Transport and Reactivity of Contaminated Estuarine Sediments: Coupling hydrodynamics and Geochemistry in a High Capacity 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). This presentation focuses on the tracking of contaminated sediment movement and its deposition.

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) was inserted at 4.5 m (Figs. 1 & 2b) and the Rh acted as a tracer of sediment transport (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). After each run the water was drained off (Fig. 2c) and sediment cores taken. The concentrations of Rh, SPM and sediments were determined by inductively coupled plasma-mass spectrometry.

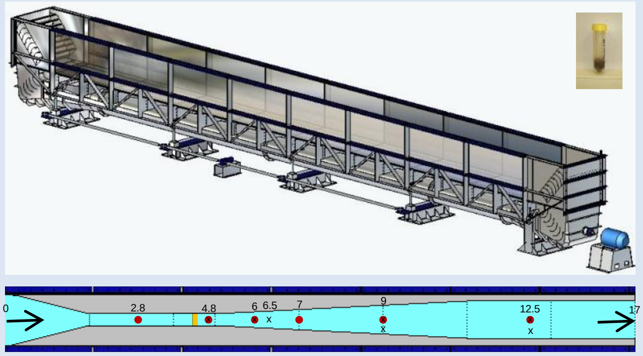

Figure 1: Schematic of the flume (for comparison the insert shows the size of test tube used for previous metal partitioning experiments, not to scale). Below the schematic is a plan view of the model estuary showing water direction (arrows), plug position (yellow rectangle) and sampling stations (red 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.

Results and Discussion

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. 3). 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).

Total sediment deposition/erosion and plug deposition were linearly modelled (Fig. 4) using bed height and core data. High rates of total sediment deposition were observed throughout the first half an hour at 6, 6.5 and 9 m (Fig. 4a),

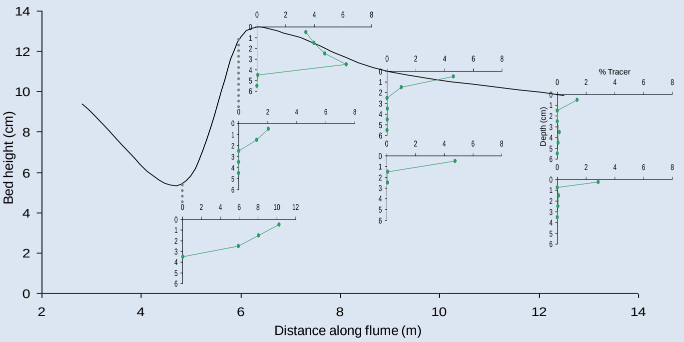

Figure 3: Mean bed height after 8 h (black line); Sediment profiles show the % of Rh tracer as a function of depth. Replicates were taken at each site and are shown here for 9 & 12.5 m.

however, high rates of plug material deposition only occur in the first half an hour at 6.5 and 9 m (Fig. 4b). The occurrence of an initial pulse of sediment deposition and high percentage plug material at these locations was considered to be related to the source availability of erodable sediment.

From the models it is possible to reconstruct tracer deposition in the collected cores and correct for the sampling artefact in the deepest sediment horizon where dilution otherwise occurs (Figs. 5 a-c). This provides the ability to determine deposition of sediment from a contaminated source in a horizon of any size and is a vital step in gaining a better understanding of horizontal and vertical contaminant distributions in estuarine environments.

This data is to be coupled with the hydrodynamic data collected simultaneously and used to improve a current contaminant transport model for macrotidal estuaries, in particular the Mersey Estuary.

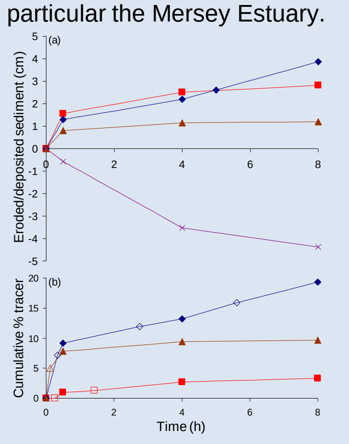

Figure 4: Modelled (a) sediment erosion and deposition and (b) % tracer accumulation in deposited sediments, over time at 4.8 m (purple crosses), 6 m (red squares), 6.5 m (blue diamonds), 9 m (brown triangles). Filled symbols = measured total sediment deposition; open symbols = % tracer measured in sediment cores.

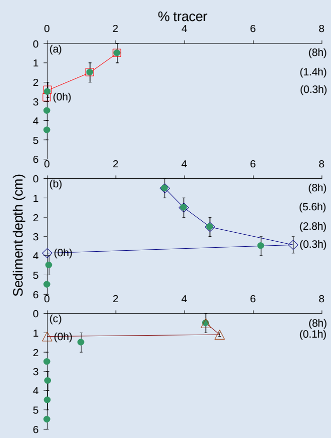

Figure 5: Measured values and reconstructions of % tracer deposition in sediment horizons at (a) 6 m, (b) 6.5 m & (c) 9 m. Filled symbols = measured values; open symbols = reconstructed values. Bars indicate sediment horizon depth & bracketed numbers show cumulative time taken for horizon deposition.

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.