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Interfacial accumulation of contaminants - Is there a problem?

By

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Introduction

Pollution management policies have been based on the assumption that toxic effects from point discharges are only likely in the mixing zone (defined as the zone of acceptable ecological impact), while diffuse inputs are unlikely to have toxic effects at all. There is now extensive evidence that there may be exceptions to these assumptions, in that there are numerous mechanisms now known that can reconcentrate persistent contaminants to concentrations that may be toxic to indigenous biota. It has been shown that biological effects of contamination along a transect running out to the central North Sea were primarily related to the occurrence of contamination at the benthic or sea surface interfaces (Stebbing et al., 1992).

This paper provides a framework within which different mechanisms of reconcentration at the sea surface and benthic interfaces are considered. At each, processes exist that may cause secondary or tertiary reconcentration of contaminants at sites where they are then more likely to exceed toxicological threshold concentrations.

It might be assumed that the localisation of contaminants in this way would minimise their potential toxicity to the indigenous biota, but it seems likely that the reverse is true. The hypothesis is proposed that such mechanisms may not only reconcentrate contaminants, but that the same mechanisms may also cause the accumulation of nutrients and organic matter (POC), which results in enhanced biological activity at the same sites. Clearly the biological impact of contaminants is likely where and when contaminant accumulation and sites of high biological activity coincide.

A scheme for different mechanisms of contaminant accumulation

If the concentration of toxic constituents in an effluent or discharge before release into the environment represents the Primary Concentration, the dominant processes thereafter are dilution and dispersion. However various chemical and hydrographic processes may have the reverse effect and reconcentrate conservative contaminants, potentially to toxic levels.

The most important sites of Secondary Reconcentration of contaminants are the sea surface and benthic interfaces. At the sea surface the Secondary Reconcentration of contaminants is partly due to atmospheric deposition of contaminants such as metals (Hardy et al., 1985), which are held up in the surface microlayer on particles or as organic complexes for long enough to result in enhanced concentrations. Other contaminants may be carried up through the water column, contributing to the enhancement of concentrations over those in the immediate waters. For example organic lipophilic contaminants may bind to fats and lipids, and many interfacially-active contaminants may be scavenged by bubbles as they rise through the water column (Hardy, 1982). The accumulation of contaminants at the benthic interface is well known and understood, so will not be considered in any detail.

Much less is known about Tertiary Reconcentration, which is likely to occur where contaminants at the sea surface or benthic interfaces are further reconcentrated by other processes. The examples given (Table 1) here identify processes that would be capable of further reconcentration, although there is some evidence that gyres, turbidity maxima and fronts may be sites of contaminant accumulation.

Recent Japanese work by Tanabe and co-workers (1991) has shown that persistent organochlorines (PCBs, DDT, HCH isomers) occur at elevated concentrations in frontal regions, due to their affinity for lipids and particles concentrated by fronts. This has been demonstrated both for water samples taken at the sea surface, but is also true for the sediments beneath frontal regions because of the deposition of particles to which organochlorines are adsorbed.

Table 1 Reconcentration of contaminants at interfaces

Secondary Reconcentration		**Tertiary Reconcentration**	
site	mechanism	site	mechanism
sea surface	atmospheric deposition	frontal systems	interfaces between water masses
	particle binding	littoral zone	wind on surface layer
	organic complexation	windrows	Langmuir circulation
	bubble scavenging	convergence slick	transverse estuarine cells on flood tide
benthic interface	sedimentation	gyre systems	centripetal forces
	biodeposition	turbidity maxima	tidal pumping of particles
		frontal systems	sedimentation

Coincident reconcentration of contaminants and biota

The central point of this paper is best put as two statements and a deduction:

1. Contaminants may be reconcentrated by numerous mechanisms, often at interfaces (see Table 1) because they bind to particulate and organic complexes upon which physical processes can act.

2. The same mechanisms often concentrate particulate and dissolved organic matter, which as substrates for biological consumption enhance biological activity at the sea surface and benthic interfaces.

3. Thus elevated concentrations of contaminants may occur at sites of locally enhanced biological activity, resulting in exposure of biota to potentially toxic concentrations of contaminants.

The oral presentation will provide examples of the different kinds of accumulation at the air/sea and benthic interfaces and the toxicity of sea surface microlayer and superficial benthic sediments, drawing on the results of the ICES/IOC Bremerhaven Workshop (Stebbing et al., 1992) and other recent work.

Chemical data demonstrate that metal concentrations may be 10 to 1000 times higher in the microlayer than the immediate subsurface. Estuarine organotin concentrations may be 2 to 27 times higher in the surface microlayer (Cleary and Stebbing, 1987); comparable enrichments occur offshore in the North Sea. Accumulation of persistent contaminants in benthic sediments is well established. However, in size-fractionated sediments, it is clear that contaminant concentrations are typically elevated in the organic-rich fine fractions (< 63 µm) and associated with particulate organic matter (POC). It appears that the methods for taking sediment samples are not always designed to ensure that the superficial, organic-rich fine sediments and POC ("marine snow") are sampled. Cores are more likely to sample the superficial sediments to which the epifauna are exposed than grabs.

Bioassays of the sea surface microlayer and benthic sediments may indicate toxicity, but evidence is required to establish the significance of toxic levels of contaminants at interfaces to the indigenous biota. While much is being done to establish the importance to the benthos, the seasonal and diurnal transience of the neuston make it more difficult to demonstrate the significance of sea surface microlayer contamination to natural communities.

Conclusions

1. Contaminants accumulate at the sea surface and benthic interfaces.

2. The enrichment of contaminants at these interfaces may reach concentrations of biological significance, even well offshore in the North Sea.

3. Any monitoring programme that is based on the assumption that contaminants are homogeneously distributed cannot serve its purpose if contaminants are heterogeneously distributed.

4. Much evidence exists which demonstrates that contaminants accumulate at interfaces and other specific locations due to biogeochemical processes.

References

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