

Sediment-bound pollutants in the North Sea Region - posing a threat to estuarine functions

Jeanette Rotchell¹, Samantha Richardson¹, Will Mayes¹, Paul Kay² and the entire WP3 Sullied Sediments team as well as: Sarah Letsinger² and Adelaide Lerebours¹

University of Hull¹ and University of Leeds²



1. Sullied Sediments: better characterisation of sediments within inland waterways (non tidal)

Aims

- Sediment characterisation at a range of catchments indicative of pollutant pressures / management needs in North Sea region – 54 sampling occasions – 3 countries, 3 sites, 6 sampling surveys (cost per survey...?)
- Chemical characterisation (inc. Watch List) with biological effects based assessment (BEBA) & ecological assessment
- Cost benefit analysis – minimum requirements for effective assessment

2. Pharmaceuticals in Estuarine Environments: focus on the Humber estuary

3. North Sea Dogger Bank: liver tumours in flatfish

Sustainable North Sea Region

<http://northsearegion.eu/sullied-sediments>

Three inland waterways sampling catchments

Interreg
North Sea Region
Sullied Sediments
European Regional Development Fund



EUROPEAN UNION



SulSed site selection and CSM development

Process:

**Scoping current
pressures**

**EA WFD
status**

**Reasons for
failure**

**Identifying trends /
historic pressures**

EA ambient data

BGS GBASE

**Defra mines
databases**

Prioritising sites

**Indicative
pressures**

**Stakeholder
interests**

**Logistics – site
walkovers**

CSM development

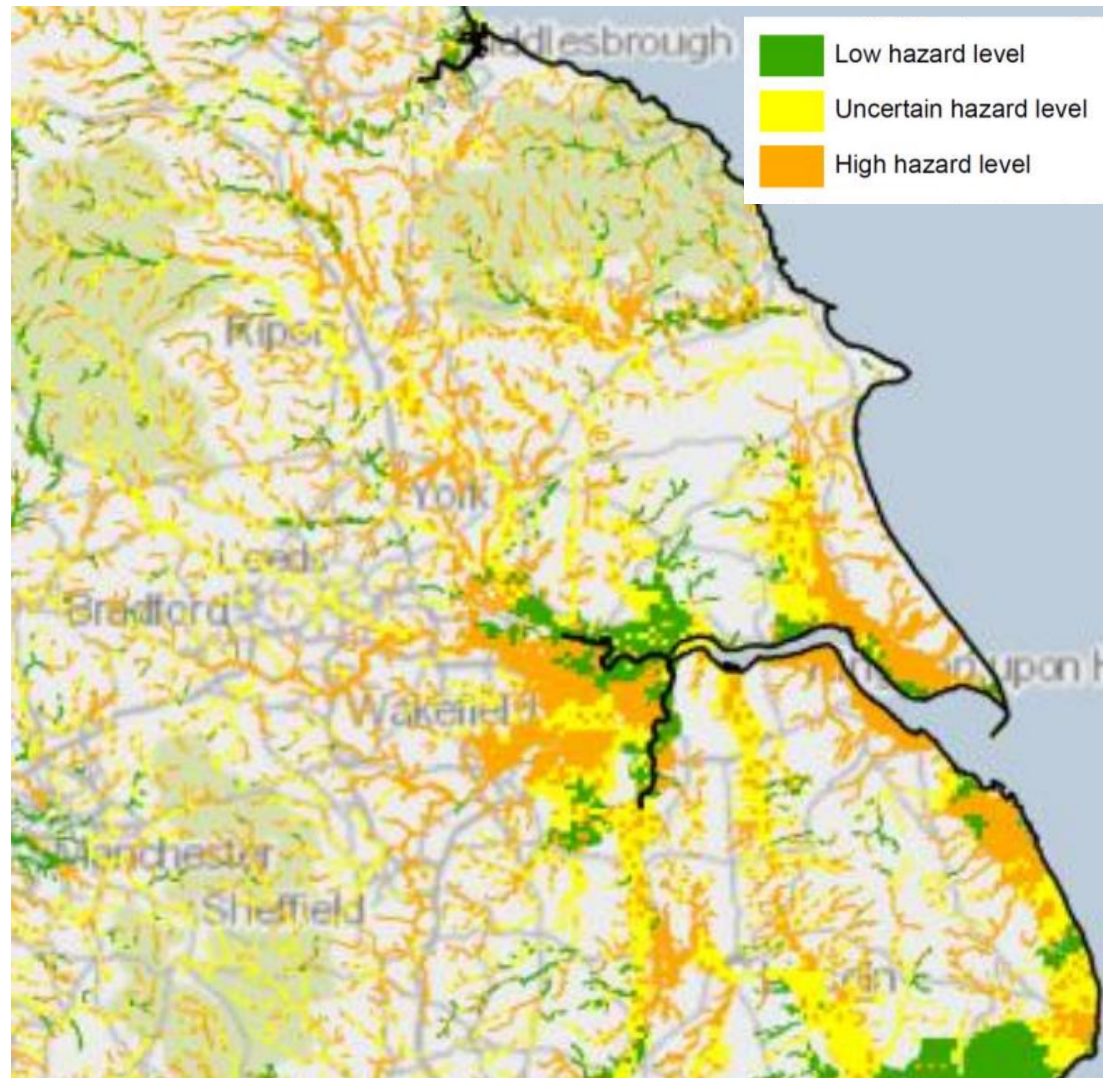
**Flux based
estimates
(OSPAR, PRTR)**

Land use maps

**Published and
grey literature /
data**

Previous state of play : Humber basin sediments

- Recent national review
- Uncertain and high risk in parts of Humber basin for contaminated sediment issues associated with flooding
- (desk-based study, cost=?)



SOURCE: Haskoning (2017) *Developing an evidence base for in-situ contaminated sediment in England*. Defra, London.

Sullied Sediments: A comprehensive chemical monitoring and broader matrix characterisation of inland waterway sediments (Richardson *et al.*, at review)

- **53 hydrocarbons**
- **26 metals and metalloids**
- **15 dioxins and furans**
- **16 EPA PAHs,**
- **7 PCBs,**
- **8 organotin compounds,**
- **10 pesticides,**
- **15 per- and poly-fluoric compounds**
- **emerging contaminants triclosan, diclofenac and estradiol.**

COST
Approx 40,000
Euros per survey for
all chemical/
ecotoxicity and
associated analysis

Sediment Ecotoxicity: Biological effect-based assessments

- led by Prof Susanne Heise and team

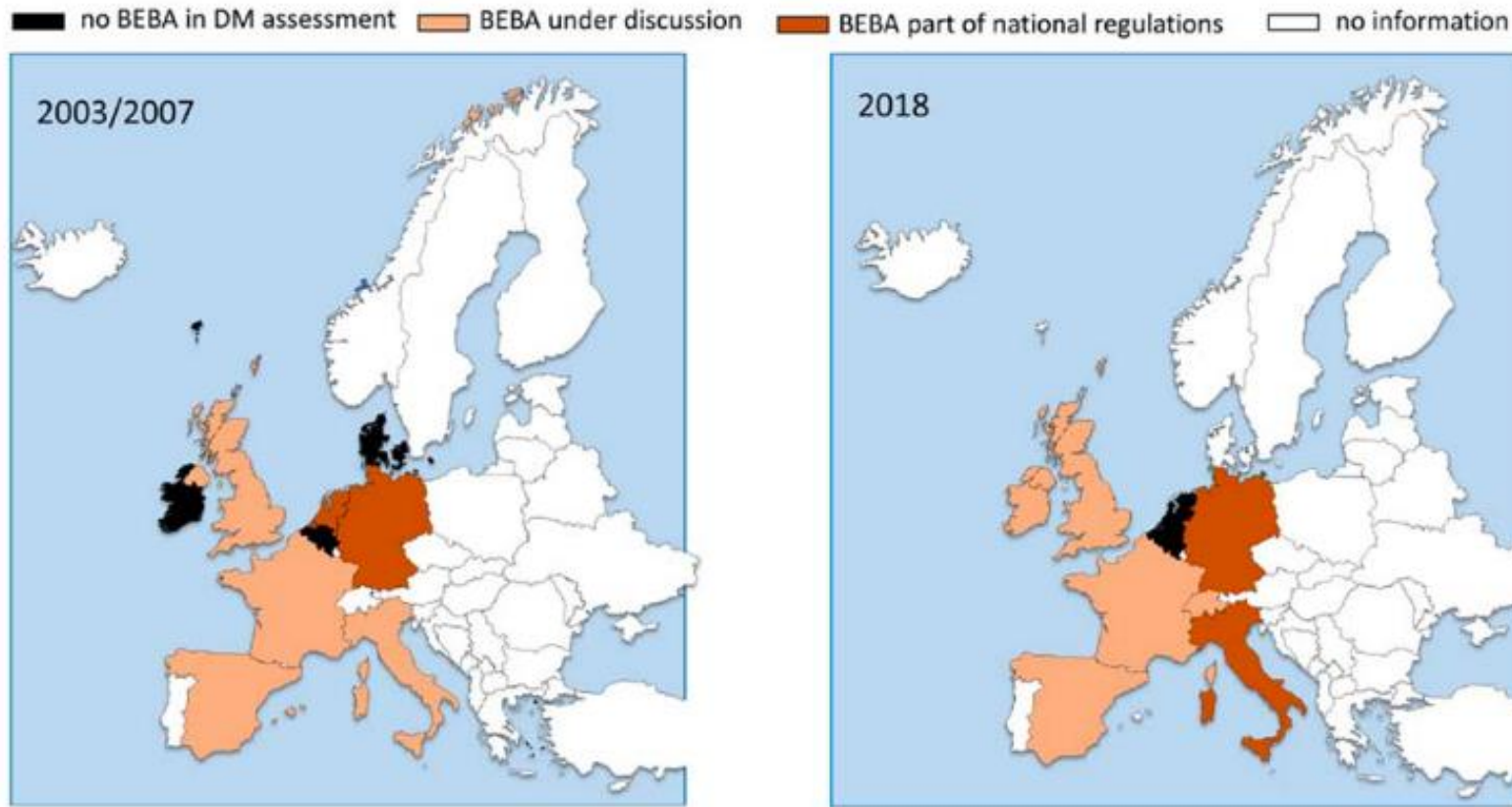


Figure 1: Status of the inclusion of biological effect-based assessments (BEBA) into national regulatory frameworks for dredged material (DM) in European states in 2003/2007 compared to 2018 ((based on den Besten et al. 2003; den Besten 2007 and the outcome of the SedNet & Sullied Sediments Workshop 2018) (from Heise et al. (2020))

<https://northsearegion.eu/media/16722/report-on-better-assessment-of-a-sediment-management-framework-final.pdf>

BEBA: 5 Hypotheses tested with the SulSed samples...

- 1) A single biotest can inform on the impairment of the biological community. **Not really, maybe growth inhibition of ostracodes**
- 2) Single bioassay responses are correlated with elevated concentrations of certain chemical contaminants. **Strong correlations: shrimp test - trichlorobenzene; sumPAHs - *Lubriculus* sp. growth inhibition. No single biotest responds to all substances.**
- 3) If there is no correlation between single bioassays and individual contaminants, the ecotoxicological response reflects the overall chemical contamination of the respective sediment. **Two biotests reliably show a moderate correlation with the overall degree of contamination in the sediment, Thamno Shrimp Test and Luminescent Bacteria Test**
- 4) The quality of the biological community is related to measured concentrations of chemical contaminants and to sediment parameters (with biotic indices (BSI; NemaSPEAR[%]), chemical data and sediment parameters). **No for NemaSPEAR; BSI is moderate correlation for fine grain size only; no for organic content or ammonium concentration**
- 5) A biotest combination can be designed that reflects the diversity of the ecological community (NemaSpear or BL-index). **No test system can be convincingly omitted from the biotest battery on the basis of its strong correlation with any other of the applied test systems**

Ecotoxicity tests and sediment hazard classification approach - also led by Prof Susanne Heise and team

Table 5: Distribution of Hazard Classes per watershed.(bold: all samples of one survey fall into the same category)

Watershed	Non-hazardous	Potentially hazardous	Moderately hazardous	Severely hazardous
DE	DE_6.2	DE_4.3 DE_5.1 DE_6.1	DE_1.1 DE_2.2 DE_2.3 DE_3.3 DE_4.1 DE_5.2 DE_5.3 DE_6.3	DE_1.2 DE_1.3 DE_2.1 DE_3.1 DE_3.2 DE_4.2
UK	UK_2.2 UK_3.1 UK_5.1 UK_5.2 UK_5.3 UK_6.3	UK_1.2 UK_2.1 UK_2.3 UK_3.2 UK_6.2	UK_1.1	UK_1.3 UK_3.3 UK_4.1 UK_4.2 UK_4.3 UK_6.1
BE		BE_2.3 BE_3.1 BE_3.2 BE_4.3 BE_5.1 BE_5.2 BE_6.2	BE_3.3 BE_4.1 BE_5.3 BE_6.1 BE_6.3	BE_1.1 BE_1.2 BE_1.3 BE_2.1 BE_2.2 BE_4.2

Applying a hazard classification approach, from 54 Sullied Sediments samples that were taken between autumn 2017 and Summer 2019,

7 are considered to be not hazardous, 15 of potential hazard, 14 of moderate hazard with high certainty, and **18 of severe hazard with high certainty**

Summary: ecotox tests can deliver an additional line of evidence for sediment classification in form of potential toxic effects of sediments, adding value to the assessment on the basis of chemical contamination and of biological quality.

OVAM : Six available Reports

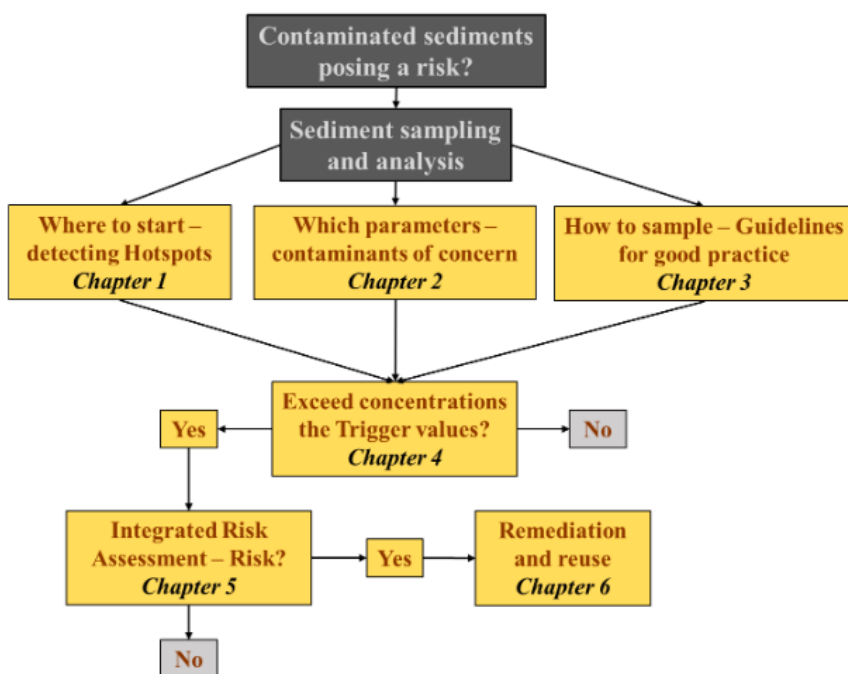
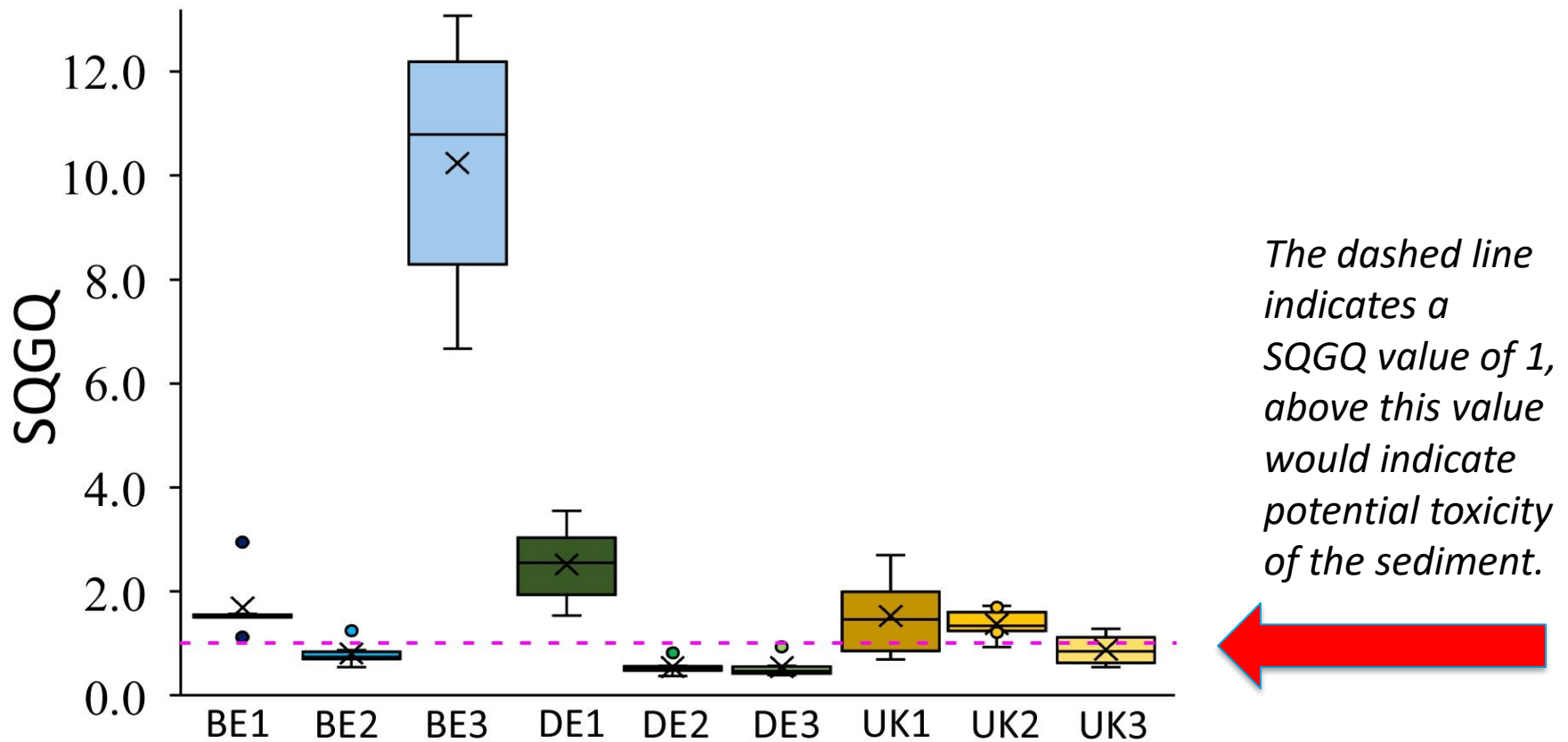


Figure 1: overview and the relation of the different chapters discussed in this report.

- Contaminated sediment risk assessment tools
- Sediment reuse and policy framework (x 2)
- Desk study on remediation techniques
- Emerging concern contaminants and reuse
- Workshop report on role of ecotoxicology testing in dredged material assessment frameworks

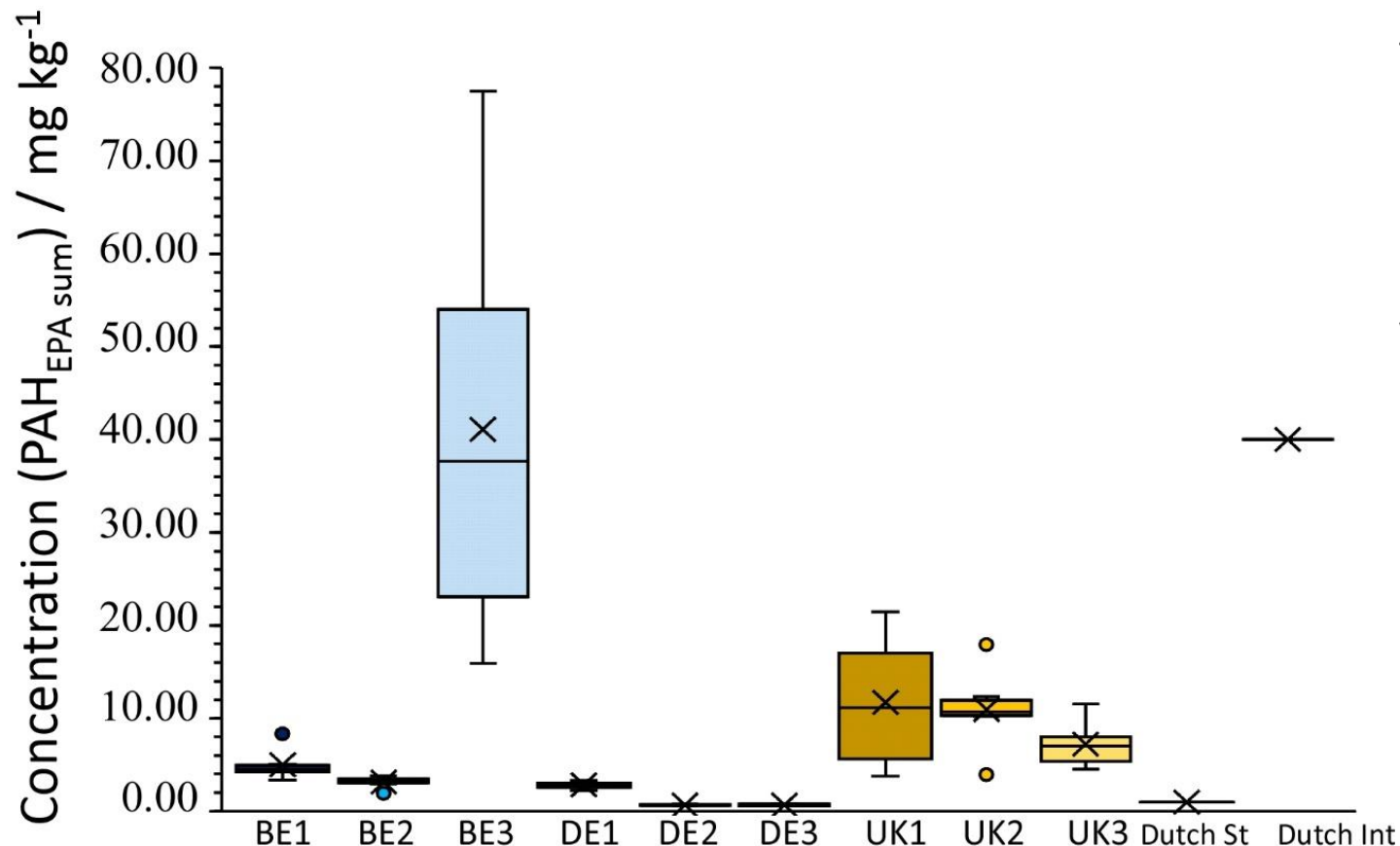
<https://northsearegion.eu/sullied-sediments/publications/>

Results of monitoring: overall toxicity measure using sediment quality guideline quotient (***averages, range and outliers***)



* centre lines indicate the median and x shows the mean, n= 6. **BE1 = Scheldt upstream** BE2, = Scheldt downstream **BE3 = Zenne**, **DE1 = Elbe, upstream**, DE2 = Elbe WWTP, DE3 = Elbe downstream, **UK1 = River Aire upstream**, **UK2 = River Aire downstream**, UK3 = Pocklington Canal.

Results of monitoring: PAHs

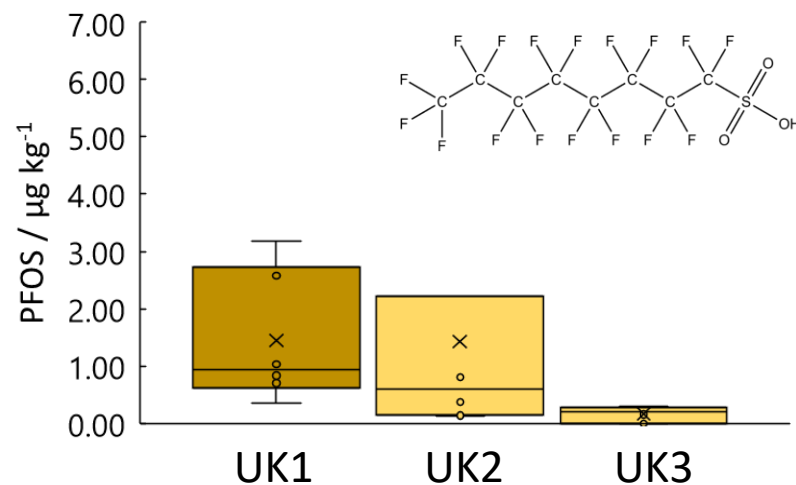
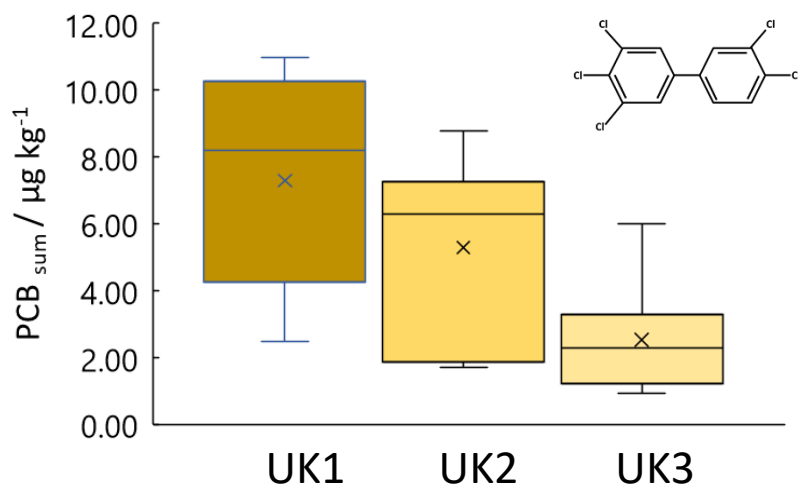
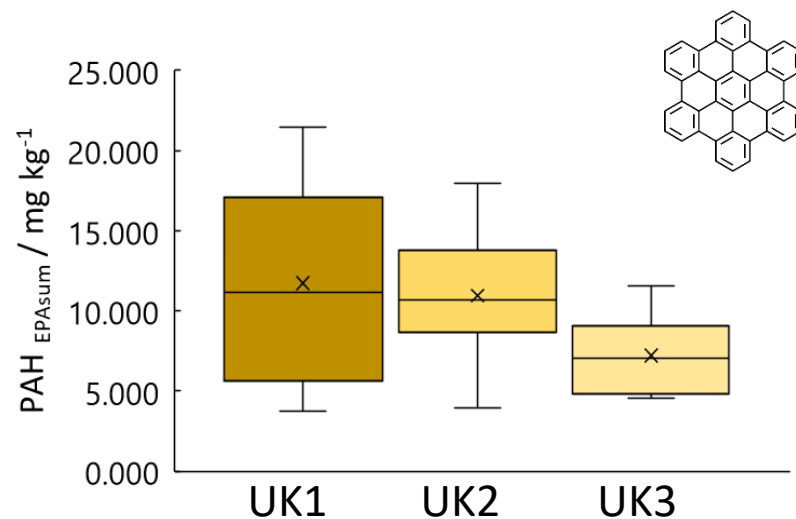
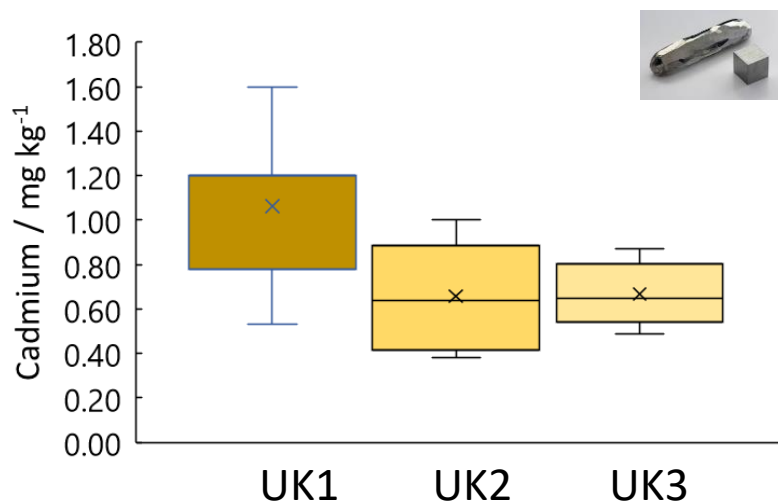


The standards on the right hand side show a screening value (Dutch St) and an Intervention value (Dutch Int).

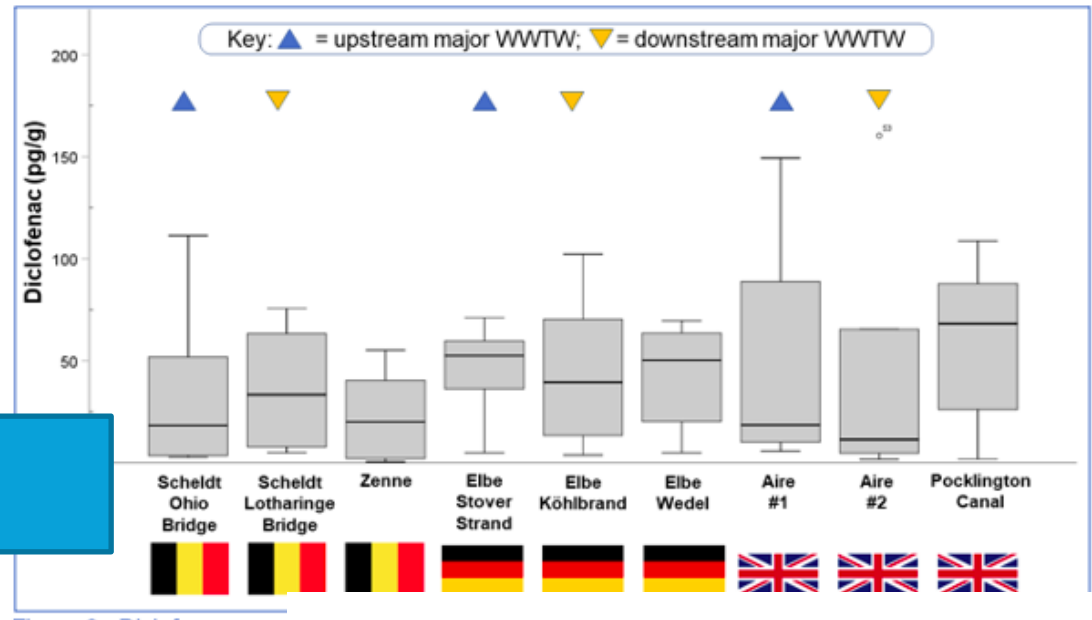
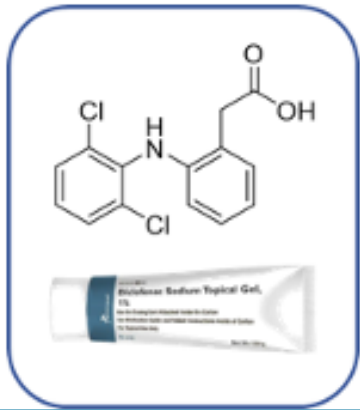


Ultimately transported to the North Sea?

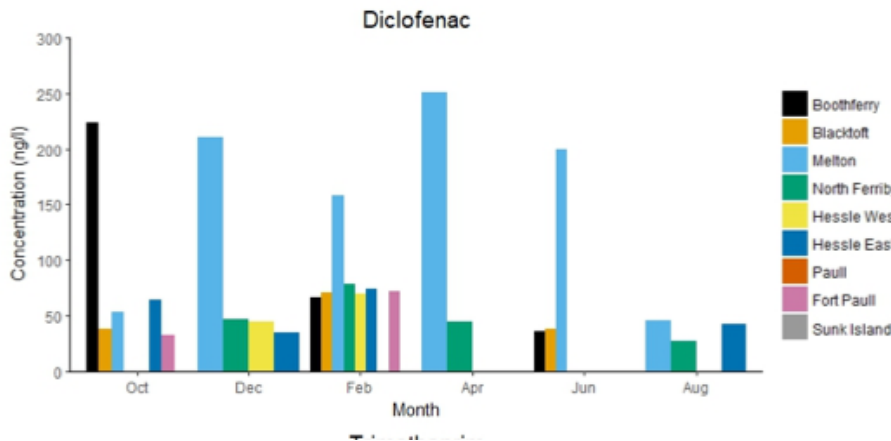
Cd, PCBs, sum PAHs and PFOS at the 3 UK/Humber catchment sites (will explain why we focus on these later...)



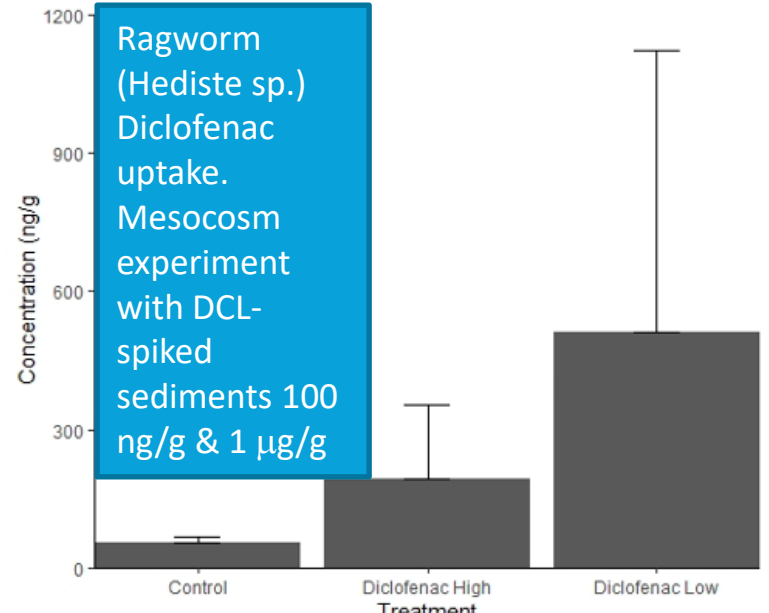
Diclofenac: from the river to the estuary and biological effects in estuarine organisms?



River Aire = approx 50-100 pg/g sediments



Humber = ng/L aqueous; (student project 833 – 2014 µg/g wet wt sediments!)



Ragworm (Hediste sp.) Diclofenac uptake. Mesocosm experiment with DCL-spiked sediments 100 ng/g & 1 µg/g

The North Sea: Dogger Bank sediments

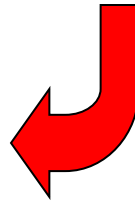
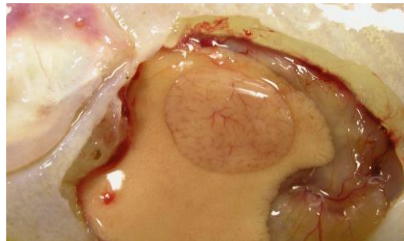


North Sea Dogger Bank: flatfish tumours



Tumour sample source & processing

Dab, *Limanda limanda*, liver samples collected during CEFAS Endeavour UK 2010 sampling dates



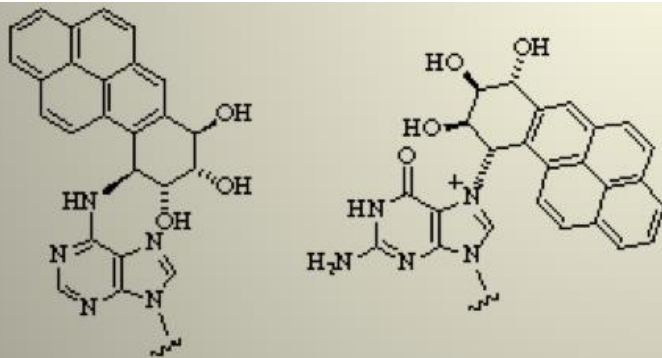
Tumour and normal tissue resected for mutational analysis of *Rb* gene

Histological confirmation of tumour type based of ICES BEQUALM adopted criteria at CEFAS Weymouth Fish Disease Laboratory

Tumour incidences & mechanistic 'cause and effect'

Table 1. Disease phenotype incidence (%) at sampling sites

Disease phenotype	Sites					
	W Dogger <i>n</i> =16	C Dogger <i>n</i> =11	N Dogger <i>n</i> =30	NE Dogger <i>n</i> =41	Rye Bay <i>n</i> =30	Newhaven <i>n</i> =37
'Normal'	56	55	37	66	63	81
Preneoplastic	31	36	43	24	37	19
Tumour	13	9	20	10	-	-



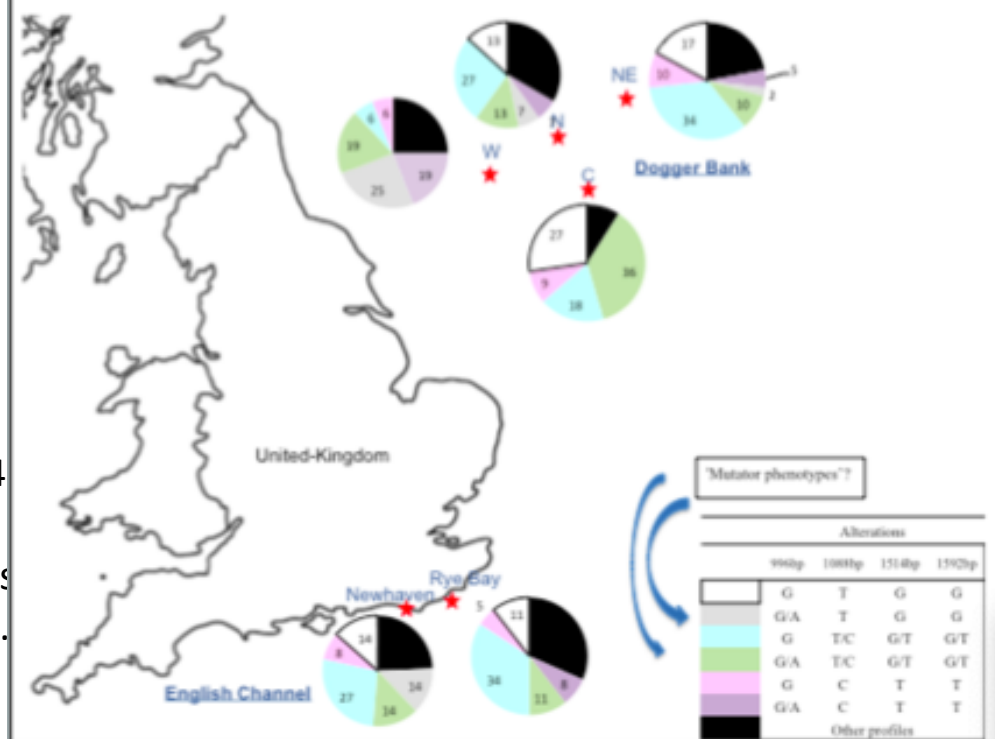
Hydrocarbon DNA adducts – mutations in key genes



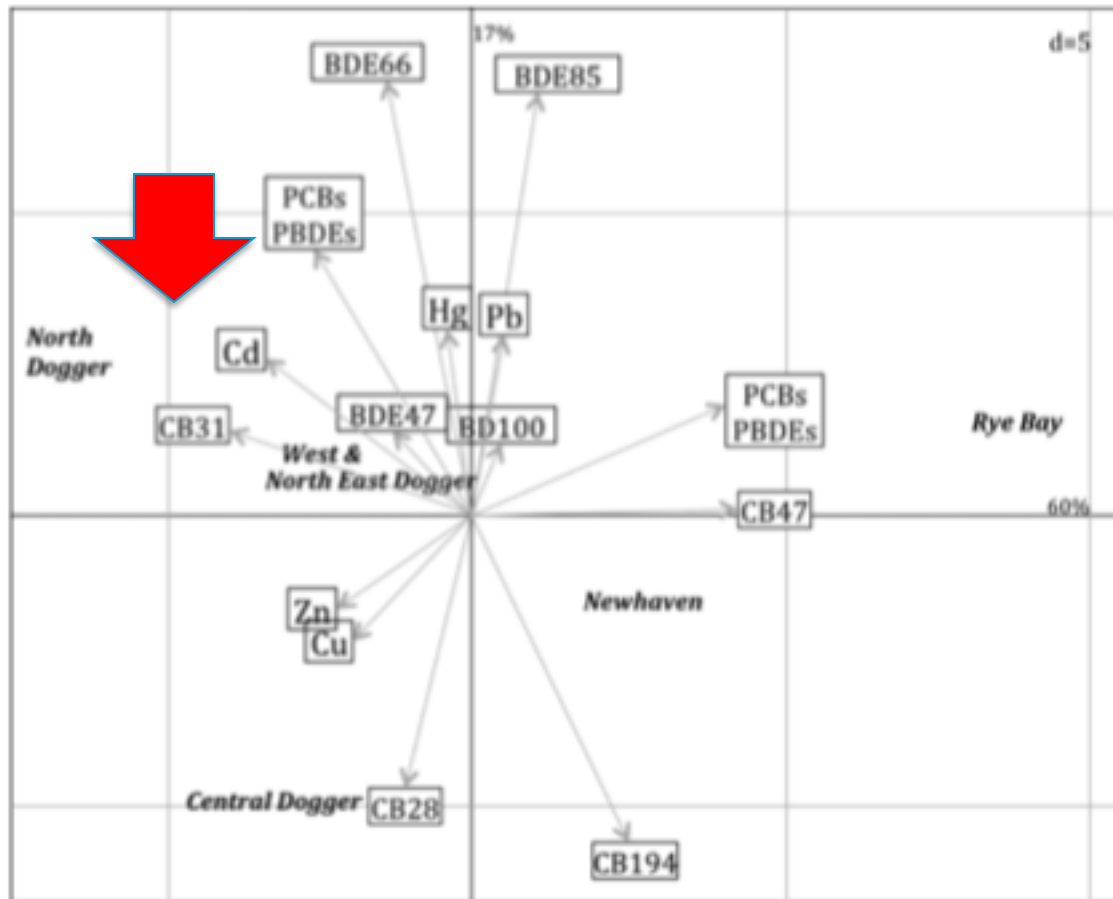
Lerebours et al., 2014

[dx.doi.org/10.1021/es02591p](https://doi.org/10.1021/es02591p) | Environ. Sci. Technol. 2014, 48, 10448–10455

Figure 2. The main *Rb* allele genetic profiles (%) found in each fish liver tissues collected at West Dogger (W, *n*=16) North Dogger (N, *n*=11), North East Dogger (NE, *n*=41), Central Dogger (C, *n*=11), Newhaven (*n*=37) and Rye Bay (*n*=38) (Lerebours et al., 2014).



Which contaminants are responsible for the tumours?



Lerebours et al., 2014

[dx.doi.org/10.1021/es502591p](https://doi.org/10.1021/es502591p) | Environ. Sci. Technol. 2014, 48, 10448–10455

High concentrations of Cd - $406 \pm 122 \mu\text{g/kg}$ liver tissue.

North East Dogger being weakly associated with metals, PBDEs, and PCB contamination

Figure 1. Principal component analysis showing the association between concentrations of chemicals in liver of fish and sampling site ($n = 30$ pools of 5 fish). Axis 1 represents 60% of variance. Axis 2 represents 17% of variance.

Summary

- Sediments are a sink for many different types of legacy and emerging contaminants
- Full characterisation of the various contaminant types shows spatial and seasonal variation (and is very costly to do)
- SulSed found no one/single ecotoxicity test that could predict the potential level of biological hazard
- OVAM reports for sediment reuse policy framework
- Chemical concentrations higher in estuarine sediments/biota? (2000s – biomarkers – cyp, MT etc, suggest exposure in biota)
- The sediments are transported to the North Sea and continue to accumulate until potential resuspension as a result of development in the area...
- Selected flatfish populations have high incidences of tumours

Thank you for your attention!

<https://northsearegion.eu/sullied-sediments/publications/>

Germany

Ecological Sediment and Soil Assessment (ECOSSA)
Elbe Habitat Foundation
German Federal Institute of Hydrology
Hamburg Ministry for the Environment and Energy
Hamburg Port Authority
Hamburg University of Applied Sciences
Institut Dr Nowak

Belgium

OVAM
University of Antwerp
VMM

The Netherlands

Foundation for Applied Water Research (STOWA)
Radboud University

Pan-European

Sediment European Network Steering Group
(SedNet)

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UK

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East Riding of Yorkshire Council
East and North Yorkshire Waterways Partnership
Environment Agency
Northumbrian Water
River Hull Board
Socotec UK
Thames Water
University of Hull (Project Lead)
University of Leeds
Yorkshire Water