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Pulp and Paper Wastewater Treatment with Bottom Ash Using Jar Test

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ABSTRACT

The wastewater generated from pulp and paper production still contains pollutants and contaminants, so appropriate and economical materials are needed to reduce pollutants by using adsorbents from bottom ash. This study examined the characteristics of bottom ash and pulp and paper wastewater, the effect of stirring time, stirring speed, and adsorbent activation temperature on decreasing the environmental parameters of wastewater. The synthesis of bottom ash as an adsorbent was carried out by heating at 100 and 200 °C for 1 hour. The wastewater treatment process with maximum yield occurs at a stirring speed of 100 rpm for 50 min. The use of bottom ash without heating as an adsorbent in the pulp and paper wastewater treatment process has reduced TSS 77.5%, COD 85.72%, chloride 26.9%, TDS 1143 ppm, and EC 2180 s/cm, which have met the environmental quality standards.

Keywords: adsorbent, pulp and paper wastewater, bottom ash, jartest.

INTRODUCTION

The pulp and paper industry is one of the leading agro-industry commodities in Indonesia. Indonesia's pulp industry ranks eighth in the world, and the paper industry ranks sixth in the world. In its development, paper is needed in great amounts in everyday life, not only as stationery, books, or magazines, but also as cigarette wrappers, food, drinks, and so on. The production capacity of the pulp industry in Indonesia has reached 10 million tons. In comparison, the paper has achieved 17 million tons, with the need for raw materials bearing 45 million m^3 (Ministry of Industry of the Republic of Indonesia, 2021).

Pulp and paper industrial waste impact the environment, because the production process requires chemicals and other supporting materials, which can be categorized as B3 waste. Further handling of waste is necessary. Pulp and paper industrial waste consist of gas, liquid, and solidfractions (Sharma et al., 2022). The wastewater generated from the pulp and paper industry contains biological oxygen demand (BOD), chemical oxygen demand (COD), phosphates, heavy metals, and other contaminants (Söderholm et al., 2019; Haq and Raj, 2020). The wastewater also contains organic and inorganic compounds, such as lignin which causes black waste and has a high chemical oxygen demand (COD) value. This disrupts the photosynthesis process in aquatic biota due to the lack of supply of sunlight entering the water (Kumar et al., 2015).

Most of the pulp and paper industry uses bleach that contains chlorine. Chlorine will react with organic compounds in wood to form toxic compounds, such as dioxins (Mandeep et al., 2019). Waste materials, such as leather and sawdust in the pulp and paper industry are used as fuel in the power boiler unit. Solid waste management can be divided into two classes: solid waste, which belongs to the category of B3 waste, and non-B3 solid waste. Thus far, WWTP mud waste and burning ash have only been stockpiled using the landfill method, causing problems, such as limited land and contaminated soil. In addition to wastewater, the Pulp and Paper Industry produces solid waste, including boiler fly ash and bottom ash. This research focused on utilizing bottom ash as an adsorbent to treat pulp and paper industrial wastewater. The most common components in bottom ash are silica (SiO_2) and alumina (Al_2O_3), and others in the form of iron (III) oxide (Fe_2O_3), calcium oxide (CaO), magnesium oxide (MgO), sodium oxide (NaO) and potassium oxide (K_2O) (Aprilita and Suherman, 2017; Abdullah et al., 2019; Rosales et al., 2017).

Bottom ash has a fairly large particle size compared to fly ash, a high surface area and porosity, as well as good adsorption capacity to absorb heavy metals and organic compounds (Aprilita and Suherman, 2017). Silicate and aluminate components in bottom ash can be used as adsorbents in treating pulp and paper wastewater. Thus far, bottom ash from coal combustion is widely used as an economical cement mixture (Singh et al., 2020; Argiz et al., 2017; Tayeh et al., 2019). Fly ash and bottom ash (FABA) are also used as raw materials that are environmentally friendly and ecologically beneficial in manufacturing bricks, so that FABA has the same strength as bricks derived from clay (Sutcu et al., 2019; May et al., 2021; Azevedo et al., 2019).

Several researchers have also conducted research on the use of bottom ash as an adsorbent (Mahidin et al., 2017; Wahyuni et al., 2018; Zhou et al., 2019; Jaya and Telaumbanua, 2020; Hong et al., 2021; Samaka et al., 2021; Mahmood, 2021). On the basis of the literature, bottom ash can be used as a potential adsorbent because of its affordable price. Bottom ash is abundant with the main composition of SiO_2 and Al_2O_3. Bottom ash can come from coal or lignocellulosic-based industries which can absorb pollutants in wastewater higher, as found by Zhou et al. (2019). This study aimedto reduce the concentration of pollutants and contaminants in pulp and paper wastewater with efficient, inexpensive, and environmentally friendly adsorbents. The raw material used in this study is bottom ash which is physically activated to remove impurities in the bottom ash and open pores and to improve the absorption performance of compounds in solution (Syarif et al., 2021). Bottom ash characteristics were analyzed in this study to assess the performance of the adsorbent in managing pulp and paper wastewater.

MATERIALS AND METHOD

Pulp and paper wastewater and bottom ash as adsorbents were taken from the local pulp and paper industry in South Sumatra, Indonesia. The research took place using the jartest method. The parameters analyzed in wastewater treatment with bottom ash adsorbent consisted of pH, TDS, EC, COD, TSS, and Cl^-. Bottom ash characterization was performed before and after the wastewater treatment process using X-ray fluorescence spectroscopy (PANalytical Epsilon 3 XLE XRF)

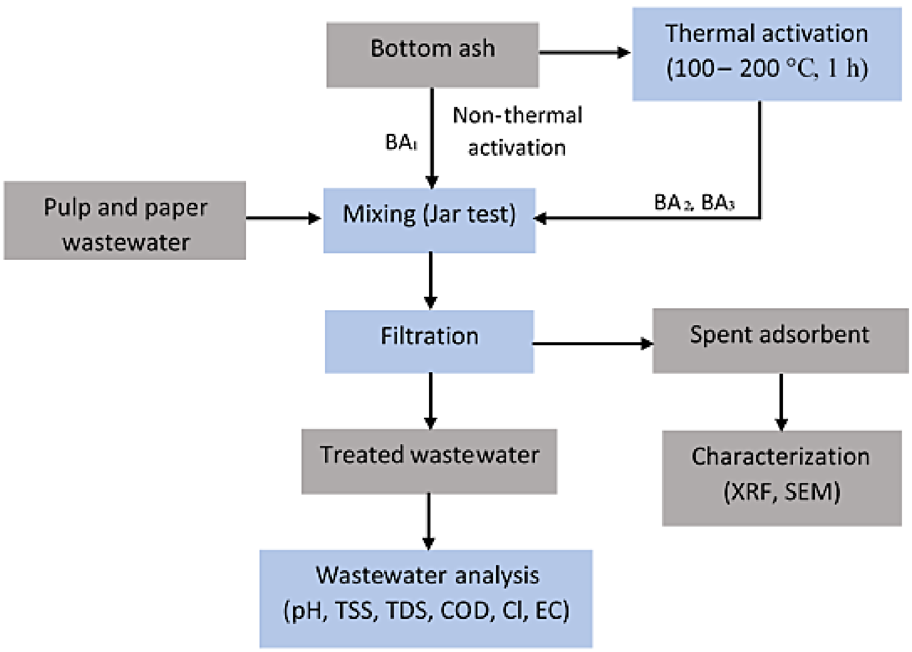

Figure 1. Diagram of pulp and paper wastewater treatment process with bottom ash adsorbent

and Scanning Electron Microscope (SEM JEOL-JSM-6510 LA) method. This research took place according to the scheme shown in Figure 1.

Bottom ash adsorbent activation

The bottom ash was activated by heating using an oven at 100 °C and 200 °C for 1 hour. The heating process is intended to remove the water in the bottom ash and open the pores of the bottom ash so that it can absorb more pollutants in the pulp and paper wastewater. The characteristics of bottom ash before and after activation were analyzed using XRF and SEM to identify chemical composition and surface morphology.

The analysis of bottom ash adsorbent by jar test

The bottom ash is weighed with a mass of 100 g in 500 ml of wastewater. Erlenmeyer was placed in a jar test with a stirring speed of 100, 200, and 300 rpm at room temperature with a time variation of 10, 20, 30, 40, and 50 minutes. Afterwards, the mixture was separated by filtering it using a filter paper. The wastewater treated with bottom ash adsorbent was then measured for hardness, electrical conductivity, pH, TSS, COD, and chloride with the standards and test methods in Table 1.

RESULTS AND DISCUSSION

Bottom ash adsorbent performance

The results of water quality measurements obtained from the wastewater treatment process using bottom ash adsorbents are summarized in Table 2. The initial raw material has a pH of 7.1, a TDS of 1455 ppm, and an EC of 2816 s/cm with a cloudy yellow wastewater color. Wastewater treatment with bottom ash adsorbent occurs under optimum conditions, namely 50 minutes of stirring time and 100 rpm stirring speed.

Bottom ash has high basicity or is more alkaline (Kim et al., 2021). Hence, bottom ash adsorbent can increase the pH of wastewater without heating or heating to 8.6. This indicates that the pH value obtained still meets the environment quality standard range based on the Minister of Environment Regulation No. 5 of 2014 concerning Pulp and Paper Wastewater Quality Standards. In the measurement of TDS, the decrease is highly dependent on the length of processing time, which can be seen for the processing time of 50 minutes, the percentage of TDS removal is up to 21.4%, and the processing time for 10 minutes is only 6%. Meanwhile, EC is directly related to the amount of metal dissolved in wastewater. According to Park et al. (2020), the FABA from the wood-burning process have great potential to reduce the heavy metal levels in wastewater and waste from the combustion process.

Table 1. Wastewater parameter analysis method

Parameter	Unit	Standard Method	Analysis Method
pH	-	SNI 6989.11-2019	pH analysis
TDS	mg/L	SNI 6989.27-2019	Gravimetric/conductivity
TSS	mg/L	SNI 06-6989.3-2004	Gravimetric
COD	mg/L	SNI 6989.73:2019	Titrimetric analysis (closed)
Cl^-	mg/L	SNI 06-6989.19.2000	Argentometry
Electrical conductivity	μs/cm	SNI 6989.1:2019	Conductivity meter

Table 2. Analysis results of pulp and paper wastewater using jar test

Stirring speed (rpm)	Time (min)	Parameter								
		pH			TDS (ppm)			EC (μs/cm)		
		BA_1	BA_2	BA_3	BA_1	BA_2	BA_3	BA_1	BA_2	BA_3
100	50	7.4–7.6	7.7–8.1	8.8–8.6	6.39–20.62	6.39–11.82	6.39–21.44	8.88–19.21	8.88–15.66	8.88–22.59
200	50	7.6–7.7	7.8–8.1	8.4–8.5	0–11.82	0.27–6.39	6.39–11.82	-6.61–14.60	-9.94–2.17	-6.61–18.86
300	50	8–8.2	7.6–7.9	8.3–8.6	3.23–11.82	0–6.53	6.39–20.62	8.88–19.92	-6.61–12.22	12.22–19.92

Note: BA_1 – without heating, BA_2 – heating at 100 °C, BA_3 – heating at 200 °C.

COD, TSS, and chloride reduction efficiency by using a jar test

The results found a decrease in COD, TSS, and chloride resulting from the processing with bottom ash adsorbent using the Jar test. In the Jar test process, coagulation and flocculation processes occur. In the coagulation process, there is a destabilization of colloids and particles in wastewater caused by heating on the physical activation of the adsorbent (Puchana-Rosero et al., 2018). The COD, TSS, and chlorine values with stirring speed in the jartest process of 100 rpm are summarized in Table 3.

Before processing, the COD, TSS, and chloride values were 893 mg/L, 80 ppm, and 66.74, respectively. The absorption process using an adsorbent without heating (BA_1) showed a decrease in the COD, TSS, and chloride values, which were 163 mg/L, 75 ppm, and 48.74, respectively. On heating bottom ash with a temperature of 100 °C (BA_2), the COD, TSS, and chloride values were obtained at 145 mg/L, 31 ppm, and 44.31. Wastewater treatment using bottom ash with heating at 200 °C (BA_3) received the COD, TSS, and chloride values of 132 mg/L, 18 ppm, and 48.74. The high metal content in bottom ash, such as aluminum, calcium, iron, and silica, has acted as a potential coagulant to form small particles (Luo et al., 2020). Fast stirring has helped mix the adsorbent in the wastewater evenly. The adsorbent in wastewater can bind suspended solids to improve the resulting precipitate.

The COD analysis calculates the levels of organic matter that can be oxidized by using strong oxidizing chemicals in acidic media. From the processing results, the COD, TSS, and chlorine levels decreased due to the activation of bottom ash by heating treatment at a temperature of 200 °C. Activation at higher temperatures has enlarged the pores on the surface of the adsorbent. According to Jamaludin (2020), coal bottom ash can reduce the values of TSS, BOD, and turbidity by 41.6%, 65.3%, and 75.6% of batik waste.

Characteristics of bottom ash adsorbent before and after the adsorption process

The morphology of the surface of bottom ash grains determines the concentration of elements

Table 3. Efficiency of COD, TSS and Chlorine reduction

Parameter	Before adsorption	After adsorption			Quality standards	Reduction efficiency (%)		
		BA_1	BA_2	BA_3		BA_1	BA_2	BA_3
COD (mg/L)	893	163	145	132	300	81.7	83.7	85.2
TSS (ppm)	80	75	31	18	100	6.25	61.2	77.5
Cl^-	66.74	48.74	44.31	48.74	-	26.9	33.6	26.9

Note: BA_1 – without heating, BA_2 – heating at 100 °C, BA_3 – heating at 200 °C.

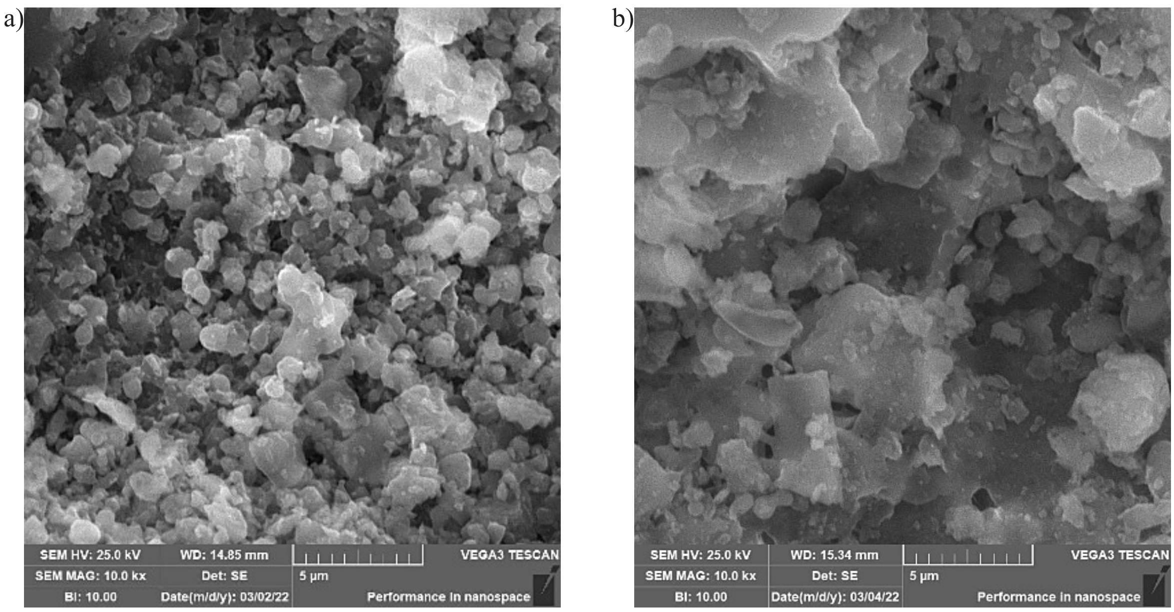

Figure 2. Morphology of bottom ash (a) before and (b) after adsorption

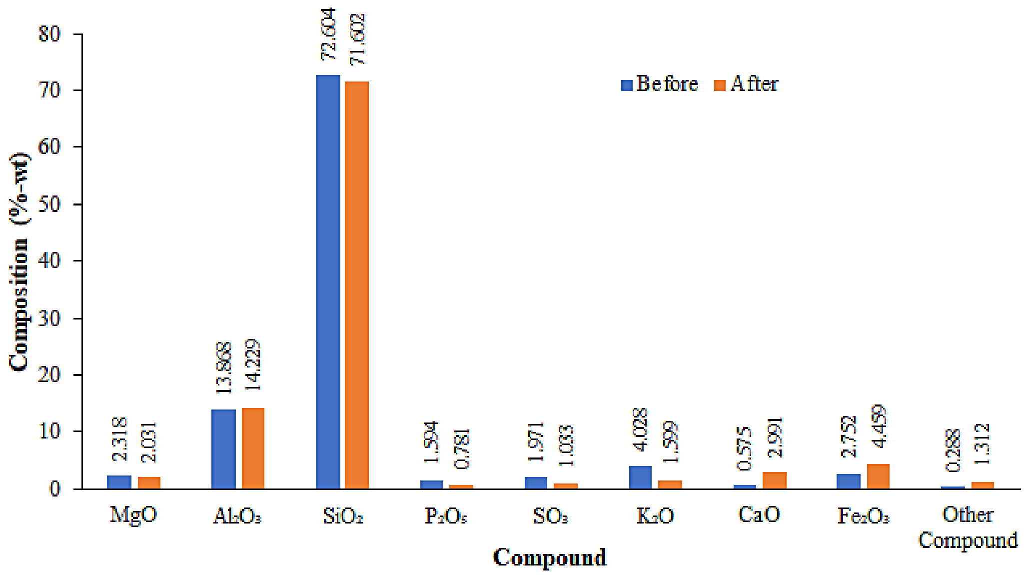

Figure 3. Chemical composition of bottom ash before and after adsorption

present on the surface of bottom ash (Mutalib et al., 2017). The surface morphology of bottom ash at 10,000 magnification is shown in Figure 2. According to Bumanis et al. (2013), bottom ash has a coarse, sandy, and angular structure caused by metal compounds deposited on the surface. After the processing occurs, it is seen that several compounds increase, such as calcium oxide, iron oxide, and a little titanium oxide which is possible from the waste water of the pulp and paper industry.

The composition of the bottom ash adsorbent determined using the XRF method is shown in Figure 3. The dominant compounds in bottom ash are MgO, Al_2O_3, and SiO_2. It can be seen that there is no significant change in the composition of bottom ash after being able to reduce the levels of COD, TDS, and TSS in wastewater.

CONCLUSIONS

Pulp and paper wastewater treatment with bottom ash using jar test has successfully reduced the value of COD, TDS, TSS, EC, and chloride, which have met environmental quality standards. The optimum percentage reduction was seen in removing COD, TSS, and Cl^- of 85.2 mg/L, 77.5 ppm, and 26.9 with a stirring speed of 100 rpm for 50 min.

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