Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

DIELDRIN

Dieldrin is a synthetic organochlorine pesticide that was used in Canada from the early 1950s to the 1980s as a treatment for a variety of insect pests. Dieldrin is also the main persistent degradation product of the synthetic organochlorine pesticide aldrin. The registration and use of dieldrin under the Pest Control Products Act were discontinued as of January 1, 1991. Dieldrin has also been identified as a Track 1 substance by Environment Canada because it is persistent, bioaccumulative, released primarily as a result of human activities, and considered "CEPA-toxic" under the Canadian Environmental Protection Act (Environment Canada 1997).

Dieldrin has entered aquatic systems primarily as surface runoff from lands treated with aldrin or dieldrin, spray drift, washoff from treated lumber, and from deposition following volatilization and aerial transport. Because of its hydrophobicity and affinity for organic materials, dieldrin in aquatic systems tends to become associated with particulate matter and accumulate in sediments. Because a wide variety of organisms live in, or are in contact with, bed sediments, sediments act as an important route of exposure of dieldrin to aquatic organisms. Canadian interim sediment quality guidelines (ISQGs) and probable effect levels (PELs) for dieldrin can be used to evaluate the degree to which adverse biological effects are likely to occur as a result of exposure to dieldrin in sediments.

Canadian ISQGs and PELs for dieldrin were developed using a modification of the National Status and Trends Program approach as described in CCME (1995) (Table 1). The ISQGs and PELs refer to total concentrations of dieldrin in surficial sediments (i.e., top 5 cm), as quantified by extraction with an organic solvent (e.g., 1:1 acetone:hexane) followed with determination by a standard analytical protocol.

The majority of the data used to derive ISQGs and PELs for dieldrin are from studies on field-collected sediments that measured concentrations of dieldrin, along with concentrations of other chemicals, and associated biological effects. Biological effects associated with concentrations of dieldrin in sediments are compiled in the Biological Effects Database for Sediments (BEDS) (Environment Canada 1998). Both the freshwater and marine BEDS data sets for dieldrin are large, with the freshwater data set containing 32 effect entries and 268 no-effect entries and the marine data set containing 25 effect entries and 157 no-effect entries (Figures 1 and 2). Both data sets represent a wide range of concentrations of dieldrin, types of sediment, and mixtures of chemicals. Evaluation of the percentage of effect entries that are below the ISQGs, between the ISQGs and the PELs, and above the PELs for dieldrin (Figures 1 and 2) indicates that these values define three ranges of chemical concentrations: those that are rarely, occasionally, and frequently associated with adverse biological effects, respectively (Environment Canada 1998).

Toxicity

Adverse biological effects for dieldrin in the BEDS include decreased benthic invertebrate diversity, reduced abundance, increased mortality, and behavioural changes (Environment Canada 1998, Appendixes VIIa and VIIb). For example, benthic species richness in sediments of Humber Bay, Lake Ontario, was lower at locations where the mean concentration of dieldrin was 9.25 µg·kg^{-1}, which is above the freshwater PEL, than at sites with a mean concentration of 1.0 µg·kg^{-1}, which is below the freshwater ISQG (Jaagumagi 1988; Jaagumagi et al. 1989). Similarly, in marine sediments from Puget Sound, Washington, significant lethal toxicity was observed in *Rhepoxynius abronius*, an amphipod, at a mean concentration of 1.17 µg·kg^{-1}, which is above the marine ISQG (Pastorok and Becker 1990). In contrast, no significant toxicity was observed at sites with a mean concentration of 0.533 µg·kg^{-1}, which is below the marine ISQG (Pastorok and Becker 1990).

Spiked-sediment toxicity tests for dieldrin report the onset of toxicity to benthic organisms at higher concentrations than those observed in field studies. This is likely a result of the shorter exposure times of these laboratory studies,

Table 1. Interim sediment quality guidelines (ISQGs) and probable effect levels (PELs) for dieldrin (µg·kg^{-1} dw).

	Freshwater	Marine/estuarine
ISQG	2.85	0.71
PEL	6.67	4.30

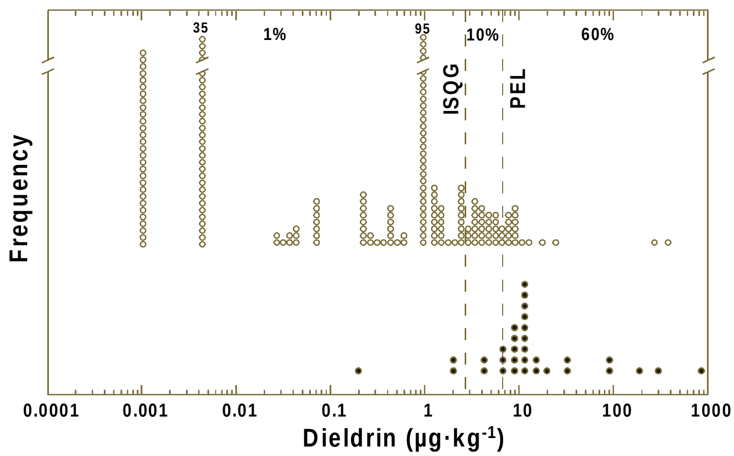

Figure 1. Distribution of dieldrin concentrations in freshwater sediments that are associated with adverse biological effects (●) and no adverse biological effects (○). Percentages indicate proportions of concentrations associated with effects in ranges below the ISQG, between the ISQG and the PEL, and above the PEL.

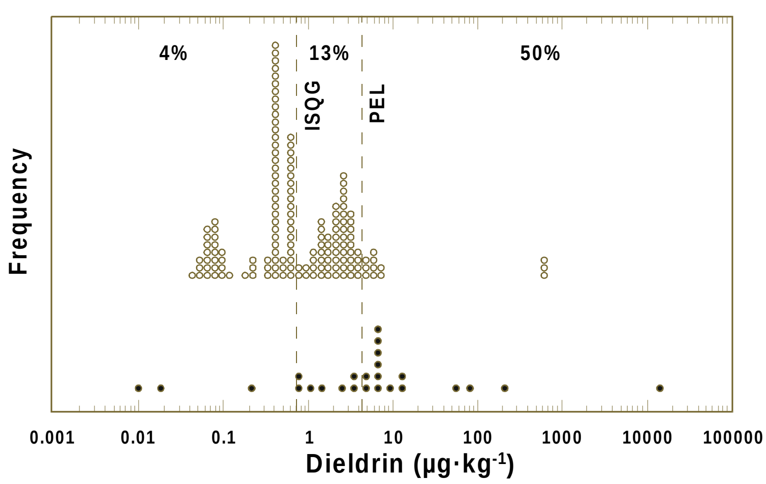

Figure 2. Distribution of dieldrin concentrations in marine and estuarine sediments that are associated with adverse biological effects (●) and no adverse biological effects (○). Percentages indicate proportions of concentrations associated with effects in ranges below the ISQG, between the ISQG and the PEL, and above the PEL.

as well as exposure to dieldrin only as opposed to chemical mixtures containing dieldrin (Environment Canada 1998). For example, Hoke et al. (1995) spiked freshwater sediments having three different concentrations of TOC with dieldrin and examined acute toxicity in an amphipod, *Hyalella azteca*. Ten-day LC_{50}s for *H. azteca* were 22.8 mg·kg^{-1}, 43.4 mg·kg^{-1}, and 442 mg·kg^{-1} at low (1.73%), moderate (3.01%), and high (8.52%) TOC levels, respectively. Thus, TOC seems to reduce the toxicity of sediment-associated dieldrin. In addition, Hoke et al. (1995) found statistically significant effects on the growth of a midge, *Chironomus tentans*, after a 10-d exposure to 100 µg·kg^{-1} dieldrin, which is greater than the freshwater PEL. McLeese and Metcalfe (1980) measured a 96-h LC_{50} of 4.1 µg·kg^{-1} for a marine shrimp, *Crangon septemspinosa*, which is similar to the marine PEL of 4.30 µg·kg^{-1}.

Results of both freshwater and marine spiked-sediment toxicity tests and field studies indicate that concentrations of dieldrin that are associated with adverse biological effects are consistently above the ISQGs, confirming that the guidelines adequately represent concentrations below which adverse biological effects will rarely occur. Further, these studies provide additional evidence that toxic levels of dieldrin in sediments are similar to or greater than the PELs, confirming that effects are more likely to be observed when concentrations of dieldrin exceed the PELs (Environment Canada 1998). The ISQGs and PELs for dieldrin are therefore expected to be valuable tools for assessing the ecotoxicological relevance of concentrations of dieldrin in sediments.

Concentrations

Currently, data on concentrations of dieldrin in Canadian freshwater and marine sediments are limited. In Canadian freshwater lake, river, and stream sediments, concentrations range from below detection to a maximum of 86 µg·kg^{-1} (Environment Canada 1998). The maximum concentration of dieldrin in sediments (i.e., 86 µg·kg^{-1}) was measured in a river draining an intensively farmed area of Nova Scotia. In marine and estuarine sediments, concentrations range from below detection to 1.6 µg·kg^{-1} in sediments from the St. Lawrence estuary, Quebec (Environment Canada 1998). Dieldrin slowly degrades in aquatic sediments; therefore, the elimination of local sources should result in a gradual decrease in concentrations over time.

Additional Considerations

Regardless of the origin of dieldrin in sediments, aquatic organisms may be adversely affected by exposure to elevated levels. The occurrence of adverse biological effects cannot be precisely predicted from concentration data alone, particularly in the concentration ranges between the ISQGs and the PELs (Figures 1 and 2). The likelihood of adverse biological effects occurring in response to exposure to dieldrin at a particular site depends on the sensitivity of individual species and endpoints examined, as well as a variety of physicochemical (e.g., temperature and pH), geochemical (e.g., sediment particle size and TOC), and biological (e.g., feeding behaviour and uptake rates) factors that affect the bioavailability of dieldrin (Environment Canada 1998).

Benthic organisms are exposed to both particulate and dissolved dieldrin in interstitial and overlying waters, as well as to sediment-bound dieldrin through surface contact and sediment ingestion. Dieldrin that is dissolved in the interstitial or overlying waters is believed to be the most bioavailable source for sediment-associated organisms and correlates well with toxicity (Adams et al. 1985; Di Toro et al. 1991). When different types of sediments with the same concentrations of total dieldrin are compared, less dieldrin is dissolved in the interstitial water of sediments with high TOC content (Karickhoff 1984; Shea 1988). Therefore, organic carbon may reduce the bioavailability and, hence, toxicity of sediment-associated dieldrin to benthic organisms. The physicochemical, geochemical, and biological factors that modify bioavailability should be considered when evaluating the potential biological impact of dieldrin in sediments (Environment Canada 1998).

Currently, the degree to which dieldrin will be bioavailable at particular sites cannot be predicted conclusively from the physicochemical characteristics of sediments or the attributes of endemic organisms (Environment Canada 1998). Nonetheless, an extensive review of the available data indicates that the incidence of adverse biological effects associated with exposure to dieldrin increases as concentrations of dieldrin increase in a range of sediment types (Figures 1 and 2). Therefore, the recommended Canadian ISQGs and PELs for dieldrin will be useful in assessing the ecotoxicological significance of dieldrin in sediments.

References

Adams, W.J., R.A. Kimerle, and R.G. Mosher. 1985. Aquatic safety assessment of chemicals sorbed to sediments. In: Aquatic toxicology and hazard assessment: Seventh symposium, R.D. Cardwell, R. Purdy, and R.C. Bahner, eds. American Society of Testing and Materials, Philadelphia.

CCME (Canadian Council of Ministers of the Environment). 1995. Protocol for the derivation of Canadian sediment quality guidelines for the protection of aquatic life. CCME EPC-98E. Prepared by Environment Canada, Guidelines Division, Technical Secretariat of the CCME Task Group on Water Quality Guidelines, Ottawa.

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Di Toro, D.M., C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas, and P.R. Paquin. 1991. Technical basis for establishing sediment quality criteria for non-ionic organic chemicals using equilibrium partitioning. Environ. Toxicol. Chem. 10:1541–1583.

Environment Canada. 1997. Toxic substances management policy—Aldrin and dieldrin: Scientific justification. ISBN 0-662-25396-5. Ottawa.

———. 1998. Canadian sediment quality guidelines for chlordane, dieldrin, endrin, heptachlor epoxide, and lindane: Supporting document. Environmental Conservation Service, Ecosystem Science Directorate, Science Policy and Environmental Quality Branch, Guidelines and Standards Division, Ottawa. Draft.

Hoke, R.A., P.A. Kosian, G.T. Ankley, A.M. Cotter, F.M. Vandermeiden, G.L. Phipps, and E.J. Durhan. 1995. Check studies with *Hyalella azteca* and *Chironomus tentans* in the support of the development of a sediment quality criterion for dieldrin. Environ. Toxicol. Chem. 14:435–444.

Jaagumagi, R. 1988. The in-place pollutants program. Volume V, Part B. Benthic invertebrates studies results. Ontario Ministry of the Environment, Water Resources Branch, Aquatic Biology Section, Toronto.

Jaagumagi, R., D. Persaud, and T. Lomas. 1989. The in-place pollutants program. Volume V, Part A. A synthesis of benthic invertebrates studies. Ontario Ministry of the Environment, Water Resources Branch, Aquatic Biology Section, Toronto.

Karickhoff, S.W. 1984. Organic pollutant sorption in aquatic systems. J. Hydraul. Eng. 110:707–735.

McLeese, D.W., and C.D. Metcalfe. 1980. Toxicities of eight organochlorine compounds in sediment and seawater to *Crangon septemspinosa*. Bull. Environ. Contam. Toxicol. 25:921–928.

Pastorok, R.A., and D.S. Becker. 1990. Comparative sensitivity of sediment toxicity bioassays at three Superfund sites in Puget Sound. In: Aquatic toxicology and risk assessment, W.G. Landis and W.H. van der Schalie, eds. American Society for Testing and Materials, Philadelphia.

Shea, D. 1988. Developing national sediment quality criteria. Environ. Sci. Technol. 22(11):1256–1261.

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian sediment quality guidelines for the protection of aquatic life: Dieldrin. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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