg·ha^{-1}$, winter wheat suffers a 12–24% decrease in yield when treated with 0.55 $kg·ha^{-1}$ (Heinonen-Tanski et al. 1985; Martin et al. 1989, 1990). Reduced yields also occur in young wild rice *(Zizania palustris)* and annual canarygrass *(Phalaris canariensis)* exposed to 0.3 $kg·ha^{-1}$ isopropylamine salt and 0.56 $kg·ha^{-1}$ ester, respectively (Holt and Hunter 1987; Ransom and Oelke 1988). Seeds and one- to three-leaved plants of oat, ryegrass and corn are more tolerant of 2-ethylhexyl ester (2-EHE) than dimethylamine (DMA) salt, where LOEARs are 0.03–0.21 $kg·ha^{-1}$ and 0.17–0.66 $kg·ha^{-1}$, respectively (MCPA Task Force II 1993a, 1993b, 1993c, 1993d). Vegetable crops including lettuce, radishes, tomatoes, cucumbers, and cabbage are also more tolerant of 2-EHE than DMA, with LOEARs of 0.011–0.083 $kg·ha^{-1}$ and 0.006–0.041 $kg·ha^{-1}$, respectively (MCPA Task Force II 1993a, 1993b, 1993c, 1993d). MCPA is more toxic to legumes. For example, three-leaved lupins *(Lupinus albus)* treated with 0.4 $kg·ha^{-1}$ MCPA Na-salt suffered 40% mortality while two- and five-leaved plants treated with 0.6 $kg·ha^{-1}$ suffered 100 and 98% mortalities, respectively (Fabre and Jouy 1987; Wiedenhoeft and Ciha 1987).

Toxicological data for MCPA are sufficient to develop irrigation water quality guidelines for cereals, tame hays, and pastures and for other crops (CCME 1993). To derive guideline values, acceptable application rates (AAR) for each nontarget crop are calculated first by multiplying the geometric mean of the LOEAR and the NOEAR by an uncertainty factor of 0.1. The AARs for ryegrass and lettuce are 1.87×10^{-3} and 2.79×10^{-4} $kg·ha^{-1}$, respectively. The AARs are then divided by the maximum irrigation rate used in Canada (i.e., 1.2×10^{7} $L·ha^{-1}$) to calculate the SMATC; 1.6×10^{-4} and 2.5×10^{-5} $mg·L^{-1}$, for ryegrass and lettuce, respectively. The lowest SMATC

Table 1. Water quality guidelines for MCPA for the protection of agricultural water uses (CCME 1995).

Use	Guideline value ($\mu g·L^{-1}$)
Irrigation water	0.025
Livestock water	25.0*

*Interim guideline.

for each crop group is adopted as the guideline for that group, namely 0.16 $\mu g \cdot L^{-1}$ for cereals (ryegrass), tame hays and pastures, and 0.025 $\mu g \cdot L^{-1}$ for other crops (lettuce) (CCME 1995). The lowest value of the two groups, 0.025 $\mu g \cdot L^{-1}$, becomes the Canadian water quality guideline for MCPA in irrigation water for all crops.

Livestock Water

The acute oral toxicity of MCPA is formula-specific, where oral LD_{50}s for rats range from 439 $mg \cdot kg^{-1}$ for MCPA acid to 1200 $mg \cdot kg^{-1}$ for MCPA amine salt (Rowe and Hymas 1954; Elo et al. 1988; NIOSH 1991). Mice LD_{50}s are 450 and 1290 $mg \cdot kg^{-1}$ for Na salt and ethyl ester, respectively (NIOSH 1991). Long-term exposure to MCPA has various effects. A dose-dependent reduction in growth rate occurs in rats after a 63-d exposure to 13–246 $mg \cdot kg^{-1}$ per day Na salt (Hattula et al. 1977). Changes in kidney, liver, brain, and heart weights and histopathological alterations appear in rats exposed for 90 d to 20 $mg \cdot kg^{-1}$ per day Na salt (Verschuuren et al. 1975). Similar effects appear in beagle dogs following a 90-d exposure to 3 $mg \cdot kg^{-1}$ per day technical grade MCPA; the 1-year LOEL is 0.75 $mg \cdot kg^{-1}$ per day (Hellwig 1986; USEPA 1989). The 10-d LOEL for weight loss in sheep is 100 $mg \cdot kg^{-1}$ per day for both MCPA alkanolamine and Na salts (Palmer and Radeleff 1969; Palmer 1972). One sheep administered 100 $mg \cdot kg^{-1}$ per day of alkanolamine salt developed anorexia, ataxia, muscle spasms, and dyspnea after 307 d and died after 383 d (Palmer and Radeleff 1969). Cattle have a 10-d LOEL for weight loss of 175 $mg \cdot kg^{-1}$ per day Na salt (Palmer 1972). White leghorn chickens undergo a dose-dependent reduction in growth rate when orally administered 10, 250, or 500 $mg \cdot kg^{-1}$ per day DMA, alkanolamine, or Na salts, respectively (Palmer and Radeleff 1969; Palmer 1972). The 4-week LOEL and NOEL for reduced hatching success and survivorship in chickens are 16.7 and 8.33 $mg \cdot kg^{-1}$ Na salt, respectively, when injected into eggs (Gyrd-Hansen and Dalgaard-Mikkelson 1974). Mallard ducklings *(Anas platyrhynchos)* are relatively tolerant to MCPA, with LD_{50}s >910 and >960 $mg \cdot kg^{-1}$ per day and LOELs of 386 and 390 $mg \cdot kg^{-1}$ per day for DMA salt and octyl ester, respectively (Dow Chemical 1988a, 1988b).

Reproduction and development are less affected by MCPA than histopathology and size of internal organs. Yasudo and Maeda (1972) reported decreased weight and increased rate of malformations in fetuses when doses of 60–100 $mg \cdot kg^{-1}$ per day ethyl ester were administered through diet to pregnant rats for 8 d during gestation. The number of fetal resorptions increases following a 10-d maternal exposure to 100 $mg \cdot kg^{-1}$ per day (Roll and Matthiaschk 1983).

Though the USEPA (1989a) concluded that MCPA is non-oncogenic and non-mutagenic at low doses, high exposure may cause and/or promote mutations and tumors. For example, rat and Chinese hamster livers increase in size and/or number of peroxisomes after 10- and 9-d oral exposure to 100 $mg \cdot kg^{-1}$ per day of MCPA acid and isooctyl ester, respectively (Vainio et al. 1982; Mustonen et al. 1989). Linnainmaa (1984) reported an increase in sister chromatid exchange in bone marrow cells from Chinese hamsters and in blood lymphocytes from rats exposed 9 d to 100 $mg \cdot kg^{-1}$ of isooctyl ester.

To develop an interim water quality guideline for MCPA, the TDI was first calculated for each species for which acceptable toxicological data were available. The TDI is the geometric mean of the LOEL and the NOEL divided by an uncertainty factor of 10. A TDI of 0.034 $mg \cdot kg^{-1}$ per day was calculated for beagle dogs having a LOEL and NOEL of 0.75 and 0.15 $mg \cdot kg^{-1}$ per day, respectively, for organ weight (Hellwig 1986). Note that the NOEL was estimated by dividing the LOEL by 5.6 (CCME 1993). An RC was calculated by multiplying the TDI by the lowest available ratio of body weight (bw) to water intake rate (WIR) (CCME 1993). White leghorn chickens have a bw/WIR ratio of 3.8 giving an RC of 0.13 $mg \cdot L^{-1}$. To account for exposure to MCPA from sources other than water, the lowest RC, that of beagle dogs, is multiplied by an apportionment factor of 0.2 to give a water quality guideline of 25.0 $\mu g \cdot L^{-1}$ for the protection of livestock (CCME 1995).

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 1988 report. Agriculture Canada, Pesticides Directorate and Environment Canada, Commercial Chemicals Branch, Ottawa.

Bjerke, E.L., L.J. Herman, P.W. Miller, and J.H. Wetters. 1972. Residue study of phenoxyherbicides in milk and cream. J. Agric. Food Chem. 20(5):963.

Bovey, R.W. 1970. Hormone-like herbicides in weed control. Proceedings of the 11th Annual Meeting of the Society for Economic Botany. Texas A&M University, College Station, TX.

Bovey R.W., and A.L. Young. 1980. The science of 2,4,5-T and associated phenoxy herbicides. John Wiley and Sons, New York.

CCME (Canadian Council of Ministers of the Environment). 1993. Appendix XV—Protocols for the 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.]

———. 1995. Appendix XVIII—Canadian water quality guidelines: Updates (March 1995), MCPA. In: Canadian water quality guidelines, Canadian Council of Resource and Environment Ministers. 1987. Prepared by the Task Force on Water Quality Guidelines.

Dow Chemical. 1988a. MCPA dimethylamine salt (2-methyl-4-chlorophenoxyacetic acid, dimethylamine salt): A dietary LC_{50} study with the mallard. Technical Committee, Industry Task Force on MCPA Research Data, Dow Chemical USA, AG Products Department, Midland, MI.

———. 1988b. MCPA octyl ester (2-methyl-4-chlorophenoxyacetic acid, octyl ester): A dietary LC_{50} study with the mallard. Technical Committee, Industry Task Force on MCPA Research Data, Dow Chemical USA, AG Products Department, Midland, MI.

Elo, H. 1976. Distribution and elimination of 2-methyl-4-chlorophenoxyacetic acid (MCPA) in male rats. Acta Pharmacol. Toxicol. 39:58–64.

Elo, H.A., H. Her Vonen, and P. Ylitalo. 1988. Comparative study on cerebrovascular injuries by three chlorophenoxyacetic acids (2,4-D, 2,4,5-T and MCPA). Comp. Biochem. Physiol. 90C(1):65–68.

Fabre, E., and L. Jouy. 1987. Selectivity and efficacy of herbicides in spring sown lupins. 1987 British Crop Protection Conference–Weeds. Thornton Heath, UK.

Frear, D.S. 1976. The benzoic acid herbicides. In: Herbicides: Chemistry, degradation, and mode of action, 2d ed., P.C. Kearney and D.D. Kaufman, eds. Marcel Dekker, Inc., New York.

Gyrd-Hansen, N., and S. Dalgaard-Mikkelsen. 1974. The effect of phenoxy-herbicides on the hatchability of eggs and the viability of the chicks. Acta Pharmacol. Toxicol. 35:300–308.

Hattula, M.L., H. Elo, H. Reunanen, A.U. Arstila, and T.E. Sorvari. 1977. Acute and subchronic toxicity of 2-methyl-4-chlorophenoxyacetic acid (MCPA) in male rat. I. Light microscopy and tissue concentrations of MCPA. Bull. Environ. Contam. Toxicol. 18(2):152–158.

Heinonen-Tanski, H., C. Rosenberg, H. Siltanen, S. Kilpi, and P. Simojoki. 1985. The effect of the annual use of pesticides on soil microorganisms, pesticide residues in the soil and barley yields. Pesic. Sci. 16:341–348.

Hellwig, J. 1986. Report on the study of the toxicity of MCPA in beagle dogs after 12-month administration in the diet. Project No. 33D0046/8341. MRID 164352. Unpub. (Cited in USEPA 1989.)

Holt, N.W., and J.H. Hunter. 1987. Annual canarygrass *(Phalaris canariensis)* tolerance and weed control following herbicide application. Weed Sci. 35:673–677.

Linnainmaa, K. 1984. Induction of sister chromated exchanges by the peroxisome proliferators 2,4-D, MCPA, and clofibrate in vivo and in vitro. Carcinogeneisis 5(6):703–707.

Loos, M.A., I.F. Schlosser, and W.R. Mapham. 1979. Phenoxy herbicide degradation in soils: quantitative studies of 2,4-D- and MCPA- degrading microbial populations. Soil Biol. Biochem. 11:377–385.

Martin, D.A., S.D. Miller, and H.P. Alley. 1989. Spring wheat response to herbicides applied at three growth stages. Argon. J. 82:95–97.

———. 1990. Spring wheat response to herbicides applied at three growth stages. Agron. J. 82:95–97.

MCPA Task Force II. 1993a. Tier II: The effects of MCPA DMAS on nontarget plants: Seed germination/seedling emergence. Research Triangle Park, NC.

———. 1993b. Tier 2 seed germination/seedling emergency nontarget phytotoxicity study using MCPA 2-EHE. Research Triangle Park, NC.

———. 1993c. Tier 2 vegetative vigor nontarget phytotoxicity study using MCPA 2-EHE. Research Triangle Park, NC.

———. 1993d. Tier II: The effects of MCPA DMAS on nontarget plants: Vegetative vigor. Research Triangle Park, NC.

Mustonen, R., E. Elovaara, A. Zitting, K. Linnainmaa, and H. Vainio. 1989. Effects of commercial chlorophenolate, 2,3,7,8,-TCDD, and pure phenoxyacetic acids on hepatic peroxisome proliferation, xenobiotic metabolism and sister chromatid exchange in the rat. Arch. Toxicol. 63:203–208.

NIOSH (National Institute for Occupational Safety and Health). 1991. Cheminfo-MCPA. Canadian Centre for Occupational Health and Safety, Hamilton, ON.

Palmer, J.S. 1972. Toxicity of 45 organic herbicides to cattle, sheep and chickens. Prod. Res. Rept. No. 137. USDA-ARS. (Cited in Bovey and Young 1980.)

Palmer, J.S., and R.D. Radeleff. 1969. The toxicity of some organic herbicides to cattle, sheep, and chickens. Prod. Res. Rept. No. 06 USDA-ARS. (Cited in Bovey and Young 1980.)

Ransom, J.K., and E.A. Oelke. 1988. Common waterplantain, *Alisma plantago-aquatica*, control in wild rice *Zizania palustris*, with MCPA and 2,4-D. Weed Technol. 2:310–316.

Roll, V.R., and G. Matthiaschk. 1983. Vergleichende Untersuchungen zur Embryo Toxizität von 2-Methyl-4-chlorphenoxyessigsäure, Mecaprop und Dichlorprop bei NMRI-Mäusen. Arzneim. Forsch./Drug Res. 33(II) Nr. 10:1479–1483.

Rowe, V.K., and T.A. Hymas. 1954. Summary of toxicological information on 2,4-D and 2,4,5-T type herbicides and an evaluation of the hazards to livestock associated with their use. Am. J. Vet. Res. October:622–629.

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.

Tyynela, K., H.A. Elo, and P. Ylitalo. 1990. Distribution of 3 common chlorophenoxyacetic acid herbicides into the rat brain. Arch. Toxicol. 64:61–65.

USEPA (U.S. Environmental Protection Agency). 1989. Drinking water health advisory: Pesticides. USEPA, Office of Drinking Water Health Advisories, Washington, DC.

Vainio, H., J. Nickels, and K. Linnainmaa. 1982. Phenoxy acid herbicides cause peroxisome proliferation in Chinese hamsters. Scand. J. Work Environ. Health 8:70–73.

Verschuuren, H.G., R. Kroes, and E.N. den Tonkecaar. 1975. Short-term oral and dermal toxicity of MCPA and MCPP. Toxicology 3:349–359.

WSSA (Weed Science Society of America). 1989. Herbicide handbook. 6th ed. WSSA, Champaign, IL.

Wiedenhoeft, M.H., and A.J. Ciha. 1987. Herbicide tolerance of white lupin. Agron. J. 79:999–1002.

Yasuda, M., and H. Maeda. 1972. Teratogenic effects of 4-chloro-2-methylphenoxyacetic acid ethylester (MCPEE) in rats. Toxicol. Appl. Pharmacol. 23:326–333.

Reference listing:

Canadian Council of Ministers of the Environment. 2001. Canadian water quality guidelines for the protection of agricultural water uses: MCPA. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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