The combination of sediment profile imagery (SPI) and DGT technology for seabed health assessments

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Introduction

The European Marine Strategy Framework directive (EMSFD) has 'seabed integrity' as a key descriptor of Good Environmental Status (GES). A challenge for regulators is to develop indicators which can be used to track seabed status and functional change (physical, chemical and biological) as a result of natural or human derived pressures.

Evaluation of the contaminant load and toxicity of sediments on disposal sites is an important element of safeguarding seabed health.

Methods are needed to improve current understanding of the contaminant profile of disposed sediments and potential bioavailability.

Sediment Profile Imagery

Sediment profile imagery (SPI) is an *in-situ* technique which takes vertical images of the upper 10-20cm of the seabed (Figure 1). Rapid temporal and spatial assessment of soft sediment state can be made by using sediment colour as a proxy for redox state – aRPD – apparent Redox Potential Discontinuity.

SPI images can also provide clear insight into the relationship between benthic communities and sediment properties. Using the conceptual diagram in figure 2, the SPI images can then be placed on a conceptual model of sediment and biological status in relation to baseline conditions and potential disturbances. Disposed materials often have different optical properties (grain size and colour) which can be observed using SPI. See Figure 4.

Figure 1. Cefas sediment profile camera

For SPI assessments to be successful, chemical detection alongside imaging is highly desirable in order to calibrate and support image interpretation. Measurements that investigate the potential availability and supply of contaminants from disposed material to biology or through a cap are needed to support existing monitoring practises. The potential of using Diffusive Graduate in Thin film (DGT) probes for this purpose was investigated in this study.

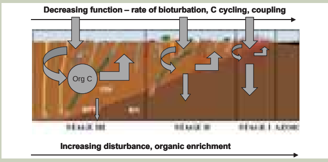

Figure 2. Conceptual diagram of sediment redox with disturbance in soft sediments (from Rhoads *et al.*, 1981)

DGT deployment in Souter Point Disposal site cores: trial study

A trial study was conducted to evaluate DGT probe methodology and performance in support of disposal site monitoring. The aims of the study were to apply DGT gel technology to;

- Test DGT deployment and analytical procedures
- Examine DGT utility for contaminant speciation and availability detection – as defined by gels, in disposal site sediments and layers

Sediment cores were taken during a 2009 monitoring cruise at the Souter Point disposal site and at a reference site (TC4) (Figure 3), transported back to the laboratory and stored (at ambient temperature, dark, complete with overlying water). Loaded DGT sediment probes (DGT Research, Lancaster, UK), were deoxygenated and inserted into the cores according to the manufacturers instructions. After 24hrs incubation, the gel probes were recovered, sliced, eluted into acid and analysed by ICP-MS. Associated sediment variables were also measured (oxygen, carbon, particle size etc).

Images of the cores taken from these sites are shown in Figure 4, alongside SPI images from these sites.

The cores and SPI images illustrate the comparative sediment types and redox level from colour : brown, grey to black. From the images alone it is possible to see the coarser sediment present in the disposal site (Cap1) and muddier sediments with significant organic loads (shallower colour transition) in the Cap2 and Cap 5 cores.

The core and SPI colour analysis would imply that there would be increased contaminant availability in the pore-water (reducing sediment) higher in the cores where disposal has occurred than the reference site (TC4).

Figure 3. Location map of disposal monitoring sites

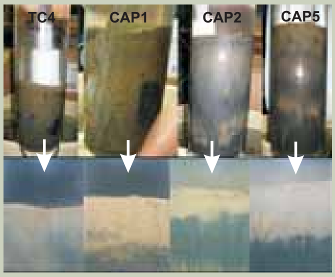

Figure 4. Core and SPI images used for DGT testing

Table 1. Overview of the cores taken and site description

Site / Core	Site description	Monitoring type	Probe number
TC4	Coastal, x 25m	Reference coastal	C4
Cap 1	Coastal	Capping site	No DGT – too coarse
Cap 2	Coastal	Disposal	C2
Cap 5	Coastal	Disposal	C3, C5

Results

Table 2. Shows the analytical handling (degassing and analysis only) and detection limits for all metals (Italics = 1stddev)

Metric	Cd	Cr	Pb	Ni	Zn	Fe	Cu	Mn
METHOD BLANK (ng ml^{-1})	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.02 *0.01*	0.09 *0.03*
DL (ng ml^{-1})	-	-	-	-	-	-	0.069	0.28
LOQ (ng ml^{-1})	0.073	0.240	0.044	0.086	0.905	12.6	0.066	0.214

Table 2 shows the methodological blank information for the 8 metals that were analysed for.

For 6 metals the blanks are below limits of detection (<LOD) and so the detection limit (DL) tends to be Limit of Quantification (LOQ) relevant to the ICP-MS which here is quoted as 10 x standard deviations of 10 runs of the lowest standard solution.

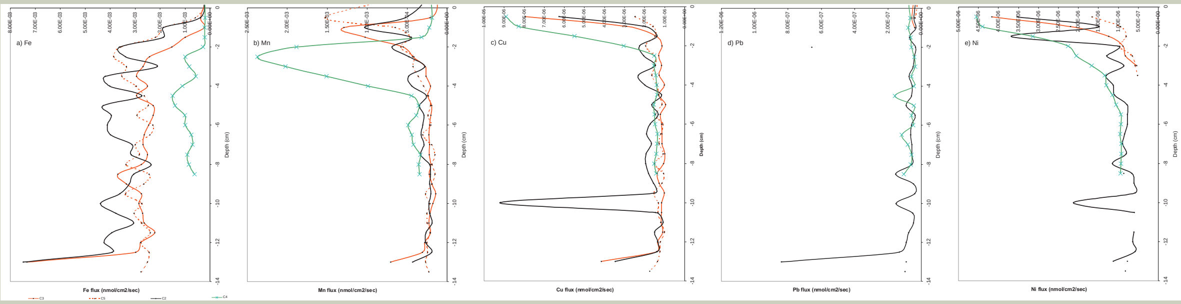

Figure 5a to e. DGT profiles from sediment cores TC4(C4), CAP2(C2), CAP5(C3,C5), CAP1-no DGT.

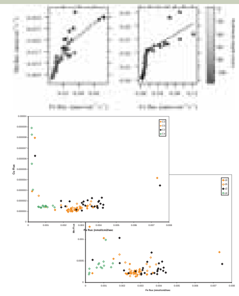

Figure 6. a) Fe/Mn plots from Teal *et al.*, 2009 b) Fe/Mn; c) Fe/Cu - this study

DGT profiles

Figure 5a to e illustrate the profiles obtained from the DGT probes.

The profiles illustrate regions of supply of metals from the sediment pore-water to the gel. Ni, Cd, Zn and Cu illustrate a maximum supply nearest the sediment-water interface. This is consistent between the disposal and reference cores, which implies it is not related to disposal activity. This could be linked to water column supply of organic matter degradation in the surface sediment (~2cm). Chlorophyll and carbon profiles may help this interpretation.

For the disturbed cores Mn remobilisation seems to be occurring within the upper 2cm whilst at TC4 (reference) this is occurring lower at approximately 2 to 4cm. Fe remobilisation occurs at all disposal cores (c3, c5 and c2) within the first cm from the sediment water interface and is evenly high down core (2 to 12cm). At the reference site this doesn't seem to occur until at least 2cm and the DGT flux is lower. This compares to aRPD assessment from SPI images and cores of <1cm for the disturbed sites and ~2-3cm for the reference site.

Fluxes overall seem comparable to other studies but the fluxes for Fe and Mn are an order of magnitude lower than at North Dogger and Oyster Ground (shelf seas reference sites) – Teal *et al.*, 2009. This has interesting implications for bioavailability of metals within disposal sites.

When plotted using the method from Teal *et al.*, 2009 it is possible to observe coupling or not between metal profiles. Teal *et al.*, observed close transition between Fe and Mn at two sites in the North Sea (North Dogger and Oyster Ground) related to depth and SPI colour. The strength of the coupling was weakened by heterogeneity at the Oyster Ground due to bioturbation processes. Figure 6 illustrates Fe and Mn flux relationships from DGT sampled from the SPI faceplate and comparative plots for 2 metals from this study. (Figure 6 a+b). The disposal site plots look very different from Teal *et al* 2009. This is likely to be linked to historical disposal legacy and layering of sediments with contrasting metal loads which disrupts the conventional diagenetic sequencing and boundaries.

Conclusion

As a preliminary study it seems that DGT measurements can work well in these types of coastal sediments although there are some issues of detection for some metals.

The DGT Fe profiles link well with SPI analysis of aRPD The gel sampling gives more detailed information on the sediment pore-water supply of metals and hence associated potential bioavailability and toxicity, whilst the SPI technique is at present, more applicable to monitoring surveys.

Future

Various future developments would be possible with respect to gel technologies and SPI to improve seabed health assessments and monitoring:

- Deployment of DGT probes or other gels in-core on the survey vessel or inclusion on the SPI face-plate (as Teal *et al.*, 2009).
- Use of other passive sampling materials tailored to for example TBT, organic pollutants or priority substances.
- Integration of optical sensing instruments within the SPI housing.
- Alignment with toxicity testing and biological sampling techniques and also other supporting data to allow fuller assessment of sediment state and function changes.

Acknowledgement

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Reference

Teal, Lorna R., Ruth Parker, Gary Fones, and Martin Solan
Simultaneous determination of *in situ* vertical transitions of color, pore-water metals, and visualization of infaunal activity in marine sediments Limnology and Oceanography -Vol 54 Issue 5 1801-1810