Study Recycling Effluents of Hospital WWTP with Reverse Osmosis

V Rochmah 1*, I N Widiasa 1

1 Department of Chemical Engineering, Faculty of Engineering, Diponegoro University, Semarang, Central Java, 50275, Indonesia.

Email: vinny.rochmah@gmail.com

Abstract. Reverse osmosis (RO) membrane technology has been used extensively in seawater desalination, drinking water production, brackish water treatment, and industrial wastewater treatment, whereas in hospital wastewater treatment plants (WWTP) has not been much studied. Effluents of hospital WWTP can still be reprocessed with filtration technology to improve its quality, so that it can replace the role of clean water that has been taken from ground water, and can even save water use by the Regional Water Supply Company. This study aims to examine the performance of reverse osmosis (RO) technology for recycling effluents of hospital WWTP. The results showed that the reverse osmosis (RO) system with a polyamide membrane proved to be effective for recycling effluents of hospital WWTP. The value of the concentration of processed water (product) RO when viewed from the TDS (Total Dissolved Solid) and COD (Chemical Oxygen Demand) parameters has decreased and meets clean water quality standards according to existing regulations. Increased operating time causes a decrease in permeate flux. Increased operating pressure causes increased permeate flux and rejection efficiency. The use of RO systems with polyamide membranes is expected to be the best choice for recycling effluents of hospital WWTP under current conditions.

1. Introduction
Hospital is a health service institution that provides complete individual health services that provide inpatient, outpatient and emergency services [5]. Waste is the residue of a business and / or activity [9]. Hospital waste is the remainder of a business and / or activity originating from the hospital. If not managed properly, it can have a negative impact on the lives of living things and the environment.

Wastewater quality is a condition of the quality of wastewater which is measured and tested based on certain parameters and certain methods based on statutory regulations. Wastewater quality standards are the limits or levels of pollutant elements and / or the tolerable amount of pollutant elements in the waste water that will be disposed of or released into the water source of a business and / or activity [7]. So far various technologies have been developed for hospital wastewater treatment. These processing technologies include Conventional Activated Sludge (CAS), Membrane Bio-Reactor (MBR), Fluidized Bed Reactor (FBR), and Activated Carbon Adsorption (ACA) [1].
Processed water from hospital wastewater treatment plants (WWTP) can still be reprocessed with filtration technology to improve its quality, so that it can replace the role of clean water that has been taken from groundwater, and can even save on the use of PDAM (Regional Drinking Water Company) water.

One example of utilizing wastewater is taking (recovery) the water contained in the wastewater to be reused at the same time in this way minimizing the volume of waste produced. This can be done by applying a membrane-based separation process. Wastewater is passed through the membrane, the contaminants will be injected into a concentrate while the water that has been separated from the waste contaminants will pass through the membrane and exit in the form of a permeate. Permeate derived from this waste can be reused as process water thereby reducing the need for raw water use. This is possible because the membrane process used is capable of correcting micron to ionic contaminants from water, thus producing quality water that not only meets quality standards but can also be reused. This process has been proven to be carried out in various industrial sectors for the benefit of waste minimization and reuse. The reuse of wastewater will save the use of raw water so that it can reduce operational costs that must be incurred [12].

The reused wastewater must be of the highest quality, and must meet applicable clean water standards. There are several membrane technology options, in particular, reverse osmosis (RO), the most important one because it has several advantages [4].

The working principle of the Reverse Osmosis filter is based on the movement of water from a solution that has a higher concentration through a permeable membrane to a solution that has a lower concentration until equilibrium is achieved [11].

Research on reverse osmosis (RO) systems that focuses on treating wastewater from hospital WWTP into clean water has not been widely studied. The use of reverse osmosis (RO) membranes is expected to provide an alternative process in treating effluents of hospital wastewater treatment plants to obtain clean water in accordance with the regulations regarding clean water quality standards, that is based on the Republic of Indonesia Government Regulation Number 82 of 2001.

Reverse osmosis (RO) system technology is widely used to produce water of high quality, both on a small scale and on a large scale, but this technology needs to be assessed for its use on the performance of RO membranes as filtration membranes in the recycling system of the hospital WWTP effluents. This study aims to examine the performance of reverse osmosis (RO) technology for recycling effluents of hospital WWTP.

2. Materials and Methods

2.1. Tools and materials

The feed water used in this study was effluents of WWTP from Diponegoro National Hospital that have passed through pre-treatment using ultrafiltration membrane. The series of RO tools used in this study consists of a spiral wound polyamide membrane unit from the Filmtec brand model TW30-1812-100 which is equipped with a pump and 2 tubs to accommodate feed water and product water (permeate).

2.2. Experimental methods

2.2.1. Characterization of feed water

The feed water sample before entering the RO equipment was tested with TDS and COD parameters. The resulting feed water characteristics are recorded as $C_f$ (solute concentration in the feed). Furthermore, the characterized feed water is used in the filtration process.
2.2.2. **Filtration process on RO equipment**

In this study, the performance RO membrane were investigated through an experimental procedure as shown in figure 1.

![Figure 1. Schematic of the RO membrane filtration set-up](image)

A total of 40 L of feed water is put into the feed tank. The system is circulated for ± 8 hours at an operating pressure of 1 bar. Every 500 ml of the permeate sample is taken using a measuring cup to calculate the time required for calculating the flux. This step is repeated for ± 8 hours. Membrane performance observation and process optimization were carried out in the same steps and repeated at variations in operating pressure of 3 and 5 bar. The resulting flux was used to graph the relationship between flux (Y axis) and time (X axis). After the filtration process is complete, characterization of the permeate is carried out.

2.2.3. **Characterization of water products (permeate)**

The product water samples after leaving the series of RO equipment were tested again for TDS and COD parameters. The resulting product water characteristics are recorded as $C_p$ (solute concentration in the permeate). The obtained $C_t$ and $C_p$ are used to calculate rejection (R).

2.3. **Methods of analysis**

Membrane performance is determined by several main parameters in the separation process, namely as follows [6]:

2.3.1. **Permeability**

A measure of the velocity of a species penetrating the membrane which is influenced by the number of pores, pore size, pressure operated, and membrane thickness. In measurement, permeability is expressed in flux, namely the amount of permeate volume that passes through one unit of membrane area in a certain time. Mathematically, the flux is formulated as follows:

$$J_v = \left(\frac{V}{A \times t}\right)$$

where $J_v$ is the permeate volume flux (ml / m$^2$.sec), $V$ is the permeate volume (ml), $A$ is the membrane surface area (m$^2$), and $t$ is the operating time (seconds).
2.3.2. Selectivity
Determined mainly by the size and shape of the solute relative to the pore size in the membrane and by which the transport of the solvent is directly proportional to the applied pressure. In measurement, selectivity is expressed in rejection, namely the percentage of results from the difference in the concentration of solute concentrations in the feed and permeate. Mathematically, the rejection is formulated as follows:

$$R = 1 - \left(\frac{C_p}{C_f}\right) \times 100\%$$

where $R$ is the rejection coefficient ($\%$), $C_p$ is the concentration of solute in permeate, and $C_f$ is the concentration of solute in feed.

3. Results and Discussion
The ability of polyamide RO membranes in treating effluents of hospital WWTP was studied by varying the operating pressure from 1, 3, and 5 bar at a set operating time of 8 hours. Several water quality parameters that can be used to indicate the quality of RO treated water are TDS (Total Dissolved Solid) and COD (Chemical Oxygen Demand).

3.1. Characteristics of Feed Water and Product Water in the Reverse Osmosis Process
The characteristics of feed water and product water in the reverse osmosis process are shown in Table 1.

| Parameters | Pressure (bar) | Feed | Product | Quality Standard Class |
|------------|---------------|------|---------|------------------------|
| TDS (mg/l) | 1             | 677  | 336     | 1000 1000 1000 2000    |
|            | 3             | 677  | 82      | 1000 1000 1000 2000    |
|            | 5             | 37.26 | 78  | 1000 1000 1000 2000    |
| COD (mg/l) | 3             | 37.26 | 28.32  | 10 25 50 100          |
|            | 5             | 37.26 | 24.11  | 100                      |

The concentration of TDS and COD in the effluents of hospital WWTP has decreased after being treated with the RO system. Feed water with an initial TDS of 677 mg / l gave a final TDS of about 78-82 mg / l, whereas an initial COD of 37.26 mg / l gave a final COD of up to 24.11 mg / l. The concentration value of RO treated water when viewed from the TDS and COD parameters has met the clean water quality standard according to the Republic of Indonesia Government Regulation Number 82 of 2001 [8]. The TDS parameter has met all classes, while COD meets class 2 for a pressure of 5 bar, as well as class 3 for pressure 1 and 3 bar. So a reverse osmosis system with a polyamide membrane can fulfill this requirement for recycling for available clean water.

3.2. Reverse Osmosis Process Performance

3.2.1. Permeate flux
The speed of a species to penetrate the membrane (permeability) can be affected by the operating time. In the measurement, permeability is expressed in flux. The effect of operating time on permeate flux can be seen in Figure 2.
Figure 2 indicates that increasing the operating time will tend to reduce the permeate flux. This causes the increased operating time, the more the number of solid molecules that are stuck on the membrane surface, thus blocking the permeate flow rate. Therefore, increasing the operating time increases the likelihood of concentration polarization. The existence of polarization can lead to fouling which can reduce the ability of the membrane to retain unwanted components [3].

The permeate flux that passes through the membrane is controlled by the thickness of the membrane, the pore size, and the pressure difference. The effect of operating pressure on permeate flux can be seen in Figure 3.

Figure 3 shows an increase in flux with an increase in operating pressure. Feed with operating pressures 1, 3, and 5 bar obtained fluxes of 6.92 L / h.m², 15.13 L / hour.m², and 28.57 L / h.m², respectively. The same phenomenon was also found by [10] with using a pressure variation of 0.5-7 bar, an increase in permeate flux was found due to an increase in operating pressure. The greater the pressure applied, the volume of fluid that can pass through the membrane will increase.
The same thing was stated by [2] that the flux will increase with increasing pressure, but there are limitations to the technical operation. The application of large pressure can damage / tear the membrane, so that the components that were originally separated from the water will be included as products.

3.2.2. Rejection of TDS and COD

The rejection percentage (% rejection) is the ability of the membrane to retain the unwanted component, namely the solute stored in the membrane. The rejection percentage of 100% indicates that a perfect membrane is able to retain the solute, and this membrane is called the ideal membrane. The rejection of 0% indicates that the solute and solvent are free to pass through the membrane [3]. Performance parameters of RO system are shown in Table 2. Feed with operating pressures of 1, 3, and 5 bar respectively obtained TDS rejection of 50.37%, 87.89% and 88.48% and COD rejection of 0%, 24.01%, and 35.31%.

| Pressure (bar) | Process | TDS (mg/l) | Rejection TDS (%) | COD (mg/l) | Rejection COD (%) |
|---------------|---------|------------|-------------------|------------|------------------|
| 1             | Before RO | 677        | 50.37             | 37.26      | 0                |
|               | After RO  | 336        | 50.37             | 37.26      | 0                |
| 3             | Before RO | 677        | 87.89             | 37.26      | 24.01            |
|               | After RO  | 82         | 87.89             | 37.26      | 24.11            |
| 5             | Before RO | 677        | 88.48             | 37.26      | 35.31            |
|               | After RO  | 78         | 88.48             | 24.11      | 35.31            |

The effect of operating pressure on the TDS and COD rejection factors can be seen in Figure 4. Figure 4 shows an increase in rejection along with an increase in operating pressure. The increase in operating pressure caused the TDS and COD rejection to increase. In addition, the quality of treated water has also improved due to the decreased TDS and COD content.

![Figure 4](image-url)
4. Conclusions
The reverse osmosis (RO) system with a polyamide membrane has proven to be effective in recycling effluents of hospital WWTP. The concentration value of processed water (product) RO when viewed from the TDS and organic parameters has met the clean water quality standards according to the Republic of Indonesia Government Regulation Number 82 of 2001. Operating pressure in the reverse osmosis system can affect the permeate flux. The increase in operating pressure causes an increase in the permeate flux and the rejection efficiency of TDS and COD.

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