Water Supply Management System And Social Capital

Volume 3

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preface

This book is a third volume from the series of international conference initiated by the Kyoto University GCOE program "Global Center for Education and Research on Human Security Engineering for Asian Megacities," which launches a network of global academic research partnerships among Asian countries since 2008. The book contains 31 selected paper of "The Third International Conference of Water Supply Management System and Social Capital " and funded by the Kyoto University GCOE program.

The third international conference on Water Supply Management System and Social Capital was held on March 21-22, 2011 at Widyaloka Building of Brawijaya University, Malang, Indonesia. The conference presented 42 selected papers and attended by 250 participants covering scholars, practitioners, undergraduate and graduate students from Indonesia, Singapore, Japan, Korea and India involved in the warm sharing knowledge and experience. The purpose of the book is to share theoretical and practical knowledge of water supply management system and social capital by providing a variety of issues of water supply and management in developing countries, as many cases exemplifed in this book occur in Indonesia and other developing countries. The book is divided into 6 parts, covering 1) collective action and water governance issues; 2) social and management issues in water provision and distribution; 3) other sustainability issues of water supply and services, 4) methods and measures for water demand and supply, 5) regulations and policies for water use, and 6) techniques for monitoring water qualities.

We would like to thank contributors of Indonesia, Malaysia, Japan, Korea and India, especially Asep Karsidi, Indonesian National Coordinating Agency For Survey and Mapping and Professor Gautam Ray, Kyoto University. We would also like to express our deep gratitude for staff efforts of Assistant Professor Dimas Wisnu Adrianto (M.Env), and Brawijaya University team for steering the workshop and publishing this book, as well as Associate Professor Matsushima KAKUYA (Ph.D), Assistant Professor Masamitsu ONISHI (Ph.D), and Hayeong JEONG (Ph.D), Department of Urban Management, Graduate School of Engineering, Kyoto University.

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Chapter 28

Produced Water Treatment Using Polyamide Thin-Film Composite Reverse Osmosis Membrane

Jono Suhartono, Sirin Fairus, Cinta Dwi Wahyuni, Riska Suci Munawar

28.1 Introduction

Water is one of the human basic needs and provided for almost three fourth of earth surface such as in ocean, lake, river, etc. Produced water is a byproduct that produced from oil wells (Murray, G.C., 2003). It also becomes the highest waste that produced during oil extraction (Ali, S.A., 1999, Khatib., Z., 2003). The method such as thermal heavy oil recovery that is oil sand processing and steam assisted gravity drainage (SAGD) the volume ratio produced between water and oil generally can be reach up to 3-12:1. This ratio shows how many produced water generated from an oil well. As Oil stock decreasing in wells, produced water generated from the well will increase because the need of injection water into well also increasing.

According to the International Association of Oil and Gas Producers (OGP), about 17 million m^3 produced water obtain in a day around the world both at *on shore* and *off shore*. This amount is equivalent to 120 million barrel oil per day. On the other hands, 15-20 billion barrel produced water generated every year in USA (Veil, J.A., 2004).

Treating and recycling produced water very important in order to maintain the production of oil and gas. Furthermore, organic impurities containing in produced water can be lead to the serious problem to environment, Industry and human life. This contaminant will make corrosion in pipe and higher energy to transport. Conventional treatment of this water consisted of gravity separation and skimming, dissolved air foatation, de-emulsifcation, coagulation, and focculation (Cline, J.T., 1998). However, it has some weakness such as at gravity separation process need longer time to separate, diffcult to separate oil and water when the oil is very small, and this process also can not yield output that meet the quality requirement. In addition, it also yielded high volume sludge and need high operation cost.

Membrane fltration process such as reverse osmosis offers many advantages for treating oiled water. For instance, this process do not need chemical additive, membrane can be used in repeatedly and easy in operation since membrane is an automatic device.

This research goal are to determine of operation condition that obtained the lowest oil content in water by varied the temperature and trans membrane pressure, to analyze pH, oil content and suspended solid in permeate, and to analyze the effect of parameter to fux and membrane permeability.

28.2 Materials and Methods

28.2.1 Materials

Produced water was obtained from one of the company in Sumatra Island. It had been passed from Gas Boot and Wash Tank, so that obtained treated produced water with oil content 26.33 mg/L.

A) Membrane Specifcation

This research was done in reverse osmosis membrane with spiral wound type membrane. The membrane was bought from a market in Indonesia and manufactured by Dow Film tech with series TW30-1812-100. Membrane module is spiral wound with material used is Polyamide Thin-Film Composite (TFC). Maximum temperature Operation that can be operated is 113F (45°C) and maximum membrane pressure operation is 150 psi (10 bar) while maximum passing fow rate on membrane is 2.0 gpm (7.6 lpm). Membrane dimension itself has diameter to length is 2" to 12".

B) Membrane Apparatus

Membrane apparatus was bought from Institute Technology Bandung (ITB) with maximum pump pressure is 110 psi and pump type is diaphragm pump. Moreover, the feed tank is modifed so that can be operated in different temperature.

28.2.2 Methods

The research started by waste sample pretreatment using centrifugation at 5000 rpm. After that the sample was passed to reverse osmosis membrane. The variable studied in this research are trans membrane pressure (TMP) from 1-5 bar and temperature from 36-40°C at operated TMP that yielded permeate with the lowest oil content.

28.2.3 Analysis

Analysis of permeate consisted of oil content, total suspended solid (TSS), and pH.Oil content analysis was done by SMWW-5520 C Partition-Infrared Method (FTIR spektrofotometri) method at wavelength 2900-3000. Meanwhile, TSS analysis was done by gravimetric method and pH value detected by pH meter.

28.3 Results and Discussion

28.3.1 Effect of trans membrane pressure and temperature on oil content in permeate

Waste produced water used in this research has been processed by Gas Boot and Wash Tank so that the oil content value measured in this sample was 26.33 mg/L.

Table 28.1 Oil content after and before *pre-treatment*

No	Sample	Oil Content (mg/L)
1	Before Pre-treatment	26.33
2	After Pre-treatment	18.33

This produced water then centrifuged at 5000 rpm for 10 minutes so that the oil content in the sample reduced to 18.33 mg/L that shown in Table28.1.

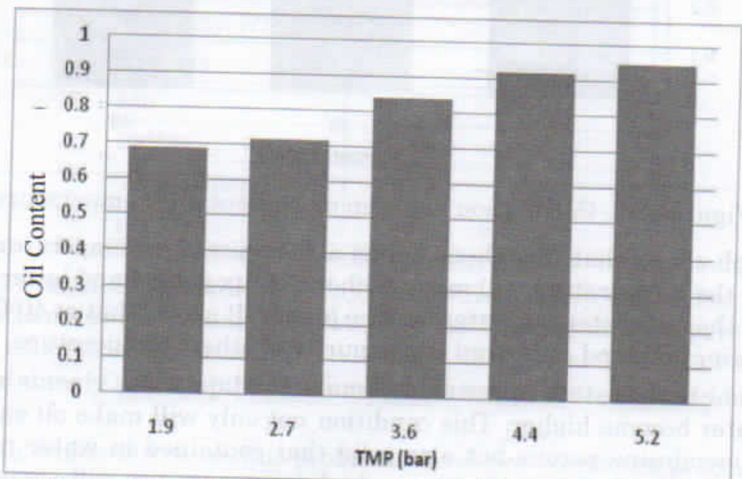

Figure 28.1 Correlation between oil content and TMP value

Membrane selectivity is membrane ability to separated components from the feed. Ideally, membrane has high selectivity and permeability. Refer to the fgure 1, higher the TMP value will make oil concentration on permeate become higher since TMP value proportional to the fux. Generally, a phenomenon that fux will oppose the selectivity occurs in membrane process so that higher the fux will tend to make lower the selectivity. The graph shows that the correlation between TMP value to the oil content that is oppose each other. This was caused by higher TMP value will make pressure in membrane become higher too and lead to the higher fux that passed the membrane. On the other hands, high pressure in membrane make oil molecules that stacked in the membrane surface pushed by those high pressure, this condition will make those molecules more easy to pass the membrane porous that lead to the decreasing in membrane selectivity.

Oil content that contaminated in permeate will be determined from this TMP variation and become the TMP that use for the next varition that is temperature. The operation itself will be choosen for TMP with the lowest oil that containing in permeate. The lowest oil content is obtained from TMP that is 1.9 bar. So that, this TMP will be used for next operation.

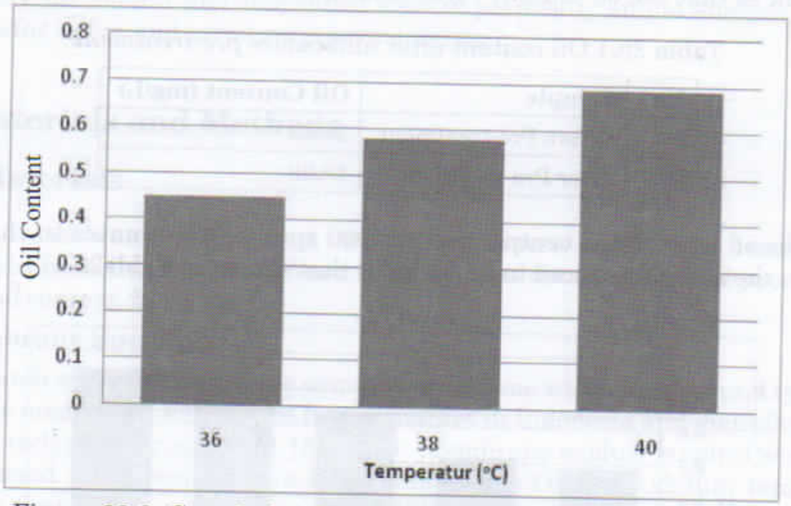

Figure 28.2. Correlation between oil content and temperature

The graph shows that this phenomenon also occurred in temperature variation that higher the temperature will make higher the fux gained and lower selectivity obtained so that oil content in water become higher. It shows that at 40°C the lowest purity of water obtained compared to the purity of others temperature.

The higher temperature operated will make the liquid less viscous and oil solubility in water become higher. This condition not only will make oil easier to penetrate the membrane porous but also solid that contained in water more soluble that make permeate less pure. Moreover, higher temperature will cause swelling in membrane and make the membrane porous larger so membrane become less selective.

Table 28.2 Oil containing in water at TMP and temperature variation

No	TMP value(bar)	Temperature(°C)	Oil Content(mg/L)
1	1.9	40	0.69
2	2.7	40	0.72
3	3.6	40	0.84
4	4.4	40	0.92
5	5.2	40	0.95
1	36	1.9	0.45
2	38	1.9	0.58
3	40	1.9	0.69

One of the purposes of this research is yielded permeate from the process hopefully can meet the reinjection water standard quality. This reinjection water will be injected to the oil well to overcome the problem that caused by less oil containing in the well. Unfortunately, reinjection water has their own standard and differ between one well to others. Table 28.3 shows the standard quality of reinjection water from Daqing oilfeld.

Table 28.3 Standard quality of reinjection water (Qiao, X, 2008)

Parameter	Water reinjection standar
Oil Content, mg/L	<0.1
SS content, mg/L	<0.1
Turbidity, NTU	/
Total Fe	<0.5
Mn	/
Sulfde	<0.5
Total Mineral	/
pH	6-9

/: no specifc standard

It shows that oil concentration in injection water is very small that is less than 0.1 mg/L, otherwise the research shows that the best result from reverse osmosis separation using this membrane only yielded 0.45 mg/L at TMP 1.9 bar and 36°C. This value did met the standard yet since it was upper than it should be that is 0.1 mg/L.

One factor which can cause this problem was at pre-treatment process that used centrifuge and gained oil content in the sample laid to 18.33 mg/L. this value still too high for reverse osmosis membrane processes.

Oil contained in produced water is dispersed oil. Addition of corrosion inhibitor at the oil well can make oil form an emulsion that has more chemically stable. In result, this oil cannot be separated by centrifugation effectively at those conditions.

It also shown from the data after and before pretreatment that was not signifcantly different.

Although this water could not meet the standard quality to be reinjection water, the result shows that it met the Indonesian standard for disposal produced water to the environment that is less than 15 mg/L. Standard regulation for this disposal produced water shown in table 28.4. Treatment produced water using reverse osmosis membrane could obtain permeate with oil content 0.4-1 mg/L. it mean that even the water cannot meet the requirement to be reinjection water it is safe to dispose to the environment according to that regulation.

Table 28.4 Standard Regulation for Produced Water Disposal (Syafruddin, M., 2008)

Waste Produced Water Disposal	Oil Concentration (mg/L)
OSPAR convention for offshore	30
US Standard for onshore	29
US Standard for offshore	29
Atlantic Ocean and North Sea	30
Indonesian Standard Regulation	15

28.3.2 Effect of TMP value and temperature on pH

Table 28.5 comparing before and after pre-treatment

No	Sample	pH
1	Before pre-treatment	5.6
2	After pre-treatment	7.1

From the table can be seen that by pretreatment done to the sample yielded that pH value after pretreatment is higher than before pretreatment. Generally, chemical additives were added to the produced water to prevent solidifcation during oil milling. Some of this additive usually has an acid base in result by adding those would make pH in produced water decreased. Moreover, natural soluble organic compound also produced in those water that lead to the high acidity in those water.

From Table 28.6 can be seen that feed pH is lower than the yielded permeate. Separation process using reverse osmosis membrane had been rejected some acid component from feed water so that permeate pH value become higher than before separation.

Lowest TMP (1.9 bar) and temperature (36°C) obtained permeate with highest purity. pH at this condition was 7.6. It proved that when then purity of permeate is high many of components in produced water separated, included acidic materials. Average permeate pH value that obtained was ranged from 7-8. It means that this pH had been fulfilling the standard quality for reinjection water.

Table 28.6 pH comparing at TMP value and temperature variety

No	TMP value (bar)	Temperature (°C)	pH	
			Sample	Permeate
1	1.9	40	7.1	7.58
2	2.7	40	7.1	7.56
3	3.6	40	7.1	7.52
4	4.4	40	7.1	7.5
5	5.2	40	7.1	7.48
1	36	1.9	7.1	7.58
2	38	1.9	7.1	7.6
3	40	1.9	7.1	7.6

28.3.3 Effect of TMP and temperature on total suspended solid (TSS)

Total suspended solid contaminated in produced water is a solid that precipitated such as sand, salts, clay, carbonate, corrosion product and other suspended solid gained from oil milling.

Table 28.7 Comparing of TSS value after and before pre-treatment

No	Sample	TSS (mg/L)
1	Before pre-treatment	527
2	After pre-treatment	15.2

The table shows, suspended solid concentration on produced water was so high and this can be seen too from the water turbidity. Commonly, turbidity is close to the suspended solid level that contained in water. It also shows that by pretreatment done to the sample had been greatly decreased suspended solid concentration. It mean that centrifugation method that applied had been effectively reduced this impurities. It separation principal is using centrifugal force in order to precipitated molecule that has bigger density and form separated layer between them.

The table above shows that TSS value that gained from TMP and temperature variation did signifcantly different. It shows that neither tempertature nor TMP signifcantly infu - enced the membrane performance to separate suspended solid.

TSS value obtained from 0-0.1 mg/L, so that, it can meet the quality of reinjection water. This result is appropiate to the reverse osmosis membrane working principal that can reject suspended solid excellently.

Table 28.8 TSS Comparing at TMP value and temperature variety

No	TMP value(bar)	Temperature(°C)	Oil Content(mg/L)
1	1.9	40	0
2	2.7	40	0
3	3.6	40	0.1
4	4.4	40	0.1
5	5.2	40	0.1
1	36	1.9	0
2	38	1.9	0
3	40	1.9	0

28.3.4 Effect of TMP on permeate fux

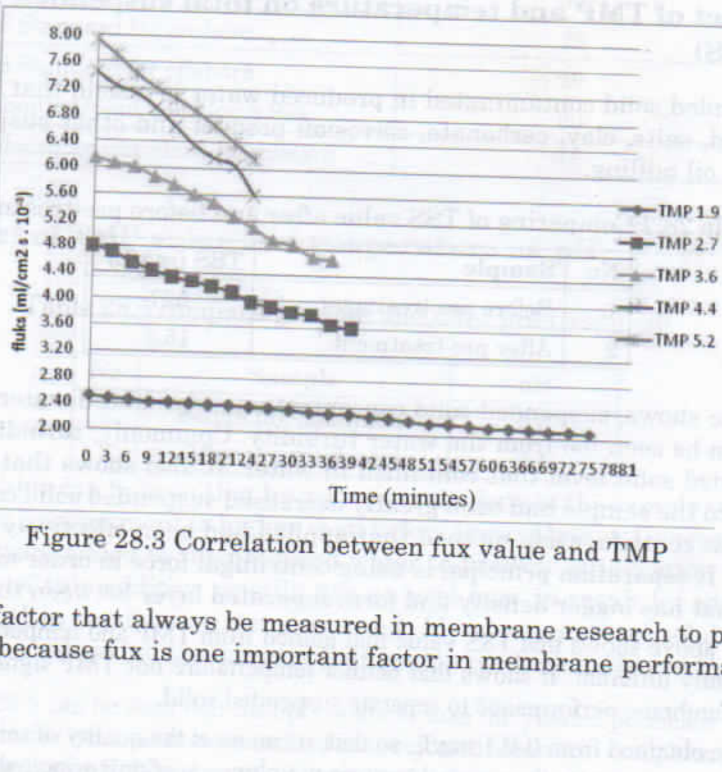

Figure 28.3 Correlation between fux value and TMP

Flux is a factor that always be measured in membrane research to process produced water because fux is one important factor in membrane performance. Flux defned as:

$$J = \frac{V}{A.t} \quad (1a)$$

Flux data in this research was obtained by calculating time required for gaining 10 mL permeate. Data sampling was done in 3 minutes interval time until obtained 5500 mL permeate. According to the fgure 3, the longest experiment time will re -

sult in smallest fux fowrate. This was caused by longer experiment time will make membrane performance decrease because of accumulation of material or impurities in membrane surface. If this condition do not solved immediately will lead to the fouling that make membrane performance signifcantly decreased.

In addition, the graph also shows the effect of trans membrane pressure (TMP) to the fux membrane. Higher TMP used in process will result in higher fux that gained.

TMP is a driving force in membrane separation. During the separation process, the pressure on feed is higher than the permeate. This differential made the feed few through the membrane porous. Higher TMP used will make pressure difference higher and vice versa. The graph shows that at the lowest TMP applied that is 1.9 bar need longer time than others TMP. Moreover, the graph shows that the fux at those TMP is lower than others.

28.3.5 Effect of temperature on permeate fux

This variation done at TMP value which yielded lowest oil content in permeate in order to gain produced water that can meet the standard quality of reinjection water. Figure 28.4 show that increasing in temperature did not signifcantly affect the fux.

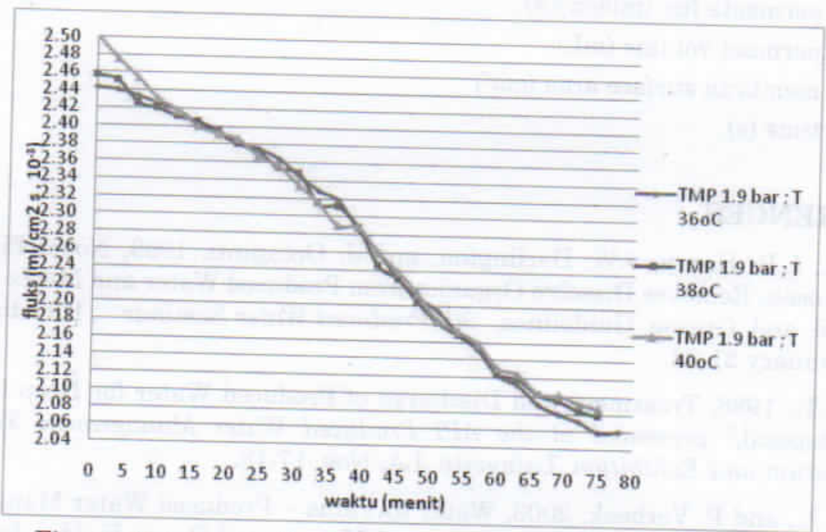

Figure 28.4 Correlation between fux value and temperature

Theoretically, temperature will affect on fux where higher temperature applied will make fux higher too. This is caused by the higher temperature will result in fuid less viscous and oil solubility and suspended solid increase. In result, the fuids tend to be easier to pass the membrane porous. In this research, the highest fux gained was at 40°C while the temperature variation did not signifcantly different so that the fux did not show signifcantly difference.

28.4 Conclusions

It can be concluded from this research that the best permeate obtained had oil content 0.45 mg/L, pH 7.6 and TSS value can be ignored since it was very small. According to the reinjection water standard quality from Daqing oilfeld,it can be claimed that this process had been fulfil the TSS and pH value but had not pass the oil content requirement yet. However, permeate that obtained from this process had meet the Indonesian produced water disposal.

The best operation that is yielded permeates with oil content 0.45 mg/L is at TMP 1.9 bar and temperature 36°C. TMP changed proportionally to the permeate fux and reversed to the selectivity. This phenomenon was also occurring in tem - perature.

ACKNOWLEDGEMENT

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Nomenclature

- J : permeate fux (ml/cm ^{2}.s)
- V : permeat volume (mL)
- A : membran surface area (cm^2)
- t : time (s)

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