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Conference Paper · October 2013

DOI: 10.13140/2.1.1808.3845

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INTRODUCTION

In headwater catchments, fine sediment transport is a main issue with regard to monitoring erosion, pollutant fluxes, and reservoir siltation. In these environments, suspended sediment concentrations exhibit high temporal variations during runoff events and commonly exceed 10 g/l. The settling velocity of suspended sediment is a key variable to understand and model sediment transport. For such concentrated events, hindered settling and flocculation processes increase the difficulty to model sediment transport. Currently, no automated method for the measurement of settling velocity and propensity to flocculate within high concentration sediment environments exists. Methods used to measure individual particle settling velocity (e.g., LISST, video) are limited to low concentrations (<1g.l). They can be adapted to higher concentration after dilution in particle-free water, however, measured settling velocities may not be representative of the initial sample as hindered and flocculation effects are eliminated or reduced.

In order to measure quasi in situ sediments settling velocity spectrum and propensity to flocculate in high concentrated environment, we assessed a processing method based on light transmission measurement within a quiescent settling column condition.

METHODS

Tests were conducted in a 20 cm high settling column, equipped with 16 regularly spaced transmission sensors along the vertical. Settling measurements were done immediately after sampling, in order to prevent any evolution of the sediment structure. In the column, the absorbance was measured as a function of time and depth, providing absorbance maps as presented in figure 1. Following recent laboratory investigations, it was considered that each iso absorbance line corresponded to a class of particles. The range of slopes of those lines defined the settling velocity spectrum of the sample. Iso absorbance lines are straight in case of non cohesive sediments (figure 1a), and curved if flocculation occurs (figure 1b). For each line, a flocculation index is defined as the relative variation between surface and bottom slopes (fitted lines in figure 1).

The tested materials were chosen to be representative of an extensive range of suspensions commonly found in upstream environments: sand, badland, clay soils and organic soils (all representative of freshly eroded materials) and reservoir sediment deposits, tropical mining area river sediment and suspended sediments from alpine rivers (all representative of suspended/resuspended sediments). Tests were conducted after thirty minutes mixing within a 100 l grid-stirred cell. Samples were pumped in the diffusive turbulence flow at a specific depth corresponding to a rate of turbulence of about 7 s^{-1}.

The settling measurements deduced from absorbances were compared with standard methods of video analysis of floc size and settling, sediment weighting scale, Andreasen pipette, laser particles sizing, and suspended concentration analysis.

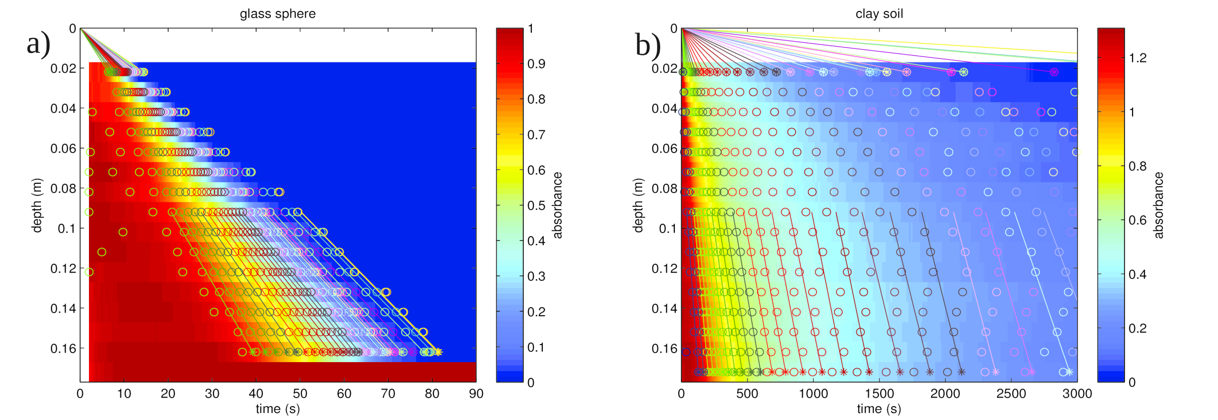

Figure 1: color-plot of measured absorbance evolution as a function of time and depth: a) glass sphere; b) clay soil suspension.

RESULTS

Preliminary tests were conducted with spherical non cohesive particles (glass spheres, figure 1a). The measured settling velocities were consistent with the Stokes' law and the measurement done with LISST-ST at low levels of concentration. At volumetric concentration above 2%, we measured a clear reduction of settling velocity with concentration due to hindered effect. The Flocculation index was zero as expected for non cohesive sediment.

For natural sediments a large spectrum of settling velocities (10^{-2} to 10^{-6} $m.s^{-1}$) were observed. The flocculation index ranged from 0 to 1 for quick settling particles (<1 $mm.s^{-1}$; generally sand or large silts) to 20 for the slow settling particles (clays) (Figure 1b).

Samples prepared within the grid-stirred cell led to concentration around $10g.l^{-1}$ with strongly hindered settling regimes, generally associated with front and relatively fast en-masse settling velocity. Badland material exhibited the strongest front associated with a settling velocity of 0.2 $mm.s^{-1}$. Riverine and reservoir sediments presented more smoothed fronts associated with settling velocities from 0.5 to 3 $mm.s^{-1}$. The organic soil presented a front comparable with riverine sediments, while clay soil did not lead to front formation.

The comparison of the absorbance data with the pipette and weighting scale settling flux allowed us to assess the advantages and inherent bias existing while calculating settling flux from conservation equations applied to optical measurements. Some specific recommendations have to be considered as optical techniques can underestimate the initial settling velocity and lead to erroneous settling flux calculations

CONCLUSIONS

The method discussed allowed for the measurement of settling velocity spectrum and propensity to flocculate for high concentrated solutions (>1g.l). It seems is robust and valid for a large range of sediments types and settlings regimes. The proposed flocculation index allows for the comparison of cohesive properties for different materials, and for the assessment of how settling velocities of high concentration river suspensions may be modified as they begin to settle on flood plains or within reservoirs. Of limitation, the absolute values of the index can not be directly compared with other flocculation indexes as it is sensitive to the calculated parameters.

The large range of settling velocities distributions observed for the natural materials shows that current modeling efforts may miss valuable information when using only one variable to represent settling velocity. This is particularly relevant when investigating cohesive sediment associated contaminant transport issues where slow settling and flocculating particles may have an important role. The proposed measurement method may allow for an improved understanding of settling flux within high sediment concentration rivers.