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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

IWRM

A recent WRC project provided the first phase towards the development of sediment quality guides for South Africa.

Sediment quality – a necessary consideration in water management

The management of water resources in South Africa places emphasis on the protection of the water resource as a whole (water quantity and quality, health of both instream and riparian habitats and of instream and riparian biota) to ensure that resources remain fit for use on a sustainable basis. Resource protection is served through the implementation of the Reserve and the establishment of various national monitoring programmes (e.g. the National Toxicity Monitoring Programme, River Health Programme and others).

Critical inputs into these activities include the development of Water Quality Guidelines (WQGs) and various aquatic biota health indices. The established South African WQGs, currently under revision, deal only with the effects of dissolved chemicals in the water column. They ignore chemicals associated with suspended and settled sediment and also the sediments themselves.

As sediment particles can act as binding sites, many contaminants ultimately accumulate within the sediments, from where they can be released into the water column and be transported to uncontaminated sites. In this way sediments can act as nonpoint sources of pollution, impacting on the quality of surface water. In addition, the sediments themselves may act as environmental stressors, either through causing physical damage to aquatic biota and changes in habitat conditions, or through acting as a source of bio-available toxins to benthic and burrowing biota that come into contact with them. It is important to be able to identify situations where either the contaminants associated with sediments, or the sediments themselves, may represent a risk to ecosystem health and integrity. The development of Sediment Quality Guidelines (SQGs) to complement the WQGs is thus essential if the challenge of water resource management is to be comprehensively met.

Initiating SQG development for SA

Initial steps, comprising Phase 1 of the development of SQGs for South African freshwaters, have already been taken. These have included a review and discussion of the complex physical and chemical characteristics of sediments and the sediment environment, an overview of international approaches to developing and implementing sediment quality guidelines, the identification of issues to be taken into consideration in deriving and implementing SQGs for South African conditions and, finally, the proposal of a research and development agenda to further support the process of SQG derivation for South Africa.

Complexity of the sediment environment

The sediment environment is highly complex, with a multitude of interacting factors affecting the bioavailability of contaminants to organisms. Sediments themselves are heterogeneous. The characteristics that alter contaminant bioavailability (e.g., size and chemical composition of the sediment particles, pH and redox potential of the overlying or interstitial water) vary both laterally and vertically over short distances within sediments.

Furthermore, organisms associated with the sediments have many different exposure routes, most of which are poorly understood. The accuracy of any derived SQG will be limited by the ability to measure and incorporate the many such factors accounting for contaminant bioavailability.

Methods used internationally for SQG derivation

SQGs fall into distinct groups, corresponding to three broad approaches for assessing the toxicity of the sediments.

In the ***mechanistic approach***, it is assumed that the critical factor controlling sediment toxicity is the concentration of the contaminant in the sediment's interstitial water. Established WQGs can be applied to interstitial water contaminants, either directly or after factoring in a partitioning coefficient based on the equilibrium partitioning (EqP) method, which was developed to take account of factors influencing chemical bioavailability in sediments.

The advantages of deriving SQGs in this way are that:

- the bioavailable fraction of the chemical in the bulk sediment sample is considered, which makes the method applicable across almost all sediment types;
- the SQGs so developed are causally linked to specific chemicals;
- levels of protection can be specified, owing to the links with WQGs;
- toxicity data for water column exposure are more readily available than for sediment exposure, allowing a wider range of species to be accommodated; and,
- the approach is based on fundamental toxicological principles.

Disadvantages are that this method does not make allowance for additive, synergistic or antagonistic effects, nor for bio-accumulative effects. There is also evidence that the accuracy of toxicity prediction is lower than for selected empirical approaches, and that guideline values derived using the mechanistic approach are less sensitive than guideline values derived empirically.

The empirical approach generally derives guidelines using data from observed biological responses to contaminated sediments. These can be concentration-response data for known concentrations of single or mixed contaminants provided by spiked sediment toxicity tests (SSTTs), or biological response data obtained from field-collected sediments or field surveys of benthic populations and/or communities.

Guidelines developed utilising SSTT data are currently applicable to only a few chemicals because of the limited availability of potential benthic test organisms. Although this approach considers causality (i.e., the specific chemical causing the biological effect is known) it does not consider bioavailability and is subject to being criticised as environmentally unrealistic because of the use of hardy laboratory organisms in conducting tests.

The consensus approach involves collating previously published SQGs and providing a unifying synthesis and addressing issues of bioavailability and causality. Field validation of the consensus guidelines has shown them to successfully predict sediment toxicity and benthic community perturbations at sites of polycyclic aromatic hydrocarbon (PAH) contamination.

Methods favoured by different countries

Although the USA has not adopted national SQGs, the US-EPA is pursuing the EqP method, while in practice, individual agencies use various empirical methods. Guidelines adopted by Australia and New Zealand, Canada and Hong Kong are based on the empirical approach. Before the establishment of the European Union (EU), which is looking into the use of a standard approach, the French national guidelines as well as guidelines of individual agencies in the UK, Italy and Germany utilised empirical data. Only the Netherlands derived national SQGs using EqP theory. Although none have been developed for South African freshwaters, SQGs have been derived for marine sediments utilising the empirical approach.

Towards deriving and applying SQGs for South African conditions

Developing SQGs for South African freshwaters is a complex process, needing interaction and collaboration among scientists, regulators and implementers. The aim of the SQGs should be explicitly stated. This would in turn dictate the type of data utilised and the derivation and implementation methods employed. The philosophical approach to the SQGs should be based on the approach being developed for the revised WQGs, which is a scenario-specific, probabilistic, risk assessment approach.

The application of the SQGs, from a regulatory point of view, should be viewed in two contexts:

- *Assessments* (i.e., the use of SQGs in monitoring programme development and in risk assessments, in order to judge how good or bad a field situation is); and
- *Setting sediment quality objectives* (i.e., the use of SQGs in risk assessments and ecological Reserve determinations in order to define an acceptable risk to the aquatic environment and determine the sediment quality associated with that risk).

Within both these contexts, the SQGs would have to align to the current resource classification system in South Africa for effective implementation.

The structure of the SQGs should be similar to that envisaged for the revised WQGs. The primary tool envisioned for facilitating the determination and use of both sets of guidelines is a software-based decision support system (DSS), still under development. Guidelines will comprise a three tier system:

- *Tier 1:* Provides 'generic' guideline values in the DSS and in hard copy manuals. These guideline values will be conservative, as the worst case scenario is assumed.
- *Tier 2:* Allows for site-specificity with the help of the DSS, thus giving more confidence in the derived value.
- *Tier 3:* Comprises a full risk assessment, yielding a scenario/site specific guideline value. Although not facilitated by the DSS, information contained within the DSS database is used.

In deriving the SQGs, the type and quality of data to be included in the DSS database, and the derivation method itself, still need to be decided upon. Very little toxicity test data utilising indigenous organisms, or biological response data using standard organisms and South African field-collected sediments, appear to be available.

Consequently the SQGs, for the present, will have to rely heavily on international data. The generation of South African-specific data for the later inclusion in the SGQ derivation process should be given high priority. This requires the development of benthic organism-based toxicity tests and the capacity to undertake these tests in South Africa.

Framework for future research

In summary, the three main issues requiring further investigation in order to develop SQGs that are scientifically defensible and applicable to South African water resource management strategies are:

- Ensuring close alignment between the SGQs (to be developed) and the WQGs (currently under revision) in terms of philosophical approach and implementation. This includes determining whether the DSS being developed for the WQGs is applicable for SQG derivation and implementation.
- Establishing which data and which derivation method are most appropriate for South Africa.
- Improving the capacity of organisations in South Africa to undertake sediment toxicity testing and analysis of contaminated sediments.

Further reading:
To obtain the report, *Developing Sediment Quality Guidelines for South Africa*: *Phase 1: Identification of International Best Practice and Applications for South Africa to Develop a Research and Implementation Framework* (**Report No: KV 242/10**) contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; E-mail: orders@wrc.org.za; or Visit: www.wrc.org.za