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Application of activated charcoal- sugarcane bagasse material for adsorption of COD (Chemical Oxygen Demand) on the sasirangan wastewater

R Noor [1], N Annisa[1], D M Paramitha[1], and H Prasetia[2,3]

[1] Department of Environmental Engineering, Faculty of Engineering, Lambung Mangkurat University, Indonesia
[2] Research Center for Chemistry-National Research and Innovation Agency (BRIN), Indonesia.
[3] Research Center for Policy and Management of Science, Technology, and Innovation, National Research and Innovation Agency (BRIN), Indonesia

Corresponding author: r_zalin_or@yahoo.co.id

Abstract. In Indonesia, there is a significant amount of sugarcane bagasse waste that has not been utilized optimally. Around 50% of sugarcane bagasse waste is discarded as waste with little economic value. Sugarcane bagasse contains lignocellulose, composed of 20% hemicellulose, 52.75% cellulose, 20% pentosan, and 37.55% lignin and converted into activated charcoal. Sugarcane bagasse can be used as an alternative raw material for activated charcoal by carbonizing it in a batch process to remove organic compounds from the waste. On this basis, a study was conducted to determine the effectiveness of bagasse activated charcoal in reducing the COD content of sasirangan waste and the optimal dose of bagasse activated charcoal as an adsorbent in reducing the COD content of sasirangan wastewater.The steps to make activated carbon are by place small pieces of bagasse in the mortar and place in a 350^{o}C furnace for 2 hours or until the sample turns black. Next, bagasse charcoal was sieved until smooth using a 100-mesh sieve. The following stage is chemical activation. Bagasse that has passed through the sieve is soaked in 0.1 N 20% HCl activator for the day—cleansing the activated charcoal with distilled water until the pH is neutral. The next step is physical activation, which involves heating the activated charcoal in an oven at 105^{o}C for six hours to dehydrate it. The results indicated that bagasse activated charcoal with a pH of 5 and a contact time of 90 minutes could reduce the COD content of the Sasirangan wastewater by up to 95.37 % and that the dose of bagasse activated charcoal as an adsorbent had a significant effect on the COD content. The quantity of 5 g/L is the maximum number of COD that can be absorbed.
Keyword: Activated Charcoal, COD, sasirangan wastewater

1. Introduction

The Sasirangan textile factory is regularly expanding. Sasirangan is a traditional batik fabric indigenous to South Kalimantan, specifically the Banjar Tribe, most of which is produced on a small scale and in the conventional manner [1]. The result of this increasingly advanced development has been the prosperity of the Banjar community economy. However, the sasirangan textile industry can negatively affect the community if waste is not processed correctly before being dumped into the river.

Sasirangan processing involves several stages, including fabric preparation, pattern creation, sewing, dye preparation, colour dyeing, washing, drying, and ironing. Sasirangan is a producer of wastewater during the colouring stage. Synthetic dyes such as naphthol (ASLB), indanthrene, and salt compounds (B red) are frequently used in Sasirangan staining. These dyes contain a high concentration of chemicals and are therefore difficult to dissolve in water. The numerous applications of chemicals in the dyeing and dyeing process necessitate a unique approach to the generated wastewater [2]. The waste produced during the colouring process results in a cloudy, viscous liquid. By and large, the colour of wastewater is determined by the dye used.

According to the survey results conducted on Saturday, May 22, 2021, The Sasirangan wastewater comes from "Indah Sasirangan" in Sasirangan Village, Seberang Masjid Street, Seberang Masjid Village, Banjarmasin City. The COD content of the wastewater is 730 mg/L, which exceeds the quality standard for Textile Industry wastewater stipulated by the Minister of Environment and Forestry Regulation Number 16 (2019) of 150 mg. Health problems, such as respiratory and digestive disorders, can result from elevated COD levels. There are also environmental consequences, such as the disruption of aquatic biota ecosystems. The need for oxygen as a source of life for aquatic creatures, such as animals and aquatic plants, cannot be met, putting aquatic creatures at risk of death. And are incapable of reproducing effectively [3]. Sewage treatment employs various techniques, including cation exchange membranes, flocculation/coagulation, adsorption, and electrochemical degradation. However, due to its high adsorption efficiency, high adsorption capacity, low operating costs, and other advantages, adsorption technology employing a variety of adsorbents remains the most profitable method to date [4].

Indonesian industries, both large and small, frequently use the activated charcoal adsorption method to remove contaminants from their products. Activated charcoal is a type of adsorbent medium composed of carbon that has been treated to increase its adsorption capacity. Industrial growth is directly proportional to the domestic and export demand for activated charcoal. Indonesia exported activated charcoal to countries throughout Asia and Europe in 2000. Indonesia exported 25,671 tons of activated charcoal in 2005, according to the Asian and Pacific Coconut Community [5]. Anticipating the current high demand for activated charcoal, individuals seek alternative raw materials containing lignocellulose that are readily available, renewable, and have a low economic value for use as activated charcoal [6].

A significant amount of bagasse waste exists in Indonesia, which has not been used to its full potential. Around 50% of bagasse waste is discarded as waste with little economic value [7]. Bagasse contains lignocellulose, 20% hemicellulose, 52.7% cellulose, 20% pentosan, and 37.5% lignin [8]. Bagasse can be used as an alternative raw material for activated charcoal by carbonizing it in a batch process to remove organic compounds from waste [9]. Bagasse charcoal can reduce COD levels in well water by up to 3.59 %, while bagasse charcoal activated with KOH can reduce COD levels by 24.75 %. The dose of the adsorbent can also affect its adsorption capacity [9]. Bagasse at a quantity of 4 grams in tofu waste resulted in a reduction of up to 84.72 % [3]. On this basis, a study was conducted to determine the effectiveness of bagasse activated charcoal in reducing the COD content of sasirangan waste and the optimal dose of bagasse activated charcoal as an adsorbent in reducing the COD content of sasirangan wastewater. Sasirangan craftspeople can use the findings of this study to develop an alternative method of processing wastewater before it is discharged into the river.

2. Materials and methods

2.1. Carbonization and Activation of Sugarcane Bagasse

Place small pieces of bagasse in the mortar and place in a 350^{o}C furnace for 2 hours or until the sample turns black. Next, bagasse charcoal was sieved until smooth using a 100-mesh sieve. The following stage is chemical activation. Bagasse that has passed through the sieve is soaked in 0.1 N 20% HCl activator for the day—cleansing the activated charcoal with distilled water until the pH is neutral. The next step is physical activation, which involves heating the activated charcoal in an oven at 105^{o}C for six hours to dehydrate it.

2.2. Characterization of Activated Charcoal
To be considered carbonized and activated charcoal, it must meet the Indonesian National Standard (SNI) requirements, SNI No. 06-3730-1995, which is attached to Table 1.

2.3. Characterization of the quality of sasirangan wastewater
The characteristics of the Sasirangan wastewater are summarized in Table 3.

2.4. COD Content Verification
The varied sample solution is taken up to 3 ml and then added to the reagent tube along with 1.5 ml of $K_2Cr_2O_7$ standard solution, Ag_2SO_4 and H_2SO_4 reagent solutions. The tube is gently shaken until the solution is thoroughly mixed. Additionally, the tube is placed on a heating block set to 150^{o}C for two hours. Next, the temperature of the test sample was lowered to room temperature. Then, using the COD and Measuring Photometer tool, determine the COD content.

Table 1. Requirements for activated charcoal quality SNI No. 06-3730-1995

Test Type	Terms of Quality of Active Carbon
Water content	Maximum 15%
Ash content	Maximum 10%
Iodine Absorption	Minimum 750 mg/gr

3. Results and Discussion

3.1. Sugarcane Bagasse Activated Charcoal Characteristics
The bagasse waste used in this study as activated charcoal originated at a sugarcane ice mill in Banjarmasin City, specifically on Jalan A. Yani Km 6.7. The characteristics of activated charcoal that is ready to use are first determined. Table 2 summarizes the characteristics of bagasse activated charcoal.

Table 2. Sugarcane bagasse activated charcoal characteristics

No.	Characteristics	Total Contained	Unit
1	Water content	13	%
2	Ash content	3	%
3	Iodine Absorption	964,44	mg/g

The results of several tests conducted on bagasse activated charcoal are shown in Table 2. The determination procedure is based on SNI 06-3730-1995, which is attached to Table 2. The water content calculation is used to determine the hygroscopic nature of activated charcoal. Activated charcoal has a strong attraction to water [10]. After 1 hour or until a constant weight at 105^{o}C was obtained, the water content of activated bagasse charcoal was 13%. As the heating temperature increases, the water content decreases. After reaching the boiling point of 100^{o}C, H_2O undergoes a phase change from liquid to gas. When the temperature rises, more water evaporates, and the water content decreases. The low water content is most likely due to the carbonization process and the activator HCl. HCl has hygroscopic properties, which means it can absorb water. The duration of the activation process affects the water content; the longer the activated charcoal is immersed, the less water is produced [11].

The ash content of activated charcoal is determined to determine the metal oxide content. The ash content is interpreted as the mineral residue remaining after combustion. Natural materials used to make activated charcoal contain carbon compounds and a variety of minerals, some of which are lost during the carbonization and activation processes. After one hour of heating at 500°C, the ash content is 3%. The low ash content is most likely due to the time required to activate the charcoal, as activation results in the enlargement of the pores and expansion of the surface. High ash content can impair adsorption capacity by clogging surface pores, making it more challenging to absorb adsorbate [12].

The purpose of determining iodine uptake is to ascertain the activated charcoal's adsorption capacity [13]. Iodine solution is added as an adsorbent and is absorbed by the adsorbent. The residual iodine concentration can be determined by titrating the iodine solution with 0.1 N sodium thiosulfate and starch as an indicator [14]. Bagasse activated charcoal absorbs 964.44 mg/gr of iodine. The adsorption capacity of activated charcoal for iodine is proportional to its surface area. The more iodine present, the more ability the activated charcoal has to adsorb the adsorbate or solute. The rate of iodine absorption increases in direct proportion to the duration of activation. The longer the activation time, the more pores open, allowing for more excellent iodine absorption into the activated charcoal pores. Pore surface area is a critical parameter in determining the adsorbent quality of activated charcoal because it affects the adsorption process.

3.2. Sasirangan Wastewater Characteristics

Sasirangan businesses with direct access to the Martapura River are concentrated in three locations in Banjarmasin City: Seberang Masjid Street, Seberang Masjid Village. The water used in the adsorption process was Sasirangan wastewater, which originates in “Indah Sasirangan”, Kampung Sasirangan, Seberang Masjid Street, Seberang Masjid Village, Banjarmasin City (L. 03 311 64 46; E. 114 594 20 64). Before being used in this study, Sasirangan wastewater is tested for parameters under the Minister of Environment and Forestry's Regulation 16 (2019). The characteristics of the Sasirangan wastewater are summarized in Table 3.

Table 3. Initial test results for the quality of sasirangan wastewater

No.	Parameter	Amount Contained	Unit
1	COD	730	mg/l
2	BOD	268,65	O_2 mg/l
3	TSS	527	mg/l
4	Total Phenol	0,016	mg/l
5	Total Chromium (Cr)	0,0528	mg/l
6	Total Ammonia	7,368	mg/l
7	Sulfide	<0,0020	mg/l
8	Oils and Fats	0,04	mg/l
9	pH	11,42	-

According to the results, parameters with a value greater than the quality threshold are as follows: COD, BOD, TSS, and pH. Because BOD and COD are determinants of other parameters for water quality conditions, they are always used as standard parameters for wastewater quality. The results of the measurements indicate that the COD value was greater than the BOD value. In comparison to BOD, COD has a higher value because BOD is influenced only by quickly decomposable organic matter, whereas COD is influenced by all organic matter present in the water body [1]. In addition, the COD test is more effective and precise than the BOD test because it is capable of oxidizing substances that are inert to biological reactions and microorganisms [15].

3.3. The Effects of Activated Charcoal Dosage on COD Content

Another factor influencing COD absorption is the adsorbent dose. The addition of the quantity can affect the adsorbent's relationship with the adsorbate. The dosage variation of bagasse activated charcoal adsorbent was divided into five groups in this study, one control and four treatment groups. The control group (K) was the group that received no dose treatment and was exposed to a pH of 5 for 90 minutes. The second group received a dose of bagasse up to 1.5gr/L with a pH of 5 and 90-minute interval (P1), the third group received a quantity of bagasse up to 3gr/L with a pH of 5 and 90-minute interval (P2), group four received a dose of bagasse up to 4gr/L with a pH of 5 and 90-minute interval (P3). Group five received a quantity of bagasse up to (P4). Figure 1, illustrates the effect of adsorbent dose on adsorption capacity and efficiency in reducing COD content.

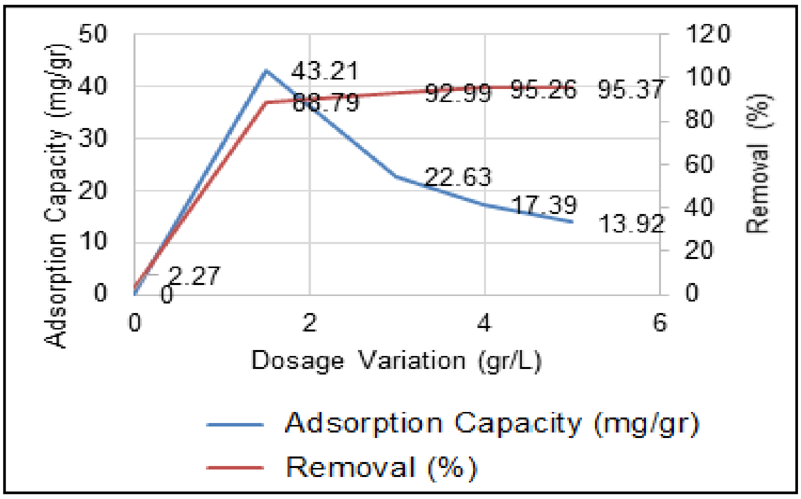

Figure 1. The Effect of Dose Variation on the Adsorption Capacity and Removal of Sasirangan Wastewater

As illustrated in Figure 4.3, the efficiency of reducing COD without dosing (control group) was only 2.27 %. Efficiency was 88.79 % in the P1 group. The adsorption efficiency of Group P2 was 92.99 %. Adsorption efficiency was 95.26 % for Group P3. The P4 group was most efficient, with a 95.37% efficiency rate. The graph demonstrates that dose is proportional to COD efficiency but not to adsorption capacity. It has increased dose results in an increase in the active site on the surface of the bagasse charcoal. The above tightens the adsorbate-adsorbent bond and loosens the adsorbent's surface-active side [16]. This event is consistent with the Langmuir isotherm principle, which states that a monolayer layer of adsorbate molecules with a uniform adsorbent surface form. Because the pores in bagasse charcoal are homogeneous, each active site on the surface can only absorb one type of adsorbate molecule. Therefore, the active area of the adsorbent increases with adsorbate concentration, increasing adsorbate absorption. The dose must be adjusted according to the volume of wastewater to avoid saturation of the adsorbent. When the dose treatment was administered, the pH parameter changed as well. Although the pH increases, it remains within the specified quality standard range of 6.00-9.00. Because turbidity is bound to the active side of bagasse charcoal, it can reduce turbidity in Sasirangan wastewater. According to Hatina et al., the use of HCl in adsorption activation can decrease COD and TSS content and increase DO and pH content [17].

3.4. Isotherm Adsorption

Because it describes the relationship between the amount of adsorbed substance and the amount of adsorbent at equilibrium, the adsorption isotherm explains the interaction between the adsorbent and the adsorbate. The adsorption isotherm was determined by converting the Langmuir (Figure 1) and

Freundlich isotherm equations (Figure 3) to a straight-line equilibrium curve. The equilibrium model was determined by the determinant coefficient (R2) value, which should be close to 1.

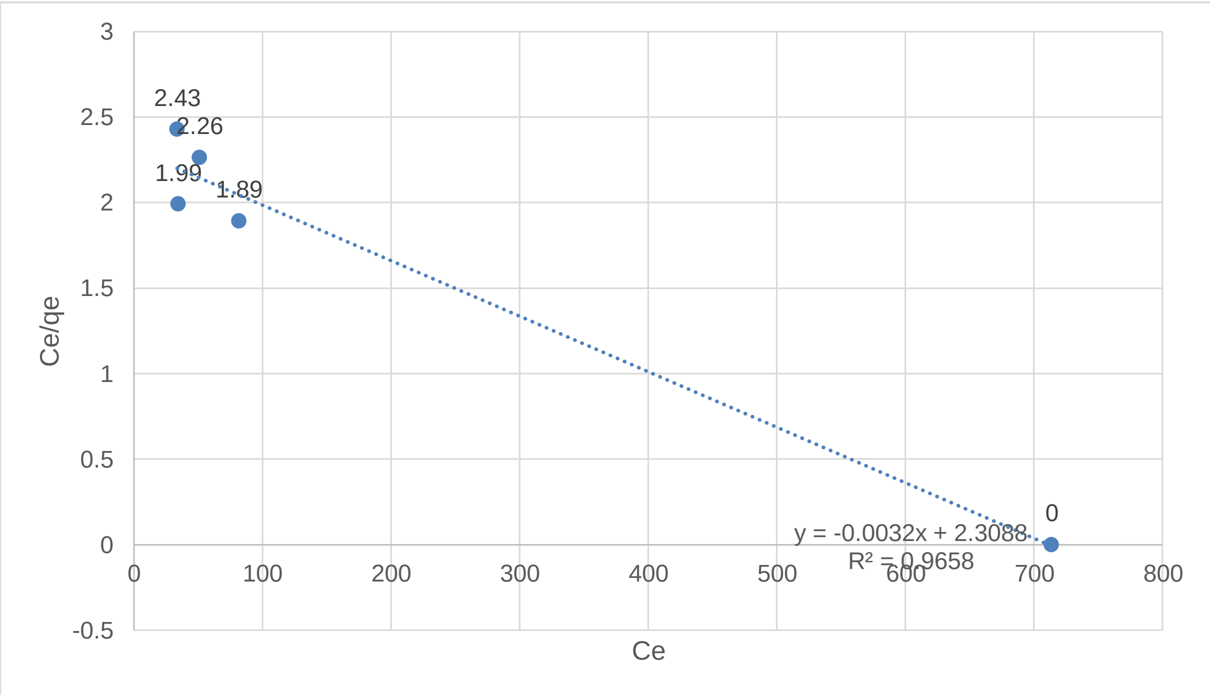

Figure 2. Isotherm Langmuir

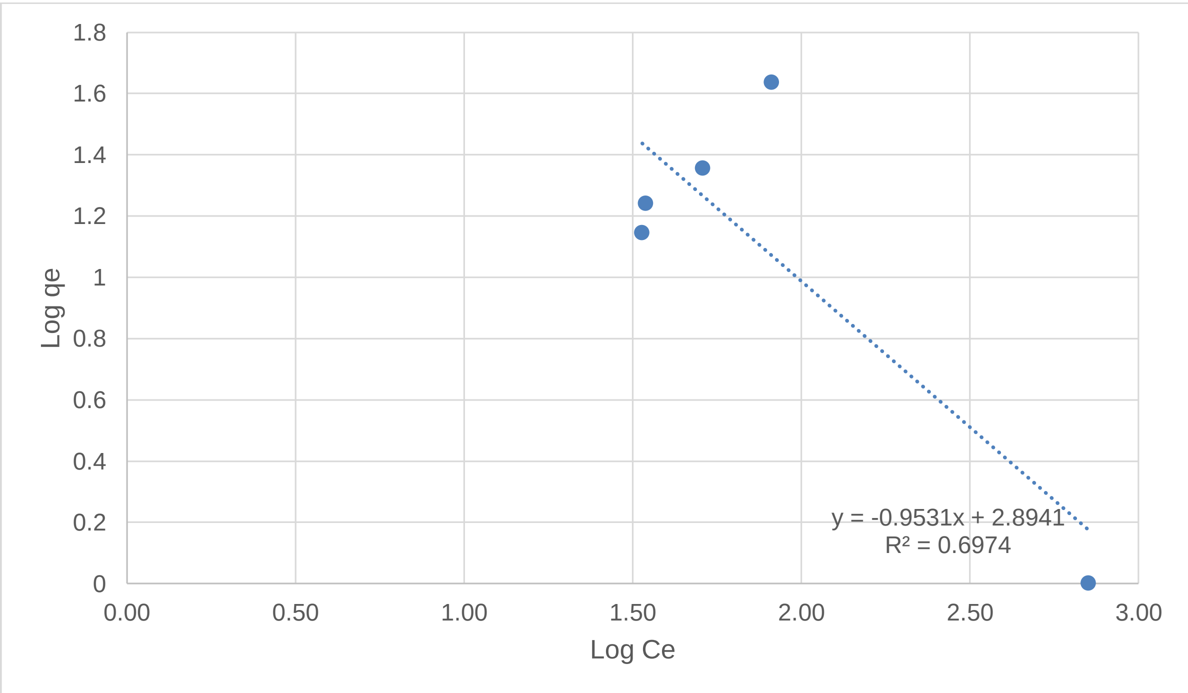

Figure 3. Isotherm Freundlich

Table 4 contains the equation and correlation coefficient value for each isotherm, as shown in the illustration above. The results indicate that the Langmuir isotherm model is the most suitable for COD adsorption in Sasirangan wastewater, with a regression coefficient (R2) close to or greater than one.

The Langmuir adsorption isotherm is based on the assumption that monolayer adsorption occurs on an adsorbent surface that is homogeneous. The Langmuir isotherm is based on the assumption that the adsorbent's surface is uniform. When the adsorption site has been completely depleted, the adsorption process at that location will come to a close for good. When the adsorption process reaches its maximum efficiency, the surface of the adsorbent will reach saturation [18].

Table 4. Equation and coefficient of isotherm correlation value

No.	Isotherm Model	Equation	Parameter	Value
1	Langmuir	y = -0,0032x + 2,3088	R^2	0,9658
			qmaks	-312,5
			Kl	-0,00139
			Rl	- 0,498
2	Freundlich	y = -0,9531x + 2,8941	R^2	0,6974
			n	-1,049
			Kf	783,61

4. CONCLUSION

Sugarcane bagasse activated charcoal with a pH of 5 and a contact time of 90 minutes was effective in reducing the COD content of Sasirangan wastewater by 88.79 to 95.37 %. The most effective dose was 5 g/L bagasse activated charcoal, which reduced the COD content of the Sasirangan wastewater to 95.37 %. The results indicate that the Langmuir isotherm model is the most suitable for COD adsorption in Sasirangan wastewater.

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