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Flocculation of Mud in Mud Bank at Purakad, Kerala Coast

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Results of laboratory experiments on flocculation and settlement of suspended mud under various salt concentrations in 3 different mud samples from the mud bank region are discussed. Flocculated settlement varies considerably with the grain size composition, and the mud of mud bank shows close response to salinity fluctuations. Rapid changes in settlement rate take place below 5‰, above which the changes are comparatively slow. Limitations of the jar experiment are discussed in detail. The results when applied to the mud bank region show that in the mud bank, even during monsoon, flocculated settlement prevails over deflocculated suspension and indicate that there is a continuous supply of suspended mud to the water column so that the mud bank continues to exist throughout the monsoon season.

FLOCCULATION plays an important role in processes like coastal shoaling, bar formation, harbour silting and mud bank formation. Suspended mud in the mud bank regions is mostly in a colloidal state during monsoon season and as the salinity of the nearshore water increases during postmonsoon, the suspended mud flocculates and settles down. There has been no attempt to determine quantitatively the effect of salinity on flocculation and settlement of mud except by Du Cane *et al.*[1] who, by observing the volume of mud deposited under various NaCl concentrations of the medium in jar experiments, have found that the mud of the mud banks remains completely deflocculated if NaCl concentration is below 2·5‰ and that complete flocculation occurs with salt concentrations above 20‰. Between these two ranges the mud is partially flocculated, i.e. part of the mud settles as floccs and the rest remain in suspension. The present paper presents some optical experiments conducted to determine quantitatively the effect of salt concentration on flocculation and settlement of suspended mud of the mud bank at Purakad on the Kerala coast and some observations on the floccules of the mud bank region.

Method

Suspension concentrations can be studied by wet ashing, direct microscopy or by optical measurements. Photometric determination of suspension concentration has successfully been made[2-4]. The present work employs photometric determination of attenuation of tungsten light in the mud suspension to determine flocculated settlement of the mud of the mud bank under different concentrations of NaCl.

A number of experiments were conducted using glass jars with optically plane surfaces filled with tap water of varying brine concentrations in which mud from the topmost layer from the mud bank region was uniformly suspended. The experimental set-up is schematically shown in Fig. 1. A parallel beam of light from a tungsten filament lamp was employed and the scattered light coming out of the suspension after travelling horizontally was measured, using a photometer, at various time intervals after stirring the suspension uniformly without entrapping air bubbles. Following the suggestion of Shibata[5], an opal glass diffuser was employed so that the fraction of the scattered light which reaches the photocell is increased and the photometer 'sees' mostly diffused light. Attenuance (ratio of radiant flux lost from a beam by means of absorption and scattering to the incident flux) of the suspension relative to that of pure water in the same glass jars was determined at fixed timings up to about 9 hr. The experiments were repeated for different salt concentrations ranging from 0 to 35‰ and with 3 different mud samples. In all cases, the concentration of the suspensions was kept as 1 g/litre.

The 3 mud samples were collected from depths of 16 m (sample A), 10 m (sample B) and 5 m (sample C) in the mud bank at Purakad (Fig. 2) during September 1972 when the mud bank had almost disappeared as indicated by decrease in turbidity and increase in wave action. Grain size composition of the samples as determined by pipette analysis[6] is shown below:

Composition, %	Sample A	Sample B	Sample C
Sand (>62 μm)	0·95	0·00	3·00
Silt (4-62 μm)	39·31	28·46	42·90
Clay (<4 μm)	59·74	71·54	54·10

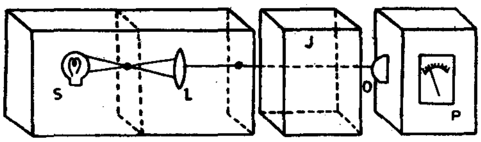

Fig. 1 — Experimental set-up [schematic — S, lamp; L, lens; J, jar; O, opal glass; P, photometer]

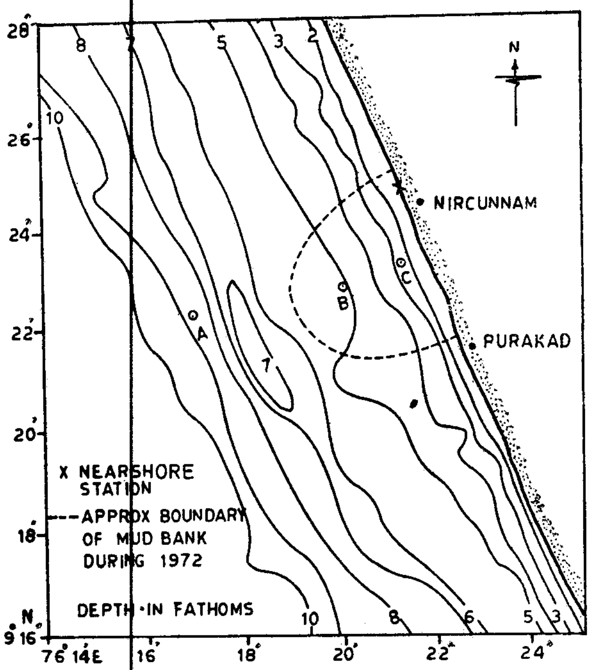

Fig. 2 — Station positions

All the 3 samples contain mostly silt and clay. Of the 3 samples, sample B is finer than sample A and sample A is finer than sample C.

Results

Fig. 3 shows variation of relative attenuance under different NaCl concentrations of the medium for the 3 mud samples. Variation in the transmittance of the suspension system due to changes in the size of the floccs are not separated from that due to settlement of mud. The experiment measures the combined effect due to flocculation and settlement. Flocculation and settlement increases with time and with increase in salt content of the medium. Both increases are more or less gradual. For suspension A, with salt concentrations 10, 20 and 35‰, complete settlement of the suspended load (relative attenuance unity) occurs in about 8 hr 15 min, 3 hr 40 min, and 2 hr respectively. In the case of suspension B, when the salt concentration is 10‰, complete settlement occurs beyond the duration of the experiment and at 20 and 35‰ it occurs in about 8 hr 40 min, and 3 hr 50 min respectively. For suspension C, complete settlement of the suspended mud occurs in about 8 hr 25 min, 2 hr 20 min, and 1 hr 20 min at NaCl concentrations of 10, 20 and 35‰ respectively. At lower salt concentrations, complete settlement occurs only beyond the duration of the experiment.

It is known that for a given type of particulate matter the attenuation is proportional to the particle concentration in suspension, expressed as mass per unit volume[7-9]. Using this proportionality, Fig. 4 is prepared showing the time required for 25, 50 and 75% of the suspended load to settle at various salt concentrations. The proportionality may not be strictly holding good at all salinities because of the changes in the size of the floccules at higher salinities. Nevertheless, the curves show that the decrease in the time required for settlement with increase of salt concentration is in a continuous and well-defined manner. At all concentrations the settlement rates are different with respect to the 3 mud samples, sample B being the slowest and sample C being the fastest.

Discussion

The processes of flocculation and settlement occurring in the natural environment may be different from those taking place in the settling jars. Addition of NaCl in fresh water does not exactly simulate the salinity conditions of sea water. The results can, however, be applied to natural conditions with a slight change except in cases where large quantities of organic matter are dissolved in the sea water in which case flocculation occurs at enhanced rates. When examined under microscope, the floccules in both the natural samples and the artificial suspensions appear identical. They are nearly-rounded masses of varying dimensions. Each clump contains grains of various sizes. At higher salt concentrations individual floccules are bigger than at lower salt concentrations. This is found to be so in the natural samples also.

Clarke and James[10] have shown that there is no appreciable difference between the attenuance of distilled water and that of filtered sea water. Corroboratory results have been obtained by comparing the absorption of distilled water with that of artificial sea water[11]. In the present study also the attenuance before any flocculation takes place is found to be more or less same under all NaCl concentrations.

As seen from Fig. 4, flocculated settlement starts even at 1‰ salt content and the increase in the rate of settlement continues even beyond 35‰, whereas Du Cane *et al.*[1] have suggested completely deflocculated state before 2·5‰ and completely flocculated state above 20‰. Observations under the microscope show that at 35‰ there are lesser individual particles than at 20‰ which become part of a floccule at higher salinities. The higher the salinity the lesser is the number of individual particles and bigger is the size of the floccules. Minimum salinity at which complete flocculation occurs is certainly above 35‰.

The sediment of the mud banks responds very quickly to salinity changes of the medium up to about 5‰ and at higher salinities the response is comparatively slower. In the jar experiment any tangential forces like those due to winds and currents or vertical forces other than gravity and buoyancy are absent whereas in the ocean the tangential forces and the turbulence of water may delay flocculated settlement. Hence the very low salinities may not be so effective in forming floccs in the sea as in the jar experiment. But in the mud bank region, the waters are free of wave disturbances owing to the damping that waves undergo in the turbid water. The south-west monsoon and the heavy fresh water runoff during that season cause considerable dilution of the nearshore waters of the Kerala coast. Variations of surface, mid-depth and bottom salinities for the

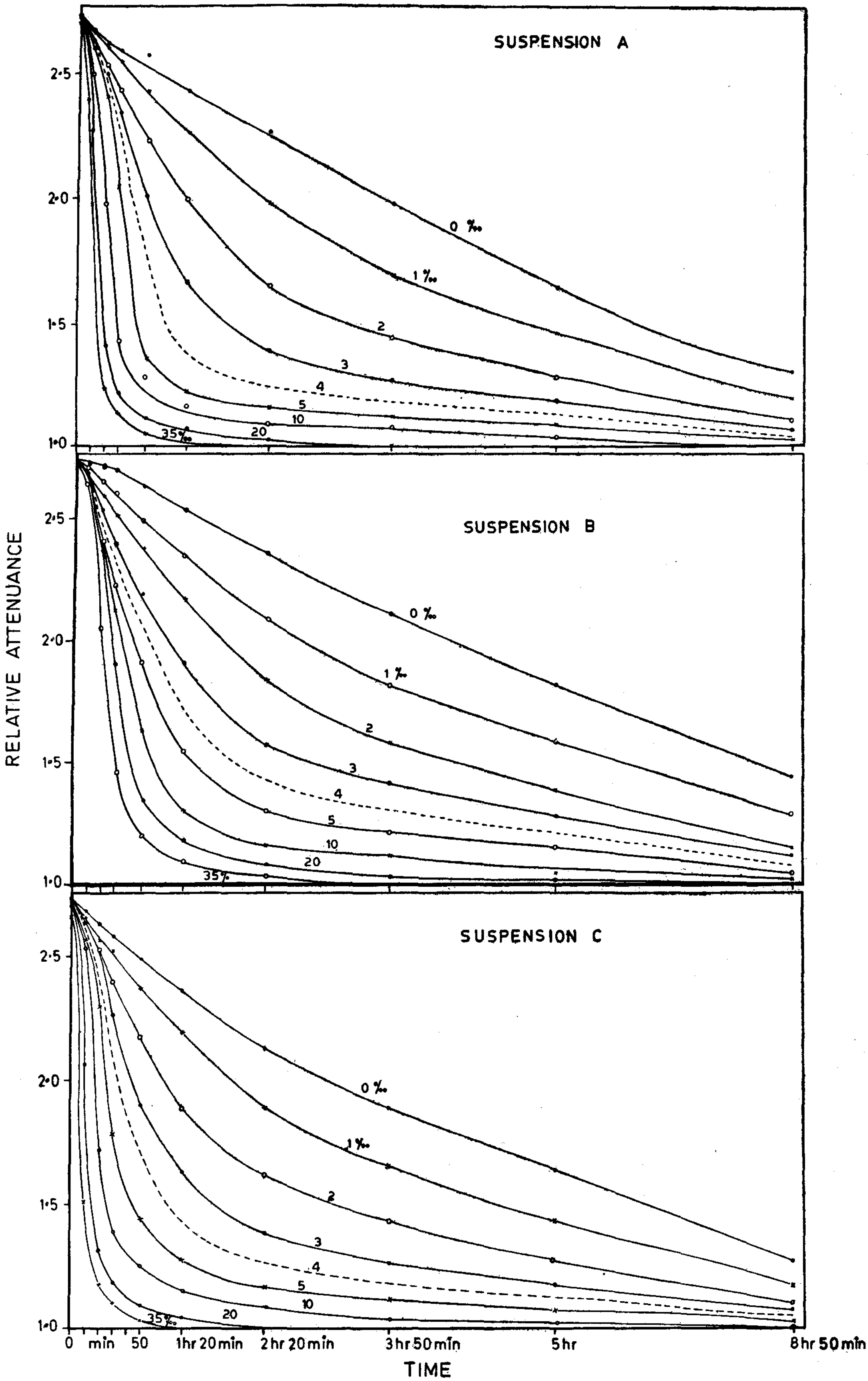

Fig. 3 — Variation of relative attenuance of suspension A, suspension B and suspension C with time under different brine concentrations

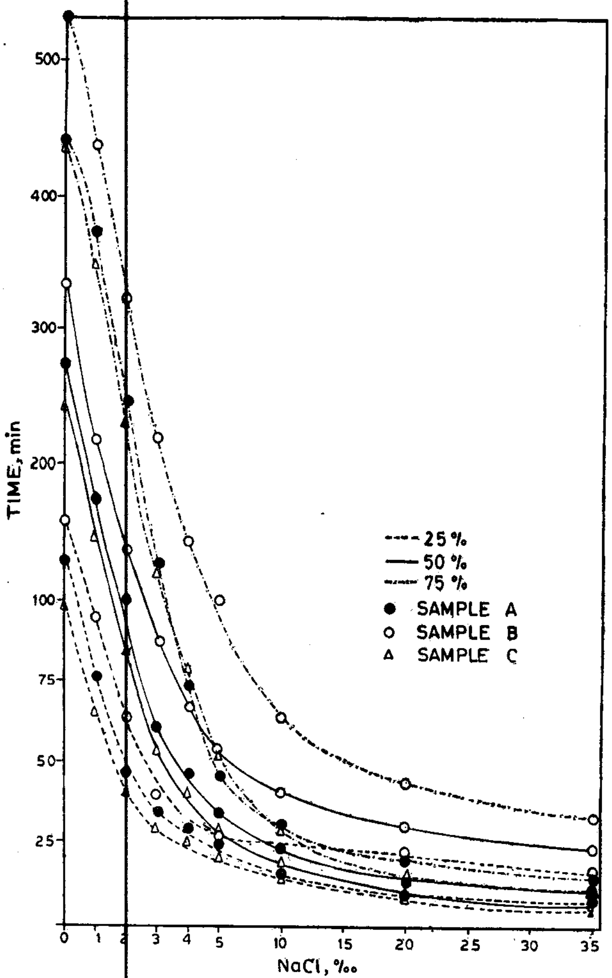

Fig. 4 — Time required for 25, 50 and 75% of the suspended load to settle at different salt concentrations

year 1972 at the station from where sample B has been collected are shown in Fig. 5. Also shown in the same diagram are the monthly variations of salinity at a station very near the shore during 1971.

The surface salinity varies between 13·7 and 34·5‰ and the bottom salinity between 29·0 and 34·4‰. Even during monsoon the salinity is never below 13‰ and by September it increases to 19‰. At a station very near the shore, the salinity reaches 8‰ during monsoon. These variations show that the monsoon season provides conditions favourable to increased deflocculation in the mud bank region and the postmonsoon conditions facilitate flocculation and settlement. As the results of the present study indicate, even at these low salinities flocculated settlement prevails

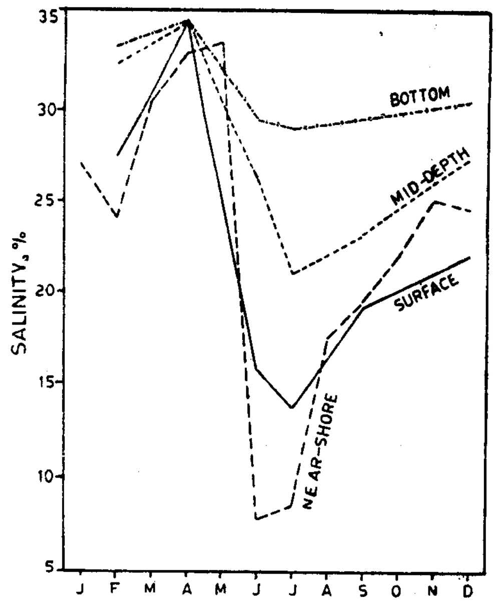

Fig. 5 — Monthly variation of salinity in the Purakad mud bank region during 1972

and it is evident that there is a continuous supply of suspended sediment to the water column so that the mud banks continue to exist throughout the monsoon season.

Acknowledgement

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