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# Utilization of Bentonite and Hybrid UF-RO in Treatment of Pulp Industry Wastewater

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**Abstract**
The purpose of this research is to investigate the performance of bentonite, hybrid of ultra-filtration and reverse osmosis (UF-RO) in improving the quality of liquid waste produced by pulp industry. The parameter used in this research is pH, turbidity, and Chemical Oxygen Demand (COD). The variable examined is operating time and feed water flow rate. The results show that the hybrid of UF-RO is able to produce permeates with optimum pH of 7.23 at 60 minutes operating time and reduce the turbidity almost 99% of the COD to 18 mg. $L^{-1}$. It is suggested that bentonite and hybrid of UF-RO can be applied in the treatment of pulp and paper industries.

**Keywords:** Bentonite, UF-RO Hybrid, liquid waste, and Cadmium.

## 1. Introduction

The increasing quantity of liquid waste produced by pulp and paper industry has caused various environmental issues. It is assumed that this is resulted from the waste containing harmful metal like cadmium. Other parameter is considered as in acidity, turbidity, and chemical oxygen demand (COD) which do not meet the disposal standard quality. One of pulp industries in South Sumatera, the liquid waste disposed into IPAL (WWTP) is separated into two streams, which are, alkali waste stream and acid waste stream. The purposed of these treatments is to decrease the use of neutralizer chemical substance so acid waste can function as neutralizer in the neutralization basin area. During primary treatment process, the whole liquid waste from the plant is stored in the primary clarifier to separate solids particle by means of gravitation. The separated liquid waste then neutralized in the neutralization basin area by adding chemical substance, while solid waste in mud-like or sludge is pumped into sludge mixing tank. After being neutralized, the liquid is transferred into equalization basin for homogenization. In the next step, the temperature of liquid waste is reduced into $35^0$C in the cooling tower. The cool liquid waste is transferred into aeration basin which is equipped with the surface aerator to supply oxygen. In the aeration basin, bacteria decompose the organic compounds so that the pollutant substances in the liquid waste decrease. In decomposing organic compounds process, bacteria require some nutrients such as nitrogen and phosphate that can be supplied from urea and phosphoric acid. From the aeration basin, the mixture compounds are sent into secondary

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clarifier to separate liquid waste from the sludge (biomass). Some sludge is sent back to the aeration basin. Overflow secondary clarifier is disposed into the river. The current research was conducted to investigate liquid waste processing in pulp industry using adsorption and membrane technology.

Bentonite is a montmorillonite based mineral compound that contains alumina octahedral crystal layers which capable adsorbing water in a big volume. Bentonite can be used as adsorbent that has capacity to exchange its cation after or without initial treatment. Chemical modification is likely performed due to the existence of water molecules on its surface and interchangeability of cation in the interlayer of montmorillonite structure. Materials or filter media normally used in the filtration process is sand, charcoal, active carbon, and other granular substances.

Ultrafiltration is membrane-based water and wastewater which is widely applied even for drinking water processing [1,2], electroplating process [3], biodiesel purification [4], fruit juice clarification [5], oil emulsion separation [6], acid mine drainage [7,8] and many others. The advantage of applying membrane ultrafiltration is to enable separation of suspended solid and microorganism in the water, to decrease turbidity, and not have to require chemical substances in its process.

Reverse osmosis (RO) is the water separation process using semipermeable membrane which was a solvent from high concentration to low concentration by applying a pressure on the difference of liquid osmotic pressure. To do this, it needs driving force so that permeate is separated from concentrate. RO is commonly applied in seawater desalination as it has advantages of not requiring much energy except for powering the pump, easily designed and operated, capable for separating organic and inorganic compounds, bacteria and viruses. RO membrane needs the feed water treatment to avoid fouling and scaling.

## 2. Research Methodology

### *2.1 Materials*

The research was conducted in the Laboratory of Separation and Purification Engineering, Faculty of Engineering, Universitas Sriwijaya. The equipment used in the experiment were feed tank and permeate tank, sand filter, adsorption column, ultrafiltration membrane (UF), reverse osmosis membrane (RO), Pump, Flow meter, Pressure gauge, Oven, analytical balance, and 60 mesh screens (250 micron). The materials used in the experiment were pulp wastewater, HCl 37%, aquadest, silica sand and active carbon.

### *2.2 Method*

Bentonite activation was performed by homogenized 25 kg of 250 µm particles of bentonite into demineralized water overnight. The bentonite produced is then soaked using 37% HCl and stirred for about one hour, dried and heated at 100$^{o}$C for about 48 h. The activated bentonite was grinded and filtered by using 60 mesh of screen. Bentonite was placed in the bottom of Fiber Reinforce Plastic (FRP) tank. Active carbon (10, kg, 20 mesh) was placed on the top of FRP tank. The sample from feed tank is transferred into sand filter column and the filtrates are stored in the tank and pumped into UF membrane. Permeates from UF membranes are stored in the UF tank prior fed to RO system. The UF and RO membrane permeate were collected every 15 min and analyzed for acidity and turbidity. All experiment was conducted at contact time of 15-90 min and at room temperature (28$^{o}$C - 30 $^{0}$C).

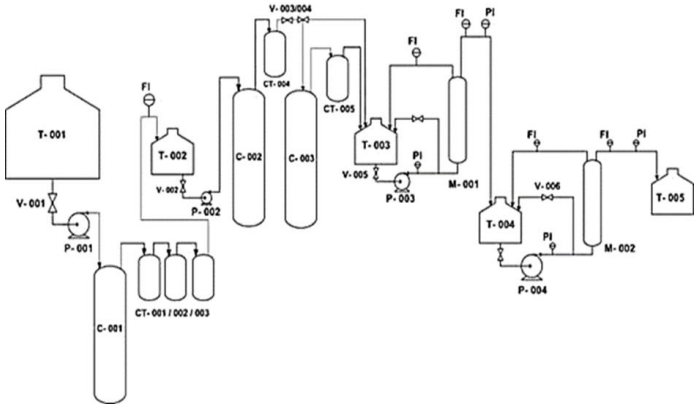


**Figure 1.** Experimental scheme of ulp and Paper Industry wastewater (T = Tank, C-001= Sand Filter, C = Adsorption Column, CT = Cartridge, V = Valve, P = Pump, PI = Pressure Gauge, FI = Flow meter, M-01 = UF, M-02 = RO)

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## 3. Results and Discussion

### *3.1 Characteristic of sample*

The sample of initial liquid waste used in this research is the effluent of a pulp industry located in South Sumatera. The characteristic of sample presented in Table 1.

**Table 1.** Characteristic of sample

| Parameter | Value | Unit |
|---|---|---|
| pH | 8.82 | - |
| *Turbidity* | 204.00 | NTU |
| COD | 380 | $mg.L^{-1}$ |
| Cd | 0.321 | $mg.L^{-1}$ |

Figure 2a. shows the morphological structure of swelling bentonite surface due to its contact with demineralized water when activated. The compact structure of bentonite after used for filtration of pulp and paper wastewater as indicated in Fig. 2b.

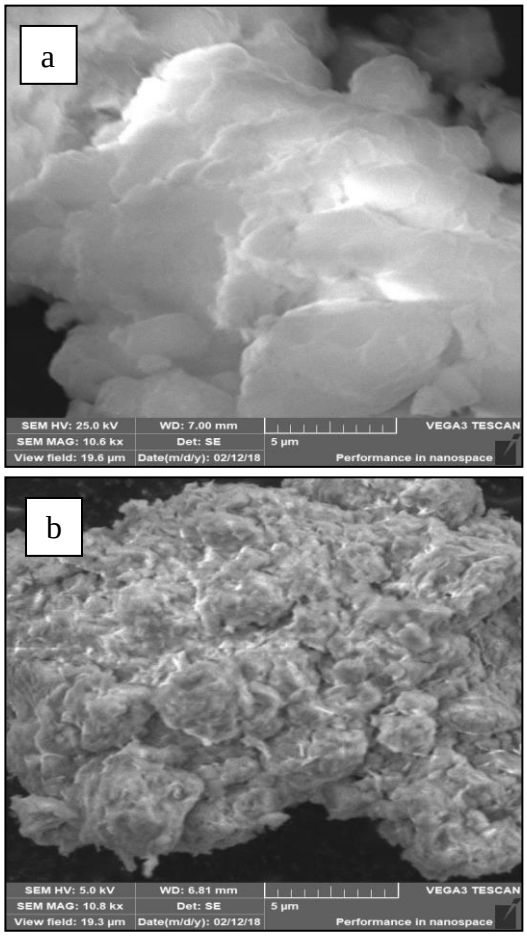


**Figure 2.** Scanning Electron Microscope of Bentonite at magnification of 10600 X of the raw bentonite (a) and the adsorbed bentonite (b)

Table 2 illustrate that silicon, iron, calcium and sodium is increase on the bentonite surface. calcium and magnesium in bentonite as well as cadmium meanwhile the percentage of oxygen, aluminum, and magnesium is decreases. The presence of cadmium on the surface of bentonite shows that the ion adsorption process has taken place as expected.

**Table 2.** Bentonite composition

| Element | Raw bentonite | Adsorbed bentonite |
|---|---|---|
| | (%) | (%) |
| Oxygen | 61.91 | 59.33 |
| Silicon | 23.86 | 25.56 |
| Aluminum | 9.00 | 8.52 |
| Magnesium | 2.74 | 2.44 |
| Iron | 1.10 | 1.15 |
| Calcium | 0.57 | 0.86 |
| Sodium | 0.81 | 0.85 |
| Antimony | - | 1.12 |
| Cadmium | - | 0.17 |
| Total | 100.00 | 100.00 |

The type of bentonite used in the experiment was calcium bentonite (Ca-bentonite) or also known as non-swelling bentonite [8,9].

### *3.2 The effect of contact time on pH*

Figure 3 presents that the sample with initial pH of 8.82 decreases after treatment using sand filter (SF), adsorption column (AD), ultrafiltration membrane (UF), and reverse osmosis membrane (RO).

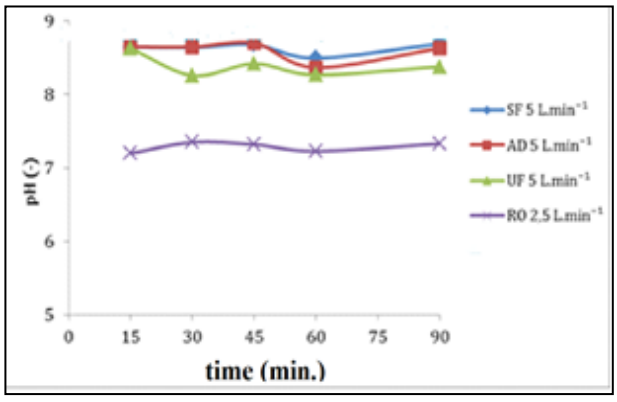


**Figure 3.** Effect of Time on pH

There is not a significant decrease in pH at the SF, AD and UF units after 90 min of contact time.

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The performance of SF and AD in reducing pH is not much different because the pH of the outlets of the two units are very close. The inability of SF and AD to significantly reduce pH is due to the fact that SF and AD are not able to reject base ions and other components present in the waste as well. Different results obtain for the UF unit because the membrane capable of rejecting bivalence ions such as $Ca^{2+}$. RO membranes have smaller pores diameter (0.5-2 nm) compared to those UF. The RO membrane is not only rejecting the bivalence ions but also anions such as $OH^-$ and $SO_4^{2-}$. Bases ions in pulp industry may derive from NaOH which is found in white liquor from pulp processing.

The optimum pH at 60 min of contact time is 8.50. At the same contact time the pH of AD filtrate is 8.37 and in the UF permeate is 8.27. The use of UF-RO hybrid at 60 min of contact time produce the final permeates with pH of 7.23. However, the use of RO without pretreatment using UF will cause the fouling problem on RO thus shorten the membrane life time.

### *3.3 The Effect of contact time on Turbidity*

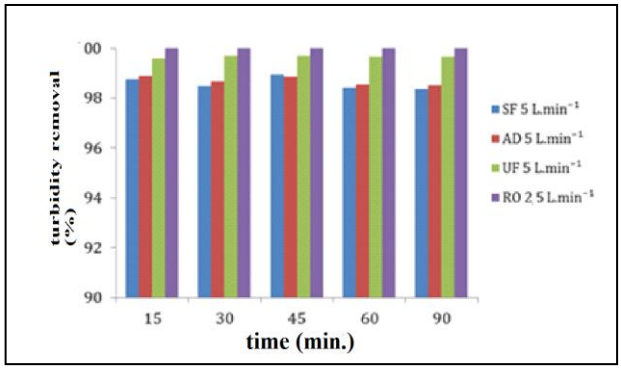


**Figure 4.** Effect of operating time on turbidity

Figure 4 shows the turbidity removal in SF filtrate up to 98%. Organic material in the sample (such as carbohydrate, cellulose, hemicelluloses, and protein) which difficult to decomposed may cause higher turbidity. At SF unit, the turbidity level can be decreased significantly as one of the filter medias used is active carbon which is capable in adsorbing organic compounds, smell, and taste. Therefore, the presence of active carbon plays important role in reducing the turbidity of sample.

At adsorption column, the percentage of turbidity removal is higher as bentonite also adsorb the remains components from SF unit. The significant decreasing of turbidity at SF and AD units is also supported by the presence of spoon filter which also rejects suspended solid, macro and micro-colloid that may increase the turbidity.

The decreasing of turbidity is caused by UF membrane which is capable of rejecting colloid particles, viruses, and protein. The turbidity removal reaches 99% at all contact time due to RO characteristic which is basically reject all particles except water [10-11]. The longer of contact time will increase the turbidity removal. The filter layer has saturation point which can only hold adsorbent in certain amount.

From the graphic above, the percentage of decreasing optimum turbidity at SF and AD unit occurs at 45 minutes operating time. After passing that point, the performance of SF and AD decreases and the percentage of decreasing of turbidity as well. The optimum decreasing percentage of turbidity at UF unit is at 30 minutes operating time, which is 96%. During operating time, UF unit still has clean pores and without suspended solids. At last, the use of hybrid UF-RO is capable of decreasing turbidity until 99%.

### *3.4 The Effect of operating time on COD*

Figure 5 shows that the value of chemical oxygen demand (COD) decreases significantly at the initial waste condition to SF unit. It is caused by the amount of macro-sized organic components held at the void of SF. In general, COD content at AD unit is not much different from SF unit. It implies that the bentonite used as adsorbent is effectively to adsorb organic components in the liquid waste. However, bentonite is capable to adsorb cadmium from pulp and paper industry.

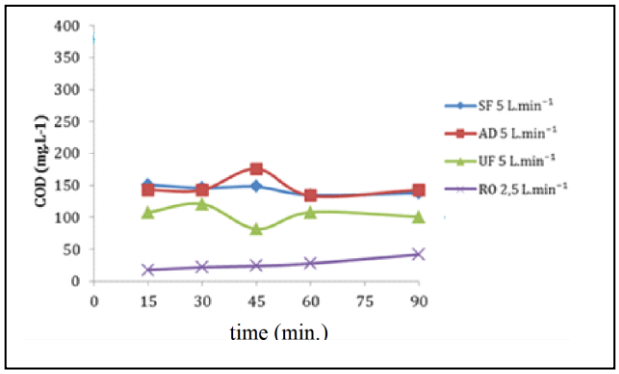


**Figure 5.** Effect of Time on COD

The COD significantly decreases in UF and RO

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permeates because the characteristic of both membranes that reject the organic substance. The final permeate the COD removal percentage is in the range of 88.9 to 95.3%.

## 4. Conclusion

Bentonite can adsorb cadmium from pulp industry. The combination of bentonite with hybrid UF-RO is capable in decrease the COD, turbidity and cadmium of pulp wastewater and neutralize the acidity to nearly neutral pH (7.23) after 60 minutes contact time, reducing 99% of turbidity, and decreasing the content of COD approximately 88.9% to 95.3%.

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