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Surface Porosity Enhancement of Activated Carbon by Synthesizing Kenaf Fiber

S. N. Zulaikha[1], Ahmed Mohamed Kadoura[2], M.F.M Alkbir[3*], Zulhaimi Mohammad[4], Shahrul Effendy Kosnan[5], Fatihhi Januddi[6]

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Abstract: Kenaf is one type of natural fibre (KF) that has been applied in a variety of industrial settings. Scientists, engineers, and researchers have recently become interested in natural fiber as a substitute component to improve the efficiency of the adsorption method. It is thought that using kenaf as an adsorbent is a creative and appealing technique. As a result, it has been applied to many different adsorption tasks. Kenaf fibre has high specific strength, is an inexpensive resource, is environmentally friendly, and has strong structural stiffness, making it suitable for a wide range of applications. Previous research concentrated on the effects of various activated carbon types on the distribution of pore volumes. The research also demonstrated the excellent performance of two distinct elements: kenaf fibre and activated carbon (AC) derived from bone char. Because of its many advantageous qualities, including its porous structure, ease of use, affordability, and ability to function well in a variety of temperatures and humidity conditions, kenaf fiber can be a useful addition to activated carbon to increase its porosity. Additionally, the overall characteristics of synthesized activated carbon (SAC) are influenced by the values of the fixed carbon determination, bulk density, pore volume, moisture content, and ash content. The degree of porosity alteration of the SAC will be determined by synthesizing AC with KF to promote the expansion of surface porosity and pore volume. The analysis from Water Quality Standards: Physical Benchmark could be used to determine SAC's performance.

Keywords: *Activated Carbon; Adsorbent; Kenaf Fiber; Surface Porosity*

1. Introduction

Environmental and nature health are the risen polemics nowadays in Malaysia. Numerous methods for removing pollution particles have evolved as a result of scientific and technological advancements [1]. Because of the growing harmful threat that it poses to both humans and the environment, the quality of the water is constantly declining. Wastewater must be treated in order to get rid of contaminants and produce high-quality water. For the enhanced treatment of wastewaters, carbon compounds such as nanotubes of carbon, fullerene and porous carbon have been used extensively. Carbon nanoparticles have emerged as a promising class of adsorbents for water purification in recent years. According to [9], adsorption is a crucial step in the treatment of wastewater, and turning waste materials into adsorbents provides a way to get around the high cost of materials associated with using commercial activated carbon. Activated carbon is an organic material that is naturally occurring and has a high carbon content, such peat and coal. Considering the findings of [8], after being heated and steam-treated to increase its extreme material-absorption affinity, amorphous carbon is transformed into activated carbon. The powder, granulated, or pelleted form of activated carbon is available and is distinguished by a large surface area per unit volume because of the large number of fine holes. Because of this characteristic, it can gather liquids, gases, or dissolved materials on the surface of these holes.

In order to reduce the first stage of water pollution, some researchers had simplified the ways to decrease the pollution by using adsorption techniques. Adsorption technique is widely used nowadays to reduce water pollution and in waste water treatment plant [3]. However, the adsorbents used for those processes are highly costed [2].

Even though activated carbon is widely available, it is nevertheless pricey. Activated carbon could be obtained from organic materials. In this project, the activated carbon will be extracted from cow bones. Various researchers simplified many types of activated carbon, but it never has been synthesized with kenaf fiber.

The source of kenaf is easily obtained in Malaysia. These natural fibers used to produce low-cost activated carbon [4]. With the synthesizing of the natural fibers into the cow bones composite, it would be able to produce a different adsorbent that has higher ability to adsorb with a high surface porosity. This study will determine the performance of activated carbon produce from cow bones that have been synthesized with kenaf fiber by performing the characterization analysis of synthesized activated carbon and conducting the efficiency by determining the wastewater quality standards: Physical Characteristics.

In previous studies, the antecedent for reporting on the synthesis and properties of activated carbon was hard carbon based on polymers. We were able to regulate the activation humidity, the activation method, and the initial carbonization temperature in order to manage the carbon material's crystal size by using hard carbon as a precursor.

It was confirmed that, the crystallite size of the first carbon intermediate plays an important role in affecting pore expansion when activating hard carbon with crystals of different sizes during the production of activated carbon.

1.1 Theory

Adsorption

All solid materials possess the potential to draw molecules of gases or liquids they come into contact with to their surfaces, a process known as adsorption. Adsorption is the process of molecules adhering to the surface of fluid or solids, either on

[1,3,4,5,6]*Plant Engineering Technology (PETech), Universiti Kuala Lumpur Kampus Cawangan Malaysian Institute of Industrial Technology, Malaysia.*
[*]*Corresponding Author Email: munir@unikl.edu.my*
[2]*Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor*

their interior or exterior (such as capillary walls or crack walls). Physical adsorption, which is dependent on the physical force of attraction, like the condensation of gases into liquids, there is a force, called van der Waals power, between the atoms of the adsorb and the solid absorbent. Chemical specificity is lacking in physical adsorption, as any gas will tend to stick to any material at low enough temperatures or high enough gas pressures. On a solid surface, gases are sucked in by chemical forces unique to each gas and surface in chemical adsorption.

Carbonization and an activation procedure are used to create activated carbons (AC) from carbon-rich materials. Carbonaceous materials can be activated chemically or physically1 to produce a porous structure and its adsorption characteristics. To create charcoal through physical activation, the raw material is pyrolyzed between 800 and 1000 degrees Celsius. After that, steam, carbon dioxide (CO2), or oxygen (O2) are used for activation.

When a precursor material is subjected to chemical activation, it is impregnated with a chemical activating agent and then heated to between 400 and 700 degrees Celsius in a nitrogen atmosphere2. Commonly employed as chemical activators include zinc chloride (ZnCl2), potassium hydroxide (KOH), and phosphoric acid (H3PO4). By preventing the development of tar and volatile materials and influencing pyrolytic breakdown, the activating chemical agents increase the yield of AC3. Chemical activation requires a substantially lower activation temperature than physical activation due to the dehydration and oxidation characteristics of the activation agent.

A report5 compares the activation processes of chemical (H3PO4) and physical (biomass fibre) AC. The study discovered that although physical activation produced a slightly larger surface area than chemical activation, Production yielded a smaller amount. High temperature carbonization of biomass would be an unpleasant process that would produce additional greenhouse gases (GHG) including carbon monoxide (CO) and methane (CH4)6.

Activated Carbon

Activated carbon or activated charcoal is well known as the porous carbonaceous materials which contain an enormous number of accessible micropores and mesopores. Activated carbon could be activated by carbonizations and followed by activation where the carbon needs to have heat treatment with and oxidizing agent [7]. There are two methods to prepare for activation: chemical activation and physical activation. In order to clear the disordered carbon that clogs the pores in the activated carbon, activation is performed. In addition, it has the ability to produce new porosity and increase the width of pores created during the carbonization process. This can lead to the production of a pore structure that is well-developed, easily accessible, and has a large internal surface area.

A great deal of attention has been focused on producing AC because of its mechanical, electrical, thermal, environmental, and adsorptive properties. The well-developed pore structure and adsorption capabilities of AC make it one of the top industrial materials, as demonstrated by earlier research. Novel uses of AC have been produced by recent advancements in contemporary technologies. Adsorbents based on coal are the most widely utilised, however they are not sustainable and are expensive. Plenty of inexpensive agricultural biomass can be used to make low-cost, environmentally friendly adsorbents by modifying it to increase its performance. This biomass contains large concentrations of natural polymers such cellulose, hemicellulose, and lignin.

The short fibre makes up the remaining 70%19 of the plant's volume, with the long fibre making up around 30% of it. The outside bark, or bast, and the inner core, which both have fibrous components, make up the stem of kenaf plants. Kenaf core and bast fibres have the potential to improve the bioremediation20 and adsorption21 processes, as shown by recent investigations. In previous research, KOH and CO2 were used in physicochemical activation to create ACs from the inner cores of kenaf. In a different study, potassium oxalate (K2C2O4) was used in varying impregnation ratios to achieve the same result. The carbon matrix's evolution porosity has been considerably raised by both investigations.

Chemical Activation

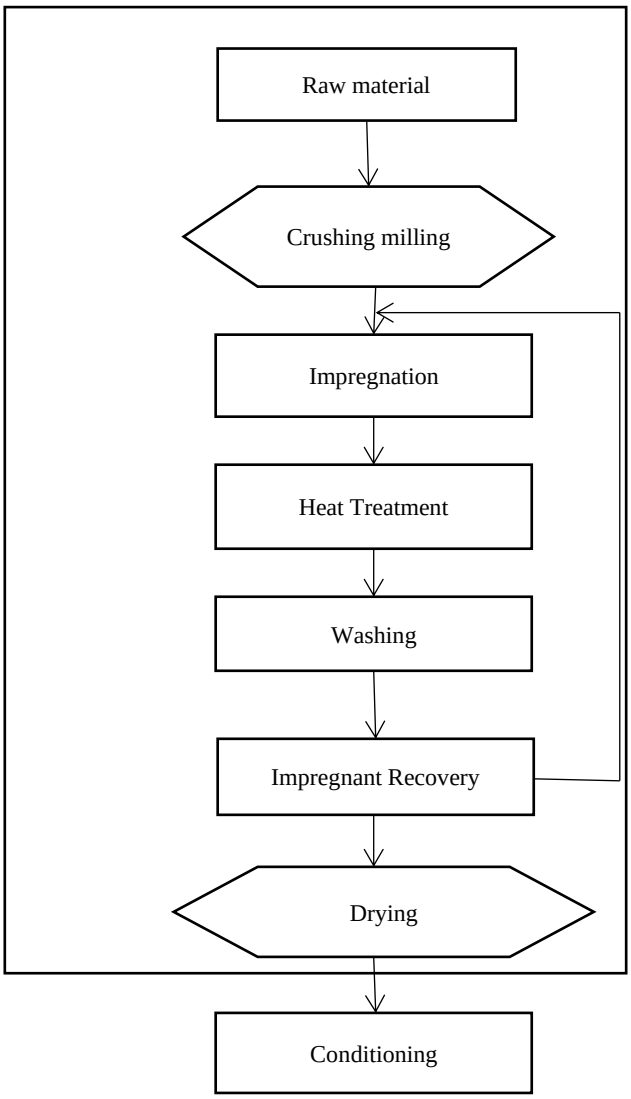

Fig. 1. Chemical Activation Process of Activated Carbon

This research was using chemical activation in order to activate normal carbon into activated carbon by using 2 Molar of Hydrochloric Acid (HCl).

Animal Bones as Activated Carbon

Animal charcoal is a granular substance made by charring animal bones; it is sometimes referred to as bone black, bone char, or abaiser. Animal charcoal has a stronger ability to extract colouring materials from a solution [5]. Four different kinds of animal bones were treated to produce activated carbon, according to research [5] Cow bone, dog bone, goat bone and chicken bone. The study proved that cow bone is the best activated carbon compared to the other bones.

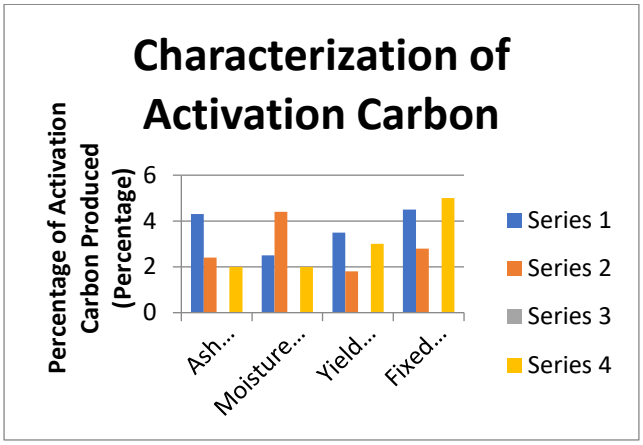

Fig. 2. Characterization of Activated Carbon Produced

Description of Activated Carbon

i.Ash Content Determination

Research [8] suggests that ash residue left over from burning can be used to measure the amount of minerals present in any given substance. Ash content refers to the residue that remains in activated carbon after all of the combustible material has completely burned off. Ash content is one of the chemical property's aspects that is related to quality ranking. Researchers are able to determine the extent of adulteration and the purity of the carbon used in activation with the fundamental assistance of ash content analysis. Consequently, it is believed that activated carbon is in the optimal condition for the adsorption process to occur when it has the lowest ash concentration.

$(W_2 – W_3) / W_0$ X 100

ii.Moisture Content Determination

According to research from [11, the existence of moisture in activated carbon is not favorable for the adsorption process. Thus, in having the lowest value of moisture content will produce an efficient adsorbent.

$\frac{(W_2 – W_3)}{(W_2 – W_1)}$ X 100

Yield of charcoal

The following formula could be used to determine the yield of charcoal:

$\frac{W_0–AC–MC}{W_0}$ X 100

Where W_0 is the original weight of dry sample, AC is the Ash Content and MC is the Moisture Content.

Fixed Carbon Determination

The following formula could be used to calculate fixed carbon:

$\frac{Y_{CH} – AC – MC}{Y_{CH}}$ X 100

Where, Y_{CH} is the yield of charcoal, AC is the Ash Content and MC is the Moisture Content.

2. Preparation of Material

Prior to commencing the laboratory experiment, the necessary supplies and equipment were identified to make sure they would all be ready for use during the procedure.

Cow bone has been obtained from local butcher house and kenaf fiber has been obtained from Lembaga Kenaf dan Tembakau Johor.

Through a chemical activation process aided by ultrasonic vibration, the precursor, or coal, was converted into activated carbon. To start, distilled water was used to clean raw coals CC and JC (sizes less than 0.425 mm) and get rid of dust and other contaminants. The cleaned coals were dried in a drying oven set at 100 °C for 24 hours in order to remove moisture in order to lower the moisture content. After precisely weighing each 100 g of cleaner coal, it was added to a 1000 ml beaker. Hydrogen peroxide (20–30% H2O2), the coal sample was oxidised by adding an environmentally safe oxidant drop-wise from the burette, and the exothermic process was regulated by churning the coal slurry in an ice-cold atmosphere.

The reaction mixture was ultrasonically shaken for five to six hours at room temperature (20–40 kHz).

The product of the oxidation is a brown-red solution. The mixture was subsequently chilled in a bath of ice water. The reaction mixture was then filtered (using Whatman 42) in a funnel after being neutralised by adding ammonia solution drop-wise until the pH reached 7. To finish the neutralisation procedure, it was further cleaned with distilled water. To obtain the oxidised products (designated as CCR1 for Changki colliery in Nagaland and JCR1 for Jadi colliery in Garo Hills, Meghalaya), the leftover portions were dried in an oven at 110 °C.

Activating agents KOH and KOH+NaOH were used in a mass ratio of 2:1 to saturate the plastic coal. Using distilled water, the plastic coal was combined with the activating agents (KOH and KOH+NaOH) during the solution phase. According to previous literature, increasing the specific surface area could be achieved by fixing the ratio of plastic coal to activating agent at 2:1 (wt%). A concentration of 1.78 M was obtained for the KOH activating agent, while 0.9 M and 1.25 M, respectively, and were obtained for the mixture of activating agents. The reaction mixture was exposed to ultrasonic radiation (20–40 kHz) for a duration of one to two hours. Hot deionized water was used to wash each reaction mixture till the neutralisation point in order to eliminate the water-soluble, basic, and alkaline components. The leftover portion of the mixture was oven-dried for two hours at 110°C. In a muffle furnace, the ultrasonicated coal samples were carbonised for approximately two hours at 800 C.

In order to eliminate any last traces of inorganic contaminants, the synthesised product was lastly rinsed with distilled water and a 1 N HCl solution till neutralisation. To create activated carbon (AC) with the necessary surface area, the resultant product was dried at 110 °C. The completed goods were identified with the following labels: CCRA1 and JCRA1 for the carbons activated with KOH, and CCRA2 and JCRA2 for the carbons activated with KOH plus NaOH.

Pore Volume Determination

The weight of the sample plus the beaker was marked as W0 after 2g of activated carbon was weighed into a beaker. The beaker with the dry sample was filled with 50ml of distilled water, and the mixture was allowed to boil for 15 minutes. Following the displacement of air from the pores, the sample was drained, dried slightly, and weighed. The process was carried out twice, and the weight was noted as WF. The following formula could be used to calculate the pore volume:

$\frac{(W_F – W_I)}{W_I}$ x Density of water

Where, W_F is the final weight of sample + beaker, and W_I is the initial weight of sample + beaker.

Bulk Density Determination

The sample was filled into a 10-milliliter cylinder, and the combined weight of the cylinder and sample was noted as W2. The following formula could be used to determine bulk density:

$\frac{\text{Weight of sample}}{\text{Weight of equal volume of water}}$

A. Wastewater Quality Standards: Physical Standards

Total Solids (TS)

The substance that remains after evaporating and drying a wastewater sample at a particular temperature

TS = (Mass of evaporating dish plus residue, g) – (Mass of evaporating dish, g)

Sample Size, L

Total Volatile Solids (TVS)
TVS = (Mass of evaporating dish plus residue, g) – (Mass of evaporating dish plus residue after ignition, g)
Sample Size, L

Total Suspended Solids (TSS)
TSS = (Residue on filter, g) – (Tare mass of filter after drying, g)
Sample Size, L

Total Dissolved Solids (TDS)
Solids that make it past the filter are dried and evaporated at a predetermined temperature. Noteworthy is the measurement of total dissolved solids. Typically, colloids range in size from 0.001 to 1µm [13][14].
TDS = TS – TSS

B. Carbonization and Activation

Cow bone and kenaf fiber are collected and washed in water in order to remove dirt and flesh and sun dried. The samples are placed in different large crucible and are kept in a muffle furnace with temperature of 400°C for an hour in the absence of air. Keep the samples in desiccator to allow them cool and dried. After being carbonised, the kenaf fibre and cow bone are crushed in a mortal and added to flat mug cubs. The next step involves activating the carbonised bone and kenaf fibre by placing 200g of the crushed sample in a beaker and adding 250ml of 2 M hydrochloric acid (HCl) to it [15][16]. After an hour of heating the combination, the sample is filtered out and cleaned with distilled water to get rid of the acid on its surface. The samples were subsequently dried for 24 hours at 80°C in an oven. The dried samples are then placed in a small tray and sieved to the desired size. The synthesization of kenaf fiber and cow bones will be done in the stage where the mixture is mixed with Hydrochloric Acid and are heated for an hour. ACF is a cross between CF and AC. ACF's greater adsorption rates and high porosity set it apart from other types of ACs. One significant drawback of ACF is the additional processing step and expense involved in turning the original material into a fibrous form. A detailed presentation of the features, benefits, and drawbacks of AC and ACF may be seen in Table 1. It's noteworthy to note that, although using a similar thermochemical technique for manufacturing, the ACF and CF are very distinct from one another.
Compared to ACF, which has a modest tensile strength (between 70 and 400 MPa), CF has an outstanding tensile strength (between 3000 and 7000 MPa). ACF, on the other hand, offers an exceptionally porous structure and a high specific surface area (> 3000 m2/g). The high micropore volume and specific surface area of ACF contribute to its excellent adsorption kinetics and capacities. Chen has offered a thorough analysis of the distinctions between the traits of CF and ACF.

C. Characterization of Activated Carbon

Ash Content Determination
A crucible containing 2 grammes of dry activated sample was weighed, and the combined weight of the crucible and the dry sample was recorded as W2. After that, the sample was heated to 450°C for six hours in a furnace. The process was then performed twice for all activated carbon simple to obtain the average ash content value. After that, it was taken out, put in a crucible, and its contents were reweighed and recorded as W3. The following formula could be used to determine the amount of ash present:
$(W_2 – W_3) / W_0 \times 100$
where W0 is the dry sample's initial weight, W2 is the dry sample plus crucible weight, and W3 is the heated sample plus crucible weight.

Moisture Content Determination
The sample was placed in an oven at 100°C for 24 hours after 5g of it was weighed into a crucible and the weight of the sample plus crucible was recorded as W2. It was taken out and allowed to cool in a desiccator after that. After weighing the sample and crucible once more, W3 was recorded. To get the average moisture content value, it was done twice for each sample. One could use the following formula to determine the moisture content:

$\frac{(W_2 – W_3)}{(W_2 – W_1)} \times 100$

In this case, W1 represents the weight of the beaker, W2 the weight of the crucible plus the dry sample, and W3 the weight of the crucible plus the heated sample.

Turbidity of Treated Water
The amount that suspended material in water absorbs or scatters light is measured. The term "nephelometry turbidity units" (NTU) is frequently used to denote that the test was conducted in accordance with the scattering principle. Turbidity units are formazin turbidity units (FTUs).

3. Results and Discussion

3.1 Characterization of Activated Carbon

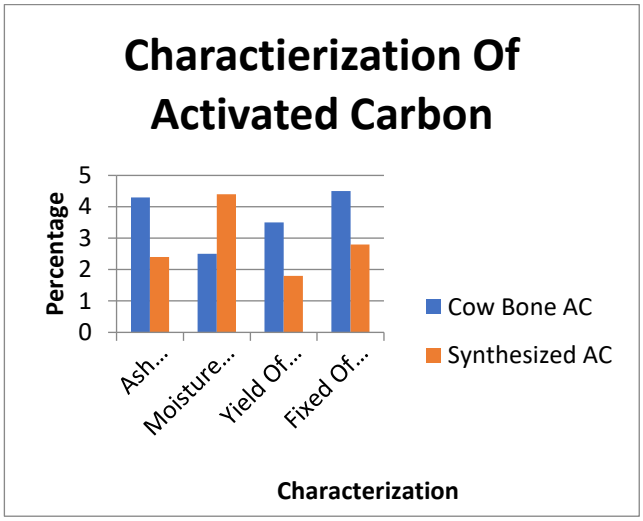

Fig. 3. The Classification of Activated Carbon Produced

Pore Volume Determination

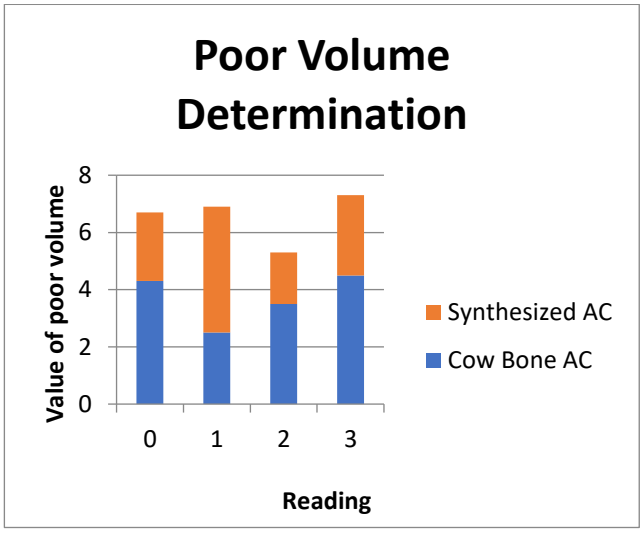

Fig. 4. Value of the corresponding activated carbon's pore volume

Analysis of Total Suspended Solids

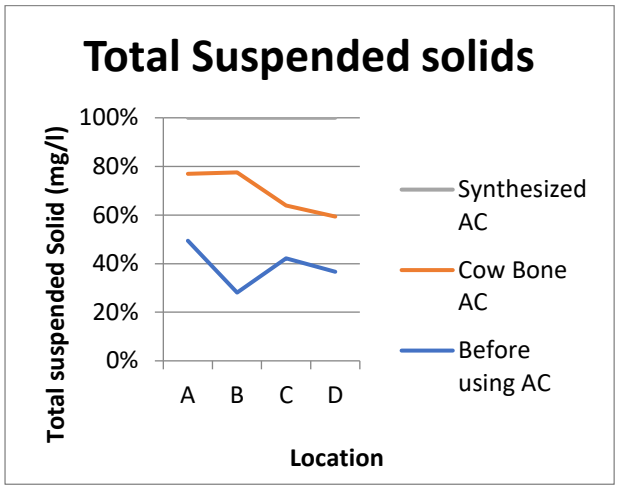

Fig. 5. Total Suspended Value

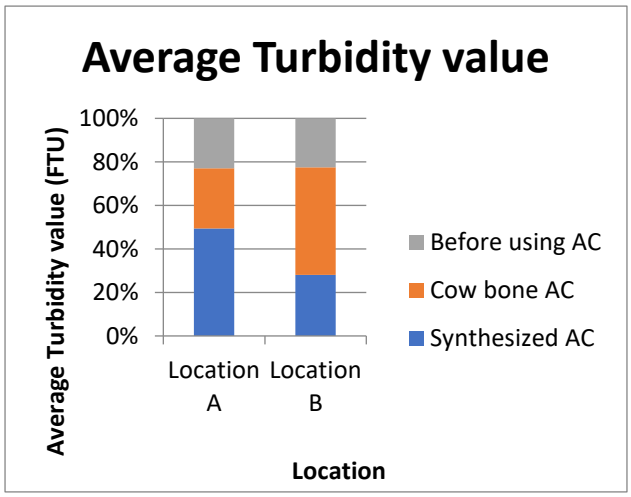

Fig. 6. The mean level of turbidity at locations A and B

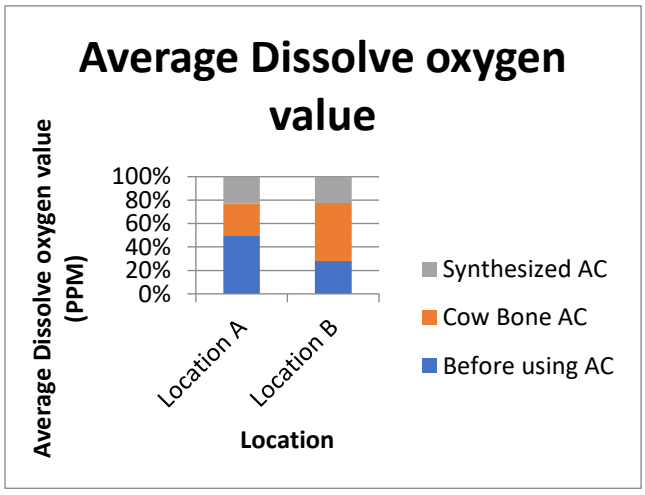

Fig. 7. Location A and B's Average Dissolved Oxygen Values

Figure 3 demonstrates the properties of activated carbon made from cow bone and synthesized activated carbon. After being carbonized at 400 degrees Celsius, bone and kenaf fiber were sieved to 212 µm in size. It was found that the ash concentration (25.25%), moisture content (%), pore volume (15.68), yield charcoal (99.48), and fixed carbon (70.40%) of synthesized activated carbon are all higher. Because of this, the most effective carbon must have low ash, moisture, and pore volume values. Higher levels are a characteristic of fixed carbon and charcoal output. The activated carbon that is produced is more effective the greater the carbon concentration and surface area. The pore value of the matching activated carbon volume determination is displayed in Figure 4. When compared to activated carbon made from cow bone, synthetic activated carbon has a smaller pore volume. The three standard tests for water quality are the dissolve oxygen value, turbidity value, and total suspended value. Synthesized activated carbon has low total suspended value (200 mg/L), low turbidity value (8.89 ftu) and high dissolve oxygen value (4.32 ppm).

Table 1. An overview of the produced activated carbons' characteristics

Activated Carbon	Cow Bone	Synthesized Activated Carbon
Weight of sample (g)	5	5
Particle size (µm)	212	212
Ash content (%)	72	25.25
Moisture content (%)	6.2	4.2
Yield Charcoal (%)	99.43	99.48
Fixed Carbon (%)	21.35	70.40
Pore volume	29.23	15.68

Table 2. Results of Water Quality Standards: Physical Characteristics

Activated carbon	Cow Bone		Synthesized Activated Carbon	
Location	A	B	A	B
Total Suspended Solid (mg/L)	300	300	300	200
Turbidity (ftu)	12.81	11.37	8.89	7.20
Dissolve Oxygen (ppm)	4.15	4.12	4.32	4.31

4. Conclusion

This study's objective is to assess the effectiveness of activated carbon made from cow bone that has been synthesised using kenaf fibre. Additionally, this study will demonstrate how kenaf fibre can act as activated carbon to increase the surface porosity of cow bone.

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