Fouling Monitoring during Microfiltration of Surface Water by Filtration Resistance and Streaming Potential

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ABSTRUCT

The fouling properties of PVDF hollow fiber Microfilration membrane during the filtration of surface water or model suspension(Kaolin and Humic acid) were studied with the dead-end filtration equipment with backwashing and streaming potential measurement systems. The change in fouling status during the filtration was monitored by the filtration resistance R_f , the filtration resistance at the backwashing R_b, and streaming potential. By comparing R_f with R_b the fouling resistance could be classified into the internal fouling, which means the standard blocking, and the external fouling, which means the cake filtration, and in the filtration of both the surface water and the model suspension it was shown that the fouling was the internal fouling in the early stage of filtration followed by the external fouling. The zeta potential, which was estimated by the streaming potential measurement, was changed during filtration depending on the change in the fouling status.

KEYWORDS

Microfiltration membrane, Streaming potential, Fouling

INTRODUCTION

The introduction of the membrane filtration system to drinking water production plants is rapidly increasing because of the demand for safety water against accidents caused by microbes. Although the membrane fouling is one of the major factors limiting the efficiency of the membrane filtration process, the fouling mechanism has not been fully understood and the prediction and control of the membrane fouling is still a difficult technology. In order to develop a technique for fouling control we have been developing a conceptual filtration system with fouling status monitoring[1-4)]. In this system the membrane system will be controlled based on the fouling status monitored by streaming potential in addition to pressure dropping across the membrane. In this study the fouling properties of PVDF hollow fiber Microfilration membrane during the filtration of surface water or model suspension(Kaolin and Humic acid) were studied with a constant flow rate dead-end filtration equipment with backwashing and streaming potential measurement systems.

EXPERIMENTAL

Fig.1 shows the experimental apparatus. The filtration mode was constant flow rate dead-end type with backwashing at a constant time interval. The electrodes for measuring streaming potential were equipped at inlet and outlet of the membrane module. Filtration pressure and backwashing pressure were measured with pressure transducers. All measured data were recorded in a PC. Membrane used was PVDF hollow fiber microfiltration membrane(I.D. 0.7mm ϕ , O.D.1.3mm ϕ) having 0.1 μ m pore size and $0.2m^2$ filtration surface area. Surface water(Doshi river) and the model suspension containing Humic acid(Aldrich) and Kaolin(sigma: particle size 0.1-0.4 μ m) were used as feed water. Fig.2 shows filtration and backwashing cycle. Filtration rate and backwashing rate was adjusted to 1.5 and 3.0 m/day, respectively. Streaming potential was measured at start and end points of both filtration and backwashing steps.

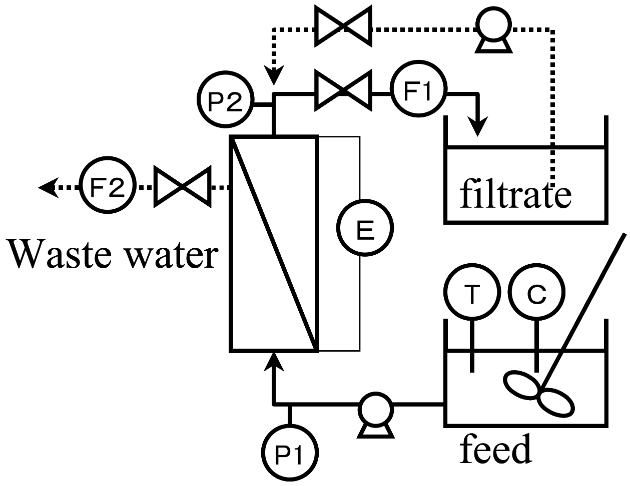

Fig.1 Experimental apparatus.

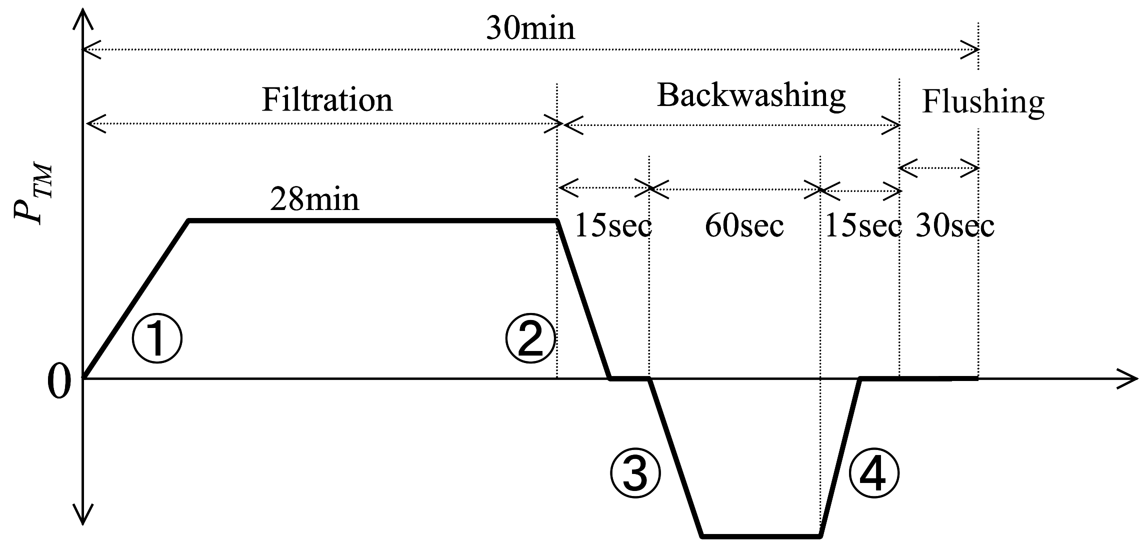

Fig.2 Time schedule for filtration and backwashing cycle

Analysis

Filtration resistance

The filtration resistance was obtained by following equation.

$$R = \frac{P_{TM}}{\mu J} \quad (1)$$

The filtration resistance at two minutes after the start of a filtration step in an operation cycle, $R_{f, t=2}$, was employed as the represent value for the filtration step. The filtration resistance for the backwashing step was measured at the end of the backwashing step.

Zeta potential

The streaming potential(SP) was defined as Eq.(2).

$$Streaming\ Potential\ (SP) = \frac{\Delta E_{TM}}{\Delta P_{TM}} \quad (2)$$

The observed zeta potential, ζ_{obs}, was estimated using Helmholtz- smoluchouski equation,

$$\zeta_{obs} = \frac{\mu\ \lambda}{\varepsilon_0\ \varepsilon_r}\frac{\Delta E_{TM}}{\Delta P_{TM}} = \frac{\mu\ \lambda}{\varepsilon_0\ \varepsilon_r} SP \quad (3)$$

where μ is the solution viscosity, λ is the solution conductivity, ε_0 is the permittivity of vacuum, ε_r is the dielectric constant of the medium.

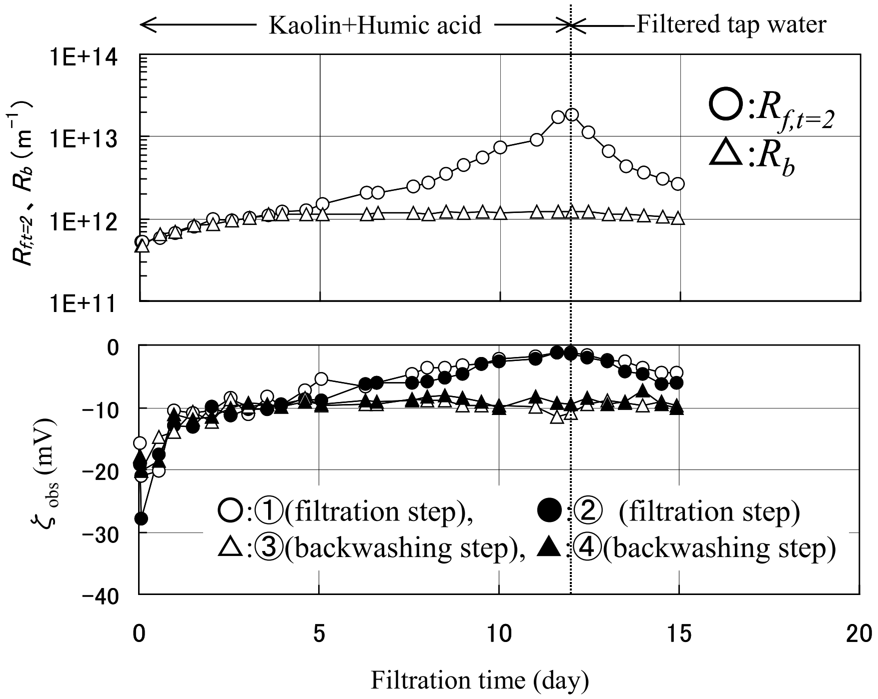

Fig.3 Change in the filtration resistance and zeta potential during the filtration of the model suspension(Kaolin 100mg/L and Humic acid 5 mg/L).

Result and discussion

Fig. 3 shows the change in the filtration resistance, $R_{f,t=2}$, R_b, and ζ_{obs} during the filtration of the model suspension(Kaolin 100mg/L and Humic acid 5 mg/L). In the early stage of the filtration $R_{f,t=2}$ and R_b were almost same value and increased gradually. After 5 days filtration $R_{f,t=2}$ increased rapidly and R_b became almost constant. Assuming R_b only reflects the internal fouling and $R_{f,t=2}$ reflects both the internal and external foulings, it was expected that in the early stage of the filtration the internal fouling increased by adsorption of macromolecule onto pore surface while the external fouling was removed by the backwashing and in the later stage the internal fouling become constant because of the saturation of the macromolecule adsorption and the external fouling increased by the accumulation of particles on membrane surface which could not be removed by the backwashing. In order to confirm the mass-transfer condition inside and outside of the membrane after 12 days filtration the feed water was changed from Kaolin and Humic acid mixture suspension to the filtered tap water. After this feed water changing $R_{f,t=2}$ decreased with time while R_b was almost constant. This observation shows that the external fouling was reversible fouling and $R_{f,t=2}$ was determined by the balance between accumulation rate and removal rate of the substance causing external fouling during a filtration cycle and the internal fouling, i.e. the macromolecule adsorption onto pore surface, was irreversible.

The zeta potential was measured 4 times during one filtration cycle, which were ① start and ②end points of filtration and ③start and ④end points backwashing steps. The zeta potential changed during the filtration reflecting the change in the filtration resistance. The zeta potentials measured at the filtration step and the zeta potentials measured at backwashing step showed almost the same change, respectively. In the early stage of the filtration these zeta potentials increased from about –20 mV, which would be the zeta potential of clean membrane, to –10 mV and after 5days filtration the zeta potential measured at the filtration step increased and approached to zero while the zeta potential measured at the backwashing step became almost constant at –10mV. These changes of the zeta potential were almost same trend observed in the filtration resistance during the filtration, which means the change in zeta potential will reflect the change in fouling status during the filtration.

The streaming potential can be expressed as a function of solution conductivity λ, surface charge density q_p, and pore radius r_p as following equation[5)].

$$SP = f(\lambda, q_p, r_p) = \frac{q_p}{\lambda_{eff}\,\kappa\,\mu}\frac{I_2(\kappa r_p)}{I_1(\kappa r_p)} \qquad (4)$$

where $1/\kappa$ is Debye length, λ_{eff} is effective conductivity and I is Bessel function. By the combination Eq.(4) with Eq.(3) the zeta potential can be also expressed as a function of λ, q_p, and r_p. As it is expected that λ should be constant and q_p would be changed by macromolecule adsorption onto pore surface and r_p would be changed by pore blocking by macromolecules or particles during the filtration, the change in the zeta potential measured at backwashing step would reflect the macromolecule adsorption onto pore surface and the zeta potential measured at filtration step would reflect the decreased in the apparent pore radius due to the pore blocking by fouling substance in addition to the macromolecule adsorption. This observation showed the pore size can be monitored during the filtration by streaming potential measurement.

Fig.4 shows the change in the $R_{f,t=2}$, R_b and the zeta potential during the filtration of surface water from Doshi river in Kanagawa prefecture. The changing patterns of the filtration resistances and the zeta potentials were almost same as the results obtained with the model suspension of Kaolin and Humic acid mixture. This observation shows that the internal fouling followed by the external fouling is specify to the employed experimental system regardless of feed water and the measuring the filtration resistances and the zeta potential will be useful for the monitoring for fouling status during filtration.

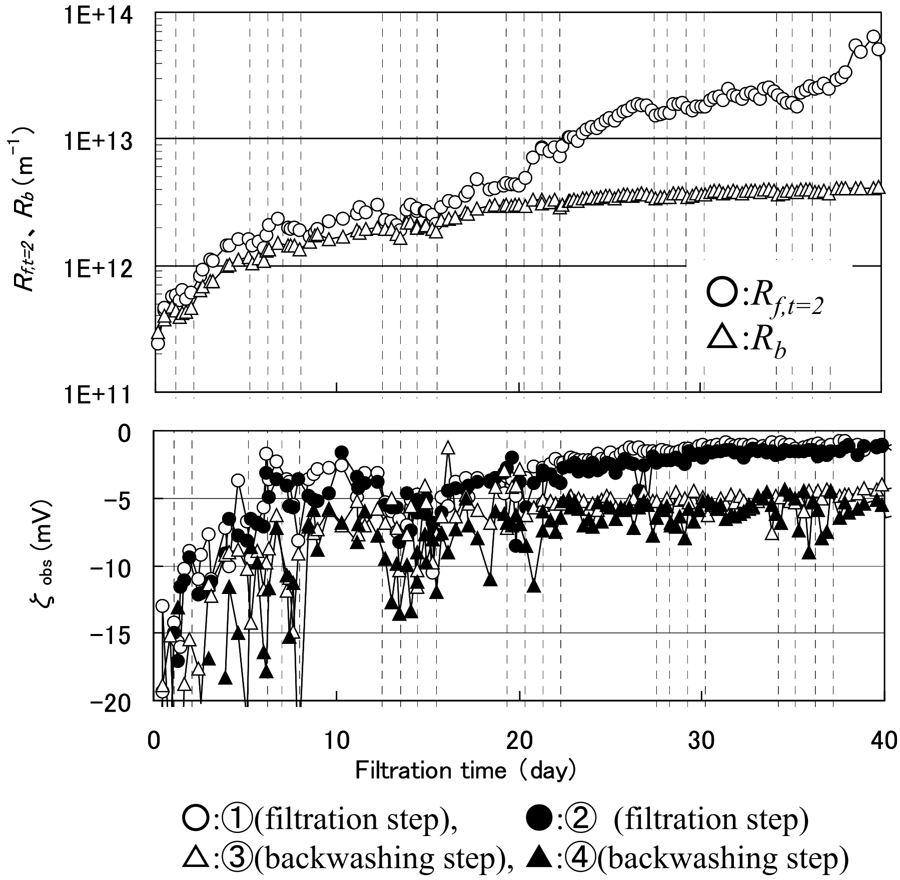

Fig.4 Change in the filtration resistance and zeta potential during the filtration of the surface water from Doshi river.

Conclusion

The fouling properties of PVDF hollow fiber Microfilration membrane during the filtration of a model suspension(Kaolin and Humic acid) and surface water from Doshi river were studied with a constant flow dead-end filtration equipment with backwashing and streaming potential measurement systems. The change in fouling status during the filtration was monitored by the filtration resistance R_f , the filtration resistance at the backwashing R_b, and streaming potential. By comparing R_f with R_b the fouling resistance could be classified into the internal fouling and the external fouling and it was shown that the fouling was the internal fouling in the early stage of filtration followed by the external fouling regardless of the feed water studied. The zeta potential reflected the change in the pore structure due to fouling during the filtration. It is shown that the measuring the filtration resistances and the zeta potential will be useful for the monitoring for fouling status during filtration.

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