Canadian Water Quality Guidelines for the Protection of Aquatic Life

STYRENE

Styrene (CAS 100-42-5, molecular weight 104.14) is a volatile, monoaromatic hydrocarbon with the structural formula of $C_6H_5CH{=}CH_2$, vapour pressure of 880 Pa, Henry's law constant of 305.48 $Pa \cdot m^3 \cdot mol^{-1}$, and a log octanol–water partition coefficient of 3.05. Synonyms for styrene include vinylbenzene, vinylbenzol, phenylethylene, styrolene, styrol, styrole, ethenylbenzene, cinnamene, cinnamenol and cinnamol (Government of Canada 1993). Pure styrene has a sweet aromatic odour at low concentrations (0.02 ppm) (Hoshika et al. 1993) and a disagreeable odour at higher concentrations (e.g., 100 ppm) (EPS 1984; Bond 1989). Styrene is only sparingly soluble in water at approximately 300–350 $mg \cdot L^{-1}$ (Mackay et al. 1993).

The dominant use of styrene is to make polymers for the manufacture of plastics, synthetic rubbers, and latexes such as polystyrene, acrylonitrile-butadiene-styrene (ABS), styrene-acrylonitrile (SAN), and styrene-butadiene (SB). These finished products are used in packaging material, disposable food and drink containers (molded expandable polystyrene, EPS), pipes (ABS), automobile instrument panel windows, clear housewear items (SAN), automobile tires (SB elastomer), paint (SB latexes and styrene-maleic anhydride), ion exchange resins for water treatment (styrene divinylbenzene resins), other plastic products, and fibrous glass products (Santodonato et al. 1980; USEPA 1992; Government of Canada 1993). Styrene is also an ingredient in floor waxes and polishes, paints, adhesives, putty, metal cleaners, autobody fillers, fibreglass boats, and varnishes (Howard 1989).

Styrene is produced in Canada at two plants in Ontario and one in Alberta (Government of Canada 1993). Canadian production of styrene in 1990 was reported to be 718 kt, of which approximately 490 kt were exported (CIS 1991). It is used in several industries across Canada (Ontario, Quebec, Alberta, British Columbia, and Nova Scotia) (Government of Canada 1993).

Styrene can be released into the environment during any stage of its manufacture, transport, disposal, or use. In addition to anthropogenic sources, styrene occurs naturally in the sap of styraceous trees, in bituminous-coal, and in shale-oil tars (RSC 1989), and is a natural by-product of the fungal and microbial metabolisms of a few species (Chen and Pepler 1956; Clifford et al. 1969).

In 1994, Environment Canada's National Pollutant Release Inventory (NPRI) recorded emissions of 1793 t of styrene (NPRI homepage: http://www.ec.gc.ca/pdb/npri.html).

Styrene concentrations are low in surface waters, generally below 1 $\mu g \cdot L^{-1}$ (detection limit 0.2 $\mu g \cdot L^{-1}$) (Government of Canada 1993), but can reach higher levels due to localized discharge events (e.g., 47.0 $\mu g \cdot L^{-1}$) (Barton 1994).

Dissolved styrene will rapidly volatilize to the atmosphere (Mackay et al. 1993). Fu and Alexander (1992) estimated the half-life for styrene in lake water and distilled water as 1–3 h and 6–7 h, respectively. The shorter half-life in lake water was explained as significant aerobic biodegradation in addition to volatilization. The half-life of styrene in rivers has been estimated at 3 h (Howard et al. 1991), which is strongly affected by water mixing. In ponds (shallow water) and lakes (deep water), the half-life of styrene has been modeled to be 3 d and 13 d, respectively (USEPA 1984).

Styrene can also partition into animal tissue, however, the log BCFs of 0.83 and 1.13 determined from goldfish (Ogata et al. 1984) indicate that the bioconcentration of styrene in aquatic organisms is not likely to be significant. Although the K_{ow} indicates a moderate tendency for styrene to partition into fat, the low BCF is likely a result of the relatively rapid metabolism and excretion of styrene from the organism (USEPA 1992).

Styrene is known to cause tainting in fish tissue. The concentration in water impairing the flavour of yellow perch *(Perca flavescens)* was reported to range from 0.15 to 0.25 $mg \cdot L^{-1}$ (Persson 1984). A concentration of

Table 1. Water quality guidelines for styrene for the protection of aquatic life (Environment Canada 1998).

Aquatic life	Guideline value ($\mu g \cdot L^{-1}$)
Freshwater	72*
Marine	NRG†

*Interim guideline.
†No recommended guideline.

0.037 $mg \cdot L^{-1}$ was found to impart an odour to water in one older study (Rosen et al. 1963), while Persson (1984) found odours detectable at 0.11 $mg \cdot L^{-1}$.

Water Quality Guideline Derivation

The interim Canadian water quality guideline for styrene for the protection of freshwater life was developed based on the 1991 protocol (CCME 1991). For more details, see the supporting document (Environment Canada 1998).

Freshwater Life

The interim guideline for styrene for the protection of freshwater life is 72 $\mu g \cdot L^{-1}$.

Rainbow trout *(Oncorhynchus mykiss)* fry were the most sensitive fish species tested, with a 96-h LC_{50} of 4.1 $mg \cdot L^{-1}$ (Exxon Biomedical 1993) and a 96-h LC_{50} of 2.5 $mg \cdot L^{-1}$ (Qureshi et al. 1982). For fathead minnows *(Pimephales promelas)*, 96-h LC_{50}s of 10 $mg \cdot L^{-1}$ and 32 $mg \cdot L^{-1}$ are reported by Machado (1995) and Mattson et al. (1976), respectively. For bluegill sunfish *(Lepomis macrochirus)*, goldfish *(Carassius auratus)*, and guppies *(Lebistes reticulatus)*, the 96-h LC_{50} values were 25, 65, and 75 $mg \cdot L^{-1}$, respectively (Pickering and Henderson 1966).

The cladoceran *Daphnia magna* was the most sensitive of the invertebrates studied. The 48-h EC_{50}s (immobilization) are reported at 4.7 $mg \cdot L^{-1}$ (Putt 1995a), 23 $mg \cdot L^{-1}$ (LeBlanc 1980), and 59 $mg \cdot L^{-1}$ (Qureshi et al. 1982). *Hyalella azteca* was less sensitive than *D. magna*, with a 96-h LC_{50} of 9.5 $mg \cdot L^{-1}$ (Putt 1995b). Erben and Pišl (1993) reported a 48-h LC_{50} of 69 $mg \cdot L^{-1}$ for the isopod *Asellus aquaticus* and 580 $mg \cdot L^{-1}$ for the snail *Lymnaea stagnalis.*

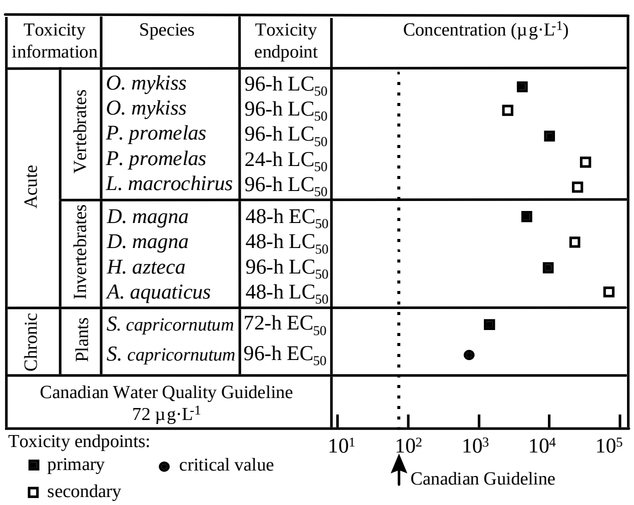

Figure 1. Select freshwater toxicity data for styrene.

The only plant used in acceptable toxicity studies was the green alga *Selenastrum capricornutum*. The 72-h EC_{50} (inhibition of cell density, chronic) was found to be 1.4 $mg \cdot L^{-1}$, and the 96-h EC_{50} was 0.72 $mg \cdot L^{-1}$ (Hoberg 1995). This is the most sensitive organism in the available data set, and the interim guideline value was calculated by multiplying the 96-h EC_{50} of 0.72 $mg \cdot L^{-1}$ by a safety factor of 0.1, yielding an interim guideline value of 72 $\mu g \cdot L^{-1}$.

References

Barton, S.C. 1994. Annual report of the Water Quality Assessment Program. Prepared for Lambton Industrial Society. Ortech, Sarnia, ON.

Bond, J.A. 1989. Review of the toxicology of styrene. CRC Crit. Rev. Toxicol. 19(3):227–249.

CIS (Camford Information Services). 1991. CPI product profiles: Styrene. CIS, Don Mills, ON.

CCME (Canadian Council of Ministers of the Environment). 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. [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.]

Chen, S.L., and H.J. Peppler. 1956. Conversion of cinnamaldehyde to styrene by a yeast mutant. J. Biol. Chem. 221:101–106.

Clifford, D.R., J.K. Faulkner, J.R.L. Walker, and D. Woodcock. 1969. Metabolism of cinnamic acid by *Aspergillus niger*. Phytochemistry 8:549–552.

Environment Canada. 1998. Canadian water quality guidelines for styrene. Supporting document. Environment Canada, Environmental Quality Branch, Ottawa. Unpub. draft doc.

EPS (Environmental Protection Service). 1984. Enviro-technical information for problem spills: Styrene. Environment Canada, Ottawa.

Erben, R., and Z. Pišl. 1993. Acute toxicity for some evaporating aromatic hydrocarbons for freshwater snails and crustaceans. Int. Rev. Gesamten Hydrobiol. 78(1):161–167.

Exxon Biomedical. 1993. Acute fish toxicity test: Rainbow trout. Project No. 140358. Exxon Biomedical Sciences, Inc., Environmental Toxicology Laboratory, East Millstone, NJ.

Government of Canada. 1993. Styrene. Canadian Environmental Protection Act Priority Substances List Assessment Report. Environment Canada and Health Canada, Ottawa.

Fu, M.H., and M. Alexander. 1992. Biodegradation of styrene in samples of natural environments. Environ. Sci. Technol. 26:1540–1544.

Hoberg, J.R., 1995. Styrene: Toxicity to the freshwater green alga, *Selenastrum capricornutum*. Project No. SLI rep. 95-6-5933, SLI study 13555.0195.6101.430, SIRC ref. SIRC-SBL-TOX-ALG-9401. SIRC, Washington, DC.

Hoshika, Y., T. Imamura, G. Muto, L.J. van Gemert, J.A. Don, and J.I. Walpot. 1993. International comparison of odor threshold values of several odorants in Japan and in the Netherlands. Environ. Res. 61:78–83.

Howard, P.H. 1989. Handbook of environmental fate and exposure data for organic chemicals. Vol. I, Large production and priority pollutants. Lewis Publishers, Chelsea, MI.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko. 1991. Handbook of environmental degradation rates. Lewis Publishers, Chelsea, MI.

LeBlanc, G.A. 1980. Acute toxicity of priority pollutants to water flea *(Daphnia magna)*. Bull. Environ. Contam. Toxicol. 24(5):684–691.

Machado, M.W. 1995. Styrene: Toxicity to fathead minnow *(Pimephales promelas)* under flow-through conditions. Project No. SLI rep. 95-5-5862, SLI study 13555.0195.6103.106, SIRC ref. SIRC-SBL-TO-MIN-9401. SIRC, Washington, DC.

Mackay, D., W.S. Shiu, and K.C. Ma. 1993. Illustrated handbook of physical–chemical properties and environmental fate for organic chemicals. Vol III, Volatile organic chemicals. Lewis Publishers, Chelsea, MI.

Mattson, V.R., J.W. Arthur, and C.T. Walbridge. 1976. Acute toxicity of selected organic compounds to fathead minnows. U.S. Environmental Protection Agency, Duluth, MN.

Ogata, M., K. Fujisawa, Y. Ogino, and E. Mano. 1984. Partition coefficients as a measure of bioconcentration potential of crude oil compounds in fish and shellfish. Bull. Environ. Contam. Toxicol. 33:561.

Persson, P.E. 1984. Uptake and release of environmentally occurring odorous compounds by fish: A review. Water Res. 18(10):1263–1271.

Pickering, Q.H., and C. Henderson. 1966. Acute toxicity of some important petrochemicals to fish. J. Water Pollut. Control Fed. 38(9):1419–1429.

Putt, A.E. 1995a. Styrene: Acute toxicity to water fleas *(Daphnia magna)* under flow-through conditions. Project No. SLI rep. 95-6-5945, SLI study 13555.0195.6102.115, SIRC ref. SIRC-SBL-TO-DAPH-9401. SIRC, Washington, DC.

———. 1995b. Styrene: Acute toxicity to amphipods *(Hyalella azteca)* under flow-through conditions. Project No. SLI rep. 95-7-5997, SLI study 13555.0195.6104.162, SIRC ref. SIRC-SBL-TO-AMP-9401. SIRC, Washington, DC.

Qureshi, A.A., K.W. Flood, S.R. Thompson, S.M. Janhurst, C.S. Inniss, and D.A. Rokosh. 1982. Comparison of a luminescent bacterial test with other bioassays for determining toxicity of pure compounds and complex effluents. In: Aquatic toxicology and hazard assessment: Fifth conference, J.G. Pearson, R.B. Foster, and W.E Bishop, eds. American Society for Testing and Materials, Philadelphia.

Rosen, A.A., R.T. Skeel, and M.B. Ettinger. 1963. Relationship of river water odour to specific organic contaminants. J. Water Pollut. Control Fed. 35(6):777–783.

RSC (Royal Society of Chemistry). 1989. Chemical safety data sheets. Vol. 1, Solvents (styrene). Cambridge, England.

Santodonato, J., W.M. Meylan, L.N. Davis, P.H. Howard, D. Orzel, and D.A. Bogho. 1980. Investigation of selected potential environmental contaminants: Styrene, ethylbenzene and related compounds. 560/11-80-018. U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1984. Health and environmental effects profile for styrene. EPA-600/X-84/325. USEPA, Office of Research and Development, Cincinnati, OH.

———. 1992. Toxicological profile for styrene. TP-91/25. Agency for Toxic Substance and Disease Registry, Public Health Service, Washington, DC.

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Styrene. 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.