Analysis of The Combined Adsorption-Microfiltration (AMFIL) Process for WWTP Effluent to Process Water

Abstract. The seaweed processing industry produces Alkali Treated Cotton Chips (ATCC) requires large amounts of process water used for the washing and soaking processes, where process water is generally obtained from groundwater. On the other hand, wastewater from the production process after being treated in Wastewater Treatment Plant (WWTP) and meeting quality standards is discharged into the environment. The effluent of WWTP in large volumes (150 - 200 M^3 per day) contains TDS, TSS, turbidity, pH, odor, and organic matter that are relatively small, so it has the potential to be reused as process water. Theaims of the research are to investigate the removal of pollutants from the combined adsorption and membrane microfiltration (AMFIL) process on a pilot plant scale from the effluent of WWTP in the seaweed processing industry to process water. The real effluent from the WWTP flows into an adsorption column containing granular activated carbon with varying weights and sizes, then the effluent from the adsorption column flows into a membrane microfiltration with varying weights and sizes membrane. Parameters measured in this study were turbidity, TDS, total hardness, Fe^{+2}, Mn^{+2}, and pH. Using an adsorption capacity of 0.352 $mg.g^{-1}$ and the size of the membrane is 5μm can obtain the total removal pollutants of the AMFIL processas turbidity, TDS, total hardness, Fe^{+2}, Mn^{+2}, and pH were86.67, 94.00,95.83,96.36,93.33%, and (6.5 - 7.5), respectively.

Keywords: Adsorption, Effluent, Membrane Microfiltration, Reuse, Seaweed.

1. Introduction

In the seaweed processing industry, producing ATCC (Alkali Treated Cotton Chips) requires a large amount of processed water, whereas for a production capacity of 2tons of ATCC per day requires process water of ± 150 $M^3.day^{-1}$. Process water is used for the raw material washing process and the seaweed soaking process. Process water is obtained from groundwater and continuous withdrawal of large amounts of groundwater can result in a decrease in environmental quality, in the form of subsidence, landslides, and an imbalance in the distribution of groundwater usage. In addition, excessive groundwater extraction can result in high production costs.

Effluent from the WWTP process has a large volume and meets quality standards and is discharged directly into the aquatic environment (river). The characteristics of WWTP effluent are odorless, color (15 - 25 Pt-Co), Turbidity (8 - 14 NTU), pH (6 - 7), TSS (20 - 30 mg. L^{-1}), TDS (4,000 - 4,500 mg. L^{-1}), Total hardness (700 - 900 mg. L^{-1}), BOD (30 - 40 mg. L^{-1}), and COD (60 - 80 mg. L^{-1}). By considering the potential and characteristics of WWTP effluent and problems in obtaining process water, the WWTP effluent has the potential to be reused as process water through a combination of adsorption (GAC) and microfiltration (MF) processes which is known as the AMFIL process.

Granular activated carbon (GAC) fixed bed adsorption technology was applied to remove carbamates carbaryl, methomyl, and carbofuran from a public water supply. To minimize the effect of clogging and to evaluate adsorbent saturation for carbamates, microfiltration (MF) was previously used to adsorb, and the backwash procedure of the GAC bed was carried out. The MF of the water previously adsorbed in the GAC fixed bedcan removal of 100 % of the carbamate's pesticides with an initial concentration of 25 $\mu g.L^{-1}$ during the first 48 h of operation(Alves et al., 2020).The combination of adsorption and microfiltration processes has the ability to remove contaminants in water such as hardness, nitrate, and heavy metals(Bakalár et al., 2019).The combination of adsorption and deep-bed filtration proved to be a robust and economic process combination for the removal of micropollutants with economic advantages over membrane filtration(L Pillay & Jacobs, 2007).PAC/Alum)/MF achieved 75% to complete removal of total microcontaminants with 4-18 mg. L^{-1} of a mesoporous PAC and 2 h contact time, with a reliable particle separation (turbidity < 0.03 NTU) and low aluminum residuals(Campinas et al., 2021).

In wastewater treatment, membrane technology is called a major technology in the field of water treatment in the 21st century. With the development of membrane technology and the development of other emerging technologies in combination, microfiltration membrane technology is widely used in the treatment of various types of wastewaters such as radioactive wastewater and heavy metal wastewater(Abdel-Fatah, 2018; Wang et al., 2020).

The physicochemical characterization of this sample before and after treatment showed a remarkable increase in removal rate from 1 hour to 3 hours of filtration; 54.8% after 1 hour and 73.28% after 3 hours for COD (73.28%) after 3 hours for BOD5 (26.48%) after 3 hours of filtration for conductivity and a total elimination rate of turbidity that was achieved 99% after 3 hours of treatment(El Khalfaouy et al., 2017).

The combination of coagulation and adsorption processes for fulvic acid uptake shows that the effectiveness of fulvic acid uptake is quite effective compared to the coagulation process. This system provides sufficient contact time for PAC to adsorb organics compared to the system with in-line adsorbent addition. More than 85% of FA was removed from water containing 8 mg. L^{-1} of FA.The removal efficiency also increased with the increase in mixing intensity and mixing time. The permeate flux slightly improved when a membrane of pore size 0.22 μmwas used with shorter hydraulic residence time and lower PAC concentration so from this study it is evident that the combined membrane process has a potential application for organic dye removal(Jirankova et al., 2010).

The study on the effect of powder-activated carbon (PAC) adsorption on microfiltration (MF) membrane performance are showed that PAC pretreatment offered high organic matter removal rates for both dissolved organic carbon (DOC) and ultraviolet absorbance at 254 nm (UV254) during 10–200 mg. L^{-1} PAC dosage. The removalefficiencies of organic matter by MF membrane filtration decreased with the increase of organic matter removal rate by PAC adsorption. PAC mainly removed organic matter of about 3 kDa molecular weight (MW). MF membrane maintained more than 5 kDa MW organic matter on the membrane after PAC adsorption. The results of membrane filtrationindicated that PAC pretreatment slightly promoted membrane flux, regardless of PAC dosage. It seems that the organic matter fouling membrane was concentrated in more than3 kDa MW. PAC removed markedly less than 3 kDa MW organic matter and had less effect on more than 3 kDa organic matter. Thus, PAC cannot reduce membrane fouling Löwenberg, 2016).The AF2B/GAC process was able to reduce contaminants such as TSS, BOD, COD, NH3N and Chlorine by 98 %, 99 %, 97.3 %, 97.8 %, and 100 % respectively. Furthermore, in the CNTs process, all pollutants are not detected until they meet drinking water quality standards(Prayitno et al., 2022).

2. Materials and Methods

2.1 Materials and equipment preparation

The feedwater used in this study is effluent from WWTP in the seaweed processing industry, where the feedwater meets quality standards. Feed water contains odorless, color (15 - 25 Pt-Co), Turbidity (8 - 14 NTU), pH (6 - 7), TSS (20 - 30 mg. L^{-1}), TDS (4,000 - 4,500 mg. L^{-1}), Total hardness (700 - 900 mg. L^{-1}), BOD (30 - 40 mg. L^{-1}), and COD (60 - 80 mg. L^{-1}). Furthermore, feedwater is fed into the influent column of 2,000 L to have flowed into the treatment system as fed in the AMFIL process which operates continuously as Fig. 1.

The equipment used in this study includes an adsorptioncolumn, microfiltration column, pump, and storagecolumn. The adsorption column was made from PVC material with a diameter of 25 cm, a height of 150 cm, and at the top of the column, there is a distributor for feedwater.The adsorption columncontaining granular activated carbon (GAC) of 20 - 25 kg thatGAC from YUJIA production had specifications: total ash content max 4%, moisture content max 5%, apparent density 0.4 -0.5 $g.cm^{-3}$, mean particle diameter 4 - 8 mesh, iodine number 900 mg. g^{-1}.

While the microfiltration membrane used cellulose membrane is type UF 280 with specifications: PVC Alloy; Shell Material: U-PVC; Size: 8 x 40 inch; Filtration Method: Inside - Out; Flow Rate: 1500 - 2500 $L.h^{-1}$; Area: 28 m^2; In/Out: 2″; pore diameter of 1 – 10 µm.

2.2 Operational procedure

Real wastewater discharged from the WWTP in the seaweed processing industry was used as feed water in this study, where 2,000 L of feed water was collected in a storage column, and sampling was carried out to analyze the characteristics of the feed water.Furthermore, the feed water is flowed by a pump into an adsorption columnthat already contains 20 kg of granular activated carbon, while the effluent of the adsorption column is collected in a temporary storage column which is then sampled to analyze the effluent characteristics. The effluent from the adsorption column is pumped using a jet pump of 1-10 bar into the microfiltration column where the 2-membrane tube is arranged in parallel.The effluent from the membrane tube (filtrate), hereinafter known as process water, is sampled, and analyzed for its characteristics. The experiment was repeated using the weight of the adsorbent and the number of different membrane tubes.

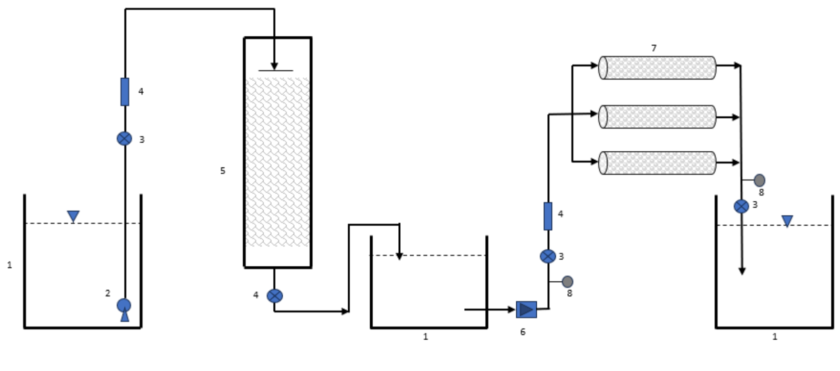


Figure 1. The Process Flow of AMFIL System

2.3 Analysis Method

The samples were analyzed by using APHA standard procedures to investigate the pH, Ferro (Fe^{+2}), Mangan (Mn^{+2}), Turbidity, TDS, and Total Hardness. The pH was measured using a Fisher Scientific type pH meter (Model XCL25) previously calibrated with pH 6,7, and 8 standard solutions. Fe^{+2} and Mn^{+2}were measured using UV-Vis's spectrophotometry(Shimadzu UV-1280). Fe^{+2} analysis used the phenanthroline method, while Mn^{+2} analysis used the persulfate method. Fe^{+2} testing can be done using the phenanthroline complexing compound and analyzed at a wavelength of 480 nm – 560 nm. By making a standard curve, the concentration of Fe^{+2} in the sample can be determined.While determination of manganese in samples was carried out by the persulfate method at a wavelength of 400 - 700 nmaccording to the APHA standard method, with a calibration curve including standards of 0.5, 1.0, 1.5, 2.0 and 2.5 mg·L^{-1}.

The determination of Total DissolvedSolids (TDS), according to the analytical method (MA115-S.S. 1.2), was carried out by filtering a sample portion (normally 100 ml) through a previously dried and weighed Whatman 934 AH glass microfiber filter (pore size 0.5µm) under vacuum. When the filtration was completed, the residue was dried at 103-105 C overnight or at least 1hour. The weight of dissolved solids is obtained by calculating the difference of the filter weights before and after drying. To determine pH using an electrical conductivity method in the form of measuring instrument pH Meter EZ-9910. The quality standard used as a reference is based on the Decree of the Minister of Health of the Republic of Indonesia No.32 of 2017.

Furthermore, to determine the adsorption capacity of total dissolved solids in the adsorption column, it is estimated to use equation 1.

$$q_t = (C_o - C_t)(V/m) \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

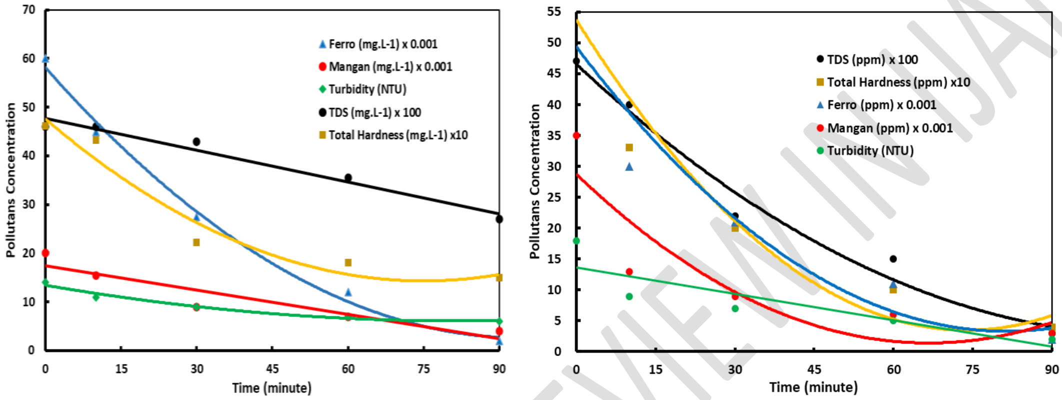
Which:

q_t is the adsorption capacity in mg. g^{-1}.
C_o is the TDS initial concentration in mg. L^{-1}
C_t is the TDS concentration in mg. L^{-1} attime.
V is the solution volume in liter
M is the adsorbent mass in gram

3. Results and Discussion

3.1 The effect of adsorbent weight

In the AMFIL process, especially in the adsorption column containing granular activated carbon, using an adsorbent weight of 20 kg and 25 kg and different feed characteristics, experimental results were obtained as shown in Figure 2.

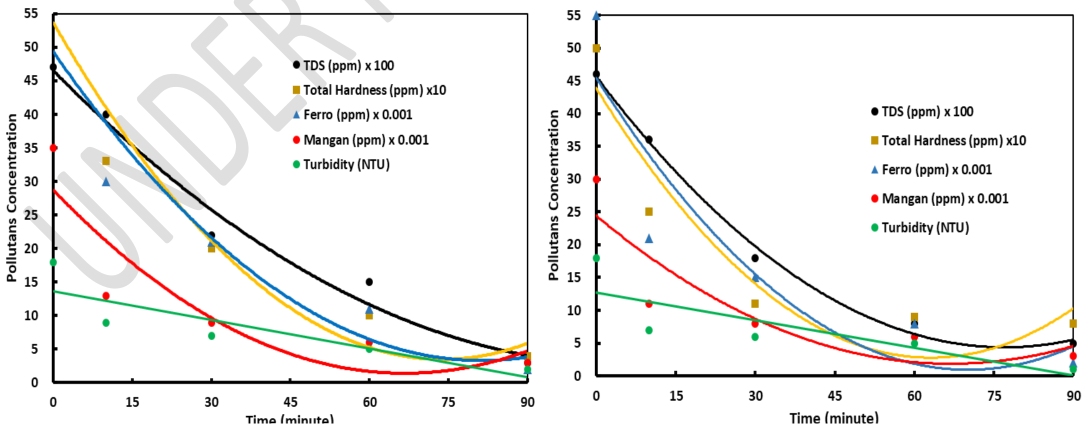


(a) (b)

Figure 2. The performance of the adsorption column at different adsorbent weights

a. Weight 20 kgb. Weight 25 kg

3.2 The effect of the size of the microfiltration membrane



(a) (b)

Figure 3. Performance of microfiltration membranes at different membrane sizes

a. Size of membrane 5 µm b. Size of membrane 10 µm

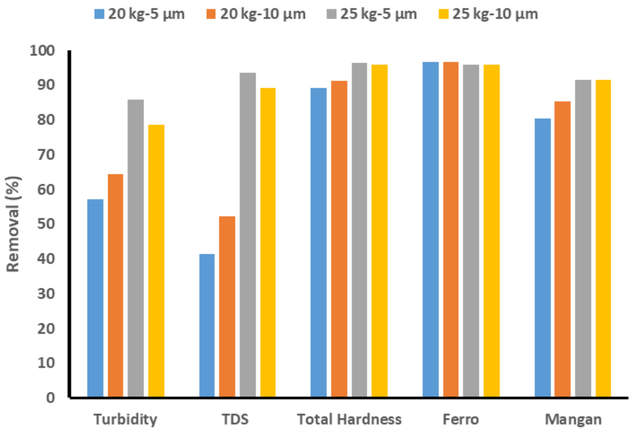


Figure 4. The performance of the AMFIL process

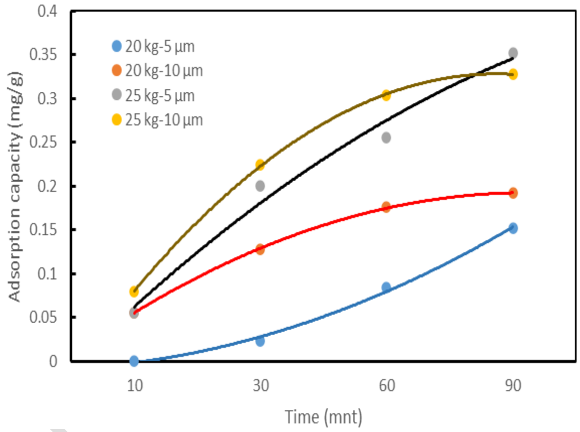


Figure 5.

4. Conclusion

The AMFIL process with an adsorption capacity of 0.352 mg.g^{-1} and the size of a microfiltration membrane is 5µm are capable of processing effluent from WWTP into process water according to standard quality with the total removal pollutants such as turbidity, TDS, Fe, Mn, and pH are 86.67, 94.0, 95.83, 96.36, 93.33%, and (6.5 – 7.5), respectively.

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