SEDIMENT QUALITY

Method Indicator		
Bottom-Up	Hybrid	Top-Down
		YES

Summary of key issues

Issue	Description
Description	Techniques to establish the transport pathways of sediments and the way in which contaminants are adsorbed and released from the sediments.
Temporal Applicability	Typically applied to the short to medium-term (single tide up to several months).
Spatial Applicability	Varying from a single point to estuary wide including the open coast.
Links with Other Tools	Numerical modelling can support these assessments by linking both local hydrodynamics and sediment dispersion with water quality parameters in a computational domain (see also water quality).
Data Sources	Sediment information, hydrodynamic information, estuary volumes, areas, hypsometry, sediment budget/availability.
Necessary Software Tools / Skills	Sediment transport and hydrodynamic modelling, good understanding of the sediment pathways and estuary processes.
Typical Analyses	Changes in estuary morphology, erosion and deposition patterns.
Limitations	Requirement for calibration data (flow, water levels) and sediment characteristics (type, consolidation, thickness, density).

Naturally occurring and synthetic contaminants such as heavy metals, hydrocarbons, organotins (TBT), pesticides, organochlorides, organophosphates, solvents and polychlorinated biphenyls (PCBs) tend to be associated with fine sediments (silts and clay) due in part to their greater surface area for geochemical binding.

The re-suspension and bioavailability of sediment bound contaminants in the water column is often an important consideration by regulators and statutory agencies when determining the acceptability of capital and maintenance dredging operations. The risks associated with such operations may be a determining factor when stipulating developmental controls such as seasonal restrictions and monitoring thresholds.

The potential risks for marine environmental receptors (biology and water quality) can be inferred initially through comparison with sediment quality standards. In the absence of statutory sediment quality values that define thresholds for acceptability (for licensed disposal for instance) the quality of material for dredge and disposal operations is typically assessed through comparison with Dutch (IADC/CEDA, 1997) and Canadian Standards (CCME, 1999).

Whilst such standards are based on biological effects for a range of organisms, the testing conditions used to derive the standards are unlikely to be representative of different dredging and construction techniques in the field. In particular, the degree of re-suspension of host suspended sediments is likely to vary.

Understanding particle-water interactions provides a means of estimating the degree of contamination of the water column (near and far-field effects) through the process of geochemical modelling.

Particle-water interactions

Interactions of chemical constituents between suspended particles and water result from a variety of physical, chemical and biological processes, including colloid aggregation, ion exchange, adsorption-desorption, absorption, precipitation-dissolution, hydrophobic bonding, sating out, microbiological activity and degradation of particulate organic matter.

When a contaminant is associated with the solid phase, it is not known which of these processes dominates and the transfer between solid and aqueous phase effected by chemical processes is defined by the general term *sorption* (Turner & Millward, 2002).

Sorption is frequently quantified by the empirically derived partition or distribution coefficient, 'K_d', which defines the concentration ratio of chemical sorbed to the different components of suspended particles (solid phase), C_s, to chemical dissolved in water (aqueous phase), C_w:

$$K_d = C_s / C_w \qquad\qquad\qquad (1)$$

Values for K_d vary greatly between contaminants and also as a function of aqueous and solid phase chemistry.

Sorption models

Information on sorption models is provided in detail in (USEPA, 1999a; USEPA, 1999b) and is summarised here.

Constant partition coefficient (Kd) model

The constant partition coefficient model, K_d, attempts to account for various chemical and physical mechanisms that are influenced by a range of variables, including, sediment composition and concentration, contaminant concentration, salinity and pH together with other complex chemical/physical interactions.

Given the range of influencing factors on partitioning, site-specific Kd values would ideally be needed for the system to be modelled.

Parametric K_d model

A limitation of using K_d values is that they are representative for only one set of environmental conditions.

In the Parametric K_d model, the partition coefficient varies as a function of empirically derived relationships with aqueous and solid phase independent parameters. Thus, it has the distinct advantage of being more robust and removes the burden of determining new K_d values for each environmental condition.

Isotherm adsorption models

The Isotherm model can be applied where sorption relationships deviate from linearity. Since K_d is a function of contaminant concentration, the effect of contaminant concentration on adsorption can be tested, while other parameters are held constant. This results in a series of adsorption isotherms.

Applications

With knowledge of the partition coefficient (including uncertainty) for a particular contaminant, it is possible to apply project specific information on suspended sediment concentrations from for example, dredging activities, to estimate the concentration of contaminant released into the water column.

This approach can be applied to examine the effects on water quality in the near field (close to the source), where deterioration in water quality will primarily be a function of contaminants associated with the solid phase, and far field, where there is dispersion of aqueous phase contaminants and the risk of exceeding the relevant marine Environmental Quality Standards (EQS).

Numerical modelling can support these assessments by linking both local hydrodynamics and sediment dispersion with water quality parameters in a computational domain (see also water quality).

Relationship between sediment transport and contaminant transport

Given the affinity between fine sediments and contaminants, knowledge of sediment transport pathways may allow identification of sinks for contaminated sediments. Likewise, mapping of contamination in an estuary may assist the identification of sediment transport pathways.

The method of Sediment Trends Analysis (McLaren & Bowles, 1985) provides one method for testing this relationship. Sediment Trend Analysis attempts to determine the patterns of net sediment transport over an area through the grain-size distributions of the sediments (McLaren & Bowles, 1985). The sampled sediments are described in statistical terms (by the moment measures of mean, sorting and skewness) and the basic underlying assumption is that processes causing sediment transport will affect the statistics of the sediments in a predictable way. Following on from this assumption, the size frequency distributions of the sediments provide the data with which to search for patterns of net sediment transport.

When used in conjunction with sampling of the sediments for contamination, these methods have been applied to examine potential sites for dredge material disposal and environmental monitoring (McLaren, 1987; McLaren et al. 1993; McLaren, 1993).

References

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