

PRODUCTION AND CHARACTERIZATION OF ACTIVATED CARBON DERIVED FROM PALM KERNEL SHELLS AND SAWDUST WOOD**Okiy . S. and Aziza A.E.****Department Of Wedding and Underwater Operation Technology.****Department Science Laboratory Technology, Petroleum Training Institute Effurun, Delta State, Nigeria.****ABSTRACT**

This study focuses on the production and characterization of activated carbon derived from palm kernel shells and sawdust wood, both abundant and sustainable local resources, for wastewater treatment applications. Two activation methodologies—carbonizing before activating and activating before carbonizing—were employed, using potassium hydroxide (KOH) as the activating agent. The produced activated carbon was characterized to evaluate its physical and chemical properties, including surface area, porosity, adsorption capacity, pH, ash content, and functional groups. Advanced techniques such as BET analysis, FTIR, SEM, and TGA were utilized to obtain detailed insights into the material properties. The performance of the activated carbon was assessed in treating wastewater contaminated with heavy metals, dyes, and organic compounds. The results demonstrated significant removal efficiencies, particularly for iron (up to 97%) and zinc (96.7%), with moderate removal rates for nickel, lead, cadmium, and chromium. The study revealed that activation conditions and material origin influence adsorption performance. Comparative analysis with commercially available activated carbon highlighted the cost effectiveness and sustainability of using palm kernel shells and sawdust as raw materials. Recommendations include optimizing activation conditions, combining activated carbon with other adsorbents, and exploring multi-cycle regeneration for enhanced pollutant removal. This research underscores the potential of locally sourced activated carbon as an efficient and sustainable solution for wastewater treatment

KEYWORDS: *activated carbon, palm kernel shells, sawdust wood, potassium hydroxide (KOH), heavy metals, adsorbents*

INTRODUCTION

Activated carbon has long been recognized as one of the most versatile adsorbents to be used for the effective removal of contaminants in waste water treatment. Charcoal is the fore runner of modern activated carbon whose ability to purify water dates back to 2000BC (Inam, Etim, Akpabio, and Umoren, 2017). It is a tasteless, solid, micro crystalline, non-graphitic form of black carbonaceous material with a porous structure and has been regarded as a unique and versatile adsorbent because of its extended surface area, microporous structure, high adsorption capacity, and high degree of surface reactivity (Kalderis, Bethanis and Paraskeva, 2018).

Activated carbon also widely known as activated charcoal or activated coal is a form of carbon which has been processed to make it extremely porous and thus to have a very large surface area available for adsorption or chemical reaction. It is a unique material because of the way it is filled with holes (void, spaces, sites and pores) of zero electron density, these pores possess intense vanderwaals forces (from the near proximity of carbon atoms)

and these are responsible for the adsorption process —Adie and others|| (2014).

It can be made from hard woods, coconut shell, animal bones, fruit stones, coals and synthetic macro molecular system —Harry and others|| (2006). The abundance and availability of agricultural by products makes them good sources of raw materials for activated carbon production (Karaman, Yagmur, Banford and Aktas, 2014). Activated carbon are carbonaceous materials that can be distinguished from elemental carbon by the oxidation of the carbon atoms found on the outer and inner surface. The surface oxygen functional groups can be easily introduced to the carbon by different activation methods including dry and wet oxidizing agents. Activated carbon are used for waste water treatment, drinking water purification and liquid phase adsorption and have wide

applications in domestic, commercial and industrial settings (Katesa, Junpirom and Tangsathitkulchai, 2013).

In the food industry, activated carbon is used in de-colourization, deodorization and taste removal. It is used to remove heavy metals and organic contaminants from liquid. Activated carbon is used in water de-chlorination and processing of foods. It is also used in medicine for adsorption of harmful chemicals and drugs. In gas cleaning application activated carbon is extensively used in air filters at industrial level as well as in general air conditioning application (Khalili, Khoshandam and Jahanshahi, 2015).

Animal charcoal also known as bone black, bone chair and abaisoris a granular material produced by charring animal bones. Animal bones are part of the composite that form the body of animals. It basically gives shape and support to animals (skeletal system). It contains about 10% carbon, the remainder being calcium and magnesium (80%) and other inorganic materials present in the bones. Adie and other 2014 in their work used parkiabiglobosa pod (African locus bean) to reduce chemical oxygen demand nitrogen and phosphorous that may cause eutrophication. The results obtained were as follows: COD was reduced from

250mg/liter, 6.2mg/l (which is 97.52%) nitrate had 87.5% while phosphorous been reduced by 51.2% (Kundu, RedzwanandSahu, 2014) also used activated carbon in treating industrial waste effluent and was able to achieve 47.68% and 34.20% removal efficiency for TDS and BOD. (tansengco and others 2015) used activated carbon for post treatment of abattoir waste water after treating with anaerobic sequence batch reactor and recorded 94%,

93%, 54, 58 and 53 for COD, BOD, TSS, Turbidity and colour removal respectively. The knowledge of physical and activity of characterization of activated carbon made of cow bone will help in determining the stability of absorbent made from palm kernel shell and sawdust wood.

The conversion of both palm kernel shell and sawdust wood to activated carbon would therefore serve as an alternative use of these abundant natural resources.

flow system. GAC can be either in the granular form or extruded. GAC is designated by sizes such as 8 x 20, 20 x 40, for liquid phase applications and 4 x 6, 4 x 8, or 4 x 10 for vapour phase application.

METHODS AND MATERIALS

Materials

Refining effluent, Oven, Furnace, pH meter, Thermometer, Weighing balance, Beakers, Measuring cylinder, Conical flask, Petri dish, Mortar and Pestle, Atomic Absorption Spectrophotometer

Collection of Sample

The palm kernel shell was collected at Alegbo road Effurun Delta State while the sawdust wood was collected from Wood market at Uti junction Effurun, Delta State. They were washed thoroughly with water to remove dirt and impurities and then dried in an oven for 24 hours, it was grinded to powder. The Wastewater was collected from Matrix filling station inside Warri Delta state.

Method used Preparation of Activated Carbon by Carbonizing before Activating

The washed palm kernel shell and sawdust wood will be allowed to dry in an oven and ground into small particles using a grinder. The ground palm kernel shell and sawdust wood will then be carbonized by heating in a furnace at a temperature of around 400-700°C for some minutes. After carbonization, the resulting material will be washed with water to remove any impurities. The washed material will then be activated using potassium hydroxide (KOH) and then heated again at a temperature of 500-600°C to produce activated carbon before being cooled and ground into powder.

Preparation of Activated Carbon by Activating before Carbonizing

The washed palm kernel shell and sawdust wood will be allowed to dry in an oven. After completely drying the palm kernel shell and sawdust wood they will be activated using potassium hydroxide (KOH). After activation, the palm kernel shell and sawdust wood will be washed thoroughly and then placed in an oven to dry. They will therefore be carbonized by heating in a furnace at 400 for some minutes and then ground into powder to obtain the activated carbon.

Characterization of the Activated Carbon The prepared activated carbon will be characterized in the laboratory to understand its physical and chemical properties. The methods are:

Determination of surface area 1g of activated carbon sample will be weighed and placed in an inert gas stream at 150-300c for 5 hours to remove moisture and gas absorbed on the sample surface. The degassed sample will transfer into a bet analyzer. The system will be typically consist of a vacuum pump, pressure transducers, and a liquid nitrogen DeWalt flask. The system will be evacuated to remove any residual gas, and then nitrogen gas (as the adsorbate) will be introduce into the system at a range of partial pressure (typically from 0.05 to 0.35 P/P_o where P is the pressure and p_o is the saturation pressure of nitrogen at the boiling point of liquid nitrogen). The analyzer measure how much nitrogen gas will be absorbed on the surface of the sample at different pressure. After the completion of adsorption measurement, nitrogen will be slowly described from the sample by reducing the pressure and the amount of desorbed Ed gas will be measured. The BET equation will be applied to the adsorption data create a BET plot.

Determination of pore structure analysis

1g of the activated carbon will be weighed and will be placed in a degassing station to remove any adsorbed moisture from the surface and pores. Degassing is typically carried out under vacuum or flowing inert gas (nitrogen or helium) at elevated temperature (200-300°C depending on the material) for several hours. Once the sample is degassed, the sample will be transferred to the analysis portion of BET analyzer. The instrument will be calibrated and set to the appropriate parameters for the analysis. The sample tube will be immersed into the liquid nitrogen to maintain a constant low temperature (typically 77k or -196°C) during the adsorption process. Once the adsorption is complete d, the nitrogen pressure will be gradually reduced to allow for adsorption. And the adsorption isotherm will be recorded, showing how the nitrogen gas will be released from the sample.

Determination of fourier transform infrared spectroscopy

The sample will be grinded into fine powder and will be mixed with potassium bromide (KBr), it will be pressed into a thin film. A small drop of potassium bromide (KBr) will be placed in the IR-transparent plating, the gas sample will be enclosed in a gas cell. The sample will be placed in the sample holder of Fourier transform infrared spectroscopy (FTIR) and the data taken.

Determination of Scanning Electron Microscopy (SEM)

The activated carbon will be dried to remove any moisture. A small amount of the activated carbon will be mounted on a sample holder using conductive carbon tape.

If the sample is non-conductive, it will be coated with a thin layer of conductive material using a sputter coater. the sample will be placed in the SEM chamber and the vacuum level will be adjusted to create a high-vacuum environment.

pH determination of activated carbon 1 gram of activated carbon will be weighed and mid with 100mL of deionized water in a beaker. The mixture will be stirred for about 30 minutes to allowing the carbon to equilibrate with the water. The suspension will be filtered to remove large particles and the pH of the filtrate will measure using a calibrated pH meters. **Determination of Ash**

Content Determination The activated carbon sample will be dried in an oven at 105°C to remove moisture and 2g of the dried sample will be weighed. The sample will be placed in a muffle furnace and heated to 500-600°C for 3-4 hours or until all carbonaceous material is completely combusted. The Weight of the residue (ash) left after combustion will be calculated using this formula: Ash Content (%) = $\frac{\text{Weight of ash}}{\text{Initial weight of sample}} \times 100$

Determination of Iodine Number Determination

0.1 grams of activated carbon will be weighed and mixed with 10mL of iodine solution in a flask. The mixture will be shaken for about 30min and allow absorbing. The mixture will be filtrate and titrated with sodium thiosulfate solution. The iodine number will be determined based on the amount of iodine absorbed by the activated carbon.

Determination of Methylene Blue Adsorption 20 mg/L of methylene blue solution will be prepared and 1g of activated carbon will be weighed. The activated carbon will be added to the methylene blue solution and stir for 30 minutes allowing it to absorb the solution. The mixture will be filtered and the concentration of methylene blue remaining in the solution will be measured using a spectrophotometer at 664nm and the absorption capacity calculated. (Tanm 2019)

Determination of Thermo gravimetric Analysis (TGA)

10mg of activated carbon sample will be weighed and placed in a TGA instrument and the temperature set at 25-900C and heated at 10-20C per minute. (Aworn *et al.*, 2019)

Total Dissolved Solid (TDS)(Mg/l)

The TDS meter was put on and the probe rinsed. Immerse the probe in the sample to be read. The corresponding reading is the TDS reading in mg/l. Rinse the probe with a soft cloth (Legrouri, *et al.*, 2015).

Total Suspended Solids(TSS)(Mg/l) This is determined by filtering a well mixed aliquot (100ml) of the sample through a dried and pre-weighed Millipore filter paper using vacuum filtration apparatus. The filter paper is then dried at 105°C to constant weight and weighed again. The difference in weight of the filter paper represents the total suspended solid.

This is reported in mg/l after calculation:

Total suspended solid (mg/l) = $\frac{(A-B) \times 100}{\text{Sample volume, ml}}$

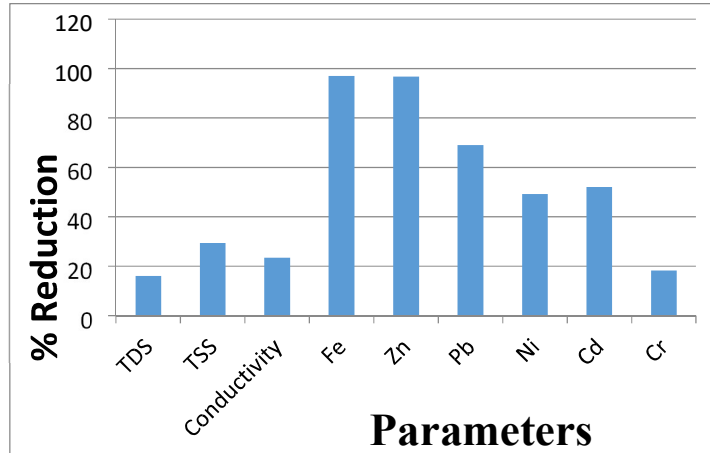
Sample volume, ml

Where: A= Weight of filter+ dried residue, mg B=Weight of filter paper, mg

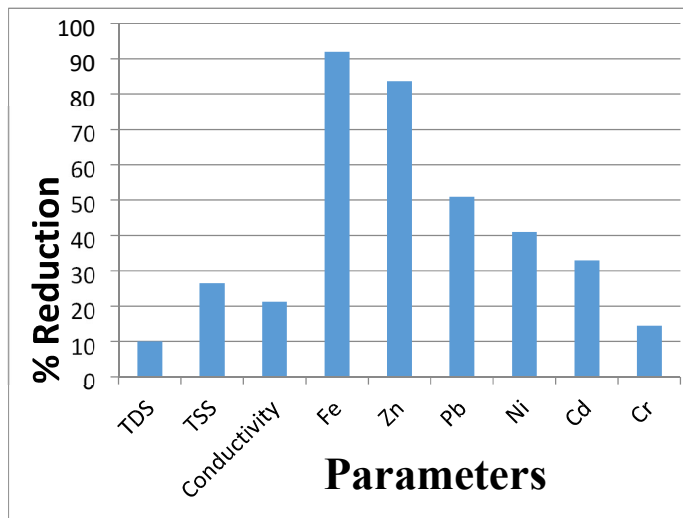
Conductivity (µS/cm)

The conductivity meter cell was rinsed with one or more portions of sample. The temperature was adjusted to 25.0 ± 0.1°C. The sample resistance was measured and the temperature noted.

4 The Results



%Reduction of some Chemical Parameter for Carbon 1



%Reduction of some Chemical Parameter for Carbon 2

DISCUSSIONS

pH

The pH of the untreated water was measured at 6.2, which is slightly acidic. After treatment using activated carbon from palm kernel shell (carbon 1), the pH increased to 7.1, indicating a more neutral condition. A further increase was observed when treated with activated carbon from sawdust wood (carbon 2), where the pH reached 7.5. This increase in pH may be attributed to the alkaline nature of the carbon materials, as activated carbon can influence the pH of the water depending on its surface chemistry and the functional groups present (Saeed *et al.*, 2010).

Temperature

There was no significant change in the temperature of the water after treatment, remaining constant at 30.3°C. This indicates that the activation process, whether from palm kernel shell or sawdust, did not significantly affect the thermal properties of the water. Similar results were reported by Jha *et al.*, (2009), who also observed no substantial temperature variation in water treated with activated carbon.

Total Dissolved Solids(TDS)

The TDS value of the untreated water was 200 mg/l, which decreased to 168 mg/l (16% removal) after treatment with activated carbon from palm kernel shell. The TDS level further decreased to 180 mg/l (10% removal) when treated with activated carbon from sawdust wood. Although both treatments resulted in TDS reduction, palm kernel shell-based activated carbon proved more efficient. This aligns with findings from Adewuyi et al. (2011), who demonstrated that different sources of activated carbon could have varying abilities to reduce dissolved solids, depending on their surface area and porosity **Total Suspended Solids (TSS)**

The TSS level in the untreated water was 204 mg/l. After treatment, the TSS was reduced to 144 mg/l (29.4% removal) with carbon 1 and to 150 mg/l (26.47% removal) with carbon 2. The reduction in TSS was more pronounced when palm kernel shell activated carbon was used. These results are consistent with those of Ogunwumi et al. (2014), who reported that activated carbon from agricultural waste sources is highly effective at removing suspended particles.

Conductivity

The conductivity of untreated water was 298.5 mg/l, which dropped to 228.7 mg/l (23.4% removal) with carbon 1 and to 234.9 mg/l (21.3% removal) with carbon 2. Both activated carbons were effective at reducing water conductivity, with palm kernel shell-based activated carbon again showing better performance. The reduction in conductivity is indicative of the removal of ions from the water, which is often a direct result of adsorption on the activated carbon surface (Kumar *et al.*, 2014).

Iron (Fe)

Iron (Fe): The untreated water contained 1810 mg/l of iron, which was reduced to 54.3 mg/l (97% removal) with carbon 1 and 144.8 mg/l (92% removal) with carbon 2. This significant reduction in iron concentration is an excellent result, with carbon 1 demonstrating superior efficiency in removing iron. Similar results were obtained by Saeed et al. (2010), who reported high removal rates of iron using activated carbon.

Zinc (Zn)

Zinc (Zn): The untreated water contained 1360 mg/l of zinc, which was reduced to 44.9 mg/l (96.7% removal) with carbon 1 and 223.1 mg/l (83.6% removal) with carbon 2. The palm kernel shell-based activated carbon exhibited much better performance in removing zinc, which may be due to its larger surface area and better adsorption capacity. This finding corroborates the work of Tan et al. (2009), who observed similar trends in the removal of heavy metals from aqueous solutions using activated carbon.

Lead (Pb)

The untreated water had 890 mg/l of lead, which was reduced to 275.9 mg/l (69% removal) with carbon 1 and 436 mg/l (51% removal) with carbon 2. While both activated carbons effectively removed lead, the palm kernel shellbased activated carbon showed superior performance. This result is in line with that of Iyamabo et al. (2013), who found activated carbon to be effective in lead removal from water. **Nickel**

Nickel concentration in the untreated water was 860 mg/l. After treatment with carbon 1, it was reduced to 437 mg/l (49.19% removal), and with carbon 2, it was reduced to 510 mg/l (40.96% removal). The palm kernel shell-based activated carbon again showed better performance. These findings align with similar studies on nickel removal, such as that by Suresh et al. (2012), who observed that activated carbon could reduce nickel concentrations in contaminated water.

Cadmium(Cd)

Cadmium (Cd): The untreated water had 910 mg/l of cadmium, which was reduced to 607.9 mg/l (52% removal) with carbon 1 and 436.8 mg/l (33% removal) with carbon 2. Carbon 1 exhibited a better removal efficiency for cadmium, which is consistent with findings by Tan et al. (2009), who reported high removal efficiency for cadmium with activated carbon.

Chromium

Chromium (Cr): The untreated water contained 740 mg/l of chromium, which was reduced to 605.3 mg/l (18.2% removal) with carbon 1 and 633 mg/l (14.5% removal) with carbon 2.

Although chromium removal was less efficient compared to other metals, palm kernel shell based activated carbon showed better results. This is in agreement with the work of Kim *et al.* (2011), who found that activated carbon removal of chromium can be less efficient depending on the specific properties of the carbon and the environmental conditions.

CONCLUSIONS AND RECOMMENDATION

This study focused on the production and characterization of activated carbon derived from local sources, specifically palm kernel shell and sawdust wood, and assessed their efficacy in treating water for the removal of contaminants. The results demonstrated that both palm kernel shell and sawdust wood can serve as viable materials for producing activated carbon with substantial surface area and adsorption capabilities. The characterization of the produced activated carbons revealed important properties such as surface area, pore volume, and functional groups, which play a critical role in the adsorption process. Palm kernel shell-derived activated carbon exhibited better adsorption performance compared to the sawdust-derived carbon in the removal of various contaminants such as iron, zinc, and lead. However, while both carbons were effective in reducing the concentration of certain heavy metals, they showed varying efficiencies, with palm kernel shell carbon performing better in most parameters. The removal efficiency of heavy metals such as iron, zinc, and lead was notable, with palm kernel shell carbon achieving the highest removal rates, particularly for iron (97%) and zinc (96.7%). However, certain metals like nickel, chromium, and cadmium exhibited lower removal efficiencies, suggesting that the adsorption capacity of the produced activated carbons is influenced by the chemical properties of the contaminants as well as the activation conditions of the carbon materials. Additionally, the study found that the pH of the treated water increased post-activation, indicating that the adsorption process slightly altered the water's chemical composition. In comparison to similar studies, the results of this study were consistent with findings from previous research indicating that activated carbon derived from agricultural waste materials such as palm kernel shells and sawdust is an effective and low-cost alternative for water purification. However, the removal efficiencies observed for some metals suggest the need for further optimization of the production process or the potential use of complementary treatments to enhance the overall performance of the activated carbons. Activated carbon derived from palm kernel shell and sawdust wood proves to be a promising and sustainable option for water treatment, particularly for the removal of specific heavy metals. Further studies on the optimization of activation conditions and the use of combined treatment methods may increase the removal efficiency for more challenging contaminants, thereby improving the overall water purification process.

Recommendation

The followings were recommended based on the study:

1. It is recommended to modify the activation conditions, such as temperature and chemical treatment, to improve the adsorption capacity of both palm kernel shell and sawdust-derived activated carbons for metals like nickel and chromium.
2. A combination of activated carbon with other adsorbents or filtration technologies should be explored to enhance the removal efficiency for metals like cadmium and lead, which showed relatively lower removal rates in this study.

3. Future studies should investigate the use of multiple adsorption cycles or regeneration techniques to assess the long-term sustainability and reusability of the activated carbons produced from palm kernel shell and sawdust.
4. To further enhance the water treatment process, the potential of adjusting the pH of the water during treatment should be explored, as the pH changes observed could impact the effectiveness of metal adsorption.

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