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Science-Based Solutions
Solutions fondées sur la science

Development of this series of factsheets was coordinated by the National Guidelines and Standards Office of Environment Canada to consolidate information on the variety of existing approaches to the assessment of sediment quality in Canada and to highlight sediment assessment programs developed by Environment Canada. Additional factsheets will be added to the series as new sediment assessment tools or programs are developed to highlight significant work across the Federal government.

SEDIMENT ASSESSMENT SERIES

Chemical-Specific Sediment Quality Guidelines

Factsheet 2

Program Description

Canadian Sediment Quality Guidelines (CSQGs) are nationally endorsed, science-based benchmarks for evaluating the potential of adverse biological effects in aquatic systems. They are developed under the auspices of the Water Quality Task Group of the Canadian Council of Ministers of the Environment (CCME), with Environment Canada's National Guidelines and Standards Office serving as the technical secretariat. CSQGs are defined as numerical concentrations or narrative statements that are recommended as levels that should result in negligible risk to biota, their functions, or any interactions that are integral to sustaining the health of ecosystems and the designated resource uses they support. To date, over 60 freshwater and marine CSQGs have been developed and published for a number of contaminants of concern in sediments including metals, PCBs, PAHs, dioxins and furans, and organochlorine pesticides (CCME 1999).

Issue Statement

As chemicals or substances are released into the environment through natural processes or human activities, they may enter aquatic ecosystems and adsorb to suspended particles. These particles may be deposited into the bottom sediments where the contaminants may accumulate over time.

Sediments may therefore act as long-term reservoirs of chemicals to the aquatic environment and to organisms living in or having direct contact with sediments. Because sediments comprise an important component of aquatic ecosystems, providing habitat for a wide range of benthic and epibenthic organisms, exposure to certain substances in sediments represents a potentially significant hazard to the health of these organisms. Effective assessment of this hazard requires an understanding of the relationships between concentrations of sediment-associated chemicals and the occurrence of adverse biological effects. Sediment quality guidelines are scientific tools that synthesize information regarding

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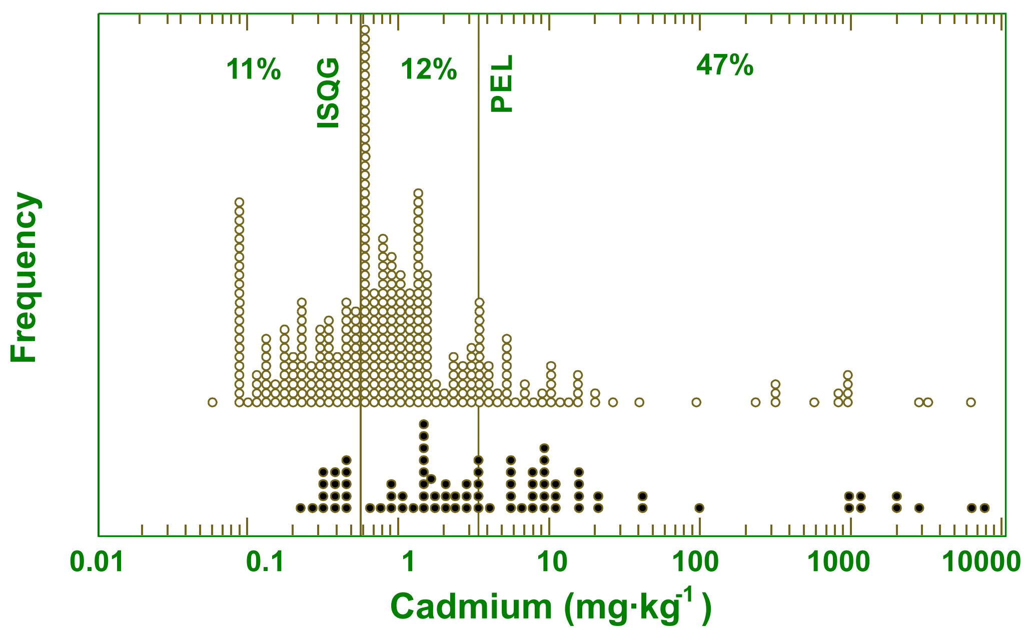
the relationships between the sediment concentrations of chemicals and any adverse biological effects resulting from exposure to these chemicals.

Approach Used

The guidelines are derived from the available toxicological information according to the procedures established by the CCME (1995). Several derivation procedures may be used, depending on the information available. In the procedure most frequently used, simultaneously collected chemical and biological data ("co-occurrence data") are evaluated from numerous individual studies to establish an association between the concentration of each chemical measured in the sediment and any adverse biological effect observed. The co-occurrence data are compiled in a database referred to as the Biological Effects Database for Sediments (BEDS) in order to calculate two assessment values. The lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely. The upper value, referred to as the probable effect level (PEL), defines the level above which adverse effects are expected to occur frequently. Figure 1 illustrates the distribution of the effects and no-effects data for the derivation of the CSQG for cadmium.

Figure 1: Distribution of Cadmium Concentrations in Freshwater Sediments Associated with Adverse Biological Effects and No Adverse Biological Effects*



Filled circles — adverse biological effects.
Open circles — no adverse biological effects.
*Percentages indicate proportions of concentrations associated with effects in ranges below the interim sediment quality guideline (ISQG; also the same as the TEL), between the ISQG and the PEL, and above the PEL.

By calculating TELs and PELs according to a standard formula, three ranges of chemical concentrations are consistently defined: 1) the minimal effect range within which adverse effects rarely occur (i.e., fewer than 25% adverse effects occur below the TEL); 2) the possible effect range within which adverse effects occasionally occur (i.e., the range between the TEL and PEL); and 3) the probable effect range within which adverse biological effects frequently occur (i.e., more than 50% adverse effects occur above the PEL). The definitions of these ranges are based on the assumption that the potential for observing toxicity resulting from exposure to a chemical increases with increasing concentration of the chemical in the sediment (Long et al. 1995). The TEL is recommended as the CSQG, whereas the PEL is recommended as an additional sediment quality assessment tool.

To derive full guidelines, the co-occurrence data should be complemented by spiked-sediment bioassays measuring the response of test organisms to specific chemicals in sediments under controlled laboratory conditions. These bioassay data do not currently exist; consequently, all of the CSQGs developed to date have an interim status.

Strengths and Limitations

Using CSQGs as sediment assessment tools has many advantages. For example, CSQGs are a nationally endorsed, conservative tool for evaluating chemical contaminants. The results of comparisons between sediment concentrations of contaminants to CSQGs can be easily communicated, and the results can lead to both preventative and restorative action. In a comparison of sediment chemical analyses and results of sediment toxicity tests, Long et al. (1998) found that although sediment quality guidelines were not perfect predictors of toxicity, they were able to provide reasonably accurate estimates of chemical concentrations that are either nontoxic or toxic in laboratory bioassays. Type 1 (false positive) and type II (false negative) errors for TELs and PELs have been found to range from 5%-30% for most substances (Ingersoll et al. 1996). MacDonald et al. (2000) tested the accuracy of consensus-based sediment quality guidelines. The consensus-based guidelines were calculated as the geometric means of three or more guideline values for a particular contaminant developed by different jurisdictions using different approaches. They found that the predictive ability of the consensus-based TELs and PELs ranged from 71%-100% for the various substances (MacDonald et al. 2000).

CSQGs have a few limitations — for example, CSQGs are limited to chemical stressors, and there are many chemicals for which guidelines have not yet been developed. Another limitation is the potential for confounding effects of the physicochemical attributes of the sediment, such as grain size, total organic carbon content, sulphides, chemical species and complexes. These attributes may increase or decrease the potential for toxic effects at a specific site, particularly by influencing the bioavailability of contaminants. It should be noted, however, that these factors can be taken into account through the development of site-specific guidelines. Incorporation of biological guidelines that are based on body burdens also offer future potential to further strengthen CSQGs.

Sediment quality guidelines need not be used on an individual chemical basis. An alternative approach includes the use of sediment quality guidelines and PELs for a mixture of chemicals to evaluate the quality of sediments (Long and MacDonald 1997; Long et al. 1998). This approach uses the number of chemical substances exceeding the sediment quality guidelines, as well as the magnitude to which the guidelines are exceeded, to screen and prioritize contaminated aquatic sites (Long and MacDonald 1997; Long et al. 1998). The degree by which guidelines are exceeded is estimated by dividing the concentration of each chemical present in the sediment by its corresponding PEL to obtain a PEL-quotient. The PEL-quotients of the various chemicals in the sample are then summed and normalized according to the number of PEL-quotients in the sample. The two endpoints (the normalized PEL-quotient and the number of guidelines exceeded) then serve to prioritize sites of concern. This approach has been shown to have a high reliability of predicting impairment.

Outcome

Canadian Sediment Quality Guidelines define three levels of protection:

- concentrations of chemicals in sediments below the guidelines that are not associated with biological effects
- concentrations between the guidelines and the PEL that may occasionally be associated with adverse effects
- concentrations above the PEL that are expected to be frequently associated with biological effects

Sediment quality guidelines have a broad range of potential applications. They can serve as final goals or interim targets for national and regional toxic chemical management programs, as benchmarks, targets or prioritization tools for the assessment and remediation of contaminated sites, or as the basis for the development of site-specific objectives. In addition, they may be used as environmental benchmarks for international discussions on emission reductions; as environmental guidelines on trade agreements; in reports on the state of regional or national sediment quality; in the assessment of the efficacy of environmental regulations; in evaluations of potential impacts of developmental activities; and in the design, implementation and evaluation of sediment quality monitoring programs.

Sediment quality guidelines are generally used as screening tools and in the formulation of initial management decision, and they are often used in combination with other sediment assessment approaches such as toxicity tests, community assessments or bioaccumulation.

WANT MORE INFORMATION?

Website: www.ec.gc.ca/ceqg-rcqe/

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