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Field measurements and lab investigations to determine soil exchange characteristics for sediments from the Weser estuary

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For An Improved Understanding Of Estuarine Sediment Transport – FAUST

The project FAUST (see also Poster from Intercoh2019) addresses challenges in modelling sediment exchange at the water / soil interface by extracting natural soil samples from the Weser estuary, collecting quasi-in-situ experimental data and performing lab experiments to analyze factors influencing the erodibility of "freshly deposited" cohesive sediments. This poster focusses on the erosion behavior.

1. Motivation

- Deposition and accumulation of fine sediments even in the fairway is an increasing challenge for authorities of waterways
- Improved prediction of location and amounts of deposited sediments is required
- Therefore estuary-specific and extended parameterization of the sediments soil exchange characteristics (e.g. erosion, deposition) is required for modelling sediment transport in estuaries

2. Concept

- Collect natural samples at sedimentation sites in the fairway
- Examine quasi-in-situ behavior (erosion, density, corn size distribution)
- Use natural material to produce lab samples and perform sensitivity analysis of erodibility to parameters like settling/consolidation time, initial density, salt content, …
- Determine critical shear stress and erosion rate (e.g. at key points of erosion (modes))
- Use lab and field data to adapt existing erosion models and propose an updated/improved version specifically for the Weser estuary

3. Site & Sampling

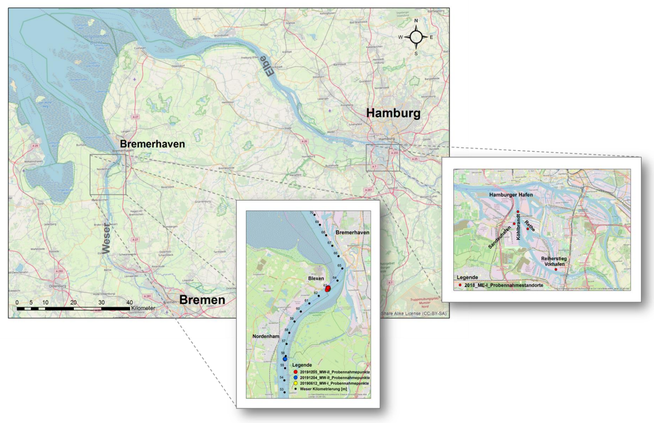


Fig 1.: Investigated sites of project FAUST. The focus of this poster is the Weser estuary with sites in Nordenham and Blexer Bogen.

Sediment cores from the fairway (depth~8-14m) of the Weser estuary within the ETM have been collected. Samples from two sites were taken in field trips during slack water:

- **Blexer Bogen (BB),** Weser-km65
- **Nordenham (NH),** Weser-km57

4. Experimental Methodology

An adapted **gust microcosm** (gems) approach is used to perform erosion experiments quasi-in-situ and ex-situ (lab). Eroded sediments are kept in the system to simulate natural conditions, hence SSC rises during experiments when erosion occurs, see fig 2.

Erodibility and critical shear stress for erosion are investigated by **stepwise increase of applied shear stress** in the erosion chamber, see fig 3. SSC and erosion rates are determined by measurements of turbidity (1/s) and density (1/5min) during experiments.

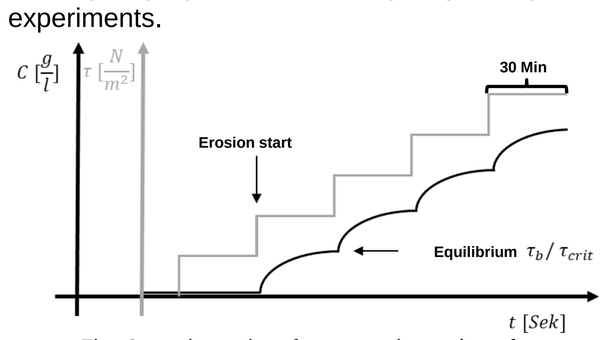
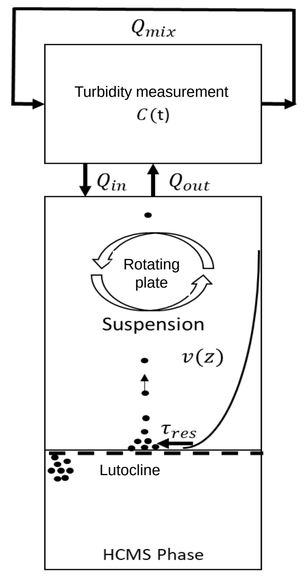


Fig 3.: schematic of expected results of an erosion experiment

Fig 2.: schematic of the adapted gust erosion microcosm system



6. Erosion characteristics

The **experiments of quasi-in-situ sediments** (see Fig. 5 + 6) reveal site specific erosion behavior between the analyzed samples:

- BB samples show a steady increase in SSC after surpassing τ_b = 0,05-0,075 N/m².
- Erosion rate stays mostly below $\epsilon = 0.2 * 10^{-3} \frac{kg}{m^2 s}$, no mode-change is observed up to 0.25 N/m².
- NH samples show floc erosion at similar shear stress but exhibit clear change of erosion mode already at τ_b = 0,1 N/m².
- Erosion rate of the NH sample then jumps to ~ $\epsilon = 0.8 * 10^{-3} \frac{kg}{m^2 s}$

Lab generated samples using the collected natural sediments exhibit similar behavior with same critical shear for floc erosion. The shift in the erosion mode is found to be dependent on the initial density of homogenized samples and

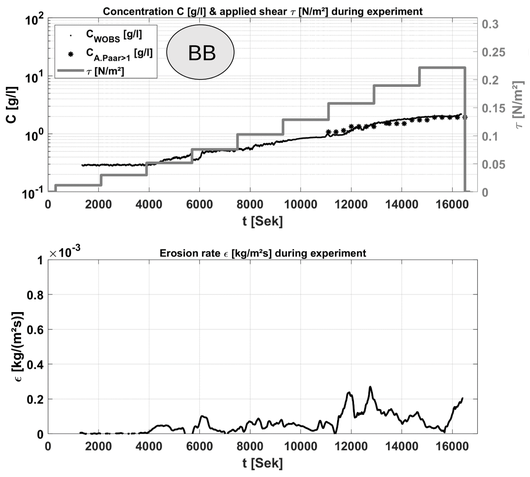


Fig 5.: SSC (top) and erosion rates (bottom) during experiments with natural, quasi-in-situ sediments from Blexer Bogen.

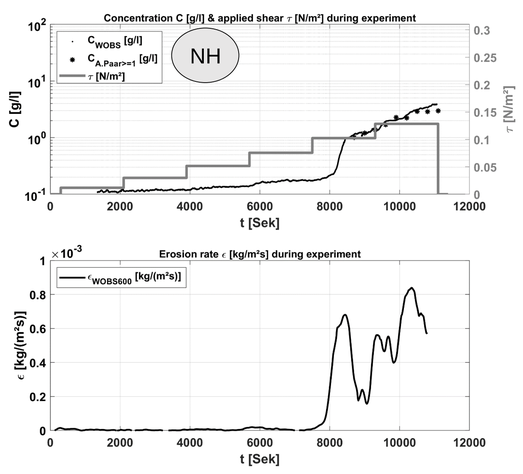


Fig 6.: SSC (top) and erosion rates (bottom) during experiments with natural, quasi-in-situ sediments from Nordenham

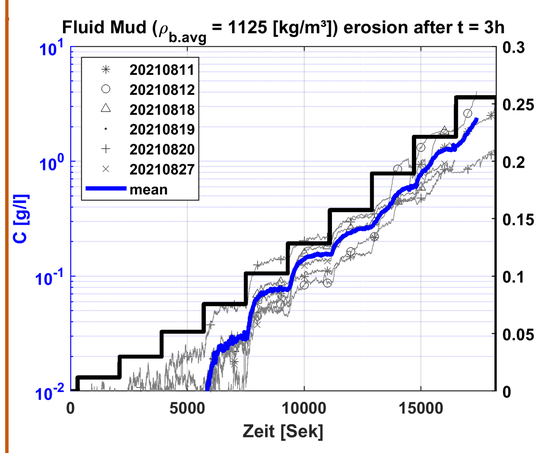


Fig 7.: Repeated experiments of sediments from Nordenham with 3h settling time

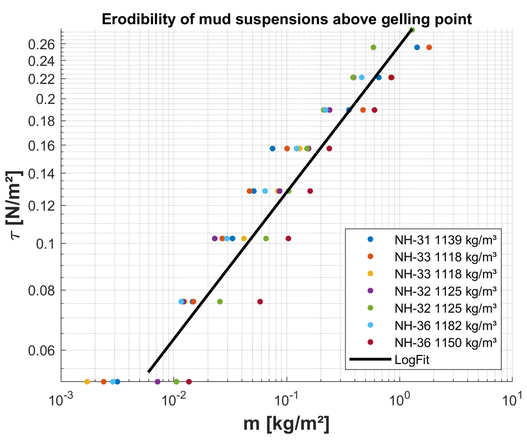


Fig 8.: Experiments with initial C_i > 1100 kg/m³ (appr. gelling conc.) and settling time of 3h.

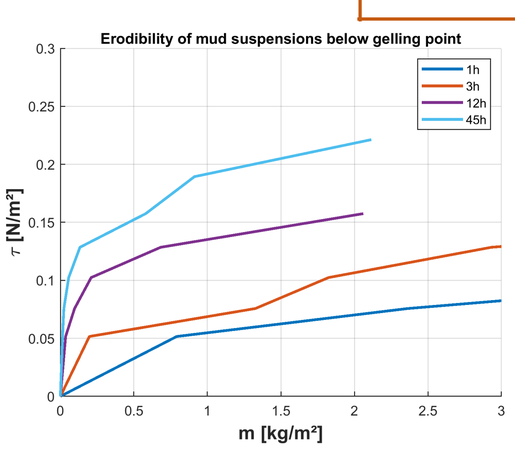


Fig 9.: Experiments with homogeneous initial conc. of 1060 kg/m³ and varied settling time from 1h to 45h.

Reproducibility. Replicate lab experiments show good reproducibility of results with a Pearson's correlation coefficient of R~0.95. An example is shown for experiments with homogeneous sediment samples and initial bulk densities of approx. $\rho_b = 1125 \frac{kg}{m^3}$ and a settling time of 3h, see Fig. 7.

Erodibility. Measured turbidity and densities in experiments with mud suspensions slightly above gelling conc. show a linear relation between shear stress τ and eroded mass m (prop. to erosion rate ε) on a log-log-scale, see Fig. 8. Since no direct relation between erodibility and initial density is expected for the considered range of conc., Fig. 8 shows the bandwidth.

Time dependency. The erodibility of mud deposits decreases with settling time. For deposits below gelling point we found that the shear stress increases by a factor of approx. 4 within 1h and 45h settling time, see Fig. 9. Further analysis of experimental data will provide information to set up a functional relation between shear and erosion depending on settling time and initial concentration

5. Sample characteristics

Classical sediment analysis reveales the grain size distribution. The **clayey silts** of BB and NH consist of about 60 % silt. Differences of ~5% are found in both the clay and the sand fraction, see table 1. Segregation occurs: the sand fraction increases with depth while TOC and clay proportion decrease accordingly.

	Blexer Bogen	Nordenham
Clay	19	25
Silt	59	60
Sand	22	15
TOC	11	13

Fig 4.: Grain distribution in samples of natural sediments from Weser estuary

Density profiles have been measured by layer-wise separation of sediment-cores. Measurements are taken using **AntonPaar DMA35** and, for redundancy, a suspension balance.

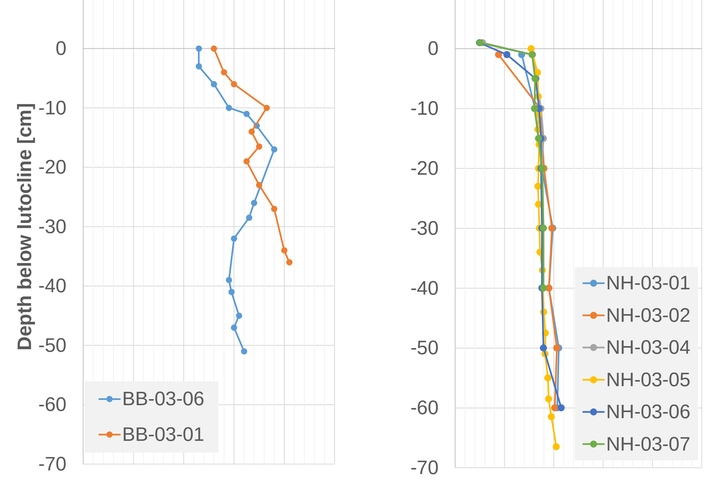


Fig 4.: Density profiles of sediment cores exctracted at Blexer Bogen (BB, left) and Nordenham (NH) in the Weser estuary

Samples from BB show increasing density over depth, densities from NH samples are almost constant over depth (approx. 1140 kg/m³). NH samples consist of fluid mud in the whole core while samples from BB exhibit a lutocline at a water-sediment interface and a consolidating sediment body beneath.

Take Home Messages

Project FAUST investigates sediment exchange at the sediment / water interface:

1. With our experimental facility reproducible exp. are possible.
2. Quasi-in-situ & ex-situ experiments show floc erosion at $\tau_c = 0.05 \frac{N}{m^2}$, Floc erosion rate is about $\epsilon_f = 10^{-5} \frac{kg}{m^2 s}$
3. Mass erosion occurs site and time specific (Fig. 5 + 6)
4. Density profiles (Fig. 4) of natural samples show a consolidating bed at Blexer Bogen and a Fluid Mud Layer in Nordenham
5. Beneath gelling concentration settling time dominates the erosion behavior (Fig. 9)

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