Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

ENDRIN

Endrin is a synthetic organochlorine pesticide that was used in Canada from the early 1950s to the early 1980s as a treatment for a variety of insect pests. The registration and use of endrin under the Pest Control Products Act were discontinued as of January 1, 1991. Endrin 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).

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

The Canadian ISQG and PEL for endrin in freshwater sediments were developed using a modification of the National Status and Trends Program (NSTP) approach as described in CCME (1995) (Table 1). Insufficient information was available to derive a marine ISQG and PEL according to the formal protocol (CCME 1995). Therefore, the corresponding freshwater ISQG and PEL, derived using a modification of the NSTP approach, were provisionally adopted for marine sediments given that they were the lowest biological effects-based guidelines available. The ISQGs and PELs refer to total concentrations of endrin 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 the freshwater ISQG and PEL for endrin are from studies on field-collected sediments that measured concentrations of endrin, along with concentrations of other chemicals, and associated biological effects. Biological effects associated with concentrations of endrin in sediments are compiled in the Biological Effects Database for Sediments (BEDS) (Environment Canada 1998). Only the freshwater BEDS data set was sufficiently large to develop an ISQG and a PEL, with 59 effect entries and 281 no-effect entries (Figure 1). The BEDS represents a wide range of concentrations of endrin, types of sediment, and mixtures of chemicals. Evaluation of the percentage of effect entries that are below the ISQG, between the ISQG and the PEL, and above the PEL in freshwater sediments (Figure 1) 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).

In order to derive a marine ISQG and PEL according to the approaches described in CCME (1995), additional data would be required. These data would include field studies that demonstrate relationships between adverse biological effects and concentrations of endrin in marine sediments, and spiked-sediment toxicity tests on sediment-dwelling invertebrates.

Toxicity

Adverse biological effects for endrin in the freshwater BEDS include decreased diversity, reduced abundance, increased mortality, and behavioural changes in benthic organisms (Environment Canada 1998, Appendix VIII). For example, low abundance of Amphipoda and Gastropoda was observed in the Toronto Outer Harbour and eastern headland of Lake Ontario at locations where the mean concentration of endrin in sediments was 4.14 $\mu g \cdot kg^{-1}$, which is above the freshwater ISQG (Jaagumagi 1988; Jaagumagi et al. 1989). In comparison, higher abundance was observed at sites with a mean

Table 1. Interim sediment quality guidelines (ISQGs) and probable effect levels (PELs) for endrin ($\mu g \cdot kg^{-1}$ dw).

	Freshwater	Marine/estuarine
ISQG	2.67	2.67*
PEL	62.4	62.4†

*Provisional; adoption of freshwater ISQG.

†Provisional; adoption of freshwater PEL.

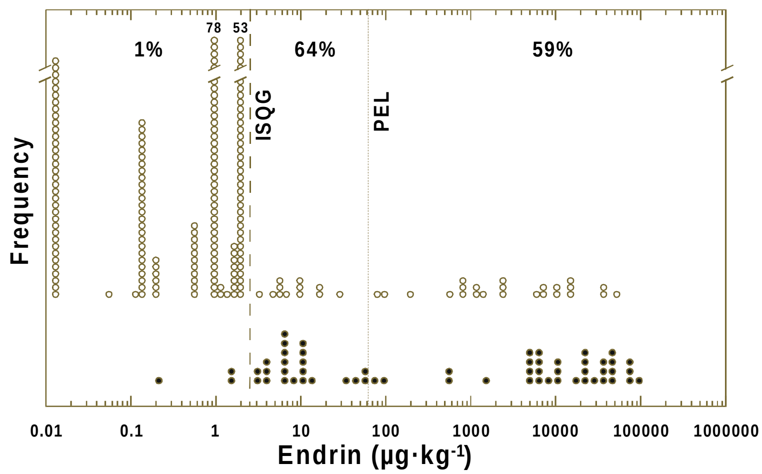

Figure 1. Distribution of endrin concentrations in freshwater sediments that are associated with adverse biological effects (●) and no adverse biological effects (○). Percentages indicate proportions of concentrations associated with effects in ranges below the ISQG, between the ISQG and the PEL, and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

concentration of 2.0 µg·kg^{-1}, which is below the freshwater ISQG (Jaagumagi 1988; Jaagumagi et al. 1989).

Spiked-sediment toxicity tests for endrin 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, as well as exposure to endrin only as opposed to chemical mixtures containing endrin (Environment Canada 1998). For example, Keilty et al. (1988) assessed the toxicity of Lake Michigan sediments spiked with endrin to achieve concentrations ranging from 0.0161 to 81.4 mg·kg^{-1} to *Limnodrilus hoffmeisteri*, a tubificid. A significant increase in mortality and reduced body weights were observed in organisms that had been exposed to a concentration of 81.4 mg·kg^{-1} for a period of 1300 h. In addition, sediment reworking rates were significantly different from controls at concentrations as low as 5.5 µg·kg^{-1}. In marine sediments spiked with endrin, the 97-h LC_{50} for *Crangon septemspinosa*, a shrimp, was determined to be 47 µg·kg^{-1} (McLeese and Metcalfe 1980). The toxicity of endrin can also be mitigated by organic matter, which has been found to reduce the toxicity of sediment-associated endrin. For example, Nebecker et al. (1989) spiked freshwater pond and lake sediments containing three different levels of TOC to achieve measured concentrations of endrin ranging from 1.1 to 73.8 mg·kg^{-1}. Ten-d LC_{50}s for *Hyalella azteca*, an amphipod, were 4.4 mg·kg^{-1} at 3.0% TOC, 4.8 mg·kg^{-1} at 6.1% TOC, and 6.0 mg·kg^{-1} at 11.2% TOC. Similarly, Schuytema et al. (1989) spiked freshwater sediments having two different levels of TOC (3.0% and 11%) with endrin and evaluated the acute toxicity to *H. azteca*. Two separate tests were conducted with the sediment containing 11% TOC. The 10-d LC_{50}s were 5.1 mg·kg^{-1} at 3.0% TOC and 10.3 mg·kg^{-1} and 19.6 mg·kg^{-1} at 11% TOC (Schuytema et al. 1989).

The results of freshwater and marine toxicity tests and field studies indicate that concentrations of endrin that are associated with adverse 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 endrin in sediments are similar to, or greater than, the PELs, confirming that effects are more likely to be observed when concentrations of endrin exceed the PELs (Environment Canada 1998). The ISQGs and PELs for endrin are therefore expected to be valuable tools for assessing the ecotoxicological relevance of endrin in sediments.

Concentrations

Currently, data on concentrations of endrin in Canadian freshwater and marine sediments are limited (Environment Canada 1998). In Canadian freshwater lake, river, and stream sediments, concentrations range from below detection to a maximum of 923 $\mu g \cdot kg^{-1}$ measured in Nova Scotia (Environment Canada 1998). In marine and estuarine sediments, concentrations range from below detection to 0.072 $\mu g \cdot kg^{-1}$ near Ice Island in the Arctic Ocean (Environment Canada 1998). Endrin degrades slowly 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 endrin 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 range between the ISQG and the PEL (Figure 1). The likelihood of adverse biological effects occurring in response to exposure to endrin at a particular site depends on the sensitivity of individual species and the 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 endrin (Environment Canada 1998).

Benthic organisms are exposed to both particulate and dissolved endrin in interstitial and overlying waters, as well as to sediment-bound endrin through surface contact and sediment ingestion. Dissolved endrin in interstitial and 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 sediments with the same concentrations of total endrin are compared, less endrin is dissolved in the interstitial water of sediments with high TOC content (Karickhoff 1984; Shea 1988). Therefore, TOC may reduce the bioavailability and, hence, the toxicity of sediment-associated endrin to benthic organisms. The physicochemical, geochemical, and biological factors that modify bioavailability should be considered when evaluating the potential biological impact of endrin in sediments (Environment Canada 1998).

Currently, the degree to which endrin 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 for freshwater sediments indicates that the incidence of adverse biological effects associated with exposure to endrin increases as concentrations of endrin increase in a range of sediment types (Figure 1). In addition, the limited marine toxicity data available indicate that concentrations associated with adverse biological effects are consistently above the marine ISQG (Environment Canada 1998). Therefore, the recommended Canadian ISQGs and PELs for endrin will be useful in assessing the ecotoxicological significance of endrin in sediments.

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