Chemical Monitoring in the Context of Sediment Management in Estuaries

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Objectives of monitoring contaminants in sediments and suspended particulate matter

- Assessment of sediment quality
  - Trend assessment, i.a. for the no-deterioration objective of the Water Framework Directive and the EQS-Directive 2008/105/EC
  - Derivation of criteria for the assessment of dredged material quality
  - Selection of disposal sites
- Contribution of contaminants as tracers to a better understanding of the transport of estuarine cohesive fine-grained solids
Contaminants as tracers for transport of fine-grained sediments in estuaries

- Estimation of the ratio marine/fluvial cohesive solids
- Evaluation of the impact of natural or anthropogenic changes on contaminant concentrations
- Medium to long-term destination of relocated dredged material
- Identification of areas of sediment accumulation, i.e. in wadden areas
  - Retention of (contaminated) cohesive particulate matter
  - Potential secondary source for contaminants (remobilisation)
- Contribution to the estimation of input of particle-associated contaminants into the German Bight
  - Support for optimising dredged material and sediment management
Monitoring programme in German North Sea estuaries

- Investigations on and assessment of contaminants in sediments and suspended particulate matter
- Surface samples and sediment cores
- Spatial and temporal monitoring
- Analyses of grain size distribution, trace metals, organic contaminants, organotin compounds
- Assessment of contaminant concentrations in the fine-grained fraction <20 µm
 Investigations

- Grain-size analysis, TOC, N, P, S

- Trace metals:
  - cadmium, chromium, copper, mercury, nickel, lead, zinc, and arsenic

- Organic contaminants:
  - chloroenezenes, PCBs,
  - hexachlorcyclohexanes, DDT and metabolites,
  - PAHs, oil hydrocarbons, organo-tin compounds

- Contaminant concentrations are measured in or normalised on the fine-grained fraction <20 µm
Long-term monitoring sites in estuaries: surface sediments, SPM

- Bunthaus, Seemannshöft:
  - ARGE Elbe

Other stations: BfG

- High frequency of 4–12 samples /a
- Sediments from sampling sites with high sedimentation rates
- Sampling of SPM 2 – 4 weeks
a) Long-term monitoring in the river:

Contaminants in SPM and in recently deposited surface samples

- High frequency of 4 – 12 samples/a

- Sampling of SPM 2 – 4 weeks

- Sediments from sampling sites with high sedimentation rates
Survey in sedimentation areas: sediment cores

Depth profiles, surface layers
one-off studies or low frequency of sampling (several years)
Results and assessment: Long-term monitoring in estuaries

Surface sediments

Suspended particulate matter
Contaminant concentrations in estuaries

Elbe estuary

Weser estuary

Ems estuary

Tidal weir

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Temporal trend of Cd concentrations
Annual averages in spm in the Elbe estuary

Geesthacht (km 584)

Scheffe-Test:

* statistically significant lower concentrations than in the reference year (   )

Wedel (km 642)
Temporal trend of Cd concentrations
Annual averages in spm in the Elbe estuary

Geesthacht
Elbe-km 584
Temporal trend of Cd concentrations
Annual averages in spm in the Elbe estuary

![Graph showing temporal trend of Cd concentrations in the Elbe estuary with annual averages in spm.](image-url)
Spatial and temporal variations of contaminant concentrations (<20 µm) in the Elbe estuary
Spatial and temporal variations of contaminant concentrations (<20 µm) in the Elbe estuary

- High discharge: 15 – 30 % marine
- Low discharge: 60 – 80 % marine
- High discharge: 60 – 70 % marine
- Low discharge: 75 – 85 % marine

North Sea level
Räumliche und zeitliche Änderung der Schadstoffgehalte im Elbeästuar

![Cd-Konzentration in mg/kg und Discharge Neu Darchau in m³/s](image)

- Geesthacht km 584
- Brunsbüttel km 696
- Cuxhaven km 628
- Seemannshöft km 629
- Wedel km 642
- Bützfleth km 657,5

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Variationen der Zinkgehalte in Schwebstoffen und Sedimenten (<20 µm) in der Tideems

Zn-Konzentrationen in mg/kg

Abfluss Versen in m³/s

Nordsee-Niveau: 150 - 200
nQ/hQ: 70-90 % marin
nQ/hQ: 85-95 % marin

Herbrum OW
Bollingerfäh
Herbrum UW
Terborg
Knock

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Percentage of marine particulate matter in German North Sea estuaries

- Ems
- Elbe ab 2000
- Till tidal limit
- till Elbe-km 608
- till Weser-km 20-25
- Weser

- from tidal limit
- from Elbe-km 625
- from Weser-km 50

- >80 % marine
- <20 % marine

Length of estuaries in %

Anteil mariner Feststoffe in %
Transport times of fine-grained solids in the Elbe estuary

Transport time of freshwater solids after Qmax:
till Wedel: 3 – 7 weeks
till Brunsb.: 7 – 12 weeks

Maximal percentage of fines:
Wedel: 6 – 16 weeks after Qmin
Bruns.: 20 – 24 weeks after Qmin

Flood August 2002

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Transport times of particulate matter in estuaries

- Transport of freshwater solids towards the North Sea after $Q_{\text{max}}$:
  - Elbe: till Wedel: 3 - 7 weeks
  - till Brunsbüttel: 8 - 12 weeks
  - Weser: till Farge: 2 - 4 weeks

  $\Rightarrow$ partially input to the German Bight

- Return of solids of marine origin at low river discharge ($Q$)
  - Elbe: Wedel: till the next increase of $Q$ (till 8 – 16 weeks after $Q_{\text{min}}$)
    Brunsbüttel: still during next increase of $Q$ (till 20 – 24 Wochen after $Q_{\text{min}}$

  - Weser: Farge: till 2 - 7 weeks after $Q_{\text{min}}$
b) Investigations in flat zones (wadden areas, branches)

**Sediment cores:**
- Depth profiles, surface layers
- one-off studies or low frequency of sampling (several years)
Results and assessment: Investigations in flat zones

box corer

vibrocorer
Elbe: Cd (mg/kg) 1994-1998

Legende
- Watten
- Vorland
- Kantenstörungen

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Elbe: Cd (mg/kg) (2008)
Contaminant loads in sedimentation areas of the Elbe estuary (1994-1998)

Schnackenburg: average annual load (2004 – 2006), ARGE Elbe
Temporal development of Cd concentrations in spm at Wedel, Elbe-km 642

Cd in suspended particulate matter (<20µm)
Station Wedel, Elbe-km 642

1996/97
3,4 mg/kg

2006/07
2,1 mg/kg
Cd (mg/kg) in sediment cores 1997 and 2008 - Fährmannsander Watt (Elbe)
Cd (mg/kg) in sediment cores 1997 and 2008

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Cd (mg/kg) in sediment cores 1998 and 2008
Weser estuary: Cd concentrations in sediment cores (1999)
Weser estuary: Zn concentrations in sediment cores (1999)
Summary

- Results of long-term contaminant analyses
  - confirm the upstream transport of fine-grained solids as predicted by model calculations,
  - Indicate a larger extent of upstream transport in the river Elbe after the year 2000
  - how a different extent of upstream transport for the estuaries of Elbe, Weser and Ems
  - give an indication on transport time of fine-grained solids

- Results from depth profiles in wadden areas
  - Contaminated layers in tidal flats and branches of Elbe and Weser have a thickness of up to 3 m.
  - Contaminant quantities accumulated in sediments of tidal flats of the Elbe estuary amount to ca the 20-fold of loads entering the estuary annually.
  - Re-investigation of contaminants in tidal flats may give an indication of deposition rates.
Conclusions and perspective

➢ Results of chemical monitoring should be considered
  • In the planning of construction works, capital dredging, and sediment management measures for navigation,
  • In the planning of measures for improving waterbodies in the implementation of the EC-Water Framework Directive
  • In the estimation of particle-bound contaminant input to the North Sea

➢ Future planning
  • Use of trace metal data for verifying numerical models for transport of fine-grained sediments
  • Re-investigation of wadden areas and branches
  • Investigations in further flat zones and floodplains
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