RISK ASSESSMENT OF PCB-CONTAMINATED DOCK SEDIMENT USING GEOSTATISTICAL TECHNIQUES

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Introduction

As dredging activity continues to increase, the UK government has become conscious of the need to more adequately address the issues surrounding the disposal of dredged material. Although disposal at sea remains the most cost-effective means of disposing of dredged material, beneficial uses are being developed for the management of foreshore erosion and for positive intervention in coastal and estuarine sediment budgets. In encouraging such uses, the accuracy with which contaminant concentrations in dredged sediments can be assessed becomes crucial. This study assesses the within-site variation in PCB concentrations in a commercially active dock.

Aims

- Evaluate the spatial structure and patterns of 25 chlorobiphenyl congeners, total PCBs, total organic carbon (TOC) and particle size (%<63µm) in dock sediments.
- Determine the variogram structure of sediment PCBs and produce maps of their kriged estimates.
- Investigate possible mechanisms and processes that might control their spatial distribution.

Methodology

The sampling strategy used for this study incorporates a range of sampling intervals in a three-fold geometric progression. This is based on a coarse grid of 150 m. Additional sampling points were located randomly from each grid node, but with a fixed range of distances between them of 405, 135, 45, 15 and 5 metres. Surface sediment samples (1-2cm) were collected by a Van Veen grab.

King's Dock - Swansea

Sediment analysis

- PCBs were analysed by gas chromatography with electron capture detection (GC-ECD).
- Particle size was determined using standard wet and dry sieving procedures.
- Total Organic Carbon (TOC) was measured using a standard loss on ignition technique.

Data were subjected to both univariate and multivariate statistical analysis, using principal component analysis, to investigate whether some of the 25 congeners might explain more of the variation than others. Geostatistical methods were used for estimating PCB contamination in the dock and experimental variograms were computed from original CB data and from the scores of the principal component analysis.

Results

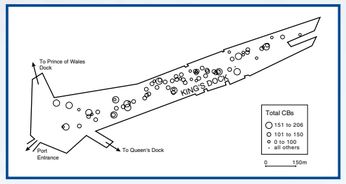

Figure 1: Total PCB concentrations (µg kg -1) sampled in King's Dock sediment

The distribution of total CBs in dock sediments is shown in Figure 1. Experimental variograms and the fitted model of selected congeners, TOC and particle size are shown in Figure 2. The first two principal components (Figure 3) account for almost 80% of the variation. The congeners that explain most of the variation on PC1 are CB#110, CB#118 and CB#153 which are intermediate in the spectrum from less to more chlorinated PCBs. For PC2, it is the less chlorinated congeners (CB#28 and CB#66) that explain most of the variation.

The circular model provides the best fit for the less chlorinated congeners, whilst the spherical and circular models provided the best fit for the penta-CBs. The hexa- and some hepta-CBs are fitted best by a linear model whilst other hepta- and octa-CBs are fitted with either a spherical or circular model. The linear model provides the best fit for total PCBs and is also the best fit for particle size. However, the large nugget variances of the individual CBs shows that a considerable proportion of the variation remains unresolved by the sampling or that there is considerable measurement error or both.

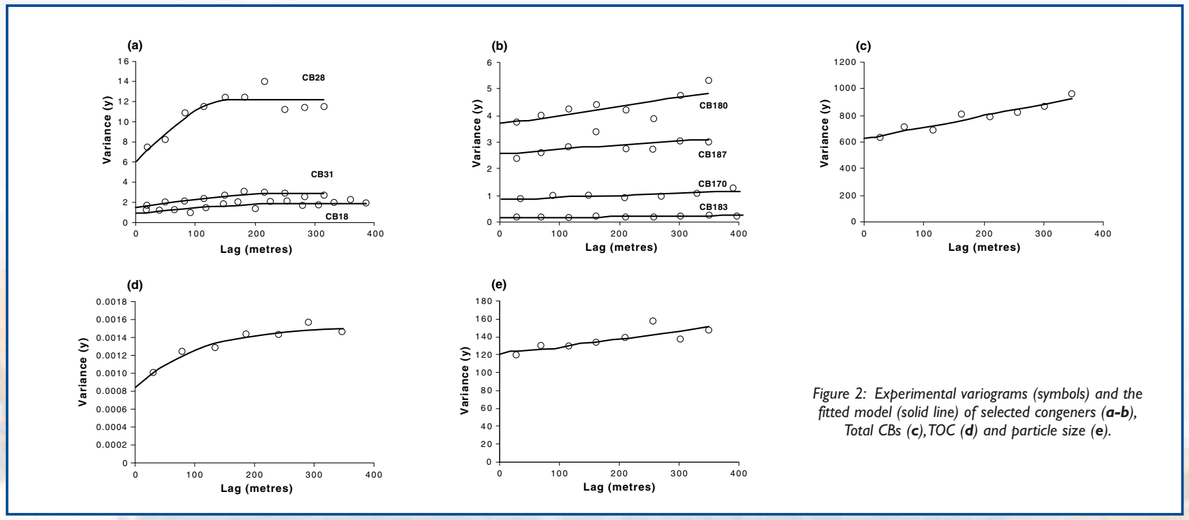

*Figure 2: Experimental variograms (symbols) and the fitted model (solid line) of selected congeners (**a–b**), Total CBs (**c**), TOC (**d**) and particle size (**e**).*

Figure 4 shows the kriged maps of CB#18, Total PCBs, TOC and particle size. Elevated concentrations of individual congeners occur in specific areas. The more chlorinated CBs have high concentrations that are localised and these correspond to high % TOC. In contrast, particle size is more spatially heterogeneous, although the western side of the dock has a larger concentration of fine sediment. The map of TOC suggests that total PCBs occur in discrete patches towards the west and the south east of the dock.

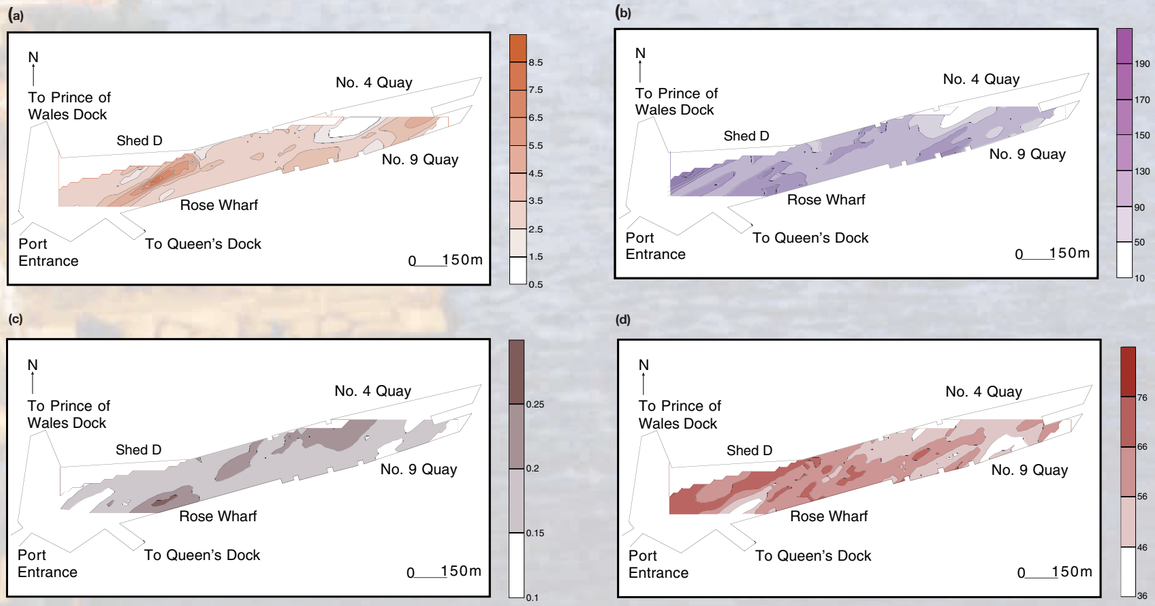

*Figure 4: Kriged map of (**a**) CB#18 (µg kg⁻¹), (**b**) Total CBs (µg kg⁻¹), (**c**) TOC (g) and (**d**) particle size (% <63µm).*

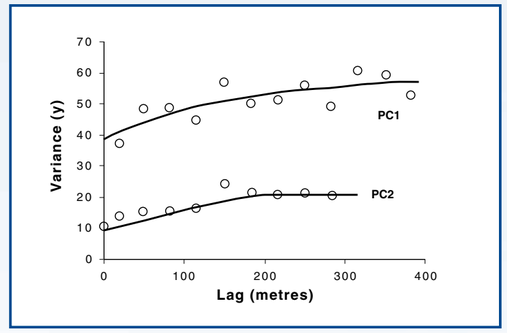

Figure 3: Sample variograms of principal component 1 and 2.

Discussion

- Spatial variation in the less chlorinated CBs (i.e. tri-, tetra- and penta-CBs) is more patchy and more structured than the more chlorinated CBs (i.e. hexa- and some hepta-CBs) which have unbounded variograms. Spatial structure in less chlorinated CBs is attributed to such properties as relatively high volatility and solubility and movement influenced by their behaviour in the dissolved phase.
- Spatial dependence of the more chlorinated CBs is possibly a response to rapid immobilisation by their association with the organic fraction and partitioning into lipids and waxes in the sediment. These CBs have a greater tendency to adsorb on to sediments and these are retained in the longer term.
- The variograms and kriged maps of individual CBs can illustrate possible environmental processes operating within the dock system, and have demonstrated close links with TOC.

Conclusion

- A nested sampling strategy is effective in determining the spatial scale of variation, source and spatial structure of CBs locally.
- Geostatistical modelling provides a means of interpolating environmental variation over a known extent.
- Sample and modelled variograms allow inferences to be made concerning processes controlling the distribution of PCBs within the dock.

Future work

- Develop cost effectiveness and practicality of this approach.

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