Mobilisation, Transport and Reactivity of Contaminated Sediments in a High Capacity Estuarine Flume

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Background

Estuarine sediments can contain a legacy of contaminant metals discharged by industrial activity, often over decades. The recovery of estuarine sediments from metal contamination is highly dependent on factors such as variable fluvial input, tidal oscillation, wave action and chemical reactivity. Coupled hydrodynamic-geochemical models aiming to predict the behavior of metal contaminants in estuaries (e.g. Wu, Falconer & Lin, 2005) involve the simultaneous integration of algorithms describing particle transport and metal behaviour. The study aims to improve understanding of processes affecting sediment transport and chemical reactivity by up-scaling experiments (by approximately four orders of magnitude) to a more environmentally-relevant scale. The test bed was a high capacity flume, 17 m in length, which was modified to accommodate a model estuary (Fig. 1). The process data from the experiments will be used to refine existing numerical models of estuarine contaminant transport.

Method

The model estuary was filled with fine sand (mean grain diameter 150 µm) to a depth of 10 cm. A plug of Mersey sediment (Fig. 2a) tagged with rhodium (Rh) and nickel (Ni) was inserted at 4.5 m (Figs. 1; 2b). The Rh acted as a tracer of sediment transport and the Ni as an exchangeable metal (Couceiro *et al*, 2007). The flume water depth was 30 cm and it was run for 8 hours with a water velocity of 0.5 m s^{-1}. Runs were made in tap water and at a salinity of 3. Water samples were taken axially and simultaneously with vertical velocity profiles and bed depth measurements at 0.5, 4 and 8 h. Water samples were collected from the near bed (NB) and at 40% of the water column height (0.4H) to give total and plug suspended particulate matter (SPM) concentrations and partition coefficients (K_d) for Ni. After each run the water was drained off (Fig. 2c) and sediment cores taken. The concentrations of Rh and Ni in the water, SPM and sediments were determined by inductively coupled plasma-mass spectrometry.

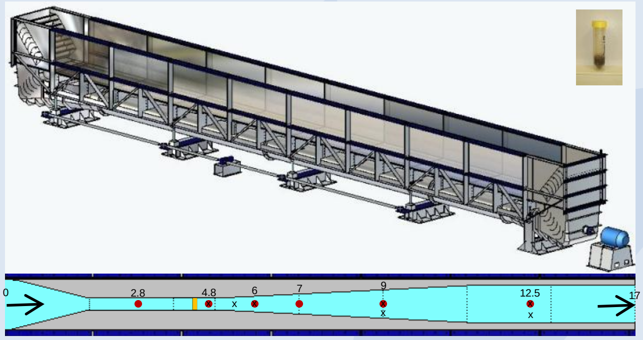

Figure 1: Schematic of the flume (for comparison the insert shows the size of test tube used for previous metal partitioning experiments, not to scale). Below the schematic is a plan view of the model estuary showing water direction (arrows), plug position (orange rectangle) and sampling stations (red circles = water column; x = sediment; numbers = position in meters along flume).

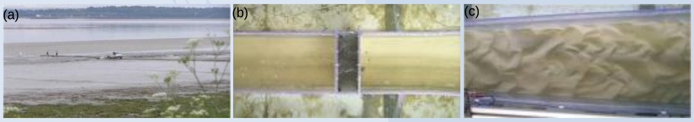

Figure 2: (a) the Mersey Estuary sediment collection site; (b) a metal-doped plug of Mersey sediment in the flume; (c) overview of ripple patterns along the flume bed after an experiment.

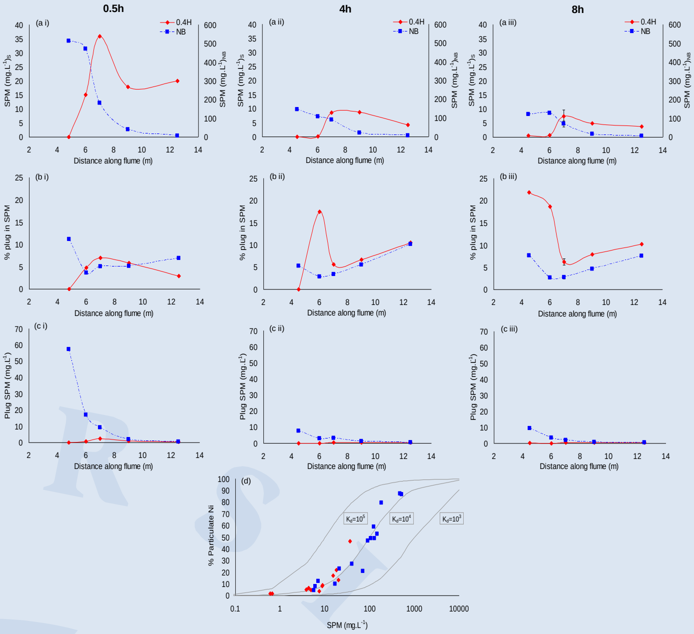

Figure 3: Results for a flume run salinity=3. Values for (a) total SPM concentrations, (b) % Rh tagged sediment in SPM and (c) concentrations of plug in SPM at times 0.5 h (i) 4 h (ii) and 8 h (iii). (d) % particulate Ni versus total SPM concentrations, the solid lines are K_d values for Ni.

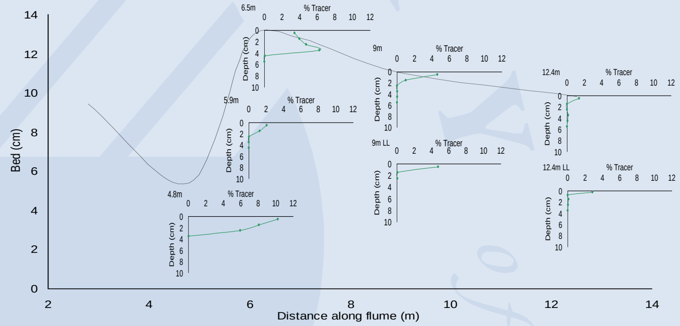

Figure 4: Mean bed height after 8 h (dashed line); The sediment profiles show the % of Rh tracer as a function of depth; LL = core taken laterally.

Results and Discussion

Concentrations of total SPM were consistently greater at the near bed while the concentrations of tagged sediment remobilised from the plug , in the SPM, was usually greater in the upper water column (Figs. 3 a, b, c). In the near bed the plug-derived SPM is diluted by clean sediments migrating from upstream of the plug.

The K_d for Ni was fairly constant over time, with total SPM concentration and with distance along the flume, at approximately 10,000 L.kg^{-1} (Fig. 3d).

The main region of erosion in the model estuary occurred in the vicinity of the plug (~4.5 m) followed by deposition at about 6.5 m (Fig. 4). The sediment cores showed tagged sediment (directly comparable with % tracer) was generally concentrated in the surface of the core nearest the plug (4.8 m). However, significant vertical mixing of the tagged sediment, to a depth of 5 cm, was found at the greatest area of deposition, 6.5 m. The majority of the tagged sediment migrated as bed load ripples downstream.

This data is to be coupled with the hydrodynamic data collected simultaneously and used to improve the current contaminant transport model for the Mersey Estuary.

References

Couceiro F., Turner A. & Millward G.E. (2007) *Mar. Chem.* 107: 308-318.
Wu, Y., Falconer R. & Lin B. (2005) *Estuar. Coast. Shelf Sci.* 64: 699-709.

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