

The effect of electric field on the surface of nanoparticles (TiO₂ & SiO₂) and its application to retardation of membrane fouling

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ABSTRACT

The recirculation of raw water containing 0.1 wt% nanoparticles through 30 kV electrostatic device induced the change of zeta-potentials for TiO₂ and SiO₂, respectively, by 40 mV (from +20 mV to -20 mV) and 6 mV (from -18 mV to -24 mV). The electrostatic field increased the zeta potential of colloidal particles negatively through the electrostatic device, consequently leading to the retardation of membrane fouling due to more electrostatic repulsion.

Key Words: Electric field, Zeta-potential, Membrane fouling, TiO₂, SiO₂

1. INTRODUCTION

In recent days, membrane technology has been employed into various fields of scientific applications. The main obstacles of this technology, however, comes from the irreversible fouling of the membrane surface, i.e., resulting in the rapid decrease of permeate flux. Membrane fouling includes pore blocking, scale formation, and biofouling. Electrostatic treatment has

been practiced for many years for anti-foulant effect on processing the industrial wastewater. Electrostatic system can generate high voltage (e.g., 10~40 kV) that is very effective not only to kill the micro-organisms but also reduce the deposition of insulating solids on the surface[1]. The anti-foulant effect by electrostatic device is probably due to the alteration of surface charges of colloidal particles toward more negative values, and thus reducing the deposition of insulating particles on the solid surface.

The objective of the research is to investigate the effect of electrostatic field on the surface charge of colloidal particles and membrane materials. The electrostatic device (Enoclean-20, EcoNovel Co.) was operated in a batch mode constantly to create an electrostatic force throughout the plate-frame UF system. The effect of electrostatic field on the retardation of membrane fouling was systematically investigated with the variation of zeta-potentials of colloidal particles[2].

2. EXPERIMENTAL

The bench-scale UF system equipped with electrostatic

device (Enoclean-20, EcoNovel Co.) was used to demonstrate the membrane performance (such as permeate flux and fouling rate) with the variation of solution pH of colloidal particles under electrostatic voltages (Figure 1). The plate-frame UF module has the dimension of $15 \times 10 \text{ cm}^2$, and the height of the feed channel was 0.5 mm. DDS polysulfone membrane (MWCO=2000, 10000) has surface area of 0.1 m^2 . The raw water was prepared by diluting 0.1 wt% SiO_2 (dia.=ca. 200 nm) in water.

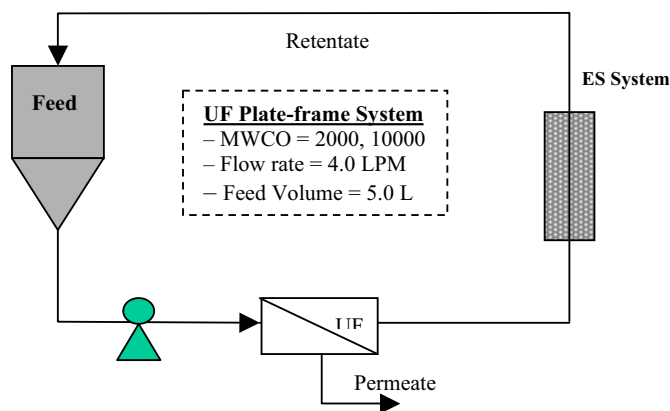


Figure 1. The effect of electrostatic force ($V=30000$ volt) on the zeta-potential of 0.1 wt% TiO_2 with the elapse of recirculation times.

The electrostatic system (Enoclean-20, EcoNovel Co.) can generate DC voltages ranged in from 10000~40000 volts that is very effective to enhance the dispersion of colloidal particles by inducing the negative zeta-potentials on the surface.

3. RESULTS & DISCUSSION

As shown in Figure 2, the recirculation of colloidal particles (0.1 wt%) through the electrostatic device

distinctly altered the zeta-potential of TiO_2 nanoparticles (dia.=ca. 270 nm) from ca. +20 mV to -20 mV.

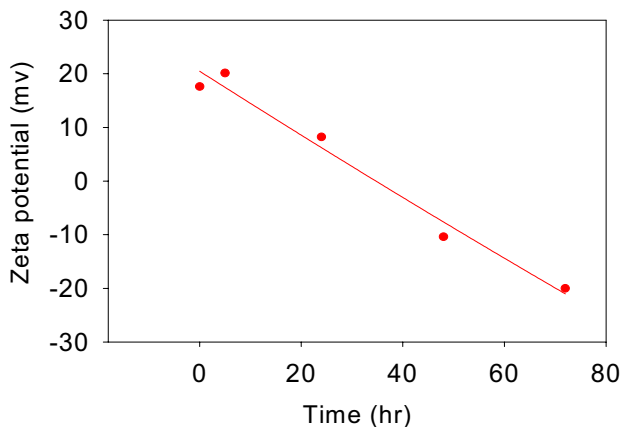


Figure 2. The effect of electrostatic force ($V=30000$ volt) on the zeta-potential of 0.1 wt% TiO_2 with the elapse of recirculation times.

On the other hand, the electrostatic device slightly changed the zeta-potentials of SiO_2 from -18 mV to -24 mV, and the diameter of SiO_2 was reduced from ca. 230 nm to 180 nm, probably due to the increase of electrostatic repulsion by negative zeta-potentials (Figure 3).

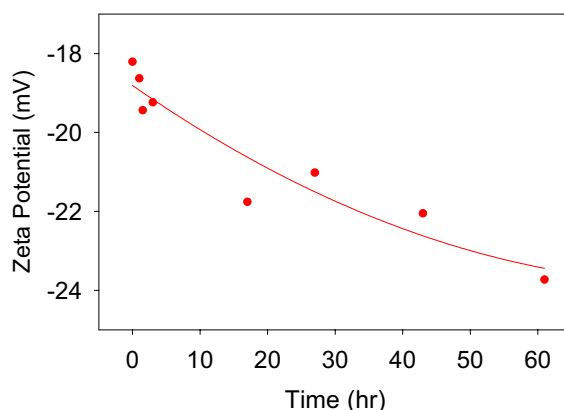


Figure 3. The effect of electrostatic force ($V=30000$ volt) on the zeta-potential of 0.1 wt% SiO_2 solution with the elapse of recirculation times.

The bench-scale UF system was used to demonstrate the membrane performance (i.e., permeate flux and fouling rate) in terms of transmembrane pressure, flow

rate, and solution pH[3]. As shown in Figure 4, pure water flux through DDS membrane (MWCO=2000) was linearly increased with rising transmembrane pressure at various feed flow rates.

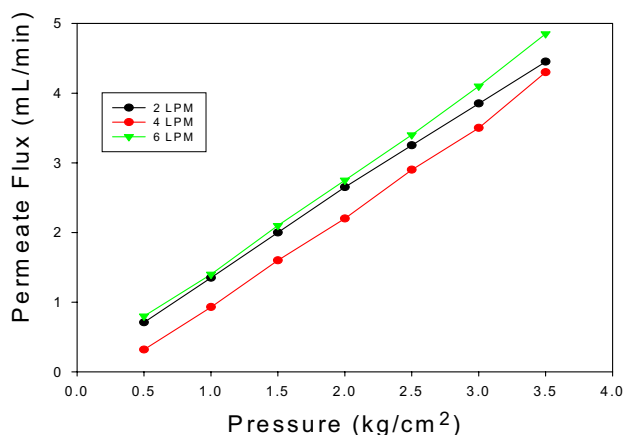


Figure 4. The permeate flux of pure water through DDS membrane (MWCO=2000) with the increase of transmembrane pressure.

As shown in Figure 5, the solution pH was adjusted by the addition of HNO₃, in which the zeta potential of SiO₂ was rapidly increased up to -4 mV at pH 3.3 that is more liable to be agglomerated.

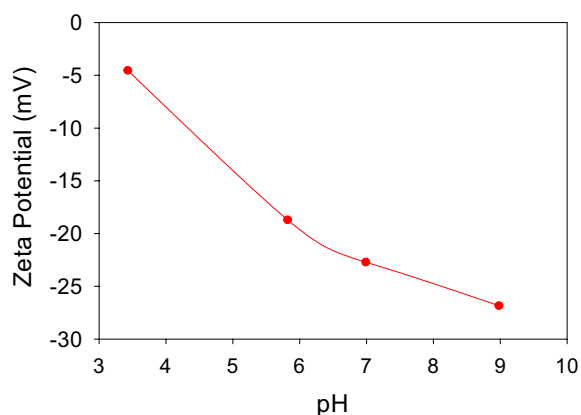


Figure 5. The variation of zeta potential of 0.1 wt% SiO₂ solution with the increase of pH.

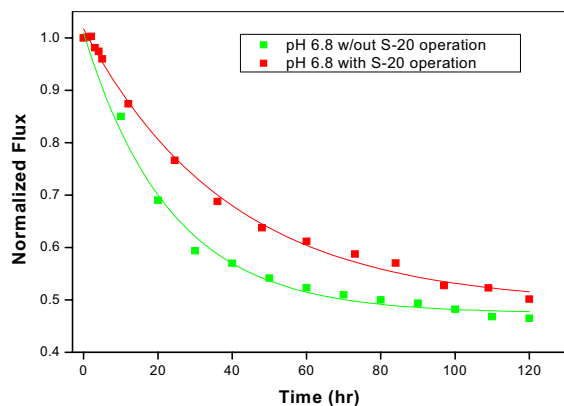
The effect of electrostatic force on the retardation of membrane fouling was investigated at various solution pH. The permeate flux at solution pH6.8 was kept higher for long time in comparison to solution pH2.6. As shown in

Figures 6, the membrane fouling rate without electrostatic device was increased with the decrease of solution pH, whereas for the operation of electrostatic device the retardation of membrane fouling rate was distinctly increased at lower solution pH, i.e., the discrepancy of permeate fluxes was getting higher at lower pH2.6.

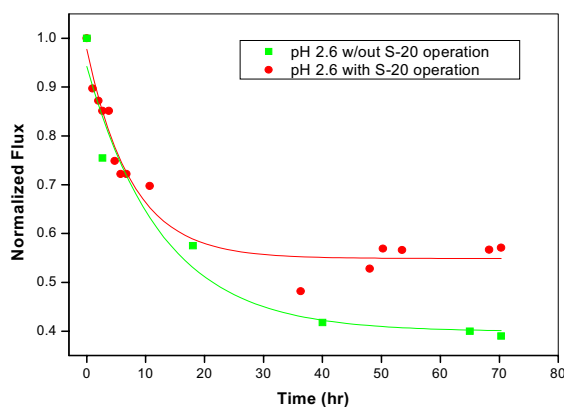
The electrostatic device installed before UF module effectively delayed the fouling rate by reducing the accumulation of colloidal particles on the membrane surface. The effect of electrostatic force seems to induce the electrostatic repulsion between colloidal particles and membrane surface, consequently leading to high permeate flux at longer operation time. As already seen in TiO₂ with positive zeta-potentials, the electrostatic force significantly changed the zeta-potentials into more negative values. Even though without electrostatic force the initial fouling rate was higher for SiO₂ at lower solution pH, the membrane fouling rate was distinctly retarded at lower solution pH with the operation of electrostatic device. That is, normalized flux difference, Δ , at solution pH2.6 was much higher in comparison to solution pH6.8.

Conclusively, the electrostatic device effectively induced the stronger electrostatic repulsion between the membrane surface and SiO₂ nanoparticles with less negative zeta-potentials, resulting in the higher permeate flux at longer operation time. The acidic solution increased the zeta-potentials of SiO₂ more positively, and

the permeate flux declined more rapidly without the operation of electrostatic device.



(a)



(b)

Figure 6. Permeate flux of raw water containing 0.1 wt% SiO₂ through DDS membrane (MWCO=10000) with the operation of electrostatic system: (a) solution pH 6.8, (b) solution pH 2.6.

4. CONCLUSIONS

The recirculation of raw water containing 0.1 wt% SiO₂ through 30 kV electrostatic device changed the zeta-potential of SiO₂ by 6 mV (from -18 mV to -24 mV) as well as the increase of solution pH by 1.2[3]. The effect of electrostatic force on the membrane fouling was investigated at variable solution pHs. With the decrease of solution pH, the electrostatic device prior to UF modules effectively delayed the fouling rate of the membrane

surface. Electrostatic device was also effective in dispersing colloidal particles by inducing more electrostatic repulsion. The electrostatic field was concluded to increase the electrostatic repulsion between colloidal particles and the membrane surface, consequently leading to the retardation of membrane fouling.

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