# Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

# INTRODUCTION

As chemicals or substances are released into the environment through natural processes or human activities, they may enter aquatic ecosystems and partition into the particulate phase. These particles may be deposited into the bed 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 the organisms. Effective assessment of this hazard requires an understanding of relationships between concentrations of sediment-associated chemicals and the occurrence of adverse biological effects. Sediment quality guidelines are scientific tools that synthesize information regarding the relationships between the sediment concentrations of chemicals and any adverse biological effects resulting from exposure to these chemicals.

This chapter provides information regarding the derivation and implementation of Canadian sediment quality guidelines. In addition, detailed chemical-specific fact sheets have been developed for those chemicals for which national guidelines have been derived.

Sediment quality guidelines provide scientific benchmarks, or reference points, for evaluating the potential for observing adverse biological effects in aquatic systems. The guidelines are derived from the available toxicological information according to the formal protocol established by the Canadian Council of Ministers of the Environment (CCME 1995). The protocol, reprinted in this chapter for reference, includes general guidance on the implementation of sediment quality guidelines, in conjunction with other relevant information, in order to prioritize and focus sediment quality assessments. The formal protocol used to derive sediment quality guidelines relies on both a modification of the National Status and Trends Program (modified NSTP) approach and the spiked-sediment toxicity test (SSTT) approach.

To derive sediment quality assessment values, the modified NSTP approach uses data from North American field-collected sediments that contain chemical mixtures (Long and Morgan 1990; Long 1992; Long and MacDonald 1992; MacDonald 1994; CCME 1995; Long et al. 1995). Synoptically 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. 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 effect 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 definition of the TEL is consistent with the definition of a Canadian sediment quality guideline. The PEL is recommended as an additional sediment quality assessment tool that can be useful in identifying sediments in which adverse biological effects are more likely to occur.

The SSTT approach involves an independent evaluation of information from spiked-sediment toxicity tests for estimating the concentration of a chemical below which adverse effects are not expected to occur. In this approach, an SSTT value is derived using data from controlled laboratory tests in which organisms are exposed to sediments spiked with known concentrations of a chemical or specific mixture of chemicals. Such studies provide quantifiable cause-and-effect relationships between the concentration of a chemical in sediments and the observed biological response (e.g., survival, reproductive success, or growth). Spiked-sediment toxicity tests may also be used to determine the extent to

which environmental conditions modify the bioavailability of a chemical, and ultimately the response of organisms exposed to the spiked sediments.

Minimum toxicological data requirements have been set for the SSTT approach to ensure that the derived SSTT values provide adequate protection to aquatic organisms. Spiked-sediment toxicity tests that meet the minimum data requirements are currently available only for cadmium in marine (and estuarine) sediments. In addition, concerns regarding spiked-sediment toxicity testing methodology limit the degree to which these values may be used as the scientific basis for recommending sediment quality guidelines at this time.

Subsequent to an evaluation of the toxicological information, Canadian sediment quality guidelines are recommended if information exists to support both the modified NSTP and the SSTT approaches. (These are referred to as *full* sediment quality guidelines.) Generally, the lower of the two values derived using either approach is recommended as the Canadian sediment quality guideline. Interim sediment quality guidelines (ISQGs) are recommended if information is available to support only one approach.

The guidelines may also be derived to reflect predictive relationships that have been established between the concentration of the chemical in sediments, and any environmental factor or condition that may influence the toxicity of a specific chemical (e.g., sediment characteristics, such as total organic carbon content [TOC] or acid volatile sulphides [AVS]; or water column characteristics, such as hardness). Consideration of these relationships will increase the applicability of guidelines to a wide variety of sediments throughout Canada.

If insufficient information exists to derive interim guidelines using either the modified NSTP approach or the SSTT approach, guidelines from other jurisdictions are evaluated and may be provisionally adopted in the short term as ISGQs. Further details on the derivation and evaluation of Canadian ISQGs and PELs for both freshwater and marine sediments are outlined in the protocol (CCME 1995, reprinted in this chapter).

Canadian ISQGs are recommended for total concentrations of chemicals in freshwater and marine surficial sediments (i.e., top 5 cm), as quantified by standardized analytical protocols for each chemical. For the analytical quantification of metals in sediments, the choice of digestion method is dependent on the intended use of the results (e.g., for quantification of the bio-available fraction or for geochemical evaluation). Because ISQGs are intended to be used for evaluating the potential for biological effects, “near-total” trace metal extraction methods that remove the biologically available fraction of metals and not residual metals (i.e., those metals held within the lattice framework of the sediment) are recommended for determining sediment metal concentrations. A strong extraction method using hydro-fluoric acid would remove both the bioavailable and residual fractions of metals in the sediment. Therefore in this chapter, the concentration of “total” metal refers to the concentration of metal recovered using a near-total (mild digestion; e.g., aqua regia, nitric acid, or hydrochloric acid) method.

To date, spiked-sediment toxicity data are limited; therefore, ISQGs, which are derived using only the modified NSTP approach (i.e., the TEL), are reported instead of full sediment quality guidelines. Currently, ISQGs and PELs are recommended for 31 chemicals or substances (7 metals, 13 PAHs, and 11 organochlorine compounds). Tables 1 and 2 list the chemicals and corresponding ISQGs and PELs that are recommended for freshwater and marine (including estuarine) sediments as well as the percentages of adverse biological effects found within concentration ranges surrounding the ISQGs and PELs. Although these sediment quality guidelines are considered interim at this time, they should not be used differently than if they were full sediment quality guidelines. During their application, it should however be recognized that these values reflect associative information only because insufficient reliable spiked-sediment toxicity data currently exist to evaluate cause-and-effect relationships.

Sediment quality guidelines have a broad range of potential applications, as do other environmental quality guidelines. They can serve as goals or interim targets for national and regional toxic chemical management programs, as benchmarks or targets in the assessment and remediation of contaminated sites, or as the basis for the development of site-specific objectives. They may also 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. Despite the variety of potential uses, sediment quality guidelines are likely to be routinely applied as screening tools in the site-specific assessment of the potential risk of exposure to chemicals in sediment and in formulating initial management decisions (e.g., acceptability for open-water disposal, required remediation, further site investigation, and prioritization of sites).

In the application of the existing framework for assessing sediment quality, it is important to recognize that

Canadian ISQGs are intended to be used in conjunction with other supporting information. Such information includes site-specific background concentrations and concentrations of other naturally occurring substances, biological assessments, environmental quality guidelines for other media (e.g., water, tissue, and soil), and Canadian ISQGs and PELs (or other relevant sediment quality assessment values) for other chemicals. It should also be noted that the ISQGs and PELs are developed using scientific information only. Socioeconomic (e.g., cost) or technological (e.g., remedial technology) factors that may influence their application are not considered in the development process, but may play a varying role in their application (and/or in the development of site-specific sediment quality objectives) within the decision-making framework of different jurisdictions and programs.

It is widely recognized that no single sediment quality assessment tool should be used to predict whether adverse biological effects will occur as a result of exposure to chemicals in sediments. Rather, the appropriate use of different tools will provide the most useful information (Luoma and Carter 1993; Chapman 1995). The use of ISQGs to the exclusion of other supporting information can lead to erroneous conclusions or predictions about sediment quality. Decisions are more defensible if they are administered in a manner that acknowledges scientific uncertainties and allows for management modifications as scientific knowledge improves (Luoma and Carter 1993). In the framework discussed above, Canadian ISQGs and PELs provide nationally consistent benchmarks with which to evaluate the ecological significance of concentrations of sediment-associated chemicals and determine the relative priority of sediment quality concerns. Canadian ISQGs should be used along with all other relevant information in making practical and informed decisions regarding sediment quality. These considerations are equally important whether the focus is to maintain, protect, or improve sediment quality conditions at a particular site in Canada.

### References

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. [Reprinted in Canadian environmental quality guidelines, Chapter 6, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]

Chapman, P.M. 1995. Sediment quality assessment: Status and outlook. J. Aquat. Ecosyst. Health 4:183–194.

Long, E.R. 1992. Ranges in chemical concentrations in sediments associated with adverse biological effects. Mar. Pollut. Bull. 24:38–45.

Long, E.R., and D.D. MacDonald. 1992. National status and trends program approach. In: Sediment classification methods compendium, EPA 82-3-R-92-006, B. Baker and M. Kravitz, eds. U.S. Environmental Protection Agency, Office of Water (WH-56), Sediment Technical Oversight Committee, Washington, DC.

Long, E.R., and L.G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. National Oceanic and Atmospheric Administration. Seattle, WA.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ. Manage. 19:81–97.

Luoma, S.N., and J.L. Carter. 1993. Understanding the toxicity of contaminants in sediments: Beyond the bioassay-based paradigm. Environ. Toxicol. Chem. 12:793–796.

MacDonald, D.D. 1994. Approach to the assessment of sediment quality in Florida coastal waters. Vol. I. Prepared for the Florida Department of Environmental Protection. MacDonald Environmental Sciences, Ltd., Ladysmith, BC.

Reference listing:

Canadian Council of Ministers of the Environment. 2001. Canadian sediment quality guidelines for the protection of aquatic life: Introduction. Updated. 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

© Canadian Council of Ministers of the Environment 1999
Excerpt from Publication No. 1299; ISBN 1-896997-34-1

Aussi disponible en français.