Chemical and Physical Activation Using a Microwave to Increase the Ability of Activated Carbon to Adsorb Dye Waste

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Abstract. This study aims to develop an android-based application to calculate the amount of fuel adjusted to the distance and speed of the ship based on the trajectory (way point). The calculation of distance in this application uses the concept of a spherical triangle which is used in voyage navigation. This development adopts the Waterfall model with the stages of Requirement Engineering, Design and implementation, Testing, Release and Maintenance. At the product review stage, it involves software experts (to provide criticism and suggestions for improvement), then testing is carried out by comparing the results of calculations using applications with manual calculations and ECDIS (electronic Chart Display Information System). The test results show that there is no significant difference between the results of calculations using the application with manual calculations and ECDIS. Thus, this application can be used to calculate the amount of fuel needed according to the distance traveled and the speed of the ship based on the selected trajectory.

1. Introduction
Mangrove trees are used as coastal protection from seawater abrasion and protect the coast from sea breezes. Besides that, another benefit of mangrove trees is that mangrove wood can be used as charcoal through the carbonation process. Carbonated charcoal is used as fuel for various needs. Utilization as charcoal fuel will have a low economic value because of the low selling price. One way to increase the economic value is to process it into activated carbon. Activated carbon is made by activated charcoal to have an increased ability to adsorb.

Activation is the process of opening the pores in charcoal to have a large active outer surface and an increased absorption ability. The carbon activation process is carried out in several ways, including chemical activation, physical activation, and a combination of chemical and physical activation. Chemical activation is a process to open the pores in charcoal by using chemicals through immersing charcoal in a chemical solution. The activators used include KCl, NaCl, ZnCl2, CaCl2, MgCl2, H3PO4, Na2CO3, and other mineral salts [1]. Physical activation is the process of opening pores on the surface of charcoal using physical treatment, namely by heating. The heating process is carried out by heating charcoal in a furnace at a temperature of 800°C-900°C. Besides heating using a physical activation furnace, it can also be done using a microwave [2]. Combined chemical and physical activation is carried out by chemical activation followed by physical activation.

Activated carbon has a better absorption ability than charcoal before activation. The increase in absorption ability is caused by the characteristics of activated carbon being better than charcoal without activation. Characteristics include active surface area, iodine number, and surface morphology. The benefits of activated carbon, among others, as an adsorbent in the treatment of heavy metal waste such as Pb(II), Cr(IV), and Mn(II)[3]. Besides, it is also used for adsorption of textile industry color waste [4][5].
Several studies on the manufacture of activated carbon include the manufacture of activated carbon made from palm oil shells with chemical and physical activation with a furnace for absorption of acetic acid with an absorption % of 66% [1]. Activated carbon from plastic waste which is chemically activated using KOH and physical activation with a furnace for processing color waste has an Iodine number of 990 mg/g [4], manufacture of activated carbon from bagasse for the absorption of dyes in the songket industry[6], activated carbon activation from fruit chemically and physically activated bintaro using water vapor for chromium metal absorption resulted in 99.4% absorption [7]. The processing of batik dyed Palembang waste uses chemically activated activated carbon adsorbent with an absorption of 76.4% [5] Pekalongan batik waste treatment uses activated carbon without activation.[8]

In this study, mangrove charcoal was activated using a combination of chemical and physical activation using a microwave for the adsorption of dyes waste. The activation process carried out is chemical activation using an H₃PO₄ activator followed by physical activation at variations in microwave power. In the application of activated carbon for the adsorption of dye waste.

2. Experimental Methods

2.1. Materials

The materials used in this study were mangrove charcoal purchased from shops around the Mangrove Surabaya with 90,470 m²/g surface area, H₃PO₄, dye waste.

2.2. Equipment

![Apparatus of Activation Process Equipment using Microwave](image)

**Figure 1.** Apparatus of Activation Process Equipment using Microwave

![Apparatus of Adsorption Process Equipment](image)

**Figure 2.** Apparatus of Adsorption Process Equipment

2.3. Procedure

Research on the activation of mangrove charcoal for processing dye waste was carried out in 4 (four) step, namely material preparation, chemical activation, physical activation, and activated carbon application for processing dye waste.

**Material preparation**

At this stage, the mangrove charcoal is cleaned from the remnants of combustion or dirt on the surface of the charcoal. Furthermore, the charcoal is crushed to 1-2 mm, then washed and dried using an oven.

**Chemical Activation**
This stage was carried out by immersing the mangrove charcoal in a 1 M $\text{H}_3\text{PO}_4$ solution. The immersion was carried out for 8 hours, followed by filtering and drying. Drying was carried out in an oven at 110°C for 1 hour. The result of chemical activation is then called activated carbon and is followed by physical activation.

**Physical Activation**

At this stage, physical activation is carried out using a microwave. Activated carbon from chemical activation as much as 10 grams was activated in a microwave with a stream of $\text{N}_2$ for 10 minutes at a microwave power of 80, 240, 400, 560, and 800 W. The flow of $\text{N}_2$ gas was intended to remove the air in the microwave. The results of physical activation are then stored in a desiccator and are ready to be analyzed and applied for dye waste treatment.

**Activated carbon application**

The application stage of activated carbon was carried out to determine the adsorption capacity of activated carbon as a result of activation. This stage is carried out by inserting activated carbon into an Erlenmeyer containing colored waste at various mass of activated carbon followed by stirring for 3 hours. Furthermore, filtering and color analysis is carried out.

3. Results and Discussion

Activated carbon that has been made was tested for characterization of iodine number, moisture content, active surface area, surface morphology, and application test for adsorption of dye waste.

**Iodine Number**

The iodine number test is intended to determine the ability of activated carbon to adsorb Iodine. According to the quality standard of SNI No.06-3730-1995, the value of the technically activated carbon iodine number that meets the quality standard is at least 750 mg/g. Based on the analysis, the iodine number of charcoal before activation was 261.22 mg/g. The iodine number of activated carbon at various microwave power variations presented in Figure 3.

![Figure 3. The relationship between microwave power and Iodine Number](image)

Figure 3 shows that in the microwave power range of 80 to 560 watts, there was an increase in the iodine number, but at 800 power, there is a decrease in the iodine number. This happens because in the 80 to the 560-watt range, the higher the microwave power, the more pores formed so that the ability to adsorb Iodine is more extraordinary. The Iodine number indicates the ability to adsorb Iodine. On heating, with 800 microwave power, there is a decrease in the Iodine number because the temperature is too high. Most of the organic matter escapes too quickly, and many of the previously produced pores become burned.

The highest Iodine number was obtained at 1196 mg/g. The value of Iodine number in this study is higher than that of making activated carbon from cocoa shells using chemical and physical activation, but physical activation using a furnace is 1194 mg/g [9]. These results indicate that activation using a combination of chemistry and physics with a microwave can improve the characteristics of activated carbon which is indicated by a greater iodine number than the combined chemical and physical activated carbon with a furnace.
Moisture content

The water content in activated carbon can affect the quality of the activated carbon. The purpose of testing the water content on activated carbon is to determine the amount of water that can be evaporated, not to cover the surface or pores because activated carbon is hygroscopic. When exposed to air, it can absorb moisture in the air. Based on the quality standard of SNI No.06-3730-1995, the water content of technical activated charcoal that meets the maximum quality standard is 15%.

![Figure 4. The relationship between microwave power and moisture](image)

Figure 4 shows that the higher the microwave power, the lower the water content on the activated carbon surface. The higher the microwave power, the more water on the surface of the activated carbon that evaporates. What is left on the surface of the activated carbon is getting smaller? In this study, the minor water content produced was 0.79%. This value is higher than that of activated carbon from corn cobs activated by Na2CO3 by 0.2%[10]

Active surface area

A surface area analyzer using the BET method measures the surface area of activated carbon as a result of activation. Based on the test results, the surface area of the charcoal before activation was 90,470 m2/g. Activated carbon was activated on activated carbon with the highest value of iodine number, namely the power parameter of 560 watts and the activation time of 10 minutes obtained at 936,221 m2/g. This indicates that the activated carbon has formed pores after chemical activation and microwave heating. This value is higher than activated carbon from empty palm oil bunches activated using a furnace of 272.9 m2/g[3]. These results indicate that activation using a microwave can produce a larger surface area than activation using a furnace.

Surface morphology

Surface morphology testing was carried out to determine the difference in surface porosity using activated carbon before and after activation. In this study, the surface morphology was analyzed using an electron microscope with a magnification of 2000x. The surface morphology of the charcoal before activation is presented in Figure 5. While the activated carbon resulting from the activation is shown in Figure 6.
Figure 5 shows that the surface of the charcoal before activation had pores, but not much. This was due to the carbonation process causing the surface to be slightly porous. While the activated carbon from the activation in Figure 6 shows a more porous surface than Figure 5. This is because chemical and physical activation using a microwave can remove impurities on the surface and open the pores on the surface to be more porous. The more pores formed, the better the quality of activated carbon as an adsorbent.

Figure 6. Surface morphology of activated carbon as a result of chemical and physical activation

Application of activated carbon on the absorption of dye waste

The application of activated carbon as a result of activation for waste treatment is carried out to test the ability to adsorb. The activated carbon applied for the adsorption of dye waste in this study was activated carbon with the highest active surface area. Tests carried out to determine the effect of activated carbon mass on the percent color removal are presented in Figure 7.

Figure 7. Effect of activated carbon mass on % removal

Figure 7 shows that in the mass range of 0.2 to 1 gram, the % dyes removal increased, while at masses above one gram, the percent removal decreased. This is because the increase in adsorbent mass can increase the active surface of adsorbing dyes in wastewater. The highest % removal was 98% at 1 gram of activated carbon mass. The results of this study are higher than the study of absorption of textile color waste using activated carbon which is activated using a furnace, which is 78% [5]. This
shows that activation using a combination of chemistry and physics with a microwave can increase the active surface area so that it will increase the absorption ability.

4. Conclusion

Based on the research that has been done, it can be concluded that in the range of 80 to 560 watts, the higher the microwave power, the higher the iodine number and the moisture content of the activated carbon. The best operating conditions are 560 watts of power and 10 minutes of heating time, with the highest iodine number produced at 1196 mg/g and 0.79% moisture content. The highest activated carbon surface area is 936 m²/g. From the morphological analysis, it is known that the surface morphology of activated carbon after activation is more porous than before activation. In the application of activated carbon for adsorption of color waste, it is known that the mass that produces the highest color removal is 1 gram.

5. References

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