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COMPARISON OF THE ACTIVATION OF GIGANTOCHLOA APUS TO INCREASE THE ADSORPTION ABILITY OF MEDICAL LIQUID WASTE

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Abstract

Medical facilities are exposed to substantial health and safety hazards as a result of the existence of perilous substances such as germs, viruses, and mold. The integration of drug use courses in medical education is hindered by constraints such as time limitations, a scarcity of well-informed personnel, and insufficient institutional backing. In order to mitigate these dangers, a comprehensive assessment of the risks, effective instruction, and stringent procedures are required. Effective waste management systems and precise detection of influent are crucial. Activated carbon, a highly porous material, is extensively utilized as an adsorbent in several industrial applications. Bamboo charcoal, a desirable lignocellulosic substance, is employed in the manufacturing process of activated carbon. The objective of the study was to generate and examine activated carbons obtained from Gigantochloas Apus (GA) through the utilization of sodium hydroxide (NaOH) and sodium chloride (NaCl) activation methods. The study determined that was the most efficient activating agent for achieving ideal ash content characteristics, resulting in the lowest ash percentage of 6.21%. The acidity of medical liquid waste is increased and its adsorption duration is extended by activating GA with NaCl and NaOH.

Keywords: *Gigantochloas Apus, Activated Carbon, Adsorption, Medical Liquid Waste.*

1. INTRODUCTION

Hazardous substances in medical institutions pose significant health and safety risks to personnel, students, and patients[1]. These substances include bacteria, viruses, and mold, which can cause infections, infertility, cancer, dermatitis, and respiratory illnesses[2]. They can also cause persistent problems like biomagnification in the food chain[3]. Medical education faces challenges in incorporating substance use courses due to limited training time, a shortage of knowledgeable staff, and inadequate institutional support[4-5]. Addressing these hazards requires thorough risk evaluation, efficient training, and strict protocols.

Colleges use various methods to manage wastewater, ensuring safe disposal of harmful substances and preventing environmental pollution and health hazards[6-7]. Bacterial metabolism plays a crucial role in biological treatment efficacy[8]. Electrochemical disinfection technology is being suggested to improve treatment methods[9-10]. Efficient waste management systems and accurate identification of influent are essential.

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Activated carbon possesses several desirable characteristics, including a notable adsorption capacity[11], thermal stability[12], rapid adsorption kinetics[13], and a very straightforward regeneration process[14]. Additionally, it exhibits commendable chemical stability[15]. The aforementioned substance is characterized by its porous nature and is widely employed as an adsorbent in many industrial contexts[16-17]. The distinctive attributes of this phenomenon provide unparalleled benefits. The usage of its resources had a notable rise throughout this period as a result of advancements in contemporary civilization, specifically in response to the progressively strict measures implemented for environmental conservation. The primary constituents utilized in the production of activated carbon consist of lignocellulosic materials[18-19]. The process of manufacturing activated carbon from lignocellulosic materials involves two primary steps, namely carbonization and activation[19].

The availability of precursors is widely recognized as a significant element in the generation of activated carbon. Bamboo is considered to be a favorable lignocellulosic material[20]. These plants have rapid growth rates and are found in several regions including Asia, Latin America, and Africa[21]. Bamboo is utilized in several applications, including construction materials, sustenance, and as a primary resource. Additionally, it is frequently portrayed in artistic expressions, such as bamboo paintings and the practice of bamboo working. There is a scarcity of research conducted on the attributes and outputs of biomass obtained from various bamboo species. Numerous prior investigations have documented the capacity of GA to be utilized in the treatment of wastewater.

The objective of the current investigation was to produce and analyze activated carbons derived from GA as a precursor, utilizing the NaOH and NaCl activation technique. Various procedures and analysis methods were employed to examine the quality of the generated activated carbon and morphological features after exposure to medical liquid waste.

2. MATERIALS AND METHOD

2.1. Materials

The bamboo charcoal was acquired from a nearby farmer in Malang, located in East Java. The production of bamboo charcoal is carried out using traditional processes. The NaOH and NaCl utilized in this investigation were sourced from Merck, specifically of analytical quality. This investigation also utilized distilled water with a conductivity of less than 1 μS/cm.

2.2. Production of Activated Carbon

The GA charcoal weighed 0.12 grams (Mettler Toledo) after carbonization. Subsequently, it was stored at ambient temperature for a duration of 48 hours, fully submerged in 40 millimeters of a 0.1 M NaCl solution. The activation procedure is conducted within a sealed glass container. After a period of 48 hours, the GA charcoal underwent filtration and were thereafter subjected to a drying process for 60 minutes at a temperature of 200°C in an oven (Sharp). The activator, consisting of a 0.1 M NaOH solution, was subjected to the identical process.

2.3. The Proximate Analysis

Understanding the composition and application of charcoal is aided by this proximate analysis of bamboo charcoal, which offers a summary of the material's qualities. Water content, ash content, volatile matter content, and carbon content are the primary components that need to be measured. Weighing 100 grams of bamboo charcoal (Mettler Toledo) and heating the sample in a Sharp oven at 110°C for three hours were the steps involved in measuring the water content. Eq. (1) was used to determine the water content[22].

$$\text{Moisture content (\%)} = \frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100 \quad (1)$$

In contrast, 100 grams of charcoal sample are burned in a furnace (Nabertherm) at 1100°C until only ash is left, which is how the ash content is determined. After that, the leftover ash is weighed, and the following Eq. (2) to find the ash content:

$$\text{Ash content (\%)} = \frac{W1}{W2} \times 100 \quad (2)$$

Meanwhile, heating a sample of charcoal to 950°C will cause the volatile components to evaporate, allowing you to calculate the quantity of volatile matter. The EQ. (3) can be used to calculate volatile matter levels.

$$\text{Volatile matter (\%)} = \frac{\text{weight of oven-dried sample} - \text{weight of sample}}{\text{weight of oven-dried sample}} \times 100 \quad (3)$$

Subtracting the total of the water content, volatile matter content, and ash content from 100% will then yield the carbon content.

2.4. The process of adsorption

Prior to commencing the adsorption method, a quantity of 40 mL of medical liquid waste is created with activated GA by NaOH (GA-NaOH) and activated GA by NaCl (GA-NaCl). After the completion of the two components, they are subsequently amalgamated within a beaker vessel and securely enclosed using aluminum foil as a measure to impede evaporation. The glass is subsequently subjected to agitation using a magnetic stirrer (Baku) operating at a rotational speed of 150 rpm for different durations, namely 24 hours, 36 hours, and 48 hours, while maintaining ambient temperature. Following agitation, the amalgamation of activated carbon and medical liquid waste takes place, and a period of 24 hours is allocated for the sedimentation of the combination. Until each variant had been assimilated, the process of adsorption was iterated.

2.5. pH and TDS Analysis

The hydrogen potential (pH) and total dissolved solids (TDS) levels of GA-NaOH and GA-NaCl, which was exposed to liquid medical waste, were measured using a pH TDS meter 3596. Experiments were conducted for durations of 12, 24, 36, and 48 hours for both categories of activators.

2.6. Surface Morphology Analysis

The surface morphology was examined using a Field Emission Scanning Electron Microscope (FESEM FEI Quanta 650) at a magnification of 10,000X. Experiments were conducted on GA, GA-NaOH and GA-NaCl that had been in contact with liquid medical waste.

3. RESULTS AND DISCUSSION

The quality features of GA activated carbon have been analyzed and the findings are presented in Table 1. The purpose of calculating the water content of activated charcoal is to ascertain its hygroscopic qualities, namely its propensity to absorb water. The sample activated with NaOH had the maximum water content of 7.21%, whereas the sample activated with NaCl had the lowest water content of 6.84%. GA-NaCl has a reduced water content compared to GA-NaOH. This occurs because to the increased degradation of oxygen complexes during NaCl activation, resulting in a decrease in the polarity of the activated carbon. Both samples nevertheless have a water content percentage that is lower than the SNI norm of 15%.

Table 1. Characteristics of GA carbon active quality

	water content (%)	ash content (%)	volatile matter content (%)	carbon content (%)
NaOH	7.21	6.31	11.34	~~11.34~~75.14
NaCl	6.84	6.21	10.36	~~10.36~~76.59
SNI [23]	Max 15	Max 10	Max 25	Min 65

However, ash is a metal oxide found in charcoal that is composed of non-volatile minerals during the ashing procedure. The ash content has a significant impact on the quality of activated carbon. Excessive ash can obstruct the pores of activated carbon, leading to a decrease in its surface area. Both samples' ash content percentages comply with the ash content quality criteria for activated charcoal, as specified in SNI 06-3730-1995, which stipulates that it should be below 10%. NaCl is the most effective activating agent for achieving optimal ash content characteristics, as it results in the lowest ash content of 6.21%, in contrast to NaOH as an activating agent for bamboo charcoal.

Meanwhile, the purpose of detecting volatile matter is to ascertain the quantity of volatile compounds present in activated charcoal. The research findings indicate that GA-NaOH had a volatile matter level of 11.34%, whereas GA-NaCl had a volatile matter level of 10.36%. Both samples have been characterized, and the quantities of volatile matter in both samples match the quality criteria outlined in SNI for technical activated charcoal. These standards specify that the maximum fraction lost on heating should be 25%.

Fixed carbon refers to the quantity of carbon that is tightly bonded in active carbon. The magnitude of this carbon content is affected by the presence of water, ash, and volatile chemicals in the material. The sample, when activated with NaCl, had a carbon content of 76.59%. Concurrently, the sample that underwent NaOH activation had a carbon content of 75.14%. The minimal required for carbon content in activated charcoal, as per quality standards, is 65%. It may be stated that a larger production of fixed carbon results in a superior quality of activated charcoal.

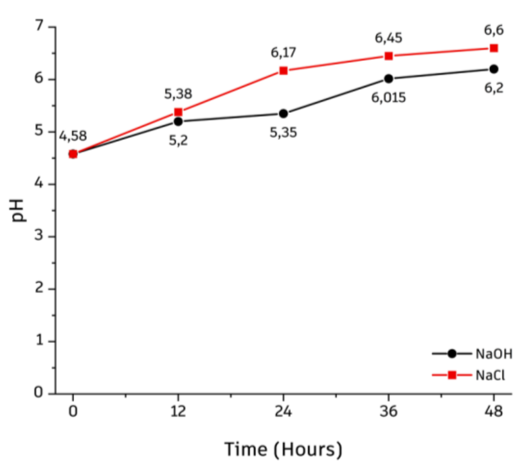

Figure 1. Acidity levels in liquid medical waste following the adsorption procedure using GA-NaOH and GA-NaCl

The correlation between the duration of adsorption for medical liquid waste and pH is seen in Fig. 1. GA-NaOH and GA-NaCl have been found to enhance the acidity of medical liquid waste, as well as prolong the adsorption period. While both GA-NaCl and GA-NaOH have shown a rise, NaCl surpasses NaOH in its efficacy for purifying liquid medical waste.

pH testing is conducted to assess the quality of liquid medical waste. The pH level is a crucial determinant for understanding the chemical composition of liquid medical waste. A higher pH value indicates that activated carbon is absorbing a greater number of chemical substances.

Fig. 2 illustrates the impact of adsorption time on the quantity of dissolved particles or the concentration of positively charged cation ions and negatively charged anions in the water. The overall solid content often consists of inorganic salts, such as NaCl, $CaCO_3$, $CaSO_4$, and $Mg(HCO_3)_2$ [24].

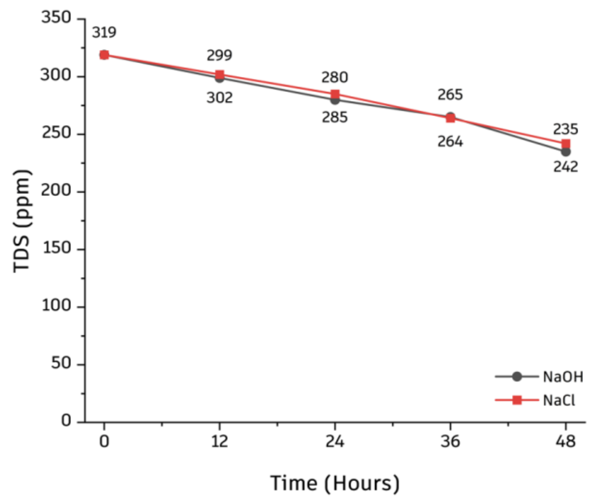

Figure 2. The quantity of solute present in liquid medical waste following the adsorption procedure

The purpose of TDS test is to ascertain the concentration of the solution in liquid medical waste. The TDS test allows for the determination of the total dissolved chemicals in liquid medical waste. A higher TDS value indicates a greater concentration of dissolved compounds in the waste. The price of liquid medicine will increase. The acceptable concentration range for liquid medical waste that may be safely discharged into the environment is between 100 and 300 ppm. If TDS level in liquid medical waste exceeds 300 ppm, it is inferred that the waste still retains several hazardous components.

The graph clearly illustrates that both NaCl and NaOH have the capacity to decrease the solute concentration as the adsorption period progresses. There is negligible disparity between the two chemicals employed to activate bamboo charcoal.

The primary factor that elevates the pH level and reduces the TDS level is the quantity and dimensions of pores present on the surface of activated carbon. A high porosity number in activated carbon indicates a uniform distribution of pores[25]. The adsorption capacity and rate of activated carbon are heavily reliant on its porosity, with higher porosity values corresponding to greater adsorption capabilities. The adsorption capacity of activated carbon is influenced by the size of its surface pores, while the rate of adsorption is determined by the quantity of these pores[26]. An increased number of pores facilitates the entry of molecules or particles from liquid medical waste, but hinders their exit. Flocculation and adsorption events can lead to an elevation in the pH level and a reduction in the TDS value [27]. The flocculation process aids in the aggregation of dissolved molecules that are too tiny to be directly adsorbed by activated carbon, resulting in the formation of bigger flocs that can be more readily adsorbed by activated carbon. The adherence of chemicals in liquid medical waste to activated carbon is due to the influence of van der Waals forces, which impact the carbon's absorption capacity for large quantities of molecules[28]. Van der Waals forces contribute to the attraction of molecules in liquid medical waste during the adsorption process.

The pH and TDS tests revealed that initially, the activated carbon pores on the surface of the GA-NaCl and GA-NaOH had numerous vacant spaces capable of accommodating the molecules present in liquid medical waste. However, as time progressed, these molecules were adsorbed and deposited within the activated carbon pores, causing the available empty space to diminish. Consequently, the number of molecules adsorbed by the activated carbon decreased until its capacity was completely filled, rendering it unusable. Adsorb compounds included in liquid medical waste. The adsorption saturation point refers to the point at which the surface pores of activated carbon have reached their maximum capacity and can no longer absorb additional chemical content. At this stage, it is necessary to release the absorbed liquid medical waste molecules from the activated carbon in order to maintain molecular balance. Amidst liquid medical waste and activated carbon.

Fig. 3 illustrates the shape of the GA prior to the activation phase. Visible pores of a diameter of 1,224 µm had grown on the surface of the GV. In addition, several contaminants were discovered dispersed throughout the entirety of the GA's surface.

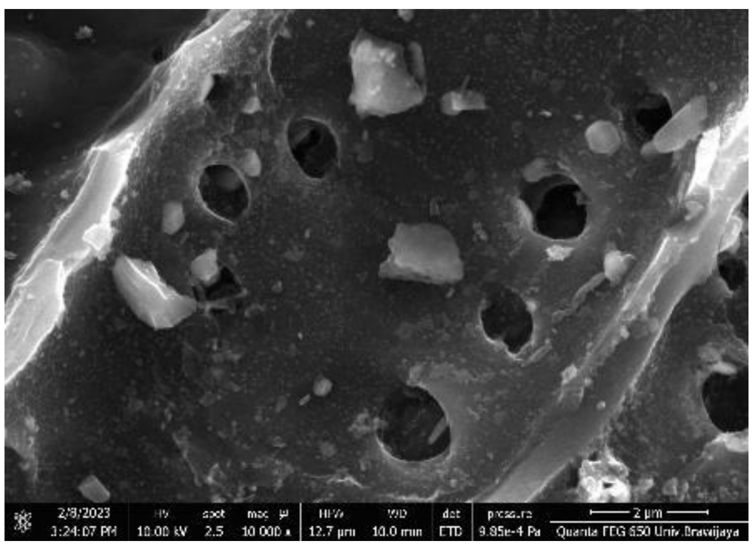

Figure 3. GA charcoal surface prior to activation

Figure 4 displays the FESEM findings of bamboo charcoal that has undergone activation using either NaCl (Fig. 4(a)) or NaOH (Fig. 4(b)). It is evident that the two activated carbons possess pores with a pristine surface and diminished contaminants on the surface. Furthermore, it is evident that the GA-NaCl surface exhibits much higher cleanliness in comparison to the GA-NaOH surface. There were residual impurities present on the charcoal surface of the GA-NaOH material. The surface of these two activated charcoals has a much broader pore width in comparison to non-activated charcoal.

Upon purification, it is evident that the pores are covered with adsorbates. From this picture, it is evident that there are variations in the surface characteristics of the activated carbon at each stage of the process. It is evident that activated carbon that has undergone activation has increased pore size, higher quantity, and a uniform distribution of pore sizes. The initial carbon pore size before to activation was 908.2 nm, and upon activation, it increased to 3,323 µm. This phenomenon occurs due to the hydrophilic qualities of the NaCl and NaOH solutions, which have the ability to efficiently absorb the residual water in GA. As a result, this leads to an increase in both the size and quantity of holes on the surface of the activated carbon. In addition, there is a phenomenon whereby the activator solution infiltrates the activated carbon and absorbs the residual water content and volatile compounds present in the activated carbon. When the activator solution undergoes a phase change to steam, it carries the absorbed water content and volatile compounds, which then react with the hydrocarbons present in the activated carbon. This reaction leads to the removal of hydrocarbons, an enlargement of pore size, and an increase in the number of surface pores on the GA activated carbon.

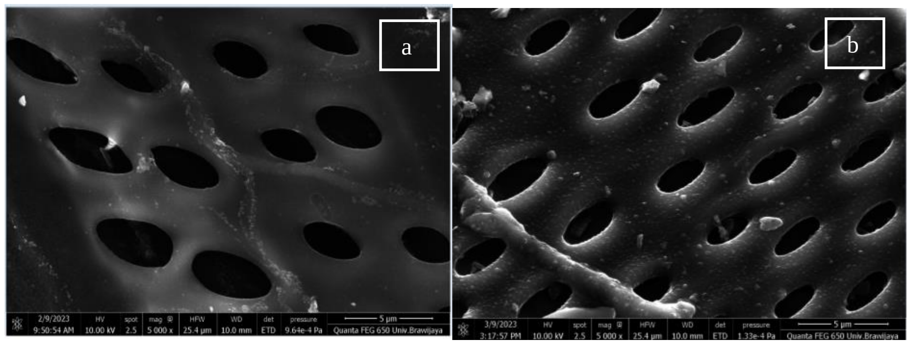

Figure 4. Surface morphology of GA upon activation (a) NaCl (b) NaOH

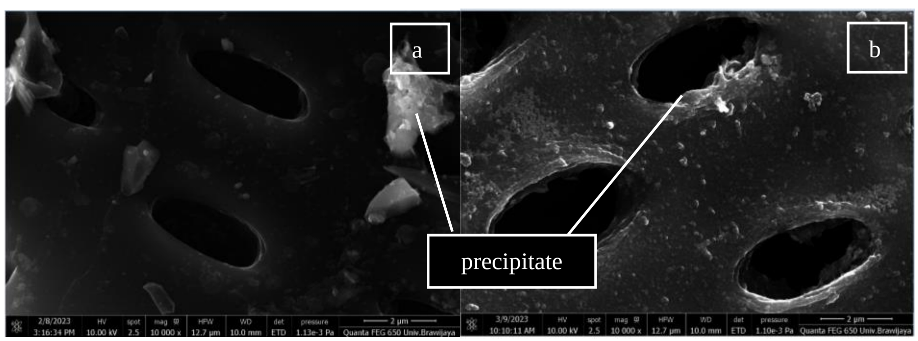

Figure 5. Morphology of the GA surface upon adsorption (a) NaCl (b) NaOH

There are visible deposits on the surface of the GA and noticeable patches on the surface of the ampel bamboo activated carbon. The presence of deposits and spots in activated carbon is attributed to the effective adsorption of molecules in liquid medical waste by activated carbon derived from ampel bamboo and apus bamboo. This process leads to a reduction in both the size and number of active carbon pores. Precipitates can form when the activated carbon surface is fully utilized, leaving no missed pores. These precipitates consist of molecules from the liquid medical waste that are evenly adsorbed and collected in specific areas. On the other hand, spots are formed due to areas on the activated carbon surface that have not been optimally utilized. These spots contain molecules from the liquid medical waste that are unevenly adsorbed.

4. CONCLUSIONS

The study investigates the water content, hygroscopic qualities, and impact on the quality of activated charcoal. The water content of samples activated with NaOH and NaCl was found to be lower than the SNI norm of 15%. Ash content, a metal oxide in charcoal, significantly affects the quality of activated carbon. NaCl was found to be the most effective activating agent for optimal ash content characteristics, with a minimum requirement of 65%. Fixed carbon, the quantity of carbon tightly bonded in active carbon, was found to be higher when activated with NaCl. Activation of bamboo charcoal with NaCl and NaOH enhances the acidity of medical liquid waste and prolongs the adsorption period. NaCl surpasses NaOH in its efficacy for purifying liquid medical waste. pH and TDS tests indicate increased chemical absorption by activated carbon. The adherence of chemicals in liquid medical waste to activated carbon is due to van der Waals forces, which impact the carbon's absorption capacity for large quantities of molecules. The FESEM findings of activated bamboo charcoal showed that the two activated carbons possess pores with a pristine surface and diminished contaminants. Precipitates can form when the activated carbon surface is fully utilized, leaving no missed pores, while spots contain molecules from the liquid medical waste that are unevenly adsorbed.

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