Effect of diatoms on flocculation of suspended bed-sediments in a large shallow lake: consequences for ecology and sediment transport processes

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Introduction: The Markermeer is a large man-made fresh water lake located in the centre of The Netherlands. Together with the northern IJsselmeer is the largest fresh water reservoir of Europe. This area is known as the IJselmeer Region. During the last decades, the lake has experienced a decrease in its ecological values. [*Noordhuis & Houwing, 2003; van Eerden & van Rijn, 2003*]. This ecological decline has been attributed to high turbidity levels and sediment transport processes in the lake [*van Duin, 1992; van Kessel et al, 2008*]. However, turbidity levels over the years cannot be fully explained by occurrence of storms and associated re-suspension events. On the other hand, the species of diatoms present in the lake have changed over the last decades as a result of measures to reduce nutrients in the lake. The current overall chlorophyll concentration varies over the year in a way that is not understood. Therefore we hypothesize that interactions between lake's diatoms and suspended bed-sediments are affecting sediment transport processes and ecology.
The aim of the current study is to investigate the effect of specific species of diatoms on the flocculation of suspended bed-sediments,over a range of turbulence levels. In the study equilibrium floc sizes and turbidity of the suspension for each of the studied turbulence levels are determined. Moreover the effect of suspended bed-sediments on the diatoms configuration in the water column is addressed as well. A final goal of the study is to contribute to the overall understanding of sediment transport processes and ecology in the lake.

Methods: Small scale flocculation experiments are performed in mixing jars. The turbulence field in the jar is induced by a rotating paddle, and is characterized by the turbulence shear rate G. An average value for G in the jar can be approximated with:

$$\log G = 0.849 + 1.5 \log(60 nf),$$

where nf is the stirring frequency of the paddle in rotations per second [*KIWA, 1976*]. The small scale experiments consist of studying the equilibrium floc size as a function of G in the jar. For every studied sediment type a sequence of six steps in G is applied. Values of G range from 65 s^{-1} to 8 s^{-1}.
Floc size distribution of suspended sediments is measured with a Malvern Mastersizer 2000.

Results: The experiment with the algae diatoms in the jar reveal much lower obscuration levels than for bed sediments, as well as the ability of the diatoms to stay in the water column independently of the magnitude of the turbulence field. When combined, suspended bed-sediments and diatoms produce a higher obscuration than any of the individual sediment fraction independently. This increased obscuration is not equal to the sum of the individual obscurations caused by each sediment fraction. Moreover obscuration increases for increasing floc sizes in some cases, which suggests a floc structure different from the case of suspended bed-sediments. These observations suggest aggregation of bed sediments and diatoms when subjected to a turbulence field. These organic-inorganic aggregates attain different equilibrium floc sizes than its individual components, as quantified with the current study. Furthermore, the co-existence of bed-sediments and diatoms in the water column resulted, in some other cases, in settling of the complete diatoms population from the suspension. The latter does not occur when diatoms are alone in the water column, which was found for all turbulence levels.
The increased turbidity caused by the co-existence of bed sediments and diatoms at the water column may be used to complete the analysis of the historical turbidity levels in the study-site. The turbidity regime is a function of the interaction of suspended bed-sediments with local species of algae. Furthermore it has been shown that algae can settle as a result of its interaction with suspended bed-sediments, which affects the nutrients balance in the lake.

Conclusions: Suspended bed-sediments and algae can flocculate in fresh-water environments. The resulting aggregates differ from the original aggregates in light-absorption and light-diffraction properties, shape, structure, and settling velocities. All these differences have been quantified over the current study. Finally it can be concluded that studying the characteristics of organic-inorganic aggregates as a function of environmental conditions like turbulence level and seasonal variations of algae provides relevant information for a proper understanding of sediment transport processes and ecology.

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