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USE OF SEDIMENT QUALITY GUIDELINES FOR THE ASSESSMENT OF CONTAMINATED SEDIMENTS OF UKRAINIAN ESTUARIES

The article describes that many countries throughout the world share similar concerns about sediment management. Scientists in several countries have developed a variety of methods for evaluating the degree to which sediment-associated chemicals might adversely affect aquatic organisms. The results of experiment where consensus approach was used for sediments assessment of Dnieper and Buh estuary and Danube estuary in Ukraine are presented in article.

Environmental scientists, engineers and regulatory authorities throughout the world have devoted considerable resources to assessment, management, and remediation of chemical contaminants in sediments. Sediment quality has become a serious and potentially costly economical and ecological issue for navigation dredging projects, waterway restoration programs, recreational and commercial fisheries management, water quality protection, and natural resources restoration.

Numerous scientific and engineering studies have shown that addressing contaminated sediments is a complex undertaking. Complexity arises from the great variability in the physical and biogeochemical characteristics of sediments; human and ecological receptors; and the cultural, social and economic values associated with different freshwater, estuarine, and marine environments.

In response to the increasing demands from society for greater environmental protection of aquatic resources and the restoration of impaired or degraded rivers and estuaries, scientists in several countries have developed a variety of methods for evaluating the degree to which sediment-associated chemicals might adversely affect aquatic organisms. While some methods have focused on the derivation of numeric chemically based sediment concentration limits, other methods have focused on less-specific narrative statements or bench-marks that frame acceptable and potentially unacceptable sediment quality.

The interaction of benthic organisms with sediments environment is complex. The demand for tools to aid decision making is ongoing and intense, and has led to the development of SQGs by a variety of methods.

Existing SQGs can be categorized into 3 groups, according to their derivation:

1) empirically based (or “co-occurrence”) guidelines;
2) mechanistically based (e.g., equilibrium-partitioning [EqP]) guidelines;
3) “consensus-based” guidelines.

SQGs for assessing sediment quality relative to the potential for adverse effects on sediment-dwelling organisms have been derived using both

- mechanistic approaches:
  – the equilibrium partitioning (EqP) approach;
- empirical approaches:
  – screening-level concentration (SLC) approach;
  – effects range approach (ERA);
  – effects level approach (ELA);
  – apparent effect threshold (AET) approach;
  – consensus-based approach;
  – logistic regression modeling approach.

These SQGs have been used to interpret historical data, identify potential problem chemicals or areas at a site, design monitoring programs, classify hot spots and rank sites, and make decisions for more detailed studies.

Empirical guidelines are derived from databases of sediment chemistry (concentrations of specific sediment contaminants) and observed biological effects (e.g., those derived from sediment toxicity tests and benthic community information). These data are arrayed on a continuum or increasing chemical concentration. Various analysis approaches are then applied to relate chemical concentrations to the frequency of biological effects.

In contrast, mechanistic guidelines are derived from a theoretical understanding of the factors that govern bioavailability of sediment contaminants, and known relationships between chemical exposure or uptake and toxicity. Existing mechanistic SQGs all have their roots in EqP theory, where concentrations of chemical in sediment are related to the corresponding concentrations in pore water.

Consensus-based guidelines aggregate guidelines developed using different methods, and generate new SQGs from the central tendencies of guidelines with different intents (e.g., threshold effect, median effect).

The mechanically based sediment quality guidelines (SQGs) have been developed and tested using laboratory spiked sediments and compared to toxicity tests by using field-collected sediments. The empirically based SQGs have typically been developed using large databases with matching measures of sediment chemistry and toxicity from field-collected samples. These databases also have been used to evaluate the ability of SQGs to predict sediments to be either toxic or nontoxic in laboratory tests or in benthic community assessments in a variety of freshwater, estuarine, and marine environments. Generally, the results of analysis conducted with these databases in conjunction with field validation studies involving contaminated sediments suggest that some effects-based SQGs can provide reasonable predictions, with associated error rates and uncertainties, for the potential for acute effects or no effects on benthic organisms.

Most industrialized countries have to deal with the regulation and management of contaminants in sediments and dredged materials in their waterways. As a consequence, a variety of approaches has been or is being developed. In many cases, sediment quality guidelines form part of these approaches.

Many countries throughout the world share similar concerns about sediment management.

Two distinct approaches to SQGs have been adopted in countries outside of North America. Particularly in Europe, the application of guidelines based on reference conditions has been widely practiced. In this context, the reference condition can be defined either as “background concentrations” or as an array of chemical and biological parameters measured at reference sites. This approach has, at least for some time, hampered the application of empirical or mechanistic SQGs that have achieved wide use in North America in recent years.

The reference condition approach is, or was, used by Flanders in Belgium, France, Germany, and Italy. However, several of these countries have begun to develop effects-based SQGs, which are or will be used instead of, or sometimes in combination with, the reference condition approach.

Australia and New Zealand have recently revised their guidelines for fresh and marine water quality and have included, for the first time, a consideration of sediment quality. Australian guidelines for ocean disposal of dredged materials have also been developed recently. Both use a common approach to SQG development: an ecotoxicological effects database. Faced with a paucity of local sediment effects data, the effects range low (ERL) values derived from the North American database were used as the basis for interim Australian and New Zealand guidelines.

The application of the Australian and New Zealand SQGs for both in situ and dredged sediments follows a tiered system, in the form of a risk-based decision tree that progresses through a hierarchy of measurements that get closer to a bioavailable fraction, in the same manner as the tiered system has adopted for water quality. For metals, the use of a dilute acid-soluble metals fraction was seen as more useful than a total measurement, although (total concentrations are used in the North American guidelines from which the tiered system was adapted). The weak link in the decision tree at this stage is the assessment of impacts by toxicity testing. Often we are dealing with multiple toxicants, where the test species may be especially sensitive to only some classes of toxicants. It is important that tests encompass the range of uptake routes and include sensitive species. The expansion of the risk-based approach to include ecological impacts as well as bioaccumularion is a logical extension of the framework, along the lines of a WOE approach. This inclusion of ecological impacts is already addressed explicitly in the Australian and New Zealand guidelines that recommend a combination of biological (biodiversity) and chemical assessments. The adoption of this integration of chemistry and biology for sediments is equally desirable.

In Belgium, sediment quality was assessed on the basis of comparisons with reference sites. Initially, 5 locations were chosen as reference sites. Previous ecological studies showed that these sites were in relatively undisturbed areas with a high ecological quality. The chemistry at these sites was considered close to reference values used in other European countries. Guidelines for dredged material are based on guidelines for the reuse on contaminated soil and differ from the reference values. Walloon and Brussels do not have SQGs yet.

Sediment quality assessment in Belgium is based on a triad approach. An equal weight is assigned to each of the 3 measurements. The underlying principle of the classification of sediment quality rests on the comparison with a reference condition. This means that, for each type of measurement (physicochemical, toxicity tests, invertebrate communities), a desirable reference condition has first to be defined.

In France sediment quality assessments are undertaken for 2 purposes: 1) the monitoring of water bodies sometimes followed by more detailed diagnostic at impaired locations, and 2) the management of dredged materials. Sediment quality monitoring was until recently based on analyses of priority pollutants and application of numerical SQGs. The use of toxicity tests is now seriously envisaged, following several demonstrative studies.

The Federal Republic of Germany does not yet have common national regulations for the management of contaminated sediments. The management of dredged materials in coastal areas in Germany is driven by the reference values. Two action levels have been defined for coastal sediments. The first reference value is based on prevailing contaminant concentrations in the Wadden Sea (part of the North Sea, mainly along German coast) between 1982 and 1992. The second level is defined as 5× the reference value for metals and 3× this value for organic compounds. Thus, they are derived by convention and are not effect based.

Sediment quality issues for Hong Kong were largely focused on marine dredged sediments. These were first managed according to 3 classes of contamination. The criteria delineating these classes were considered conservative and were too close to one another, given measurement uncertainty. It was recommended the development of interim sediment quality values (ISQVs), on the basis of published papers combined with the collection of site-specific information (e.g., through biological testing). Thus 2 sets of ISQVs were determined, that is, an ISQV-low, below which adverse effects were unlikely, and an ISQV-high, above which severe adverse effects were very likely. Only the ISQV-low was proposed for decision-making. Implementation of the ISQV-high values would follow the incorporation of regional data (toxicity test results and chemical concentrations).

In Italy, there are no national SQGs, although some work has been undertaken on the development of guidelines for freshwater sediments, dredged material, and sediments for marine disposal. Environmental quality is evaluated on the basis of ecological and chemical status of a given water body compared to a reference one, and water bodies are classified in 5 classes of quality. The ecological status is assessed on the basis of the diversity and abundance of certain types of living organisms and morphological conditions, while the chemical status is based on the occurrence and concentrations of dangerous substances (priority list) in compliance with environmental quality standards (EQSs). The list of priority substances was selected from other lists issued by organizations such as the US Environmental Protection Agency (USEPA), the United Nations Environment Programme (UNEP), and the European Commission. Other hydrological and morphological variables are also included in the monitoring requirements because of the potential impacts of human activity and water uses and the affinities of contaminants for sediments. It is recommended, in case of further investigations, that toxic effects be assessed using a multispecies approach, short- and long-term toxicity tests on sediment extracts, whole sediments, or pore water with test organisms.

In Netherlands the approach adopted for sediment quality consisted of calculating quality criteria for water and sediment from existing ecotoxicity test data (usually concentrations of toxicants in water) or product standards (in food) based on EqP theory. In theory, alternative approaches might be applied for the derivation of SQGs, either by applying assessment factors to spiked tests results or by statistical extrapolation. Nevertheless, the criteria should then be harmonized among water and sediment compartments by applying EqP theory. In the Netherlands, most of the published SQGs are obtained by EqP.

Numerical effects-based sediment quality guidelines (SQGs) have been developed by federal, provincial, or state agencies in the United States (US), Canada, Australia, Italy, the Netherlands, and Hong Kong. The approaches that have been selected by different jurisdictions for different management situations depend on the receptors to be protected (e.g., sediment-dwelling organisms, wildlife, or humans), the degree of protection that is to be afforded, the geographic area to which the SQGs are intended to apply, and their intended uses.

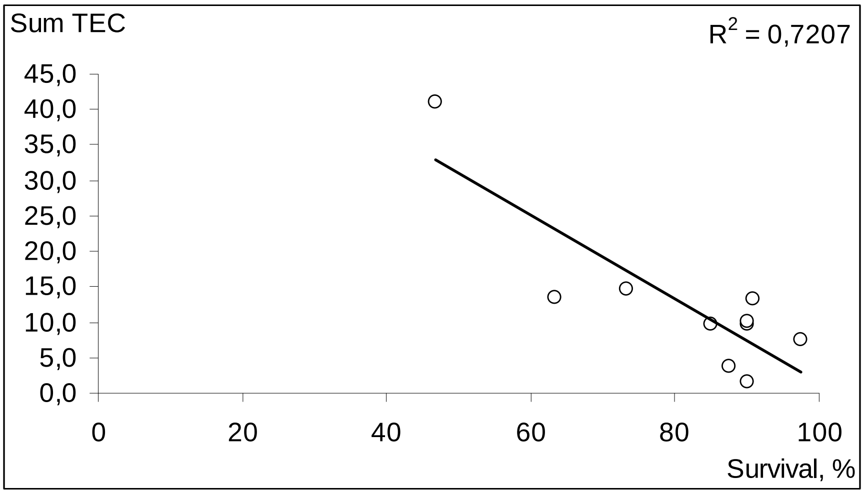
In Ukraine there are no adopted standards for sediments quality assessment. For assessment of sediment quality in Ukraine there can be used standards adopted in North America, for example.

We conducted the assessment of two water ecosystems – Dnieper and Buh estuaries and water objects of Danube estuary. The content of many toxicants was researched (heavy metals, PAH, PCBs, pesticides, etc.) in sediments of these water objects.

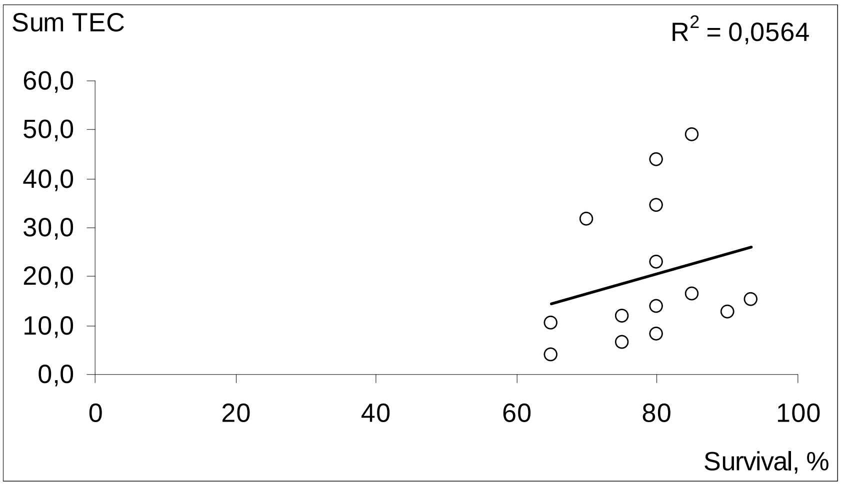
We applied consensus approach and calculated threshold effect concentration (TEC) of toxicants in each water object. TEC was proposed by Environmental Protection Agency (EPA) in USA and were used in researches because of absence of norms in our country. The data are presented as correlation of toxicants content in sediments with TEC.

The experiments were conducted on whole tests with test organism *Chironomus riparius* and on water elutriates with test organisms *Daphnia Magna*.

We observed the difference between researched water objects in character of correlation between levels of sediments pollution, their structure, and development of toxic effect on test organisms. For Dnieper and Buh estuary a high correlation between level of pollution and toxic effect in whole sediment tests for both *Chironomus riparius* and *Daphnia Magna* was observed. At the same time, for Danube estuary correlation was observed only in experiments on *water elutriates with Daphnia Magna.*



a



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Pic. 1. Dependence of toxic effect from the content of toxic substances (whole tests):
a – Dnieper and Buh estuary; *b* – Danube estuary

Obtained results give us the opportunity to conclude that at standardization of polluting substances content in sediments it is necessary to take into account regional specific of each researched water object that are different by hydrological, hydrochemical regimes, and genesis of sediments. Such approach is coordinated with Water Framework Directive of EU, that establishes main principles of water resources management. One of the main principles stated by Water Framework Directive of EU is integrated river basin model of water resources management.

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