RRB 90-25

This manuscript has been submitted to the

1990 ASCE National Hydraulic Engineering Conference

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EFFECT OF TEMPERATURE ON SETTLING OF FIRE SEDIMENTS

by

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March 1990
NWRI Contribution #90-64

ABSTRACT

Results from settling experiments in an annular flume using kaolinite clay in distilled water are presented. Identical experiments carried out at different temperatures show that as temperature decreases, a larger proportion of the material initially suspended will settle out. The overall settling velocity is also higher at lower temperatures, in direct contrast to published results from settling tube experiments. A possible cause for this temperature effect is given.

RÉSUMÉ

Les résultats d'expériences de sédimentation dans un canal annulaire à l'aide de kaolinite dans l'eau distillée sont présentés. Des expériences semblables menées à diverses températures montrent que, à mesure que la température baisse, une plus forte proportion de la matière initialement en suspension se dépose. La vitesse de sédimentation globale est en outre supérieure à faibles températures, contrairement aux résultats d'expériences sur tubes à sédimentation qui ont été publiés. Une cause possible de ces effets des températures est avancée.

MANAGEMENT PERSPECTIVE

The process of settling of fine sediments is very important to the understanding of the fate and pathways of contaminants because these sediments often carry a significant portion of the contaminants entering our aquatic environment. Previous studies of the settling process have not dealt with the effects of temperature on the flocculation and settling. In this report, results of an experimental investigation are presented which show that more settling can take place at the lower temperatures which prevail for lengthy periods of time in Canadian waters. This information is useful for the modelling of sediment and contaminant transport.

PERSPECTIVE DE GESTION

Le processus de formation de fins sédiments est très important pour comprendre le devenir et le cheminement des agents de contamination, car ces sédiments charrient souvent un pourcentage appréciable des agents de contamination qui pénètrent dans notre milieu aquatique. Les études antérieures du processus de sédimentation ne portaient pas sur les effets de la température sur la floculation et la décantation. Dans ce rapport, les résultats d'une étude expérimentale sont présentés, qui révèlent qu'une plus forte décantation peut se produire aux faibles températures qui sont celles des eaux canadiennes pendant de longues périodes. Cette information est utile pour la modélisation du transport des sédiments et des agents de contamination.

EFFECT OF TEMPERATURE ON SETTLING OF FINE SEDIMENTS

Y.L. Lau[1]

Abstract

Results from settling experiments in an annular flume using kaolinite clay in distilled water are presented. Identical experiments carried out at different temperatures show that as temperature decreases, a larger proportion of the material initially suspended will settle out. The overall settling velocity is also higher at lower temperatures, in direct contrast to published results from settling tube experiments. A possible cause for this temperature effect is given.

INTRODUCTION

Fine sediments play a key role in the transport of contaminants through the aquatic system. Many of the dissolved contaminants contained in waste products which are discharged into waterways can be adsorbed onto fine sediments because of the large surface areas which they provide. The process of flocculation increases the settling velocity of these sediments and they are able to deposit in regions of low flow. With increased flows or wave action, the deposited material can be resuspended, releasing contaminants back into the water. These sediments thus act as both sources and sinks for contaminants. In order to predict the fate and the pathways of contaminants, one must understand the dynamics of fine sediments as well as the complex chemical and biological processes which take place within them.

Experimental studies on deposition (Metha and partheniades, 1975; Lick, 1982; Kranck, 1984) have investigated various factors affecting the deposition rate and degree of deposition, including bed shear stress, sediment type and water chemistry. One factor which has not received much attention is the effect of

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temperature. Most experimental studies have been carried out at room temperatures, usually between 20°C to 30°C. In northern regions, where the water temperature is close to zero throughout the winter months and can be below 10°C for more than half of the year, the effect of temperature needs to be taken into account.

In the case of non-cohesive sediments, temperature affects settling only in so far as it changes the viscosity of the water. For cohesive sediments, the process of flocculation, i.e., the continual aggregation and disaggregation, changes the size and density of the flocs and the effect of temperature is much less well defined. The processes of aggregation and disaggregation are not well understood but they are affected by Brownian motion, fluid shear and differential settling, all of which are affected to some extent by temperature.

The only published report on the effect of temperature on settling was by Owen (1972) who carried out experiments in a settling tube. It was concluded that temperature affected settling only through the change in viscosity with temperature, resulting in a larger settling velocity at higher temperature. However, experiments in settling tubes are not representative of natural conditions because they do not simulate the effects of turbulence on the processes of aggregation and disaggregation. In this study, experiments in turbulent flows were carried out to study the effect of temperature on the settling of fine sediments.

EXPERIMENTAL APPARATUS AND PROCEDURE

Experiments were conducted in an annular channel which is housed in a temperature-controlled chamber. The channel has an outside diameter of 2 metres and a width of 20 cm. Flow was generated by the shear exerted by the rotation of a top cover which could be lowered so that it just contacted the water surface. The bed shear stress was determined by means of a 2 mm diameter Preston tube. Velocity profiles were measured using a three-holed pitot cylinder.

The sediment used was kaolinite clay with a mean diameter of 5 microns. This kaolinite would flocculate even in distilled water. Therefore, it was possible to eliminate water chemistry as a variable by using distilled water as the fluid. The flow depth was kept constant at about 8 cm. Before beginning an experiment, the water-sediment mixture was thoroughly mixed, with the top cover running at a high speed. The cover was then slowed to the desired speed to begin the experiment. Preliminary experiments had indicated that concentrations were virtually uniform over the depth. Therefore, samples were withdrawn isokinetically at mid-depth. Concentrations were determined by filtration and weighing. Sampling continued until the concentration reached equilibrium. After equilibrium had been reached, the flume was stopped and the sediment was completely mixed again mechanically. Another experiment was then performed at a different rotational speed to change the shear stress and turbulence in the flow. The experiments were repeated at four different temperatures ranging between 5°C and 26°C.

RESULTS

The concentration-time curves for runs at 20°C are shown in Fig. 1. The settling behaviour is simillar to that found by Metha and partheniades (1975). At a given rotational speed of the top cover, the concentration decreases and then levels off to a constant value. Therefore, a certain fraction of the material remains indefinitely in suspension. This constant concentration is referred to as the equilibrium concentration. As the top cover speed is reduced, i.e., as the shear stress is reduced, the equilibrium concentration decreases.

When the shear stress is kept constant and the temperature is reduced, there is a systematic decrease in the equilibrium concentration. A typical set of such curves is shown in Fig. 2. As temperature is increased, the deviation of the concentration curve from the rapid initial drop occurs sooner and a higher equilibrium concentration is obtained. The ratio between the equili-

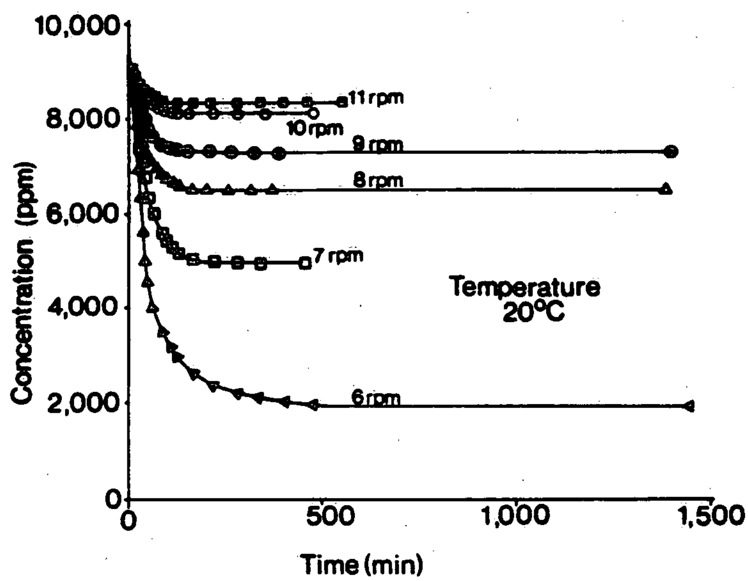

Fig 1. Concentration Decrease With Time - Constant Temperature

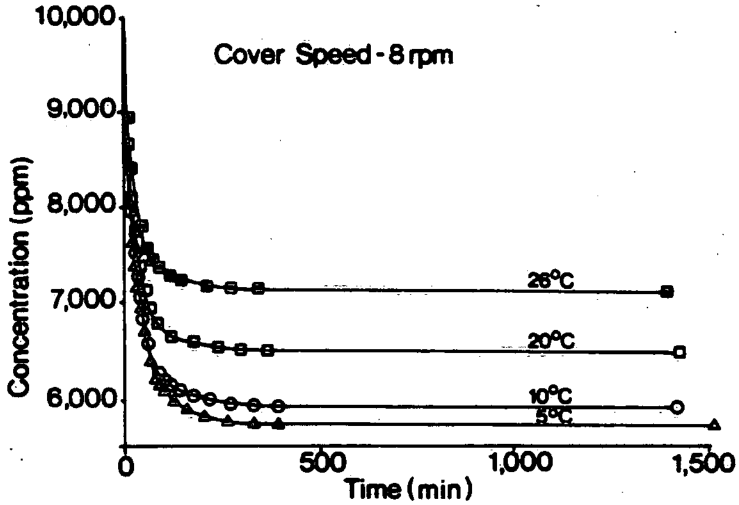

Fig 2. Concentration Decrease With Time - Constant Stress

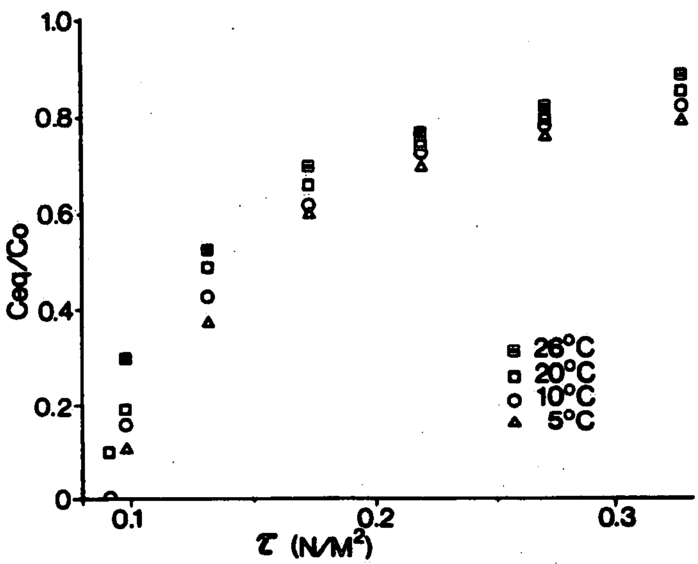

Fig 3. Variation of Equilibrium Concentration With Shear

brium concentration, C_{eq}, and the initial concentration, C_o, is plotted in Fig. 3 against the bed shear stress τ. This ratio decreases systematically with temperature for the whole range of shear stress used. The effect of temperature appears to be slightly more pronounced as the shear stress decreases. An estimate of the effective settling velocity can be made by calculating the rate of removal of material from suspension and using the equation.

$$\frac{dc}{dt} = -\frac{W_s C}{h} \tag{1}$$

where W_s is the effective settling velocity and h is the depth. Eq. (1) cannot be readily integrated as the settling velocity is changing with time. However, by considering the settling velocity to be constant over short intervals of time, W_s can be calculated by writing Eq. (1) in difference form. The settling velocities so calculated for the 7 rpm tests are plotted against concentration in Fig. 4. It can be seen that there is a substantial increase in the overall settling velocity as the temperature is reduced. The settling velocity at 10°C is larger than that at 26°C by almost a factor of three. Similar results are obtained for the other sets at different rotational speeds.

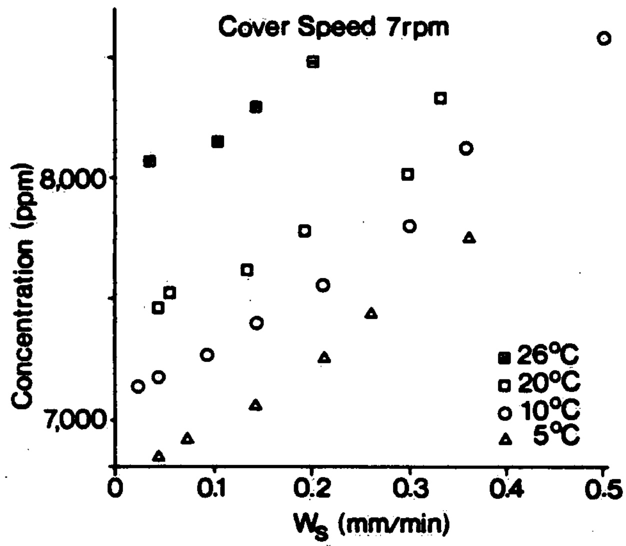

Fig 4. Temperature Effect on Settling Velocity-Concentration Curve

DISCUSSION

The experimental results demonstrate that temperature can have a significant influence on the settling of cohesive sediments. At lower temperatures, a larger portion of the sediments initially suspended will deposit and the overall settling velocity is larger than at higher temperatures. This is the opposite to what Owen (1972) discovered from his experiments using a settling tube. In the quiescent conditions of a settling tube the effect of temperature was felt only through the change in viscosity of the water. The larger viscosity at lower temperatures resulted in larger viscous drag and hence smaller settling velocity. The reduction in settling velocity was in direct proportion to the increase in viscosity, in accordance with Stokes Law.

In order to explain the difference between the present findings and Owen's, one should look at the differences in properties of the flow as well as properties of the flocs. A decrease in temperature has the effect of lowering the Reynolds number of the flow. However, for the temperature range of 5°C and 26°C, the change in Reynolds number is fairly small, by a factor of only 1.7. Measurements by Nezu and Rodi (1986) and Blinco and Partheniades (1971) have shown that there is little dependence of the turbulence intensity in channel flows with Reynolds number. The data of Blinco and Partheniades for smooth walls actually show a slight increase in the turbulence intensity as the Reynolds number is lowered. Therefore, any changes in flow properties with temperature would not lead to the present observations which are then most likely the results of changes in properties of the flocs. A possible explanation is that the flocs which are formed at lower temperatures are denser and stronger and are not as easily broken up by the turbulence in the flow. Therefore, a larger proportion of the material can settle out and the settling velocity is higher. More investigation are needed to confirm this and to find an explanation for the change in floc properties with temperature. Results from size analysis of the samples will help to shed some light on this phenomenon.

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