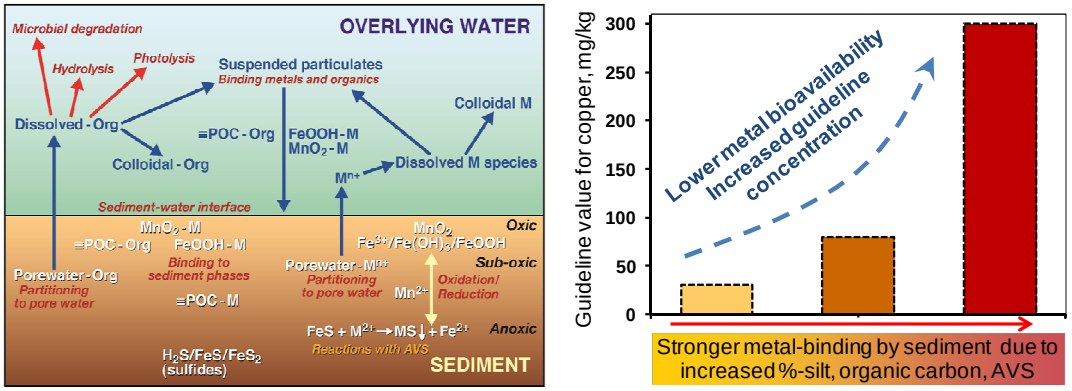
Incorporating contaminant bioavailability in sediment quality assessments

CSIRO provides a specialist capability for sampling, analysis and bioavailability assessment of metals and metalloids in sediments

In sediments, the form of the contaminants and the partitioning between the dissolved and particulate phases is strongly influenced by sediment composition. The bioavailability and toxicity of contaminants in sediments to benthic organisms will be dependent on the chemical form (speciation) of the contaminant, the properties of the sediments and the varying exposure pathways of different organisms (Simpson and Batley, 2007). The exposure and bioavailability of contaminants from both the dissolved phase (via exposure to pore water, burrow water, or overlying water) and sediment phases (via ingestion of particles as part of feeding behaviour), and the sensitivity of the organism to these contaminant exposures influences the occurrence of effects (Simpson and Spadaro, 2011). These factors make the prediction of contaminant bioavailability in sediments considerably more difficult than in waters due to the greater range of sediment phases and contaminant transformations that influence the exposure.

As an example, the ability to predict effects of metals in sediments, and more effectively apply sediment quality guidelines (SQGs), can be improved by assessing metal speciation and bioavailability (Campana et al., 2013; Simpson et al. 2013). This can be achieved by considering the solid-phase speciation (metal binding with particulate sulfide, organic carbon, and iron hydroxide phases), sediment-water partitioning characteristics (flux rates), and organism behaviour that all influence bio-uptake from porewater, overlying water, or particulates). Generally, the bioavailability of contaminants is often greater when they are in dissolved forms, and bioavailability may increase through release of contaminants from the sediment into the water column.



Conceptual models of (a) major contaminant processes in sediments (Contaminants: M = metal; Org=organic. POC = particulate organic carbon), and (b) an example of the influence of sediment properties on the predicted sediment quality guideline value for copper.

Assessing contaminant bioavailability in sediments

Although now well embedded within many risk-based SQG frameworks, contaminant bioavailability is still often overlooked in assessment and management of contaminated sediments. Within most assessment frameworks, the use of guideline values (GV) for common contaminants are a fundamental initial step in evaluating risk (Batley et al., 2005). The exceedance of a GV usually triggers additional assessment steps to determine whether there is indeed a risk posed by the contaminant (ANZECC/ARMCANZ, 2000)). Therefore successive assessment steps usually first involve assessing the bioavailability of the contaminants of potential concern (COPCs).

From a chemical speciation perspective, the bioavailability of sediment metals and metalloids is often best evaluated using analysis of (i) dilute acid-extractable metals (AEM) as a fraction of the total (extractable using concentrated acids) concentration, (ii) acid-volatile sulfide (AVS) and simultaneously-extracted metals (SEM) to assess the portion of metals bound as largely non-bioavailable sulfide phases, and (iii) through porewater and metal flux measurements to assess dissolved exposure and metal lability (Batley et al., 2005; Simpson and Batley, 2007). For organic contaminants, the concentration and form of organic carbon (OC) is the most important factor influencing bioavailability (Burgess et al., 2013), and measurement of OC and the use of equilibrium partitioning (EqP) models provide the most effective method for assessing the bioavailability of many organic chemicals.

From a biological perspective, well designed bioaccumulation bioassays can also be used to directly assess metal bioavailability, however, tissue concentrations measurements also have limitations owing to the internal partitioning and processing of contaminants (regulation, storage, excretion, metabolism).

Specialist applications

The CSIRO Centre for Environmental Contaminants Research (CECR) situated at Lucas Heights, near Sydney, has NATA-accreditation and quarantine-approved premises for its highly proficient specialist capabilities in contaminant analyses, bioavailability and toxicity assessment. This capability has been applied in a wide range of studies both within Australia and internationally within the Asia-Pacific region, particularly in sediment quality assessment and advice to industries on sediment management.

CSIRO provide a range of state-of-the-art techniques to assess the forms and potential bioavailability of sediment contaminants in both marine and freshwater environments. CECR are international leaders in sediment quality research and their much-cited Handbook of Sediment Quality Assessment (Simpson et al., 2005) is currently being updated with a new edition to be available in early 2015.

CSIRO undertakes NATA-accredited metal analyses, speciation, bioavailability and toxicity testing as part of water quality and environmental impact assessments (EIA) for both industry and regulators, including:

- sediment sampling and analyses (with sampling advice if required);
- contaminant speciation, bioavailability and toxicity assessments;
    - Metal bioavailability through considering AEM, AVS-SEM, porewaters and fluxes (including diffusive gradient in thin film (DGT techniques);
    - Organic contaminant bioavailability through use of EqP models and equilibrium partitioning sediment benchmark (ESBs);
- process-related studies to understand chemical fate and transformations of contaminants;
- bioaccumulation bioassays and in situ studies; and,
- ecotoxicological studies to link metal exposure with effects and derive site-specific guidelines.

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