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MEASUREMENT OF SIZE DISTRIBUTION OF SEDIMENT FLOCS

by

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MANAGEMENT PERSPECTIVE

Size distribution of fine sediments is one of the most significant parameters governing the sediment-contaminant interactions and the transport process of contaminated sediments in river flows. Measurement of size distribution of sediments in natural state is essential for validating models of flocculation and of transport of sediments and sediment-associated contaminants. At present, there is no reliable method to measure floc size. In this paper, an instrument and a methodology are described for an in-situ and non-intrusive measurement of size distribution of sediment flocs.

PERSPECTIVE-GESTION

La distribution granulométrique des sédiments fins est l'un des paramètres les plus importants en ce qui a trait aux interactions entre sédiments et contaminants de même qu'en ce qui concerne le transport des sédiments contaminés dans les cours d'eau. L'établissement de la distribution granulométrique des sédiments à l'état naturel est essentiel pour évaluer les modèles de floculation et de transport des sédiments et des contaminants combinés aux sédiments. À ce jour, il n'existe pas de méthode fiable pour mesurer la taille des flocons. Cet article décrit un instrument et présente un méthodologie qui permettent d'établir *in situ* et sans intervenir dans le milieu la distribution granulométrique des flocons de sédiments.

RÉSUMÉ

La distribution granulométrique des flocons de sédiments formés au cours de dépôt de sédiments très fins dans une colonne d'eau stagnante a été déterminée à l'aide d'un analyseur de dimensions de particules au laser fabriqué par Malvern Instruments Inc. Cet appareil a permis d'établir *in situ*, et sans intervenir dans le milieu, la distribution granulométrique des flocons de sédiments et a permis de faire l'économie de l'étape de prélèvement d'échantillons qui, en détruisant probablement la structure des flocons, modifie la distribution granulométrique.

Measurement of Size Distribution of Sediment Flocs

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Abstract

Size distribution of sediment flocs formed during the settling of fine-grained sediment in a still water column was measured using a Laser Particle Size Analyzer manufactured by Malvern Instruments Inc. This device facilitated the non-intrusive and in-situ measurement of size distribution of sediment flocs and eliminated the need for sample-collection which is likely to cause breakage of floc-structure and consequently a distortion in the size distribution.

Introduction

Data on size distribution of fine sediments is an important prerequisite for modelling the transport of contaminants that are associated with fine sediments, especially in the silt clay size range. Processes controlling the interaction of sediment and contaminant such as adsorption and desorption are known to depend on particle size (Bailey et al. (1970), Karickhoff et al. (1978)) and so are the processes governing the transport of fine sediments (Partheniades (1962), Mehta et al. (1975, 1979), Lick (1982), Krone (1962, 1972, 1978). Unlike cohesionless coarse-grained sediments, fine sediments undergo flocculation as they are transported by the flow; hence, the size distribution of fine sediment aggregates becomes a variable which depends on a large number of controlling parameters such as the turbulence characteristics of the flow field, the physico-chemical properties of sediment-water mixture, and the biological controls such as organic content and bacteria (Kranck (1980, 1986a, 1986b), Van Leussen (1988)). With the present state of knowledge on flocculation, it is not possible

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to completely predict the evolution of floc size distributions theoretically and the mathematical models of fine sediment and contaminant transport have to rely on direct measurements for inputs of size distribution of fine sediments.

Direct measurement of floc size distributions is also not easy. Most of the instruments that are available in the market for measuring size distribution of fine sediments (such as Coulter Counter, Sedigraph, etc.) require sampling of sediment-water mixture and sample preparation which are bound to alter the floc-structure and consequently the size distributions.

Instruments that are based on principles of optics offer the most promise for direct measurement of sediment flocs because of the non-intrusive nature of the optical beams. Recently, Bale et al. (1987) have modified the Malvern particle size analyzer, and used it for in-situ measurement of floc-size distribution in Tamar Estuary near Plymouth, England. Bale et al. revealed that the distributions measured using the Malvern Particle Size Analyzer both in-situ, and by collecting samples, are significantly different, and the difference can be attributed to the breakage of floc-structure during the collection of samples.

The Malvern Particle Size Analyzer has also been used by a number of investigators for the measurement of Particle size distributions in a batch mode in which sediment samples are collected and analyzed in a sample cell (see Lick (1989), McCave et al. (1986)). The instrument has also been compared with other instruments such as 1) Small Settling tube, 2) 2) Sedigraph, 3) Hydrophotometer, and 4) Electrozone Particle Counter, and was found to yield comparable distributions for sorted silt standards (J.K. Singer et al. (1988). Therefore, the Malvern Particle Size Analyser has, among the currently available Particle Sizers, the greatest potential for reliable and in-situ measurements of sediment flocs in the laboratory and in the field. Another instrument that has the capability of measuring sediment flocs in-situ is the underwater camera system manufactured by Benthos Ltd. This instrument requires image analysis techniques for calculating size distribution data from the photographs of particle-suspension. The drawback of the current version of the instrument is that it cannot resolve floc sizes less than 100 microns (Kranck, 1989).

In the present study, the feasibility of using the Malvern Particle Size Analyzer for in-situ measurements of size distribution of sediment flocs in laboratory experimental set-ups is investigated by using the Malvern instrument to measure the size distribution of sediment flocs as they were forming during the settling of fine sediment in still water column.

<u>Description of Malvern Particle Size Analyzer</u>

Malvern Particle Size Analyzer operates on the principle of Fraunhofer Diffraction. Full details of the instrument are given by B.B. Weiner in H.B. Barth (1984). Here, a brief account of the same is given for the sake of completeness.

The Malvern Particle Size Analyzer consists of a 2mW He-Ne laser as a light source. The beam from the laser is expanded to 9 mm and collimated. As the beam passes through a medium consisting of particles, part of the light energy is diffracted and the remaining part is transmitted. Both the diffracted and transmitted light energy are then focussed by a lens onto a detector placed in the focal plane of the lens. The detector consists of a series of photodiodes mounted in semi-circular rings and measures the light energy distribution over a range of solid angles. Using the Fraunhofer Diffraction Theory for the intensity of diffraction pattern for a spherical particle, a relationship between the light energy falling on a particular ring of photodiodes and the size distribution of particles by weight is derived. Using this relationship and by measuring the light energy falling on different rings of photodiodes, the particle size distribution is computed by a trial and error procedure. According to this procedure, an initial size distribution for the material is assumed and the light energy values for the different rings are computed. These values are then compared with the measured light energy values. The procedure is repeated until the sum of squared differences between the computed and measured values becomes minimum.

Each measurement in the Malvern Particle Size Analyser consists of taking a number of of light energy readings of different rings with no particles in the beam path to establish an average background reading for all the rings. The background reading accounts for the ambient light conditions and the imperfections in the optical alignment that might be caused by the passage of the laser beam through the side walls (transparent) of experimental set up. Care should be taken to ensure that the background reading remains steady during the course of the entire experiment. Similar readings are taken with particles in the beam path and the difference is calculated to get the light energy readings due to particles alone. Knowing the light energy distribution on all the rings, the particle size distribution is computed according to the procedure outlined earlier.

Measurement of Size Distribution of Settling Flocs

a) Experimental Set Up: The settling column used in the present study is a plexiglass parallelepiped measuring 15 cm x 15 cm x 24.5 cm (inside dimensions). The column was placed in the path of the laser beam of the Malvern Particle Size Analyzer as shown schematically in Fig. 1. The level of the laser beam is 17 cm from the top edge. In the present set up the laser beam is guided through two hollow cylindrical inserts with glass ends mounted on either side of the settling column to adjust the path length (length of the beam exposed to the sediment-water mixture) and achieve the optimum number of particles to produce a statistically significant signal representing all the different size fractions. In the Malvern Particle Size Analyzer, the range of optimum number of particles corresponds to a light transmittance of 70 to 80%. Care was taken to prevent the deflection of plexiglass walls of the settling column as it was found to affect the optical alignment of the instrument and alter the background readings. To achieve the required rigidity, an aluminum casing was built around the settling column below the laser level and metal braces were installed near the top.

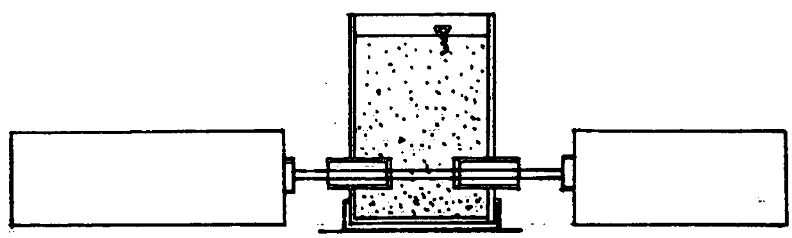

Figure 1. Schematic View of Experimental Set-up

b) Experimental Procedure: To begin the experiment, a 3% salt solution was filtered through a 0.45 micron millipore filter and was poured into the settling column to a level of 15 cm above the level of the laser beam leaving a 2 cm freeboard at the top. The path length of the laser beam was adjusted to 1 cm. After the subsidence of the initial turbulence, the Malvern Particle Size Analyzer was aligned and the measurement of background light energy distribution was taken. A sediment sample, made up of marine clay collected from the Miramichi River at Sillikers, in New Brunswick, Canada, was mixed in 50 cc of distilled water to give a concentration of 20,000 ppm. This sample was sonicated for one minute to breakup the flocs and 20 cc of this sample was pipetted out and added to the settling column. The sample was mixed uniformly in the settling column using a metal rod to achieve a uniform initial concentration of 200 ppm.

After the subsidence of turbulence generated by the mixing, measurements of size distribution of sediment particles settling past the laser beam were carried out at every 30 minute interval.

Results and Discussion

The size distributions measured at five different times are selected and plotted as histograms in Fig. 2 to show the growth of the flocs. It is interesting to note from this figure that only a certain size range of particles appears to be more active in the flocculation process. In the present case, the particles in the range between 8 and 20 micros have completely disappeared producing flocs in the range of 20 to 200 microns. Particles below 8 microns ppear to be more stable and to flocculate slowly. The rate of flocculation is fast during the first three hours of settling and the distribution reaches a more or less steady state within this period. More experiments are required to generalize the above observations and to draw firm conclusions.

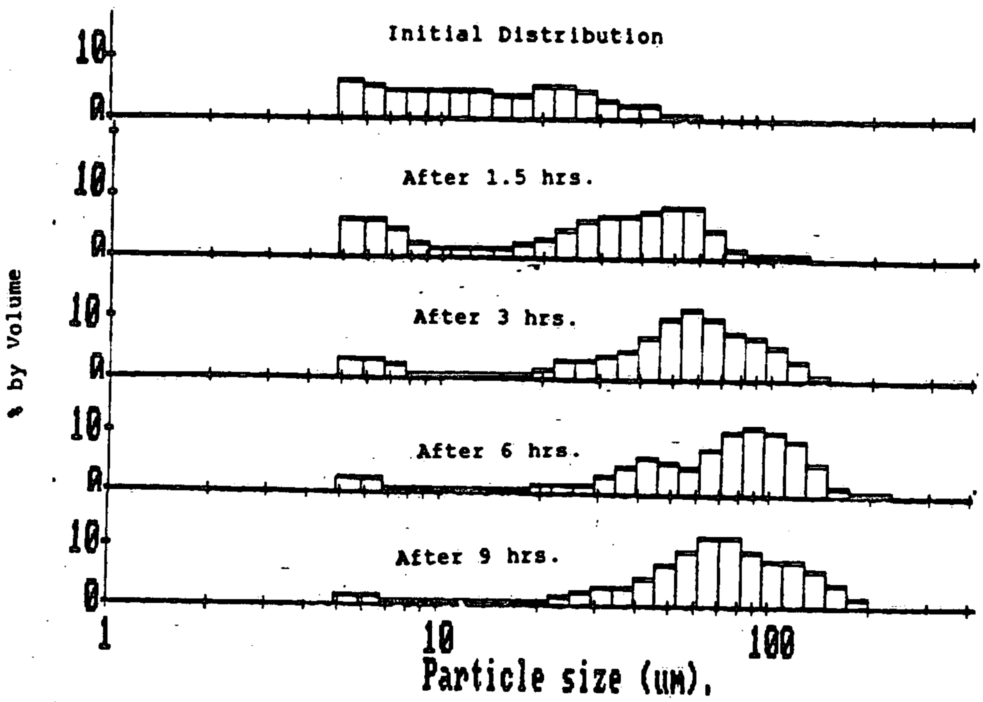

Figure 2. Size distribution of settling sediments (Floc Settling) Initial concentration 200 ppm

To check the validity of the results from Malvern Particle Size Analyzer, an experiment was performed using the same sediment settled in a 2% Calgon solution $(NaPO_3)_6$. In this experiment, the sediment settled as individual particles rather than as flocs. The size distribution for such particles is available in the literature (see Kranck (1980)). A series of distributions measured under this condition is shown in Fig. 3. The distributions indicate that under this condition, the fine sediment do not flocculate and the distributions change towards lower size fractions because of the settlement of the larger size fractions. This trend is in agreement with the measurements performed by Kranck (1980) using the Coulter Counter.

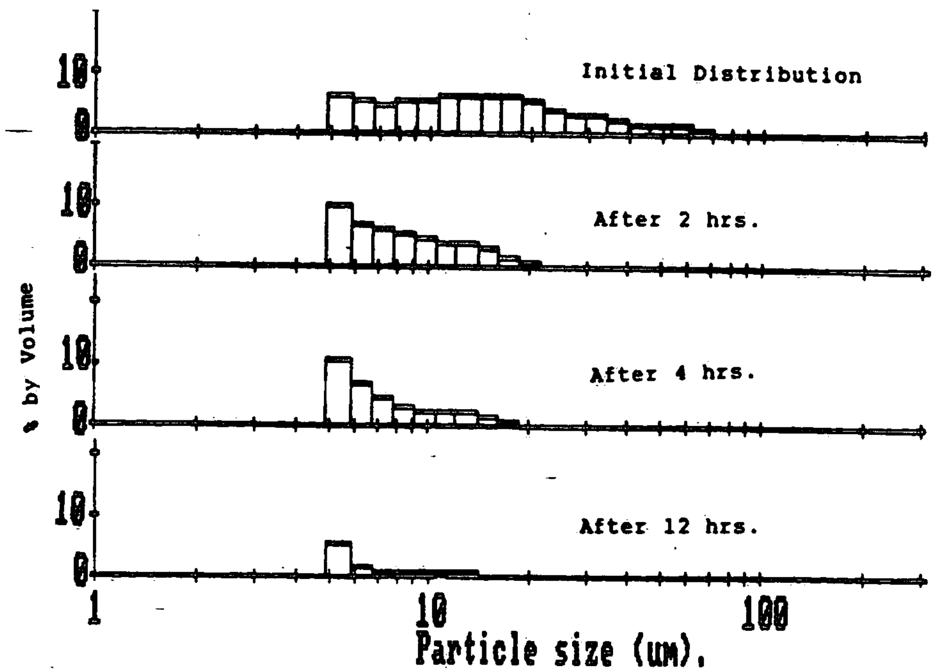

Figure 3. Size distribution of settling sediments (Single grain settling) Initial concentration 200 ppm

Conclusions

From this study and the operation of the instrument, the following conclusions can be drawn:

The Malvern Particle Size Analyzer can be used in laboratory experimental set-ups to measure the size distribution of sediment flocs as they develop, provided the following two operational requirements are met:

1) Provision is made to adjust the path length of the laser beam and achieve the optimum number of sediment particles in the measuring zone.

2) Care is taken to ensure that the background measurement of light energy falling on the sensing diodes does not change during the course of the

experiment. Ambient lighting conditions and the mechanical deflections of flume or container walls were found to cause changes in the background light energy measurements.

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Appendix

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