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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

The Sediment-Toxicity (SED-TOX) Index

Factsheet 4

Current chemical-specific sediment quality guidelines, which establish concentrations that are likely to be safe, are compared with individual chemical concentrations to determine the likelihood of adverse effects. However, current practitioners generally acknowledge that multiple lines of evidence, including both chemical and biological information, are essential to determine sediment quality. The Sediment Quality Triad proposed by Chapman (1986) promotes the incorporation of laboratory toxicity assays and field biological assessment in identifying contaminated sediments. This factsheet describes the development, and illustrates an application, of a sediment-toxicity (SED-TOX) index for integrating multiple toxicological measures.

Program Description

The St. Lawrence Centre of Environment Canada has developed the SED-TOX Index for the assessment of marine, estuarine or freshwater sediment quality. The index integrates the diverse parameters of effects for various species of several trophic positions, enabling researchers to distinguish between degraded and non-degraded areas (Bombardier and Bermingham 1999; Bombardier and Blaise 2000). The SED-TOX Index generates a single value that represents all the results of different sediment toxicity tests on a common, easily interpretable scale. This value can be used to rank a wide range of sites based on their toxic potential toward various test species and to compare present and future conditions in a given area (Bombardier and Blaise 2000). A spreadsheet program was developed on Microsoft Excel® to take advantage of built-in macro functions for the SED-TOX calculations discussed below. For a copy of the program, contact the St. Lawrence Centre.

Approach Used

Sediment toxicity tests involving various phases of exposure (pore water, fractionated and unfractionated organic extract, wet sediment, and whole sediment) are conducted on a variety of aquatic organisms such as bacteria (*Vibrio fischeri*), cnidarians (*Hydra attenuata*), micro-crustaceans (*Thamnocephalus platyurus*) and benthic macro-invertebrates (*Hyalella azteca* and *Chironomus riparius*). Such tests form the basis of the data used to derive the SED-TOX Index.

What's Inside

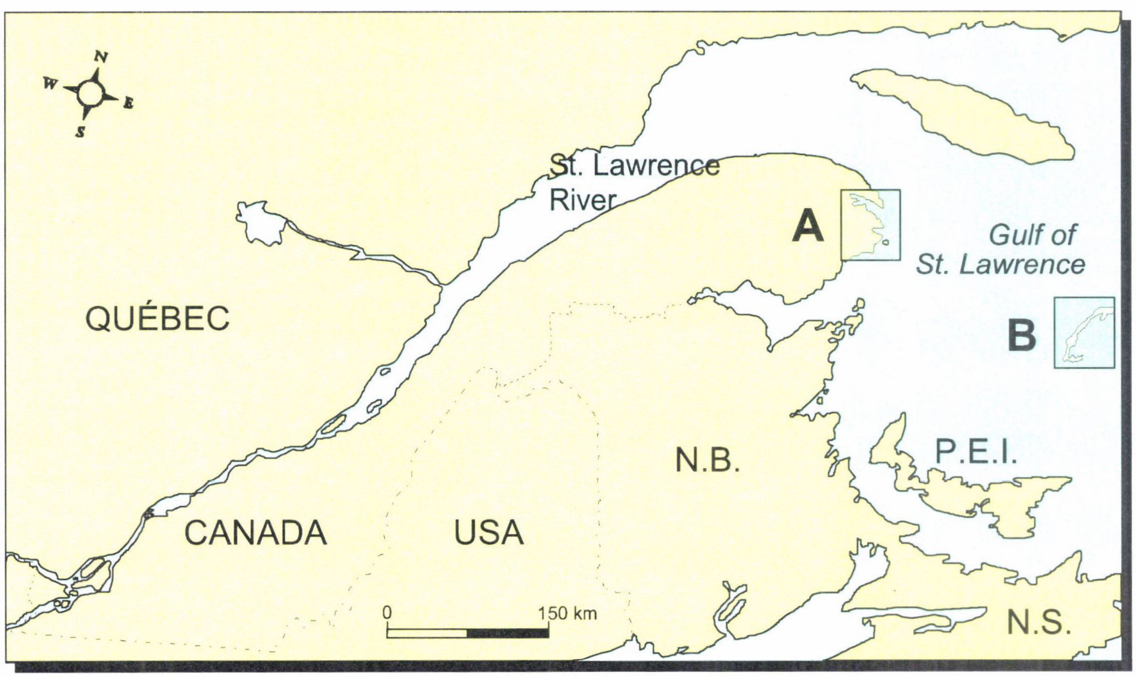
The conceptual framework of the SED-TOX approach involves two stages — data conversion and data integration. The index collates the responses generated by a battery of toxicity tests and converts each one of them into toxic units, which are dimensionless ratios. The toxicity data are organized into groups, based on the phase of exposure, converted to a single scale of measurement, and combined into a single index (the SED-TOX score) that represents the aggregate sediment toxic hazard potential (Bombardier and Bermingham 1999).

The SED-TOX scores are assigned to one of four classes of toxicity hazard potential: scores of zero indicate no hazard; scores between 0.1 and 0.9 represent a marginal hazard; scores between 1.0 and 1.9 indicate a moderate hazard; and scores greater or equal to 2.0 represent a high hazard potential (Bombardier and Blaise 2000). Scores for various sites can then be compared to set priorities for remedial action or to target further investigation.

Test Site Assessment

Application of this approach is illustrated in the following, using data from marine sediments collected in 1993-1994 from two sectors in the Gulf of St. Lawrence: Anse-à-Beaufils (Gaspé, Québec; see Figure 1, Sector A) and Cap-aux-Meules (Magdalen Islands, Québec; see Figure 1, Sector B) that were known to be contaminated with heavy metals, PAHs and PCBs. For each sector, three sites (harbour, disposal and reference) were evaluated.

Figure 1: Gulf of St. Lawrence Indicating the Two Sampling Sectors



Sector A — Gaspé, Québec; Sector B — Magdalen Islands, Québec

All sediment samples were characterized chemically and physically, and a total of seven sediment toxicity tests — three Microtox® assays (Environment Canada 1992a; Microbics 1992), the Toxi-Chromotest (Kwan 1993; Environmental Bio-detection Products Inc. 1995), the sea urchin fertilization test (Environment Canada 1992b), an amphipod survival test (Environment Canada 1992c), and the SOS Chromotest (Environment Canada 1993) — were conducted on four different sediment phases (pore water, organic extract, wet sediment and unaltered whole sediment).

For the Anse-à-Beaufils dredging site, SED-TOX scores revealed intra-site variability. Marginal to high hazard scores were obtained, depending on the sample investigated. This probably reflected a variety of spatial factors such as chemical composition, particle size and water content that may affect the concentration, distribution and bioavailability of toxicants. Sediments from the Anse-à-Beaufils disposal site and especially those from Cap-aux-Meules (dredging and disposal areas) were more homogeneous in terms of potential hazard. For the Anse-à-Beaufils site, four sediment samples showed moderate scores and four had marginal scores. Except for four samples with high scores, dredging and disposal sediments from Cap-aux-Meules were moderately toxic to exposed organisms. In contrast, all reference materials showed marginal scores; due to their chemical properties (i.e., a relatively high sand content of 57%-60%, as well as relatively low levels of organic and inorganic analytes), moderate or high scores on the SED-TOX Index scale were not expected with these materials. Overall, the Anse-à-Beaufils dredging area was clearly the most toxic site, followed by the Cap-aux-Meules disposal and dredging sites. The Anse-à-Beaufils disposal area came in fourth place, followed by the reference sites with the lowest scores. These results indicate a contamination problem that would require further investigation (perhaps field surveys) at the dredging site of Anse-à-Beaufils.

Comparisons of sediment chemistry data and SED-TOX scores among sites indicated that highly toxic effects were more frequently observed with highly contaminated sediments (Environment Canada and the Québec Department of the Environment 1992). The relationship between the SED-TOX scores and the exceeding of toxic effect concentrations was, however, not linear, which calls for caution when classifying sediment locations based on sediment quality guidelines for individual chemicals. Sediment contaminant analyses used in this study provided only limited information on contaminants present in the study areas.

Strengths and Limitations

The SED-TOX Index has several advantages. Any bioassay currently available can be incorporated in the SED-TOX Index and this provides the best current estimate of relative hazard of the sites under investigation (Bombardier and Bermingham 1999). The quality of sediments for a site or sector can be assessed by combining data from individual sampling locations. The index is an instructive and valuable tool as it examines the toxicity responses of organisms of multiple trophic positions using a variety of toxicity assays and routes of exposure.

The index generally compares well with contamination levels, as well as several indicators of benthic community degradation. The SED-TOX Index has been shown to discriminate between highly contaminated sites and relatively clean reference areas (Bombardier and Bermingham 1999; Bombardier and Blaise 2000). SED-TOX scores are also often higher at sites showing degraded benthos (Bombardier and Blaise 2000).

The SED-TOX Index also has certain limitations. The causality for the observed toxic hazard at the study sites is not determined by the index. Professional judgment is needed in the implementation and interpretation of results. In addition, the comparisons between SED-TOX scores are most meaningful when they involve sediment samples collected simultaneously and assessed with the same toxicity tests, yet this is not always possible. The effects of these inconsistencies remain to be determined. Furthermore, test methods need to be standardized, as the variability of laboratory replicates for a given sampling station is not considered in the SED-TOX Index (Bombardier and Bermingham 1999).

Outcome

The SED-TOX Index generates a single value (SED-TOX score) that represents all the results of the different sediment toxicity tests on a common, easily interpreted scale. This score can be used to rank a wide range of sites based on their potential toxicity to various test species and to make comparisons between present and future conditions in a given area (Bombardier and Blaise 2000).

Overall, this approach should be considered as a complementary tool to chemical and biological assessments of sediment quality. In some aspects, the approach requires further refinement, but it has placed the sediment toxicity data in a useful framework for hazard characterization and ranking of contaminated sediment sites.

WANT MORE INFORMATION?

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