Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

HEPTACHLOR EPOXIDE

Heptachlor epoxide is the major persistent degradation product of the synthetic organochlorine pesticide heptachlor. Because of the rapid conversion process, heptachlor epoxide is more abundant in the environment than its parent compound, heptachlor. Heptachlor was used in Canada from the mid-1950s to the early 1980s as a treatment for a variety of insect pests. The registration and use of heptachlor under the Pest Control Products Act were discontinued as of January 1, 1991. Heptachlor has been identified as a Track 1 substance by Environment Canada because it is persistent, bioaccumulative, released primarily as a result of human activities, and is considered "CEPA-toxic" under the Canadian Environmental Protection Act (Environment Canada 1997).

Heptachlor and heptachlor epoxide have entered aquatic systems mainly from direct application, surface runoff, spray drift, and deposition following volatilization and aerial transport. Because of its hydrophobicity and affinity for organic materials, heptachlor epoxide tends to become associated with particulate matter in aquatic systems 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 heptachlor epoxide can be used to evaluate the degree to which adverse biological effects are likely to occur as a result of exposure to heptachlor epoxide in sediments.

The Canadian ISQG and PEL for heptachlor epoxide 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 the modified NSTP approach were provisionally adopted for marine sediments given they were the lowest biological effects-based guidelines available. The ISQGs and PELs refer to total concentrations of heptachlor epoxide 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 heptachlor epoxide are from studies on field-collected sediments that measured concentrations of heptachlor epoxide, along with concentrations of other chemicals, and associated biological effects. Biological effects associated with sediment concentrations of heptachlor epoxide 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 39 effect entries and 243 no-effect entries (Figure 1). The BEDS represents a wide range of concentrations, 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 an ISQG and a PEL for marine sediments according to the approaches described in CCME (1995), additional data would be required. This data would include field studies that demonstrate relationships between adverse biological effects and concentrations of heptachlor epoxide in marine sediments, and spiked-sediment toxicity tests on sediment-dwelling invertebrates.

Toxicity

Adverse biological effects for heptachlor in the freshwater BEDS include decreased diversity, reduced abundance, increased mortality, and behavioural changes in benthic organisms (Environment Canada 1998, Appendix IX). For example, the abundance of Ephemeroptera, Plecoptera, and Trichoptera in the Bay of

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

	Freshwater	Marine/estuarine
ISQG	0.60	0.60*
PEL	2.74	2.74†

* Provisional; adoption of freshwater ISQG.
† Provisional; adoption of freshwater PEL.

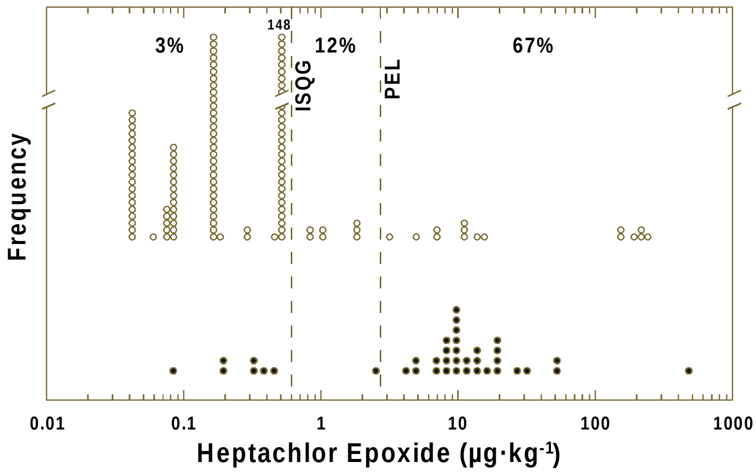

Figure 1. Distribution of heptachlor epoxide concentrations in freshwater sediments that are associated with adverse biological effects (●) and no adverse biological effects (○). Percentages indicate proportions of concentrations associated with effects in ranges below the ISQG, between the ISQG and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

Quinte, Lake Ontario, was lower at locations where the mean concentration of heptachlor epoxide was 9.4 µg·kg^{-1}, which is above the freshwater PEL. In comparison, higher abundance was observed at sites with a mean concentration of 0.5 µg·kg^{-1}, which is below the freshwater ISQG (Jaagumagi 1988; Jaagumagi et al. 1989). Studies such as this and others indicate that concentrations of heptachlor epoxide that are associated with adverse effects in freshwater sediments are consistently above the freshwater ISQG, confirming that this guideline adequately represents concentrations below which adverse biological effects will rarely occur (Environment Canada 1998).

Spiked-sediment toxicity test data provide precise dose–response information on specific chemicals, as well as quantitative data on the interactive effects of chemical mixtures and on factors that influence toxicity (Environment Canada 1998). Currently, however, literature on spiked-sediment toxicity tests that used heptachlor epoxide are not available.

Concentrations

Data on concentrations of heptachlor epoxide in Canadian freshwater and marine sediments are currently limited (Environment Canada 1998). In Canadian freshwater lake, river, and stream sediments, concentrations range from below detection to 30 µg·kg^{-1} (Environment Canada 1998). In marine and estuarine sediments, concentrations range from below detection to a maximum of 2.0×10^3 µg·kg^{-1} near Ice Island, in the Arctic Ocean (Environment Canada 1998). Because heptachlor epoxide degrades slowly in aquatic sediments, the elimination of local sources should result in a gradual decrease in concentrations over time.

Additional Considerations

Regardless of the origin of heptachlor epoxide 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 heptachlor epoxide 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 heptachlor epoxide (Environment Canada 1998).

Benthic organisms are exposed to both particulate and dissolved heptachlor epoxide in interstitial and overlying waters, as well as to sediment-bound heptachlor epoxide through surface contact and sediment ingestion. Heptachlor epoxide that is dissolved in the 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 heptachlor epoxide are compared, less heptachlor epoxide 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 heptachlor epoxide to benthic organisms. The physicochemical, geochemical, and biological factors that modify bioavailability should be considered when evaluating the potential biological impact of heptachlor epoxide in sediments (Environment Canada 1998).

Currently, the degree to which heptachlor epoxide 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 heptachlor epoxide increases as concentrations increase in a range of sediment types (Figure 1). While additional field and laboratory studies on the toxicity of heptachlor epoxide in marine sediments are necessary, the recommended ISQG and PEL for marine sediments are within the range of philosophically similar guidelines from other jurisdictions. Therefore, it is anticipated that the recommended Canadian ISQGs and PELs for heptachlor epoxide will be useful in assessing the ecotoxicological significance of heptachlor epoxide in sediments.

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