OPTIMIZATION OF MICROFILTRATION MEMBRANE CLEANING PROCESS IN PRODUCED WATER TREATMENT

Anggun Puspitarini Siswanto and Ahmad Dzul Aufa
Chemical Engineering Department, Diponegoro University
Jln. Prof. Sudharto, Tembalang, Semarang, 50239, Telp/Fax: (024)7460058
Supervisor: Dr. I Nyoman Widiasa, ST., MT
Email: femme153@yahoo.com

Abstract

Produced water is contaminated water that is extracted together with the oil in oil production operations. Produced water is a mixture of organic and inorganic material. To remove dispersed oil in produced water can use membrane technology, especially microfiltration membrane. The use of membrane filtration in produced water process can be cause fouling in membrane. Fouling is a process resulting in loss of performance of a membrane due to deposition of suspended or dissolved. One of way to treat fouling in membrane is cleaning process. This research investigates the use of microfiltration membrane in produced water treatment and its cleaning process. The purposes of this research are to determine microfiltration membrane cleaning effect of produced water using NaOH as cleaning solution, to determine concentration effect of chemical cleaning agent in membrane cleaning process as well as to determine cleaning period effect of membrane cleaning process. This research used NaOH as cleaning solution. It will be determined the effectiveness of cleaning used NaOH solution. Concentration variables are: 0.1%, 0.3% and 0.5%. Moreover the cleaning period variables are 15 minutes and 30 minutes. Analysis procedure was done by determine the recovery flux permeat of process. According to the results previously analyzed, the following conclusions can be stated: NaOH gives satisfied effectiveness in microfiltration membrane cleaning process. In this research, we use NaOH as cleaning agent for removing the organic fouling caused by produced water. The NaOH concentration as cleaning agent which increases the flux highest is 0.1% NaOH and cleaning period 15 minutes. In this condition, the flux increase about 66.66% in first cleaning and 35.27% in second cleaning.

Keywords: *microfiltration, cleaning process and produced water.*

INTRODUCTION

Produced water is contaminated water that is extracted together with the oil in oil production operations [1]. Produced water is conventionally treated through different physical, chemical, and biological methods [2]. Several method in produced water treatment are: oil removal, dissolved organic compound removal, suspended solid removal, dissolved gas removal, softening [3] and desalination [4]. Focus of produced water treatment for reinjection is suspended solid removal and oil removal in produced water. It was use coagulation combination, flocculation and sand filter to remove suspended solid. Conventional treatment system based on gravity separation (skimmer and corrugated plate interceptor or CPI), flotation [5] and centrifugal separation (hydrocyclone) can separate free oil content in produced water [6]. Furthermore, to remove dispersed oil in produced water can use membrane technology, especially ultrafiltration/microfiltration membrane.

The use of membrane filtration in produced water process can be cause fouling in membrane. Fouling is a process resulting in loss of performance of a membrane due to deposition of suspended or dissolved [7]. The effect of fouling is decrease of permeat rate and increase of pressure drop. There are 3 kinds of foulant: organic foulant, inorganic foulant and biology foulant. Membrane fouling occurs through one or more of the following mechanisms: (i) accumulation of solute and gradual irreversible changes in the polarized layer (such as cake formation), (ii) surface adsorption: deposition of solutes and (iii) adsorption: deposition of solute within the membrane. There are many factors contributing to fouling including surface properties (chemistry, morphology, etc.), hydrodynamic conditions, ionic strength and solute concentration [8].

In addition to hydraulic cleaning, chemical cleaning in which cleaning agents are used is a common way to remove foulants. Although chemical cleaning is a useful way to restore membrane performance, membrane cleaning procedures are often based on rules of thumb and are usually conservative [9]. One of way to treat fouling in membrane is cleaning process. It needs research to know the optimization in microfiltration membrane cleaning on produced water treatment. An optimum membrane cleaning needs a comprehensive understanding about interaction fouling, membrane and cleaning solution as well as effect of operation condition in cleaning process, such as: cleaning solution concentration, pH [10], temperature [11] and cleaning period.

This research investigates the use of microfiltration membrane in produced water treatment and its cleaning process. The purposes of this research are to determine microfiltration membrane cleaning effect of produced water using NaOH as cleaning solution, to determine concentration effect of chemical cleaning agent in membrane cleaning process as well as to determine time effect of membrane cleaning process.

MATERIALS AND METHOD

Materials

The primary raw material for research, produced water, were made as synthetic produced water with 100 ppm oil content. The demineralised water was taken from Water Treatment Laboratory in Chemical Engineering Department. The chemical materials used were purchased from Indrasari Store Semarang.

This research used NaOH as cleaning solution. It will be determined the effectiveness of cleaning used NaOH solution. Concentration variables are: 0.1%, 0.3% and 0.5%. Moreover the cleaning period variables are 15 minutes and 30 minutes. Analysis procedure will be done by determine the recovery flux permeat of process.

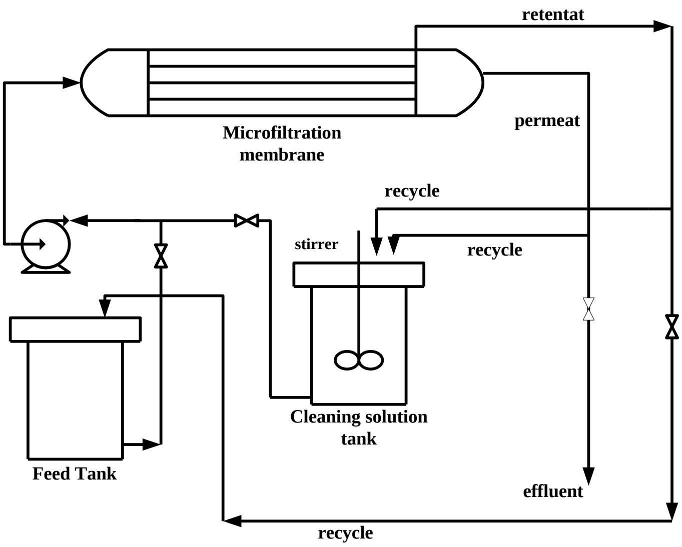

Figure 1. Design of Filtration and Cleaning Microfiltration Membrane

Experimental Setup

Experimental procedure consisted in the following three stages:

1) *Water permeability before cleaning*. Membranes were tested to determine the initial water permeability with demineralized water. All the samples were taken from the same flat sheet MF module, from different variables in the module representing the research variable. Six membrane samples were tested for each variable. The permeate flow of each sample was measured every 5 min during 30 minutes. Each experiment was done three times. The permeate flux was then calculated for each membrane.

2) *Chemical cleaning*. The produced water feed was run after the calculation of demineralized water flux. It was done three times to calculate the produced water flux. The next experimental setup is cleaning process. The chemicals used in the experiments were chosen according to the membrane literature's recommendations for organic fouling, NaOH solution, as well as a consequence of the results obtained in the previous research. The different concentrations of chemical cleaning agent were recirculated in MF membrane module at a pressure of 0 atm.

3) *Water permeability after cleaning*. After chemical cleaning, water permeability with demineralized water was again determined in order to compare it with the initial value and to calculate the recovery (in percentage) of flux restoration. The operation conditions were the same as those in the first stage.

This experimental procedure was carried out three times for each concentration of NaOH solution at two different cleaning periods: 15 minutes and 30 minutes. Cleaning conditions shown would not cause damage to the membrane since the concentrations examined in this study were within the ranges recommended by literature review. After each experiment, cleaned membranes were replaced for new fouled samples.

RESULT AND DISCUSSION

Characteristic of Feed

Analysis of feed characterization done by determine the turbidity number. We use synthetic produced water as feed with oil content 100 ppm. The determination of turbidity done by using Orbeco-Helligs turbidimeter with standard value is NTU. As comparison, we also determine the turbidity of produced water sample taken from Kawengan Reservoir, Cepu. Sample the cooagulate with PAC 100 ppm and filtered by sand filter. The turbidity result can be show on Table 4.1.

.Table 4.1 Turbidity of Produced water

Sample	Turbidity (NTU)
Synthetic produced water 100 ppm	1,4 – 3,6
Produced water SPU Kawengan	5,64

Membrane Permeability

The performance of membrane separation processes can be generally expressed by membrane permeability and selectivity. Bigger the membrane permeability and selectivity value means the membrane has better performance [12]. Membrane permeability indicates the ability of membrane to pass the water [13]. This research used flux of pure demineralized water as parameter, which is 423.225 lt/m^2.hour. Mulder [14] believes that the permeability of membrane related to the selectivity and diffusivity of its membrane.

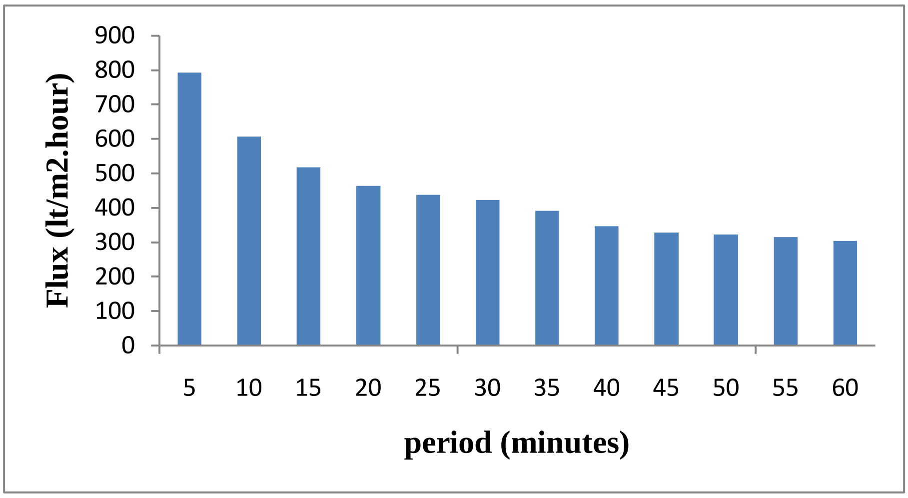

Figure 4.1. Flux Profile of Demineralized Water

In Figure 4.1 show that the flux of demineralized water is decrease but becomes stable in 40 minutes. Membrane was tested to determine the initial water permeability within 60 minutes and the flux determine for each 5 minutes. Permeability and selectivity in membrane process is an emerging factor therefore to maintain its stabilization the membrane cleanness should be holds on [15]. In tested membrane, the flux of pure demineralized water initially determine which the value will be use as reference of membrane permeability [16].

Characteristic of Flux Degradation

This research uses synthetic produced water with oil content 100 ppm as feed. Produced water is water formed by substrate from oil production which is extracted together with oil and gas in to surface area [17] (Patin, 1999). Produced water contains organic compound in form of three different kind of oil, such as dispersed oil, dissolved oil and free oil [18] (Yang dan Tulloch, 2002). This organic compound becomes the most significant factor effect flux degradation [19] (Lahoussine-Turcaud, dkk, 1990). As shown in Fig 4.2, there is flux degradation while the filtration process. This flux degradation caused by fouling in the membrane surface.

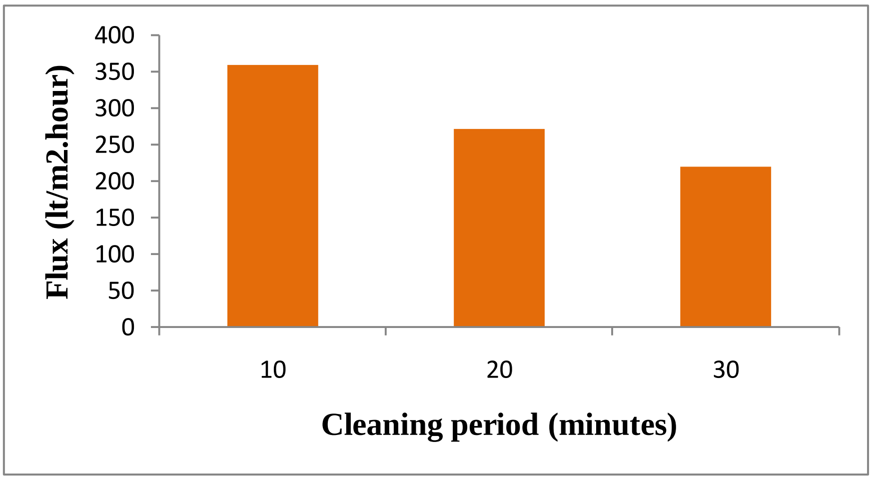

Fig 4.2. Flux profile of produced water

Membrane fouling occurs through one or more of the following mechanisms: (i) accumulation of solute and gradual irreversible changes in the polarized layer (such as cake formation), (ii) surface adsorption: deposition of solutes and (iii) adsorption: deposition of solute within the membrane [8]. In Fig 4.1 flux of produced water is plotted versus the cleaning period. The figure shows that the produced water flux decrease in every period. In the first 10 minutes, flux determined was 358.794 lt/m^2.hour while in 20 minutes the flux becomes 271.622 lt/m^2.hour and in the last 30 minutes the flux of produced water was calculated 219.193 lt/m^2.hour.

Characteristic of Permeate

Analysis also done for determining the flux of synthetic produced water after cleaning process. It gives different range of turbidity value from 0,95-1,15 NTU. Complete data abaout turbidity value of feed and permeat describe in Table 4.2.

Table 4.2 Turbidity value of synthetic produced water feed

Running	Turbidity before filtration (NTU)	Turbidity after filtration (NTU)	% Turbidity degradation
1	3,6	1,13	68,61
2	1,4	0,96	31,43
3	1,9	1,10	42,11
4	1,6	1,02	36,25
5	1,7	1,07	37,06
6	1,6	0,98	38,75

In Table 4.2 show that higher turbidity value of feed the percent turbidity degradation also higher. The table also indicate that the permeate turbidity relatively stable under 1.15 NTU. As stated by Durham dan Walton [20] that the microfiltration membrane can reduce the value of suspended solid, microorganism and turbidity in waste water.

Membrane Cleaning

Cleaning Concentration Solution 0.1% NaOH

Fig. 4.3 shows the flux profile at cleaning concentration solution 0.1% NaOH. It contains several results such as: flux of pure demineralized water, flux of initial produced water, flux of demineralized water before cleaning, flux of demineralized water after cleaning and flux of produced water after cleaning.

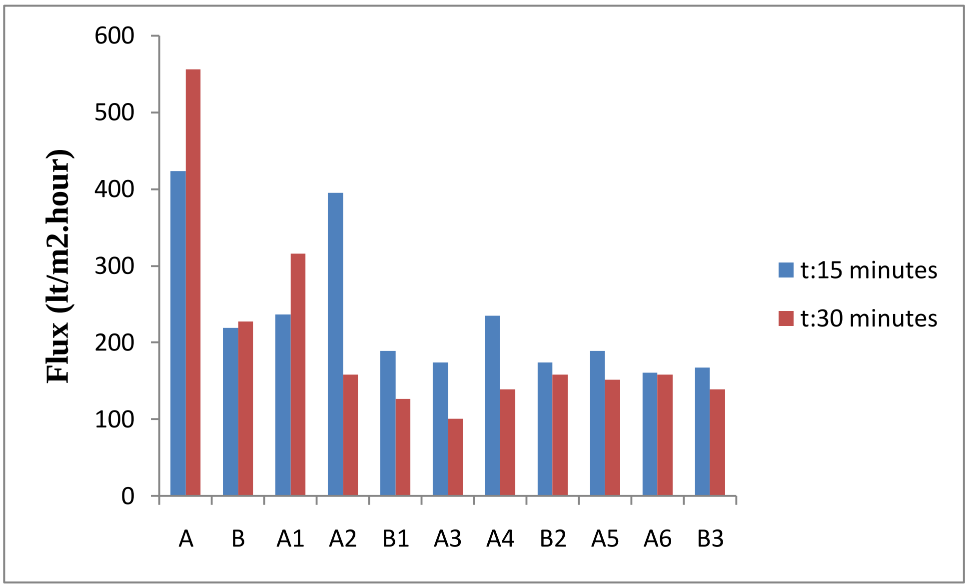

Fig 4.3. Flux Profile at cleaning concentration solution 0,1% NaOH with parameters: pure demineralized water (A), initial produced water (B), demineralized water before cleaning (A1, A3, A5), demineralized water after cleaning (A2, A4, A6), produced water after cleaning (B1, B2, B3)

The experimental data is graphically represented in Fig 4.3, showing the flux profile of each parameter. When the cleaning period is 15 minutes, the flux of demineralized water before cleaning is 236.87 lt/m^2.hour and the flux after cleaning is 394,79 lt/m^2.jam. It indicates the flux increment about 66.66%. The flux increment is also shown on second cleaning. Nevertheless, the flux decrease on third cleaning. In cleaning period 30 minutes, the flux of demineralized water after first cleaning is lower than the flux before cleaning. Moreover, the flux of demineralized water increased after second and third cleaning.

Cleaning Concentration Solution 0.3% NaOH

Fig. 4.4 shows the flux profile at cleaning concentration solution 0.3% NaOH. It contains several results such as: flux of pure demineralized water, flux of initial produced water, flux of demineralized water before cleaning, flux of demineralized water after cleaning and flux of produced water after cleaning.

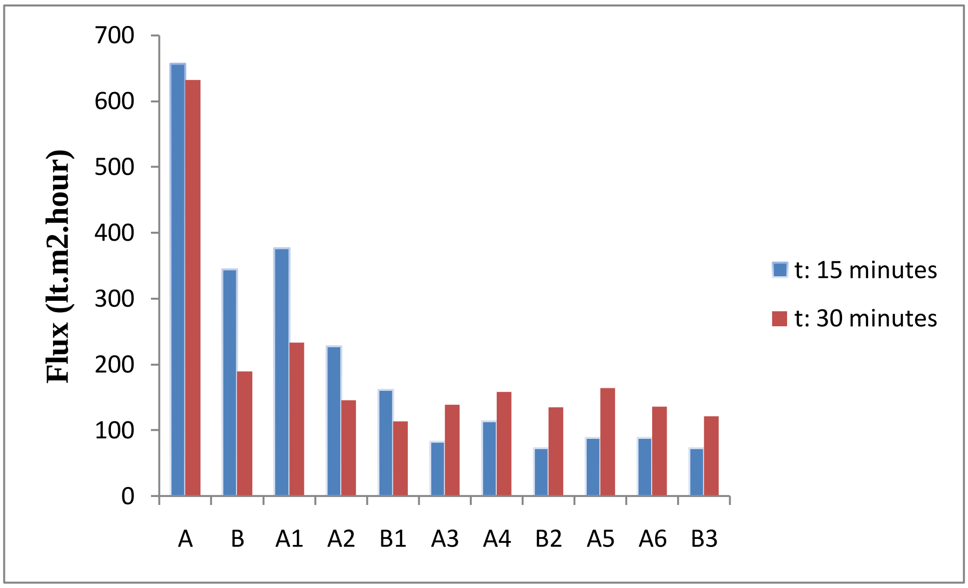

Fig 4.4. Flux Profile at cleaning concentration solution 0,3% NaOH with parameters: pure demineralized water (A), initial produced water (B), demineralized water before cleaning (A1, A3, A5), demineralized water after cleaning (A2, A4, A6), produced water after cleaning (B1, B2, B3)

Fig 4.4 represents the flux profile at cleaning concentration solution 0.3% NaOH with cleaning period 15 minutes and 30 minutes. Based on the data, the increase of cleaning period does not effect to the increase of flux. On the other hand, it shows the fluctuation of flux. It means that longer cleaning period can not increase the cleaning optimization. As stated by Delijani dan Koshky [21] that cleaning process which conduct on multi stage more optimum compare with single stage in the same total amount of cleaning period.

Cleaning Concentration Solution 0.5% NaOH

Fig. 4.5 shows the flux profile at cleaning concentration solution 0.5% NaOH. It contains several results such as: flux of pure demineralized water, flux of initial produced water, flux of demineralized water before cleaning, flux of demineralized water after cleaning and flux of produced water after cleaning.

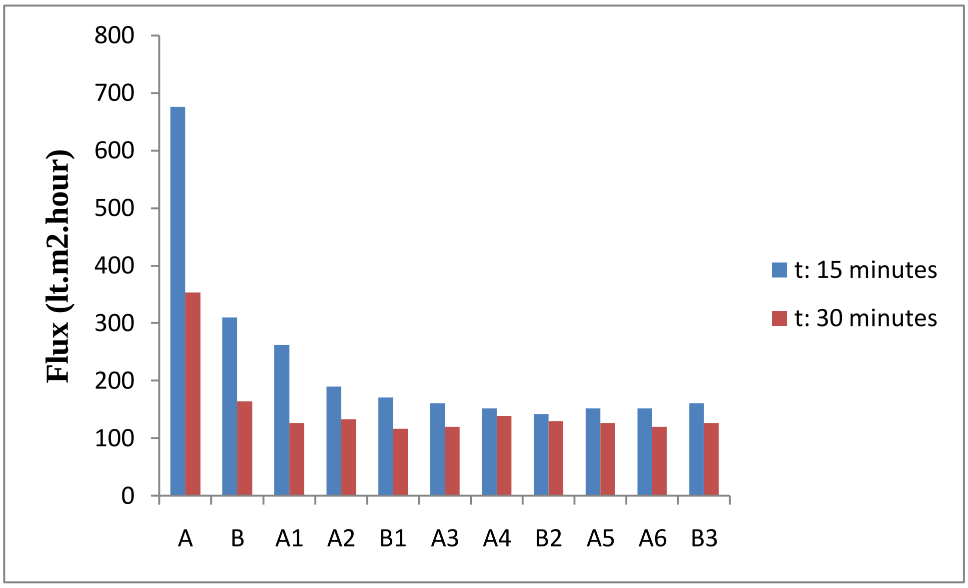

Fig 4.5. Flux Profile at cleaning concentration solution 0,5% NaOH with parameters: pure demineralized water (A), initial produced water (B), demineralized water before cleaning (A1, A3, A5), demineralized water after cleaning (A2, A4, A6), produced water after cleaning (B1, B2, B3)

In Fig 4.5 the flux profile is plotted by several research variables. The figure shows that in cleaning period 15 minutes, the flux of demineralized water after cleaning decreased relatively. While in cleaning period 30 minutes, there is a fluctuation of demineralized water flux. From the result above, the increment of cleaning agent concentration does not increase the flux but it decrease the flux. It is because of the cleaning agent compatibility with membrane. Membrane with high tolerance of chemicals will not influenced by chemical concentration increase so there is more possible alternative to choose the cleaning agents [22]. The opposite condition will be happen if the membrane tolerance to chemical is low.

Based on the research result, cleaning agent with concentration 0.1% NaOH and cleaning period 15 minutes give optimum flux increment. It is because the cleaning process occur in range of pH as allowed for membrane cleaning process (maximum pH=12). Higher pH is not allowed for this condition. In fact, fouling phenomenon can not be avoids then it needs a periodic cleaning process to maintain the membrane performance.

CONCLUSION

According to the results previously analyzed, the following conclusions can be stated: NaOH gives satisfied effectiveness in microfiltration membrane cleaning process. In this research, we use NaOH as cleaning agent for removing the organic fouling caused by produced water. The NaOH concentration as cleaning agent which increases the flux highest is 0.1% NaOH and cleaning period 15 minutes. In this condition, the flux increase about 66.66% in first cleaning and 35.27% in second cleaning.

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