1-1-2006

Development of robust guidelines and assessment procedures for metal contaminated sediments

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Abstract

Assessment of contaminated sediments and development of remediation strategies is becoming an important priority for regulators and industries worldwide. Although sediment quality assessment frameworks exist, poor scientific procedures and a limited understanding of species sensitivity to common contaminants hinders most assessment programs. Globally, sediment quality guidelines (SQGs) for metals vary over several orders of magnitude and are not based on clear cause-effect relationships. Although equilibrium partitioning approaches to developing SQGs have been attempted, the cause-effect relationships are weak due to the many other modifying factors that influence metal bioavailability and toxicity. The inherent lack of defensible SQGs for metals currently impedes decision making processes by both regulators and industries.

Keywords

contaminated, metal, procedures, assessment, sediments, guidelines, development, robust, CMMB

Disciplines

Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

Publication Details

Strom, D., Simpson, S. L. & Jolley, D. F. (2006). Development of robust guidelines and assessment procedures for metal contaminated sediments. INTERACT 2006: air, water & earth: INTERACT in Perth: program and abstracts Canning Bridge, W.A: Promaco Conventions for the Conference.

Development of Robust Guidelines and Assessment Procedures for Metal Contaminated Sediments

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INTRODUCTION

Assessment of contaminated sediments and development of remediation strategies is becoming an important priority for regulators and industries worldwide. Although sediment quality assessment frameworks exist, poor scientific procedures and a limited understanding of species sensitivity to common contaminants hinders most assessment programs. Globally, sediment quality guidelines (SQGs) for metals vary over several orders of magnitude and are not based on clear cause-effect relationships. Although equilibrium partitioning approaches to developing SQGs have been attempted, the cause-effect relationships are weak due to the many other modifying factors that influence metal bioavailability and toxicity. The inherent lack of defensible SQGs for metals currently impedes decision making processes by both regulators and industries.

Recent studies have indicated that most SQGs for metals are overly conservative and industries may be unduly penalized, identifying a need to develop cause-effect based SQGs that can be applied with greater confidence. A weight-of-evidence (WoE) approach is needed for understanding species sensitivity to individual contaminants in whole sediments. Important components of WoE risk assessment of sediments include knowledge of the (i) contaminant exposure pathways of the test species, (ii) sensitivity of the test species to contaminants from each exposure pathway, and (iii) factors that affect the bioavailability of the contaminants for each exposure pathway. An understanding of these components will improve our understanding of species sensitivity to metal contaminants in whole-sediments.

METHODS

A range benthic test species were selected to extract as much information about the bioavailability of metals as possible. The acute 10-day Juvenile amphipod *Melita plumulosa* (King et al., 2005), polychaete worm *Nephtys australiensis*, bivalve clam *Tellina deltoidalis* (Dowse et al., 2004) survival and the acute 3 & 24-h benthic algae *Entomoneis cf punctulata* enzyme inhibition (Adams & Stauber, 2004) bioassays were considered suitably robust. Given the effort required to develop a SQG for a single metal, copper is used to demonstrate the success of the approach.

Sediments of varied modifying properties including pH, acid volatile sulphides, organic carbon, reactive iron and particle size distribution were spiked with copper to simulate changes in sediment-pore water partitioning. Bonnet Bay (BB), Grays Point (GP) and Sydney Sand (SS) samples collected in Sydney, Australia, are representative of strong to weak metal binding capacities, respectively. Copper spiked sediments were allowed to equilibrate for 14 days and were prepared in accordance with Simpson et al., 2004.

RESULTS AND DISCUSION

Figure 1A. Comparative EC50's for water versus sediment exposure pathways in selected benthic organisms.

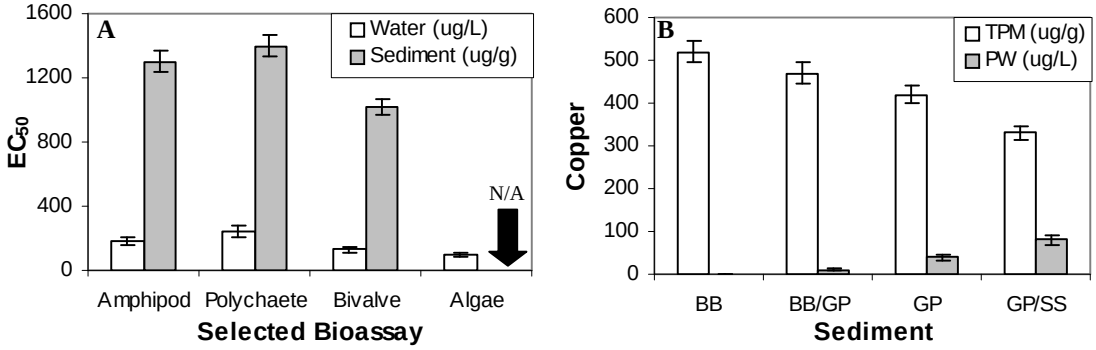

Figure 1B. Sediment-pore water partitioning with variable modifying sediment properties.

Figure 1A illustrates elevated toxicity (lower EC_{50}) to all benthic organisms in the water exposure pathway compared to the sediment exposure pathway. It may therefore be inferred that sediments with a weaker capacity to bind metals will induce a greater toxic response through alternative uptake pathways. Indeed, Figure 1B depicts prepared sediments of differing sediment-pore water copper partitioning ratios. Partitioning varies in accordance with numerous interrelated modifying factors, potentially capable of influencing bioavailability to the benthic community. The heterogenous distribution of natural sediments essentially limits the application of a single SQG value for effective environmental management.

CONCLUSIONS

Factors affecting metal partitioning in sediments indicate that the derivation of single-value SQGs (µg/g) for metal contaminants that can be applied universally to all sediment types is not a scientifically defensible approach. Generic SQGs (µg/g – sediment exposure pathway) accompanied by modifying relationships (factors) based on sediment-water partitioning (µg/L – pore water exposure pathway) may be a useful tiered approach. This will be achieved through improved understanding of the sensitivity of organisms to metals in waters and sediments, as well as understanding the relative importance of these exposure pathways.

ACKNOWLEDGMENTS

Appreciation is extended to Rio Tinto, CSIRO and the University of Wollongong for jointly funding this research project.

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