論文の内容の要旨

Separation of Colloidal and Dissolved Organic Matter by Interfacial Interaction between Hydrophilic Membrane and Water

（親水性膜と水の界面相互作用によるコロイドと溶解性有機物の分離）

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Under the context of sustainable development, green engineering is proposed as “the design of systems and unit processes that obviate or reduce the need for the use hazardous substances while minimizing energy usage and the generation of unwanted by-products”. The 12 principles of green engineering provide specified framework for science and technology innovations. According to these principles and current issues on water and energy, we believe the most important requirement for the next generation water purification technology is to be “green”, which means to minimize the use of chemicals, to be more environmentally friendly and more benign products during the processes. Unfortunately, on the basis of the present literature, there is no such “green” approach in water treatment for successful implementation. Thus, one of the primary objectives in this study is to figure out promising and possible principles for the water treatment.

Exclusion-zone (EZ) phenomenon is an unexpectedly interfacial impact on aqueous solution that separates charge from water and excludes particles/solutes in the presence of hydrophilic surface, which was firstly reported by Zheng and Pollack in 2003. EZ has the following advantages for future water treatment process that may meet the requirements of green engineering.

(1) It is a simple process.

(2) It has a capacity to remove particles, pathogens and some solutes naturally during the process.

(3) No chemical needs and hence no fouling problem.

(4) No external energy input.

(5) No harmful by-products after the process.

However, a practical use of EZ phenomenon for water treatment is limited due to low water production rate. Therefore, this study was aimed to find ways to promote EZ by investigating factors affecting the EZ size and formation rate, to combine some EZ relevant phenomena into the same system, and try to propose and develop some practice applicable purification unit based on these phenomena.

This study mainly investigated three phenomena: EZ, phase separation (PS), and void-zone (VZ) phenomenon. PS and VZ phenomenon are two new phenomena associated with EZ. To our knowledge, it was the first time to find PS and VZ that co-appears with EZ in the same aqueous system when hydrophilic membrane present. PS is a kind of liquid-solid separation phenomenon that occurs naturally in the presence of hydrophilic membrane. Both micro- and nano-scale particles moved downward from an air-liquid interface several millimeters within hours, creating particle-free water on the top of suspension. VZ is a region devoid of various kinds of particles in the suspension with relatively low particle concentration.

For EZ phenomenon, we found that surface hydrophilicity, particle properties, and solution chemistry have impact on EZ formation. Hydrophilic surface was confirmed to be one of the determinant factors for EZ. The surface with strong reaction with water is believed to generate great and clear EZ. Particle properties and solution chemistry influenced EZ in various extents. Furthermore, particle concentration was found to be an important parameter for the co-occurrence of EZ and PS or VZ. Besides, it is the first research to investigate the EZ behavior in the presence of DOM.

PS phenomenon was extensively elucidated in this research. EZ, particle properties, and solution chemistry all affect PS phenomenon. EZ and particle concentration was proved to be the two main factors for PS occurrence. It was proved that PS is possibly triggered by EZ water circulation, driven by different density between EZ water and bulk suspension. Moreover, an unexpected effect of ionic strength on PS process was found. This phenomenon may provide

implications in many water and wastewater treatment processes utilizing solid/liquid separation.

Similar to PS phenomenon, EZ and particle concentration were found to be the primary factors for VZ formation as well. Although it is not clear about the mechanism of VZ phenomenon till now, we found that EZ, particle concentration, and surrounding environment all have an impact on VZ appearance. Some hypotheses for VZ have been proposed in this study and EZ water circulation hypothesis is believed to the possible reason for the appearance of VZ phenomenon.

At last, several designs of water purification approach based on EZ, PS, and VZ phenomena were proposed and the rate of water production for each design was evaluated as well. On the other hand, a particle separation unit was examined and might be feasible for water treatment.