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Title: Particle Transport and Deposit Morphology at the Sediment/Water Interface

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Objectives/Hypothesis

The study focused on deposits formed under two conditions of two extremes of fluid flow; quiescent settling and deposition from turbulent flow. This work was to answer specific questions including:

- What does the interface look like?
- What are the transport mechanisms that determine rate of deposition and the structure of the interface?
- What are the kinetics of formation of various portions of the interface?

One premise of the work was that the morphology of the interface is intimately related to, and in some cases predictable from the characteristics of the suspended particles and the local fluid flow. This study yields critical information needed to calculate mass transport across the sediment/water "boundary", to interpret data obtained from sediment cores, to determine sampling protocols for sediments, and to assess sediment remediation schemes.

Approach

This work combined models for particle transport and transformation to describe the formation of the sediment/water interface under conditions in which particle deposition rather than resuspension dominate the overall flux of particles to and from sediment. The work was compose of four interrelated tasks:

- particle deposition under different conditions of fluid flow experiments performed using laboratory suspensions of particles of various sizes and surface chemistries;
- similar experiments were conducted using sediment material collected from Galveston Bay or another source;
- experimental results were compared with numerical simulations of the deposition process; and
- to better define the chemistry of the colloidal and fineparticle phases that exist in Galveston Bay.

Results

Computer simulations were performed to predict the rate of fineparticle deposition and the structure of the deposit. The simulations involved fineparticle transport algorithms and morphology algorithms. Theoretical and simulated predictions of deposition rate and the morphology of simulated sediments were compared to the rate of deposition and morphology of laboratory sediments. Laboratory sediments were created in both zero flow and turbulent crossflow regimes.

Influence of Turbulence on Cohesive Fineparticle Deposition Rate and Morphology

Deposit density measurements are highly variable. It is unclear whether the variability is inherent in the system, or simply an artifact of the chemical freezing and dryin process. Deposits formed under widely differing flow regimes do not display any significant difference in structure, as measured by fractal dimension. The influence of hydrodynamic diffusion and reorganization do not appear to significantly alter deposit structure from that of which would form in their absence. Both simulations and experiments suggest no difference in D with u*. Simulating reorganization by considering an artificially low probability of particles sticking upon collision more accurately predicts experimentally observed fractal dimensions. Qualitative features predicted by simulation were not observed. Again it is unclear whether the features existed prior to chemical freezing and drying of samples. The experimentally observed flux was far lower than that predicted by the McCave model. This model appears to underestimate the decrease in flux observed at higher particle concentrations due to viscous sublayer instability.

Colloidal Transport of Elements from an Urban Watershed during a Storm Event

Quantification of the colloidal material by ICP analysis and its morphological and chemical characterization by means of electron microscopy in surface waters during a storm event show that the chemical nature of the colloidal material varies during the storm event. There is a dominance of colloidal carbon at the beginning of the storm followed by a dominance of colloidal silica at the period of maximum water discharge. The different sources of material and the reasons for which colloidal materials enter the urban waterway at different times still are unknown. A watershed is a complex system where different water sources are connected to each other (streams, soil moisture and ground water). Different hypothesis can be suggested for temporal variability of colliodal materials. First, colloidal materials carried to the point of sampling may come from different locations upstream, each one with a different colloidal chemical signature. Second, the sources of colloidal material may be similar, but released at different times during the storm process. Thus the chemical signature seen at the point of sampling reflects that of the different loadings over time from similar sources. Finally, the colloidal material at any “one” location may actually represent a blend of material from surface runoff, soil moisture, and groundwater. Future work on smaller watersheds will aid in resolving this issue.

Deposit Morphology and Head Loss Development in Porous Media

Experimental observations of nondispersed latex particles filtered through a bed of spherical glass beads indicated that flow rate plays an important role in head loss development by influencing the morphology of the deposits as well as the deposit distribution along the depth of the bed. The distributions of the deposits along the depth of porous media was more uniform at higher velocities. Deposits formed at low filtration (Darcy) velocities produced higher specific head loss (head loss per unit particle mass deposited) compared to the deposits formed at higher velocities. The fractal dimensions of the deposits increased with increase in velocity at either end of the range of flow rate (0.002-0.4 cm/s) investigated. This is consistent with the low specific head losses observed at higher superficial velocities and with the theory of increasing fractal dimension as particle transport becomes more ballistic. The low fractal dimensions observed in the intermediate velocities (0.04 to approximately 0.15 cm/s) appear to be due to the formation of compact columnar structures. This conclusion was supported by Monte-Carlo simulations of colloidal deposition from 2-D stagnation flow which were performed to approximate particle deposition at the top of filter grains.

Hydrodynamics of Fractal Aggregates with Radially Varying Permeability
Hydrodynamic properties of fractal aggregates with radially varying permeability are usefully approximated by a constant porosity aggregates with appropriately averaged characteristics. A simple model coupling the Happel's cell model with fractal geometry is used to estimate the permeability of the aggregate as a function of radial distance. Resistance to the fluid flow through the aggregate is observed to increase with increasing fractal dimension of the aggregate. The fluid collection efficiency of the aggregate decreases with increasing fractal dimension and is closely related to the drag coefficient for the aggregate. For a given fractal dimension, the drag coefficient increases with aggregate size, while the fluid collection efficiency decreases. The drag on a porous aggregate is well approximated as that of an aggregate with a constant volume-averaged permeability.

The predicted ratio of the hydrodynamic radius of the aggregate to its radius of gyration compared well with an experimentally observed value reported in the literature, given the assumptions in the theoretical work and uncertainties in the experimental work.

Supplemental Keywords
Deposition, fluid flow, and suspended particles

Publications and Presentations
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