Characteristic of betel nuts activated carbon and its application to Jumputan wastewater treatment

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Abstract. Wastewater from Jumputan production contains synthetic dye which is harmful to the environment. The contaminant can be reduced by adsorption process using activated carbon. The activated carbon was prepared from betel nuts with carbonization temperature of 500°C and 0.5 M HCl as an activator. Batch mode experiments were conducted to study the effect of various factors, such as the size particle of adsorbent, the dosage of adsorbent, and the contact time on Jumputan’s dye adsorption. The volume of treated solution was 200 mL. This solution agitated using a Jar Test at 150 rpm. The objectives of this work were to analyze the characteristic of the betel nuts, to analyze the characteristic of the activated carbon and to determine adsorbent’s ability to dye adsorption. Betel nuts compositions were analyzed with proximate analysis method. The adsorbents were carried out by SEM-EDS analysis. The dye adsorptions were analyzed with a portable spectrophotometer. The result shows betel nuts contains 60.86% carbohydrate, 32.56% water, 2.17% fat, 3.35% protein, and 1.06% ash. The major component of the activated carbon is carbon (C) of 86.27%, and the rest is Oxygen (9.18%) and Aurum (4.55%). The best condition is the adsorbent that has a particle size of 250 pm (60 mesh), the dosage of 20 grams, and the contact time of 15 minutes with dye removal of 76.4%.

1. Introduction
In general, water pollution is described as harmful substances or unexpected materials that found in the water in sufficient quantities[1]. These reduced the dissolved oxygen levels for aquatic organisms, and so water quality. Jumputan wastewater is an example of water pollution. Jumputan wastewater contains dyes of organic compounds such as napthol, indigosol, procion, erionyl, auramin, and rodhamin.

Industrial wastewater can easily be known for its color. Pollutant contamination varies both types and quantities. The most widely used dye is the napthol and the indigosol substance. Naphtol is called Azo Dyes because when combined with salt diazo a new color arises. These substances are soluble in water, contains cyclic nuclei and aniline acids compounds. Naphtol invented in 1911. It is manufactured by dyestuff factories in Europe, Japan, and China. This substance is applied in batik traditional Palembang such as Songket, Jumputan, Blongsong. Indigosol is also called Leuco Sodium Esters, if the color oxidized it becomes an insoluble solution and gives the real color. The process used sodium nitrite and acids. The dye wastewater in the textile industry, as well as Jumputan, produce from dyeing and washing process.

One method to overcome water pollution is adsorption. Activated carbon is the most widely used adsorbent. The raw materials of the activated carbon were rice husk ash [2], coalite [3], banana stem [4], bark peel [5], betel nuts [6-9], and others. The previously activated carbon that utilized in Jumputan wastewater treatment were coalite [3], the shell of kemiri [10], coffee powder [11], and betel nuts [6-9]. In general, factors that affect adsorption process are the surface area (particle size), the type of adsorbent,
the adsorbate molecular structure, the concentration of adsorbate, temperature, pH, stirring rate, and contact time.

The primary component in Jumputan wastewater is a synthetic color that is utilized. The study of dye removal from Jumputan wastewater by using betel nuts activated carbon is prior being done. Considered factors such as particle size, weight of adsorbent, and contact time were varied. The aims of this study were to analyze the characteristic of betel nuts and the activated carbon, and to investigate the adsorbent’s ability to adsorb dye contaminant on Jumputan wastewater in batch mode.

2. Research methodology
The furnace, oven, analytical balance, mortar, beaker glass, measuring cup, funnel, desiccator, and pH meter were used in this work. Materials were betel nuts, HCl 0.5 M, Jumputan wastewater, and aquadest.

The activated carbon was produced from betel nuts with carbonization temperature of 500°C and 0.5 M HCl as an activator [6]. Betel nuts compositions were analyzed with proximate analysis method. The adsorbents were carried out by Scanning Electron Microscope (SEM) - Energy Dispersive Spectroscopy (EDS) analysis. The dye adsorptions were analyzed with a portable spectrophotometer. Variation in particle size, dosage of adsorbent, and contact time were applied to investigate dye adsorption. The volume of Jumputan wastewater was 200 mL. This solution was agitated using a Jar Test at 150 rpm. The size of the adsorbent was 1 mm (18 mesh) and 250 pm (60 mesh). The dosage of the adsorbent was 5, 10, 15, 20, and 25 grams. The contact time was 5, 10, 15, 20, and 25 minutes.

3. Result and discussion
Betel nuts is an ornamental plant that isn’t utilized yet. It has a hard texture that can be used as a raw material to produce activated carbon. The characteristics of betel nuts by using proximate analysis method are presented in Table 1.

| Carbohydrate’s content on betel nuts is a prime source of carbon. It produces to become activated carbon with carbonization and chemical activation process based preliminary research procedure [6]. The dried betel nuts were carbonized in an electrical furnace at temperature of 500°C and then activated with 0.5 M HCl [6]. Betel nuts that become activated carbon are 22.6%wt from its original. Highly water content on betel nuts effects the quality and quantity of the activated carbon produced. This value is lower than coconut shell activated carbon which was 30-35%wt [12]. However, betel nuts is still a promising raw material consider high ability to adsorb COD, BOD, TSS, and dye in Jumputan wastewater [6-9].

Table 1. Proximate analysis of betel nuts

| Composition | Percentage (%) |
|-------------|----------------|
| Water       | 32.56          |
| Fat         | 2.17           |
| Protein     | 3.35           |
| Ash         | 1.06           |
| Carbohydrate| 60.86          |

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Betel nuts activated carbon was characterized by Scanning Electron Microscope (SEM) - Energy Dispersive Spectroscopy (EDS) analysis. It presents topography (surface texture), morphology, porosity, and composition of the blank adsorbent. SEM micrographs of betel nuts activated carbon are shown in Figure 1. The adsorbent exhibits a caves-like, porous, uneven, and rough surface morphology [13]. The shortest pore diameter and area are 1.564 pm and 1.92 pm² respectively. The longest pore diameter and area are 1.787 pm and 2.508 pm² respectively. Figure 2 describes the composition of activated carbon. The major component is carbon (86.27%), and the rest are oxygen (9.18%) and aurum (4.55%). In the SEM-EDS analysis, the sample should be a conductive material, so aurum is added to cover the activated carbon. The carbons tie up impurities in the Jumputan wastewater, so the dye, BOD, COD, TSS, and Crom can be removed. This similar result also showed by Cundari L., et. Al. [6-9]. Although activated carbon was the most effective sorbent, other low-cost sorbents, such as betel nuts activated carbon, could be used for color removal to substitute for high-cost adsorbent [14].

Figure 1. Scanning Electron Microscope of betel nuts activated carbon.

Figure 2. Composition of betel nuts activated carbon

Another analysis that applies to the adsorbent is water content and iodine adsorption. The water content of activated carbon is equal to 1.76% and 0.05% for the size of 1 mm (18 mesh) and 250 pm (60 mesh) respectively. The water content of the adsorbent has fulfilled the standard of activated carbon quality according to SII 0258-88 which the maximum value is 4.4% for activated granulated carbon and maximum 15% for powder activated carbon. The adsorption capacity of activated carbon to Iodine for is 476.95 mg/g and 593.94 mg/g for 1 mm (18 mesh) and 250 pm (60 mesh) respectively. The result of adsorption analysis of Iodine that obtains from this research has not fulfilled the standard of active carbon quality according to SII 0258-88 which is at least 750 mg/g.

Betel nuts activated carbon is applied on dye adsorption from Jumputan wastewater. The experiment conducts in batch mode. The initial dye concentration of the Jumputan wastewater is 1293 ppm. The analysis result of the standard solution is seen in Table 2 and Figure 3.

| Absorbance | Concentration (ppm) |
|------------|---------------------|
| 1.229      | 1102.20             |
| 0.521      | 551.10              |
| 0.390      | 440.88              |
| 0.246      | 330.66              |
| 0.188      | 220.44              |
| 0.158      | 110.22              |

Table 2. The analysis result of standard solution

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Figure 3. Standard calibration curve

Table 3. Analysis data of Jumputan’s dye adsorption onto betel nuts activated carbon

| Dosage of adsorbent (gr) | Contact Time (minute) | Absorbance | Concentration | % Adsorption |
|--------------------------|-----------------------|------------|---------------|-------------|
|                          |                       | 1 mm | 250 pm | 1 mm | 250 pm | 1 mm | 250 pm |
|                          | 5                     | 0.729 | 0.553 | 793 | 616.5 | 38.7 | 52.3 |
|                          | 10                    | 0.489 | 0.505 | 552.5 | 569 | 57.3 | 56.0 |
|                          | 15                    | 0.463 | 0.426 | 526.5 | 490 | 59.3 | 62.1 |
|                          | 20                    | 0.285 | 0.282 | 348.5 | 346 | 73.0 | 73.2 |
|                          | 25                    | 0.304 | 0.242 | 368 | 306 | 71.5 | 76.3 |
|                          | 5                     | 0.374 | 0.404 | 438 | 467.5 | 66.1 | 63.8 |
|                          | 10                    | 0.357 | 0.335 | 421 | 398.5 | 67.4 | 69.2 |
|                          | 15                    | 0.286 | 0.301 | 350 | 365 | 72.9 | 71.8 |
|                          | 20                    | 0.247 | 0.280 | 311 | 344 | 75.9 | 73.4 |
|                          | 25                    | 0.275 | 0.278 | 339 | 341.5 | 73.8 | 73.6 |
|                          | 5                     | 0.371 | 0.315 | 434.5 | 379 | 66.4 | 70.7 |
|                          | 10                    | 0.316 | 0.283 | 379.5 | 346.5 | 70.6 | 73.2 |
|                          | 15                    | 0.286 | 0.270 | 349.5 | 333.5 | 73.0 | 74.2 |
|                          | 20                    | 0.280 | 0.247 | 343.5 | 310.5 | 73.4 | 76.0 |
|                          | 25                    | 0.264 | 0.232 | 327.5 | 295.5 | 74.7 | 77.1 |
|                          | 5                     | 0.454 | 0.297 | 517.5 | 360.5 | 60.0 | 72.1 |
|                          | 10                    | 0.346 | 0.268 | 410 | 331.5 | 68.3 | 74.4 |
|                          | 15                    | 0.281 | 0.241 | 345 | 305 | 73.3 | 76.4 |
|                          | 20                    | 0.274 | 0.234 | 337.5 | 298 | 73.9 | 77.0 |
|                          | 25                    | 0.256 | 0.219 | 319.5 | 282.5 | 75.3 | 78.2 |
|                          | 5                     | 0.506 | 0.258 | 569.5 | 322 | 56.0 | 75.1 |
|                          | 10                    | 0.351 | 0.240 | 415 | 303.5 | 67.9 | 76.5 |
|                          | 15                    | 0.270 | 0.235 | 334 | 298.5 | 74.2 | 76.9 |
|                          | 20                    | 0.258 | 0.219 | 321.5 | 283 | 75.1 | 78.1 |
|                          | 25                    | 0.241 | 0.214 | 305 | 277.5 | 76.4 | 78.5 |

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The linear regression that presented in Figure 3 is \( y = 0.0011x - 0.0064 \), where \( y \) as absorbance value and \( x \) as dye concentration (ppm). By using that equation, the absorbance data from spectrophotometer analysis is used to determine the dye concentration of Jumputan wastewater. The absorbance, dye concentration, and adsorption percentage data are shown in Table 3. The percentage of dye adsorption is determined by equation (1).

\[
\text{% Adsorption} = \frac{C_o - C_t}{C_o} \times 100 \%
\]  

(1)

Where \( C_o \) and \( C_t \) are the dye concentration of Jumputan wastewater at initial and time t. The average of dye adsorption is 68.6\% for 1 mm adsorbent and 72.2\% for 250 pm adsorbent. The percentage maximum of adsorption is 76.4 (1 mm adsorbent) and 78.5 (250 pm) at 25 grams of adsorbent dose and 25 minutes of contact time. The minimum is 38.7 and 52.3 for size particle of 1 mm and 250 pm at 5 grams adsorbent dose and 5 minutes contact time, respectively. The dosage of adsorbent and contact time effect the adsorption of dye. The greatest of adsorbent dose and the longest of contact time indicate maximum adsorption.

Figure 4 and 5 show the effect of contact time to dye adsorption process. Betel nuts activated carbon dosage of 5, 10, 15, 20, and 25 grams is added to each 200 mL of Jumputan wastewater. Experiments are conducted at a temperature of 298 K by variation of contact time to test the effect of contact time on the adsorption process. The results (Figure 4 and 5) indicate that the adsorption of dye onto adsorbent is very rapid in the first 15 min hence the adsorbed amount \((q_t)\) reached from 43.65\% to 71.6\% and 50.94\% to 74.2\% for 1 mm and 250 pm respectively. Then the adsorption of dye increases gradually during the following 20 min until reached equilibrium at about 25 min. The results show that the removal of dye onto betel nuts activated carbon depends on contact time [15]. The dye adsorption increase as the contact time increased. Time is required to encounter the boundary layer, diffuse to surface of adsorbent and diffuse to the porous structure of adsorbent [15]. The equilibrium conditions are reached within 20-25 minutes. At this time, the increase of contact time resulted only in about 3\% more to reach the maximum of dye removal. Thus 15 minutes of contact time is chosen as the optimum contact time. Both at 1 mm and 250 pm of particle size of adsorbent show similar trend. This also is seen from the highest correlation factor \((R^2)\) as 0.876 for 1 mm and 0.978 for and 250 pm, respectively.

![Figure 4. Effect of contact time to dye adsorption percentage at 1 mm adsorbent](image-url)
The influence of dosage adsorbent to dye adsorption is presented in Figure 6 and 7. The results in Figure 6 and 7 indicate that the dye adsorption increase as the adsorbent dosage increased. At 1 mm size of adsorbent, the optimum of adsorbent dose is 25 grams that reached the most at 76.4%. At 250 pm particle size of adsorbent, the optimum shows at 20 grams of dosage adsorbent that reached 78.2%. This value is seen from the highest correlation factor ($R^2$) as 0.940 for 1 mm adsorbent’s size and 0.946 for 250 pm adsorbent’s size, respectively. The dye adsorption is not enhanced effectively by increasing the amount of the adsorbent (from 5 to 25 grams). It may be due to increasing the overlapping and/or aggregation of adsorbent sites at high dose [16].

Figure 5. Effect of contact time to dye adsorption percentage with 250 pm adsorbent

Figure 6. Effect of dosage adsorbent to dye adsorption percentage with 1 mm adsorbent
Figure 7. Effect of dosage adsorbent to dye adsorption percentage with 1 mm adsorbent

Based on Table 3 and Figure 4-7, a particle at 250 pm shows a better result than 1 mm. It’s seen from the highest value of R². The best condition of Jumputan’s dye treatment for batch mode is 15 minutes of contact time and 20 grams of adsorbent dosage with dye adsorption 76.4%.

4. Conclusion
The result shows betel nuts contains 60.86% carbohydrate, 32.56% water, 2.17% fat, 3.35% protein, and 1.06% ash. The major component of the activated carbon is carbon (C) at 86.27%, the rest is oxygen at 9.18% and aurum at 4.55%. The best variation is adsorbent that the size of 250 pm (60 mesh), the dosage of 20 grams, and the contact time of 15 minutes with dye removal of 76.4%.

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