Flocculation in natural environment: from the lab to the field

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Flocs are constituted of an aggregation of clays and polymers in the presence of ions of variable concentration. Their structure and strength are not only depending on the properties of the constituents, but also on the history of their formation.

A few scenarios for the formation of flocs were investigated in the laboratory, based on the availability of polymers and/or salt at the onset of aggregation and on the shear stresses present during the growth of the flocs. Flocculated suspensions were created using established laboratory jar testing protocols (Mietta, 2010). The structure of the created flocs was analysed using version 2 of the LabSFLOC - Laboratory Spectral Flocculation Characteristics – instrument (Manning, 2006) by recording their floc size, density, settling velocity, and strength. A systematic investigation of the changes in floc structure after resuspension of the flocs was performed. The flocs thus obtained were compared with the flocs obtained in natural environments, for which data has been collected recently in the southern North Sea, more specifically in the Rhine ROFI at a depth of 12m, close to the Sand Motor between Hook of Holland and Scheveningen, the Netherlands.

By integrating the results of these studies, a new model for floc formation was developed. This model is based on the Population Balance Equation (PBE) which describes how a particle size distribution is evolving in time, under influence of shear stresses (Mietta, 2010; Mietta *et al.*, 2011). The new model differs from the standard PBE in the following ways:

1) The aggregation/break-up parameters of the model will integrate more measureable data to limit the amount of empiricism, following the work initiated in our group (Mietta *et al.*, 2009)

2) The model will consist of a mathematical (analytical) function which reproduces the results of the PBE derivations, but which can be more easily implemented into larger scale numerical models like Delft3D.

3) The model will be extended compared to the standard PBE model, so as to include the interaction of particles with the sediment bed, for which no model currently exists.

An example is given below, illustrating the possibility of using analytical functions, with a limited number of parameters to reproduce the time evolution of floc formation. These parameters can in turn be linked with parameters such as collision efficiency, break-up rate, etc. appearing in the PBE model, and to measurable parameters such as salinity, shear stresses and organic matter content.

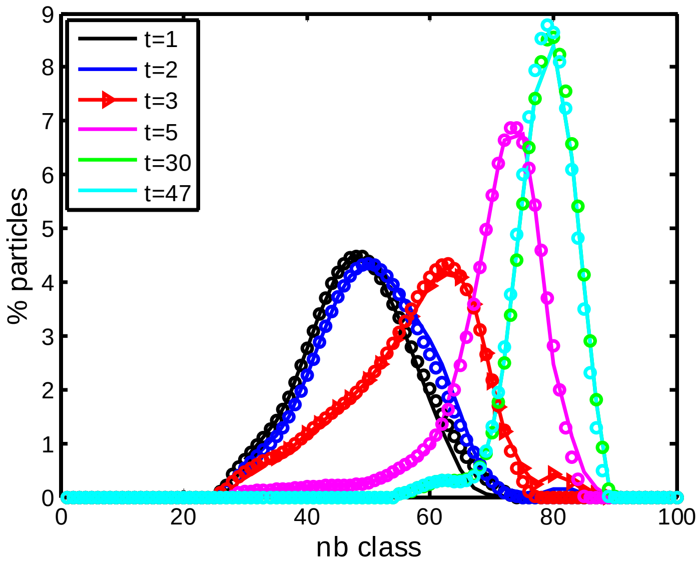

Fig. 1. Test case: River clay in presence of cationic flocculant; Evolution of the Particle Size Distribution (% particles in each class) in time; the size (in microns) of a particle in a given class (nbclass) is given by 10^(0.05*nbclass)/50; The symbols correspond to the measurements and the lines to the theoretical model; the time t = 1 corresponds to the time where the cationic flocculant is added, t = n to the situation (n-1)x30 s later.

In this example, the stirring time in the jar, and the pumping through the Light Scattering measuring device was low enough to ensure that the flocs only grow, and would not break-up. In this simple case, we found that given 3 constant parameters a1, a2, b1, and two exponentially increasing in class number parameters ta(i) and tb(i), we could integrate analytically the PBE. The time evolution of the number N_i of particles in class i was then found to be:

$$N_i(t) = \frac{a_1}{1 + a_2 \exp\left(-\frac{t}{t_a(i)}\right)}\left[b_1 + \exp(-\frac{t}{t_b(i)})\right]$$

This function could be used to model the PSD over the entire flocculation period (full lines in the figure).

References

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