Geophysical Research Abstracts,
Vol. 11, EGU2009-13000, 2009
EGU General Assembly 2009

Macro and micro scale interactions between cohesive sediment tracers and natural estuarine mud.

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Improving the understanding of dispersion patterns of the fine sediment fraction (< 63 micron) and associated contaminants is fundamental to the sustainable management of estuarine and marine environments. In order to develop sediment transport models and predict sediment dispersion, accurate and reliable field techniques for the measurement of sediment transport are required. Although this is relatively simple for the sand sized fraction, measuring transport pathways for the < 63 micron sediment fraction has been more problematic.

There has been considerable effort within the scientific community to develop a tracer for the fine/cohesive sediment fraction. This has included the use of synthetic tracer particles and the labelling of natural clays (e.g. Mahler et al. 1998, Yin et al. 1999, Krezoski 1985; Spencer et al. 2007). Synthetic tracers have included polymer-based fluorescent tracers, with the same size, density and surface charge characteristics as the flocculated clay and silt fraction.

A fundamental assumption of tracer technology is that the tracer has the same physical properties as the natural sediment it is intended to mimic. For sand-sized material matching particle size, shape and density has been easy to achieve. However, the < 63 micron sediment fraction is cohesive and in order to satisfy this assumption cohesive sediment tracers must be incorporated into and transported via floc aggregates (Black et al. 2006).

This work focuses on the use of a labelled natural clay; a Ho-montmorillonite (see Spencer et al. 2007). The aim of the research was to determine whether this tracer interacted with and was transported via floc aggregates in saline environments and would therefore be a suitable cohesive sediment tracer in estuaries. Our objectives were to examine the physical characteristics, internal structure and settling dynamics of flocculated tracer and to determine the extent to which the tracer interacted with natural estuarine muds under laboratory conditions at both macro- and micro-scales.

A series of "jar tests" were conducted to assess how the tracer behaved in a turbulent water when combined with natural estuarine mud. A comprehensive series of floc characteristics tests were conducted using tracer to natural mud ratios (T:M) of 100:0, 75:25, 50:50, 25:75 and 0:100. The floc size and settling velocity measurements were obtained using the LabSFLOC - Laboratory Spectral Flocculation Characteristics – instrument. Other parameters including floc porosity, floc dry mass, and the mass settling flux were also calculated using algorithms originally developed by Fennessy et al. (1997). Floc internal micro-structure (matrix) at a sub-micron level (1-2 nm) and elemental floc composition were observed using TEM (transmission electron microscopy) and EDS (energy dispersive spectroscopy). The flocs observed comprised tracer to natural mud ratios (T:M) of 100:0, 50:50 and 0:100 enabling examination of micro-scale interactions between tracer and natural mud.

The LabSFLOC video assessments demonstrated that pure natural muds, tracer and flocs comprising both tracer and natural mud exhibited similar macrofloc properties in terms of settling velocity, individual floc size, density and porosity.

Electron micrographs of the natural mud indicated a typical estuarine floc with a highly porous, complex matrix of structurally independent organic and inorganic constituents. Aggregation was controlled by both bio- and electrochemical flocculation. In comparison, the tracer formed dense, less porous, inorganic flocs where aggregation was controlled by electrochemical flocculation. Flocs comprising both natural mud and tracer were also observed and TEM shows individual microflocs of both dense, platy material typical of the tracer and microflocs comprising biological and inorganic particles typical of those found in the natural estuarine mud. EDS spectra of these mixed flocs were also collected and the tracer can be identified by its characteristic Ho, Al and Si peaks. There was some inclusion of tracer into the natural mud microflocs although this was not significant. Therefore, at the microscale (< 20 micron) there has been little interaction between natural mud and the tracer and microflocs predominantly comprise either tracer or natural mud.

Therefore, the tracer flocculates and has similar floc properties, in particular settling velocity, to natural estuarine mud. This indicates that under these laboratory conditions the material will travel as a floc aggregate and therefore satisfy an important assumption of tracer technology. However, its incorporation into natural floc aggregates is clearly limited and this may inform the nature of tracer deployment in the environment. In addition, when we examined flocs comprising both tracer and natural mud they were seen to comprise discrete microflocs of very different densities and structure. Sediment transport models assume a self similar fractal relationship for floc growth i.e. macroflocs are geometrically similar to microflocs. Therefore, data generated from tracer studies and used to parameterise cohesive sediment transport models may have serious limitations.