1. Introduction

Background

The settling velocity of suspended particulate matter (SPM) is a crucial parameter for predicting SPM transport and morphological development in coastal environments, such as estuaries. While settling velocities of non-cohesive particles (for instance sand) can be determined from their size and density, this becomes more difficult for fine cohesive particles which tend to change in size and density through ongoing dynamic flocculation processes.

The importance of flocculation in estuarine environments has been realized recently. Bio-flocs have been recognized as an important process in estuarine sedimentation. Bio-flocs are aggregates of microorganisms, microalgae, or macroalgae, which are held together by exopolymeric substances (EPS). They can be formed by a variety of mechanisms, including those induced by physical processes (e.g., turbulence, shear, and boundary layer development), biological processes (e.g., bacterial activity), or chemical processes (e.g., coagulation of colloidal particles).

Bio-flocs are dynamic aggregates that can change size and shape in response to environmental conditions. They can act as a suspension in the water column, a bed sediment, or a bedload material. Bio-flocs can influence sediment transport, deposition, and erosion, and can affect the biogeochemical cycling of elements.

Previous studies have characterized bio-floculation as an ephemeral process governed by SPM concentration, turbulence, organic matter and EPS suggesting the settling velocity of suspended particulate matter (SPM) and various hydrodynamic parameters, such as shear rate, flocculation rate, and concentration of colloidal and algal components, which makes them important agents for biogeochemical cycling and settling and transport of SPM.

Aim

To investigate the impact of EPS induced flocculation on estuarine SPM transport by (1) conducting laboratory experiments measuring EPS induced flocculation and settling dynamics and (2) testing the impact of altered settling velocities on SPM transport in a 1-D transport model.

2. Methodology

Laboratory experiment

The laboratory experiment takes place in a rotational flume where particle size distributions can be measured online, at different concentrations of SPM, EPS, and at various shear rates in a laboratory flume. In a laboratory setting, particle size analyser (LISST-200X) is used to measure the settling velocities of the SPM.

Two types of experiments were conducted: (a) an equilibrium flocculation size experiment and (b) a tidal flocculation experiment. (a) The equilibrium flocculation size experiment was performed with a constant shear rate (50 s⁻¹) and an initial concentration of 300 µg l⁻¹. (b) During the tidal flocculation experiment an idealized tidal cycle based on field measurements in the Scheldt was simulated by interchanging periods of high and low shear rates representing increased or reducing turbulence, which was also previously found in the field (Li & Li 2010).

To evaluate the impact of EPS on SPM transport we calculated settling velocities using the approach of Wilshire et al. (2011) and Li et al. (2011), showing that EPS is able to double the settling velocities which during our experiments was concentration independent (Fig. 2).

Model

We applied a new 1D tidally resolved hydraulic model to the 150km long Scheldt estuary coupled with a simple SPM model using the newly developed riverine sediments (SPM) transport and morphological development in coastal environments, such as estuaries. While settling velocities of non-cohesive particles (for instance sand) can be determined from their size and density, this becomes more difficult for fine cohesive particles which tend to change in size and density through ongoing dynamic flocculation processes.

3. Main findings

Our observations confirm earlier observations of shear induced flocculation, i.e., periods of high shear leads to flocculation (higher d50) whereas periods of low shear lead to flocculation (higher d50). The comparison of the idealized tidal and equilibrium flocculation size experiment revealed that during the idealized tidal cycle flocculation did not reach the shear and concentrations dependent equilibrium flocculation size (Fig. 2a,b). The addition of EPS leads to increased equilibrium flocculation size and increased flocculation rate (Fig. 2a,b).

Our experiment further revealed that higher SPM concentrations induce smaller equilibrium flocculation sizes, which became even more pronounced after EPS was added (Fig. 2a,b). During our experiments we could further observe a significant effect on flocculation and floc size related to increasing or reducing turbulence, which was also previously found in the field (Li & Li 2010).

To evaluate the impact of EPS on SPM transport we calculated settling velocities using the approach of Wilshire et al. (2011) and Li et al. (2011), showing that EPS is able to double the settling velocities which during our experiments was concentration independent (Fig. 2).

4. Conclusions

- Higher SPM concentrations lead to smaller equilibrium flocculation sizes verified the concept of “idealized” tidal cycle experiment (Fig. 2).
- In a tidal setting flocculation does not reach their equilibrium flocculation size.
- EPS increases the equilibrium flocculation size and the flocculation rate.
- EPS has a major impact on settling velocities (addition of 1.5 g m⁻³ resulted in a doubling of settling velocities).
- Estuarine SPM concentrations are highly influenced by the presence of EPS which alters settling velocities and is a potentially important factor to improve predictions in spatial-temporal SPM transport.

References