Adsorption and flocculation mediated by polymeric substances in cohesive sediment suspensions: experimental study

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Introduction

Polymeric substances are present everywhere in the water environment. They can adsorb cohesive sediments and bind particles together in large flocs, thereby enhancing flocculation. Extracellular polymeric substances (EPS), as natural polymeric substances, enhance flocculation of cohesive sediments in rivers, lakes and estuaries (Droppo, 2001; Chen *et al.*, 2005). As analogues of EPS, synthetic polymeric substances have been widely used as flocculation agents in many engineering systems, for controlling soil erosion and sediment runoff from source sites or removing suspended solids in water and wastewater treatment processes (e.g. Orts *et al.*, 2007). However, not all the polymeric substances can enhance flocculation. The size of a polymeric substance is a critical property to enhance or reduce flocculation. For example, Engel *et al.* (2004) reported that in the marine environment, small polymeric substances (e.g. cell exudates), which initially do not have flocculation capability, aggregate to large polymeric substances, thereby enhancing flocculation. Large polymeric substances in an engineered treatment system also have been reported to enhance flocculation more than small polymeric substances (Green *et al.*, 2000). Thus, this research was conducted to investigate closely the effect of the size of polymeric substances on flocculation, as well as adsorption, in a well-controlled laboratory condition.

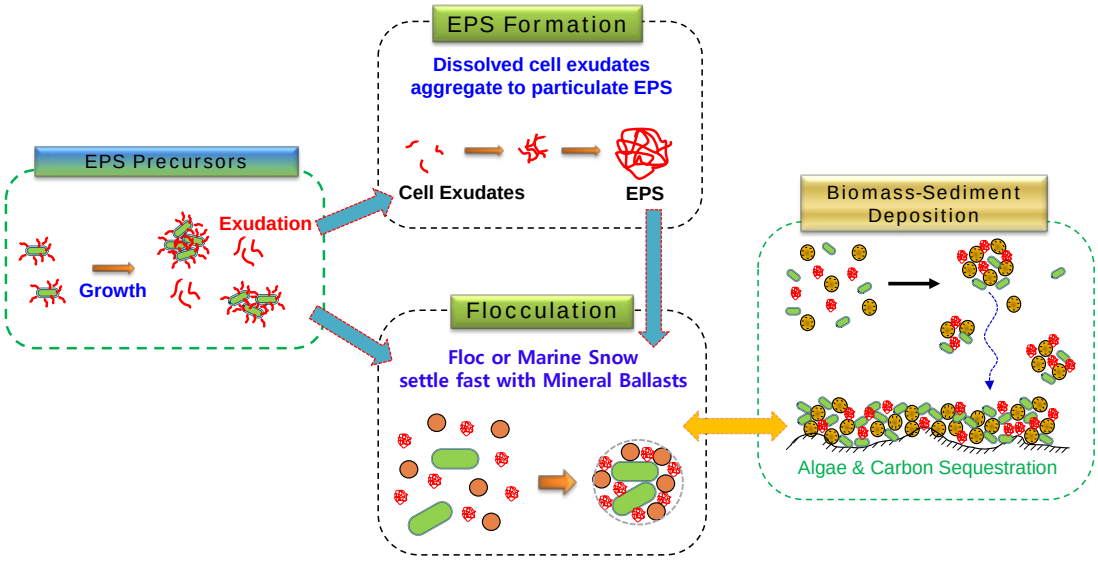

Fig. 1. Conceptual model of EPS formation and bio-mediated flocculation in the marine environment.

Materials and methods

A series of polyacrylamides (PAM) with different molecular weights (MW) (i.e. different sizes) of 1.5kg/mol, 10kg/mol, 0.6-1Mg/mol, and 5-6Mg/mol, which are denoted by 1.5K, 10K, 0.6-1M, and 5-6M PAMs in this paper, were selected and tested as polymeric substances. Those PAMs with different MWs were applied to kaolinite suspensions, to test their adsorption capacity and flocculation capability. The respective bottle-point adsorption test and shear-controlled flocculation test were used to investigate PAMs' adsorption capacity and flocculation capability.

Results and discussion

The bottle-point adsorption tests with kaolinite suspension, dosed with 1.5K, 10K, 0.6~1M, and 5~6M PAMs, indicated that PAM adsorption capacity on kaolinite increases with a higher MW. Especially, 0.6~1M and 5~6M PAMs had 20 to 30 times higher adsorption capacities than 1.5K, 10K

PAMs. In the shear-controlled flocculation tests, 1.5K, 10K PAMs did not enhance flocculation but rather stabilize particles in the kaolinite suspension. The polymeric chains of 1.5K and 10K PAM might be confined within the electrostatic repulsion layer on sediments due to their short polymer chain structure, thereby not being able to develop polymeric bridges between particles and decreasing flocculation (Fig. 1). On the contrary, 0.6~1M and 5~6M PAMs substantially increased flocculation. Especially, 5~6 M PAM was found to have higher flocculation capabilities than 0.6~1M PAM, for being more subject to non-equilibrium flocculation (Pelssers *et al.*, 1989), in which unstable, stretching polymeric structures on sediment surfaces increase particle-particle bridging and flocculation (Fig. 1).

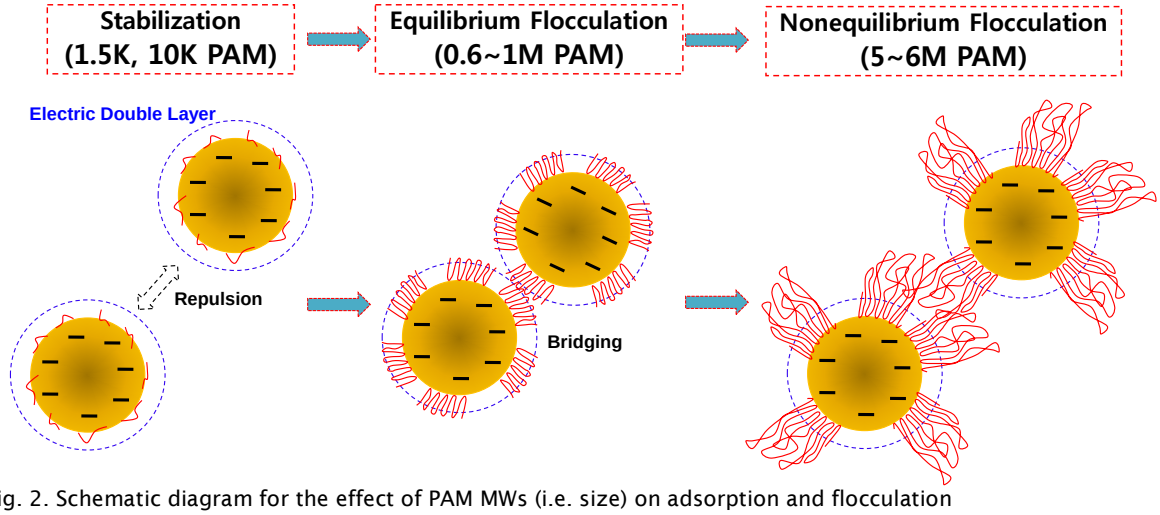

Fig. 2. Schematic diagram for the effect of PAM MWs (i.e. size) on adsorption and flocculation

Conclusion and recommendation

This experimental study revealed that larger polymeric substances are more effective adsorbates and flocculants than smaller polymeric substances. The size (i.e. MW) was found to be an important property of a polymeric substance for determining adsorption capacity and flocculation capability. However, unlike synthetic polymeric substances in a well-controlled laboratory, the functions of natural, biogenic polymeric substances for adsorption and flocculation remain mostly unknown in the natural water environment because they are hardly separated from other factors in such a complex system. This issue might present a challenging task in the scientific community. Hopefully, adopting new physical-chemical-biological analytical techniques, for characterization of polymer substances and quantification of adsorption and flocculation, may help us to get the right answer.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No: 2014R1A1A2055622).

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