Effect of Sodium Hypochlorite on Fouled Ceramic Membrane Reclamation and Flux Recovery

Prattakorn Sittisom, and Suraphong Wattanachira

Abstract—At present, a high quality drinking water is required to obtain a better life. Therefore, advanced technologies are developed in water supply plants. Among these technologies, ceramic membrane filtration is one of the best promising technologies having been received intensive attention. However, the major problem in membrane filtration is membrane fouling which lead to degradation of filtered water quality. So, this paper assesses the performance of chemical soaking with sodium hypochlorite on flux recovery of fouled ceramic membranes. The effects of sodium hypochlorite (NaOCl) concentration and soaking time on the flux recovery of fouled ceramic membrane were investigated. In the experiment, sixteen fouled membranes were soaking in the various conditions. The concentration of NaOCl was varied at 2,000, 3,000, 4,000 and 5,000 mg/L and each concentration was varied with different soaking times at 6, 8, 10 and 12 hours, respectively. The results showed that the highest efficiency of flux recovery is 69.68% which obtained at 5,000 mg/L of NaOCl concentration with 12 hours of soaking time.

Keywords—Ceramic Membrane, Sodium Hypochlorite, Natural Organic Matter, Chemical soaking

I. INTRODUCTION

NOWADAYS, water sources all over the world have been and are being polluted seriously by both common and new emerging pollutants. At the same time, a high quality drinking water is required to obtain a better life. Therefore, advanced technologies are developed and applied gradually in water treatment plants to effectively remove pollutants in water sources and to meet the strict potable water regulations. Among these technologies, membrane filtration is one of the best promising technologies having been received intensive attention. Through membrane filtration, (i) water quality regulations not only from chemical and physical aspects (such as organic matters and turbidity), but also from biological aspect such as pathogens, could be better achieved; (ii) the performance of the membrane system is less affected by fluctuate influent or other environmental factors in achieving good quality drinking water; and (iii) some conventional processes, such as the sedimentation and sand filtration processes, can be replaced by the membrane process in water treatment plants. As a result, construction area could be reduced and cost could be saved [1].

Ceramic materials are generally very stable chemically, thermally and mechanically, and in addition are frequently bio inert. They are therefore ideal materials for many applications in the chemical and pharmaceutical industry or in water and wastewater processing.

However, the major problem in membrane filtration is membrane fouling. Membrane fouling is also cause of the quality of permeate declined and membrane degradation. According to the type of fouling, membrane fouling can be categorized into 4 types: inorganic fouling/scaling, particles/colloids fouling, microbial/biological fouling, and organic fouling [2]. Maartens et al [3] reported treatment of the natural brown water with precoagulation increased DOM adsorption and decreased hollow-fiber UF (made from polysulfone) performance. Fouling control is very important procedure in membrane separation systems. A number of techniques were carried out including pretreatment processes of feed water (coagulation), improvement of operating conditions (i.e. transmembrane pressure, crossflow velocity, and backwashing), and membrane regeneration (i.e. chemical cleaning of membrane).

Natural organic matter (NOM) is defined as a complex matrix of organic materials present in all natural waters. As a result of the interactions between the hydrological cycle and the biosphere and geosphere, the water sources used for drinking water purposes generally contain NOM. Thus the amount, character and properties of NOM differ considerably in waters of different origins and depend on the biogeochemical cycles of the surrounding environments. Moreover, the range of organic components of NOM may vary also on the same location seasonally, due to for example rainfall event, snowmelt runoff, floods or droughts. Floods and droughts are the main impacts of climate change on water availability and quality. [4 - 11]
II. MATERIALS AND METHOD

A. Raw surface water

Table I summarizes the typical characteristics of raw water. Surface water from Ping River, Chiang Mai, Thailand is selected as raw surface water. The sampling point is situated 10 km upstream far from Chiang Mai municipal area. Ping River water is currently the main water source utilized to producing water supply for Chiang Mai city. In general, turbidity of Ping River varies due to season changes. However, it typically contains high concentration of suspended solid measured in term of “Turbidity value” between 50 - 220 NTU and high as 300 NTU in rainy season. Water samples from Ping River used in this study were pumped from the depth of about 30 centimeters below water surface at the sampling point.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC</td>
<td>6.746</td>
<td>mg/l</td>
</tr>
<tr>
<td>DOC</td>
<td>3.861</td>
<td>mg/l</td>
</tr>
<tr>
<td>UV254</td>
<td>0.1092</td>
<td>1/cm</td>
</tr>
<tr>
<td>SUVA</td>
<td>2.828</td>
<td>1/m(mg/l)</td>
</tr>
<tr>
<td>Turbidity</td>
<td>75.0</td>
<td>NTU</td>
</tr>
<tr>
<td>pH</td>
<td>7.67</td>
<td>s.u.</td>
</tr>
<tr>
<td>Temperature</td>
<td>26.5</td>
<td>Degree Celsius</td>
</tr>
<tr>
<td>Fe</td>
<td>0.100</td>
<td>mg/l</td>
</tr>
<tr>
<td>Mn</td>
<td>0.754</td>
<td>mg/l</td>
</tr>
</tbody>
</table>

B. Filtration experiment

The experiments operated by using batch-type ceramic membrane filtration unit which is shown in Figure 1. Ceramic membrane with 0.1 µm pore size, total surface area of 0.042 m², 3 centimeters in diameter, 10 centimeters height and 55 tubular channels utilized under up-flow mode of operation and controlled pressure of 200 kPa with the initial flux at 68.57 m³/m²-d of clean water filtration. Flux of ceramic membrane was determined from the following equation,

\[ J = \frac{dV}{dt \cdot A} \]

where \( J \) is the filtration flux, \( A \) is effective filtration area, \( dV \) is filtration volume and \( dt \) is filtration time.

The experiment did in the batch-type experiment. The fouled ceramic membrane was defined by measuring the flux of ceramic membrane with clean water. If filtration flux for filtrated water volume more than 500 ml was less than 10 m/d, the fouling was defined as a reversible fouling and ceramic membrane can be regenerated by using physically backwashed with clean water. If filtration flux was less than 10 m/d for filtrated water volume less than or equal 500 ml, the fouling was defined as an irreversible fouling and ceramic membrane can be regenerated by soaking with chemical. Fouled ceramic membranes were prepared by filtrated the ceramic membrane with Ping River water until the membrane was fouled with irreversible fouling (flux less than 10 m/d for filtrated water volume less than 500 ml). In each lab of filtration, the filtrated water was collected and analyzed for total organic carbon (TOC) concentration.

C. Backwash

When organic is accompanied by fouling formation on the feed side of the membrane surface, yielding a permeate flux reduction, increasing power consumption, and requiring more frequent periodical membrane cleaning [12 - 13]. Fouling type and accumulation rate depend strongly on feed water quality. Raw water fouling components and concentration decrease significantly when using various pretreatment methods, such as sand filtration, microfiltration, activated carbon and ultrafiltration. Despite pretreatment, a fouling layer may develop on the membrane surface during the filtration process. To resume the original product permeation rate, a backwash cleaning method must be used for the membrane followed by chemical cleaning of the membrane surface occasionally. The need for chemical cleaning is related to the need to remove fouling residues on the membrane surface that are not removed by backwashing.

1.) Physical Backwash

Backwash is generated when water is forced through the filter, counter to the flow direction used during treatment operations. This action cleans the media, when reversible fouling occurred, by dislodging accumulated particles, including microorganisms, captured by the filter media.

Backwash water typically averages 3% to 6% of total unit production and 5% of total unit production was selected for this experiment

2.) Chemical Soaking
The irreversible part of the fouling can only be removed by chemical soaking. In regular intervals the soaking is combined with application of chemical cleaners (NaOCl). A chemical soaking can be applied when the enhanced chemical backwash alone is not able to restore the membrane performance to a sufficient degree. The stability of the dead-end filtration process is governed by the efficiency of the backwash process and the degree of irreversible fouling.

In this experiment, all other conditions except NaOCl concentrations were the same for chemical soaking experiment. Effect of NaOCl on fouled ceramic membrane regeneration and flux recovery was tested at chemical doses of 2,000, 3,000, 4,000, and 5,000 mg/l at room temperature and each concentration was varied with different soaking times at 6, 8, 10 and 12 hours, respectively. These tests were conducted at a steady pressure 200 kPa.

III. RESULTS AND DISCUSSIONS

A. Ceramic membrane fouling and TOC reduction

A study was conducted to compare the changes of flux after recovery, which initial flux is 68.57 m³/m²-d, and the quality of filtrated water. Fig.2. shows the total organic carbon (TOC) concentration in filtrated water in each lap of operation. The TOC concentration was significantly removed through the ceramic membrane filtration; TOC concentration in filtrated water at the 10th lap was less than those at the 1st lap. The ceramic membrane was physically backwashed by using clean water for the reversible fouling in the first 9 laps and soaked by chemical solution for the irreversible fouling in at the 10th lap of operation. The results indicated that organic matter accumulated on the ceramic membrane surface which could not remove by using physical backwash and caused irreversible fouling that required chemical soaking.

B. Effect of chemical dose on flux recovery

Following the evaluation of ceramic membrane fouling, the effect of chemical dose on flux recovery of fouled ceramic membrane was essentially investigated. Within the chemical dose (2,000, 3,000, 4,000 and 5,000 mg/l NaOCl) tested, flux was very different after recovery in various chemical addition. Flux recovery, presented in Table 2, was calculated by using following equation,

\[
J = \frac{dV}{dt \cdot A}
\]

where \( J \) is the recovery flux, \( A \) is effective filtration area, \( dV \) is filtration volume and \( dt \) is filtration time.

From the results, it was found that flux recovery increased with the increasing of chemical concentration from 2,000 to 3,000, 4,000 and 5,000 mg/l of NaOCl, respectively. The highest flux after chemical soaking was found at 5,000 mg/L of NaOCl added which the highest NaOCl concentration in this studied. Due to NaOCl can reacted with organic matter which accumulated on the fouled ceramic membrane surface layer and caused an irreversible fouling, the higher concentration of NaOCl can cause the higher reaction and also enhanced the flux recovery of fouled ceramic membrane.

<table>
<thead>
<tr>
<th>Contact time (h)</th>
<th>NaOCl concentration (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>6</td>
<td>32.02</td>
</tr>
<tr>
<td>8</td>
<td>33.57</td>
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<tr>
<td>10</td>
<td>34.55</td>
</tr>
<tr>
<td>12</td>
<td>34.61</td>
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</tbody>
</table>

Percent of flux recovery of each chemical soaking condition were determined by comparing with the initial flux of ceramic membrane and the results are shown in Table 3.

<table>
<thead>
<tr>
<th>Contact time (h)</th>
<th>NaOCl concentration (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>6</td>
<td>46.70</td>
</tr>
<tr>
<td>8</td>
<td>48.96</td>
</tr>
<tr>
<td>10</td>
<td>50.36</td>
</tr>
<tr>
<td>12</td>
<td>50.80</td>
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The results from Table 3 showed that the highest percent flux recovery was found in the range of 66.54 - 69.68% at 5,000 mg/L of NaOCl. The increasing of NaOCl concentration was highly increased percent flux recovery. From the obtained results, it can be indicated that the different of concentration in chemical soaking was affected the flux recovery of fouled ceramic membrane.

C. Effect of contact time on flux recovery

In addition to the flux recovery enhancement, chemical contact time also investigated. Each concentration performed under following contact time: 6, 8, 10 and 12 h. Contact time effected insignificantly to flux recovery in each chemical dose. Fig.3. shows trend of flux after recovery and the percent flux recovery is presented in Fig.4. From the obtained results, it was found that percent flux recovery was increased when the contact time increase from 6 h to 8 h. However, percent flux recovery was slightly increased at the contact time higher than 8 h in each chemical dose. This indicates that the increasing of contact time was not significantly affected the flux recovery of fouled membrane.

![Fig. 3 Flux on various NaOCl concentrations and contact times](image)

![Fig. 4 Percent flux recovery on various NaOCl concentrations and contact times](image)

IV. CONCLUSIONS

In this study, the irreversible fouling is a main problem for ceramic membrane fouling, according to organic matter which covered on the membrane surface and reduced membrane flux. In term of fouled ceramic membrane reclamation and flux recovery, chemical soaking was an effective method for the irreversible fouling removal and ceramic membrane flux recovery.

Chemical dose and contact time were investigated in chemical soaking. It is important to find the optimal condition in chemical soaking which is the most effective for fouled ceramic membrane reclamation and flux recovery. In this study, there are 16 fouled ceramic membranes performed under 16 conditions by varied 4 chemical dosage and 4 contact times. The most effective condition is 5,000 mg/l of NaOCl concentration at contact time 12 h in chemical soaking which provided 69.68% of flux recovery. The increasing of NaOCl concentration during chemical soaking was higher increased of flux recovery than the increasing of soaking time. From the results, it can be concluded that the chemical concentration of chemical soaking was highly affected the flux recovery of fouled ceramic membrane.

V. ACKNOWLEDGEMENT

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REFERENCES


