

Effectiveness of Coconut Shell Activated Carbon Filter Material Produced Under Various Carbonization and Activation Conditions

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ABSTRACT

Water is an important resource on the earth surface which has been contaminated in so many ways such as with refuse and effluents from households. Various works have been done to remedy the effects of anthropogenic and industrial contamination of surface and groundwater. Activated Carbon is a very good adsorption material which has been employed in the treatment of contaminated water. In this work, activated carbon was produced from coconut shell under various carbonization temperatures and activation times, using hydrochloric acid (HCl) as the activating agent. Water treatment analyses were carried out on the product and results showed that the optimum carbonization temperature and activation time were 500°C and 180 minutes respectively. Resulting characteristics were; yield of 30.579%, bulk density of 0.704g/ml, the ash content of 7% and pore volume of 0.64ml. On treatment of contaminated surface water, this sample gave 66.9% Chemical Oxygen Demand (COD) removal efficiency and 86.7% Biochemical Oxygen Demand (BOD) removal efficiency at a carbon dosage of 0.2g/60ml.

Keywords – Coconut Shell, Carbonization, Activation, Activated Carbon.

1. INTRODUCTION

According to World Health Organization, many people in the world do not have access to improved drinking water, almost all of them in developing regions. Moreover, there is a lack of access to adequate water supply in outlying regions, such as rural areas. Even when centralized treatment plants are available, contamination of piped drinking water may occur between the distribution system and the final consumption point, that is, 'between tap and mouth' (Flavia et. al., 2012).

Coconut-based agricultural wastes have gained wide attention as effective bio sorbents due to low-cost and significant adsorption potential for the removal of various aquatic pollutants. The various parts of coconut tree such as coir, shell and pith have been extensively studied as biosorbents for the removal of diverse types of pollutants. Also, coconut shell-based carbons tend to be harder, more resistant to abrasion and lower in ash than similar grades of coal-based carbons (Shilpa and Nimisha, 2014).

The major advantage with the coconut shell activated carbon is that it is an outstanding material for applications requiring taste, odour and dissolved organic chemical removal from water with suspended particle present. In addition, its balanced pore structure gives a more efficient adsorption range and it imparts a high 'polish' to the filtered water (Clark Corporation, 2009).

Conversion of coconut shells into activated carbons which can be used as adsorbents in water purification or treatment of industrial and municipal effluents would add value to these agricultural commodities, help reduce the cost of waste disposal, and provide a potentially cheap alternative to existing commercial carbons (Chengwen et. al., 2014).

2. MATERIALS

The materials for this work include:

- Coconut Shell
- Grinding stone (for crushing shell)
- Muffle Furnace (Carbolite-CWF 1200)
- Oven
- Crusher (Mortar and Pestle)
- Draining Tray
- Distilled water
- Sieve (350µm)
- Weighing balance (S. METLER 0.01g-500g- Electro Weighing Balance)
- Tong
- Crucibles

2.1 Sample

The precursor (raw material) used for this experiment is coconut shell. It was collected as waste material from market women just before the flyover at Orji, Owerri, Imo state. The coconut shell was cleaned out and crushed to smaller size with a grinding stone after which it was placed outside under the sun for about 10 hours.

The contaminated surface water sample was gotten from *Asata* river, *Asata*, Enugu State. This river was contaminated with domestic waste from residents in the area.

3. METHOD

3.1. Carbonization

Carbonization was done after cleaning and crushing the coconut shells into smaller sizes for easy loading into the crucibles. The temperatures at which the carbonization was done were 300°C, 400°C, 500°C, 600°C and 700°C for 2hrs each. The carbonized coconut shells were further crushed using a laboratory mortar and pestle.

3.2. Activation

The samples of carbonised coconut shells were soaked in hydrochloric acid (75% conc.) for 60, 100, 140, 180 and 220 minutes. The resulting slurry formed from each sample was stirred and reinstated into furnace at a final temperature of 800°C for activation. Each activated carbon sample was washed in distilled water until the mixture got to a pH within the range of 6.8 to 7.2, after which it was further dried in the oven at 110°C for 1hr to remove water from the activated carbon and enhance storage.

3.3. Characterization

Percentage yield was derived by dividing the weight of carbon retrieved from the furnace by the original weight of the precursor used in the experiment as shown in (1):

$$\text{Percentage Yield} = \frac{W_{ca}}{W_f} \times 100\% \quad (1)$$

Where:

W_{ca} = oven dried weight of carbon sample

W_f = weight of carbon retrieved from the furnace

The Weight loss was also calculated using (2):

$$\% \text{ Weight Loss} = \frac{W_f - W_{ca}}{W_f} \times 100\% \quad (2)$$

(Kwahgher and Ibrahim, 2013)

To determine the ash content, constant weight of 0.1g of each activated carbon sample including the commercially produced sample was burnt in the muffle furnace at 650°C for 4 hours in the presence of air. In each instance, the resulting ash was weighed and recorded.

Ash content which is a measure of the amount of ash in a sample after carbonization was determined using (3):

$$\text{Ash Content} = \frac{\text{Ash Weight (g)}}{\text{Overdry Weight (g)}} \times 100 \quad (3)$$

(Kwahgher and Ibrahim, 2013)

To determine the bulk density, a volumetric bottle was provided and a volume of 2.5ml was obtained and marked on the bottle. The empty weight of the volumetric bottle was measured. Samples of the coconut shell activated carbon were poured into the volumetric bottle and the bottom of the cylinder was tapped gently on the laboratory bench top several times until there was no further diminution of the sample level. This was done until it reached the 2.5ml mark. It was then weighed again and recorded. The weight of the empty bottle as recorded earlier was subtracted from the new weight and then the bulk density was determined using (4):

$$B_d = \frac{W_s}{V_s} \text{ (g/ml)} \quad (4)$$

Where:

B_d=Bulk density

V_s=volume occupied by the packed sample

W_s=weight of the sample (Okoye, 2010).

To determine the Pore volume, 0.5g of each activated carbon sample was put in a beaker containing 0.5ml of water and stirred. The mixture was boiled for about 5 minutes in order to displace air in the sample. The content was then superficially dried and weighed (Appendix D). Pore volume was determined by dividing the increase in weight of the sample by the density of water (Gumus and Okpeku, 2015).

3.4 Water Analysis

The produced activated carbon samples and the commercially produced sample were tested using a contaminated surface water sample to determine their effectiveness in purifying the water.

Analyses were carried out on the raw water sample to determine the initial values of Turbidity, P^H, Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD). 0.2g of each sample was put in a beaker containing 60ml of the contaminated water sample, stirred and left for 1 hour to ensure adequate adsorption. For each of the samples, the solution was filtered using a clean filter paper and tests were carried out on all filtrates.

Turbidity, P^H, TDS, COD and BOD were determined.

4. RESULTS

The results of the experiments carried out are summarized in the following tables and figures. Table 1 shows the results of effect of carbonization temperature on percentage yield and weight loss of activated carbon. Table 2 shows the results of characterization of the activated carbon. Figs 1to 5 show graphically the results of percentage yield, weight loss, porosity and bulk density of resulting activated carbons. Figs 6 to 9 show the results of water treatment using the produced activated carbons.

Table 1 Results of the effect of Carbonization temperature on Percentage Yield and Weight Loss

Temperature (°C)	300	400	500	600	700
Yield (%)	53.809	34.163	30.579	28.604	27.900
Weight Loss (%)	46.1905	65.8366	69.4213	71.3959	72.1003

Table 2 Results of effect of produced Coconut Shell Activated Carbons on Activated Carbon.

Temperature (°C)	Time (mins)	%Ash	bulk density(g /ml)	pore volume (ml)	porosity
300	60	13	0.68	0.22	0.2992
	100	10	0.64	0.43	0.5504
	140	9	0.716	0.66	0.94512
	180	9	0.676	0.56	0.75712

	220	9	0.632	0.61	0.77104
400	60	11	0.716	0.66	0.94512
	100	10	0.644	0.65	0.8372
	140	8	0.672	0.52	0.69888
	180	6	0.632	0.66	0.83424
	220	7	0.692	0.44	0.60896
500	60	11	0.72	0.21	0.3024
	100	7	0.684	0.67	0.91656
	140	7	0.784	0.59	0.92512
	180	7	0.704	0.64	0.90112
	220	7	0.724	0.65	0.9412
600	60	10	0.72	0.62	0.8928
	100	7	0.652	0.67	0.87368
	140	6	0.684	0.5	0.684
	180	6	0.632	0.51	0.64464
	220	5	0.724	0.56	0.81088
700	60	5	0.72	0.53	0.7632
	100	6	0.648	0.3	0.3888
	140	5	0.628	0.53	0.66568
	180	4	0.688	0.68	0.93568
	220	4	0.644	0.71	0.91448
standard		5	0.72	0.45	0.648

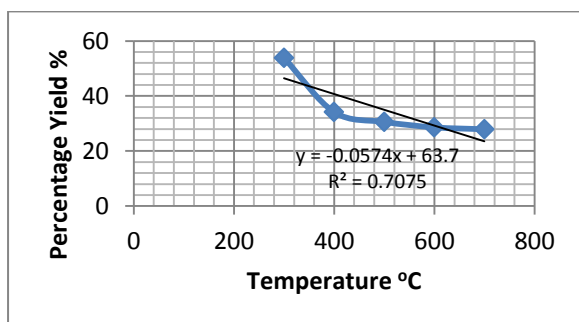


Fig. 1 Effect of Carbonization temperature on Percentage Yield

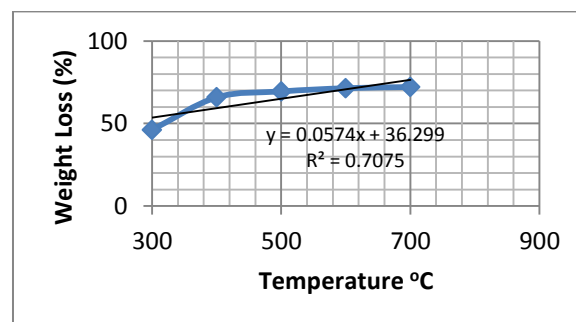


Fig. 2 Effect of Carbonization Temperature on Weight Loss

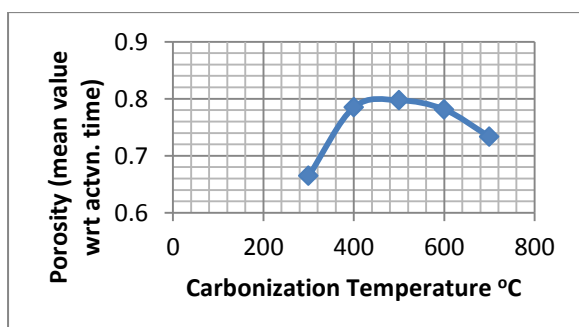


Fig. 3 Graphical relationship between Mean values of porosity (with respect to activation time) and carbonization temperature.

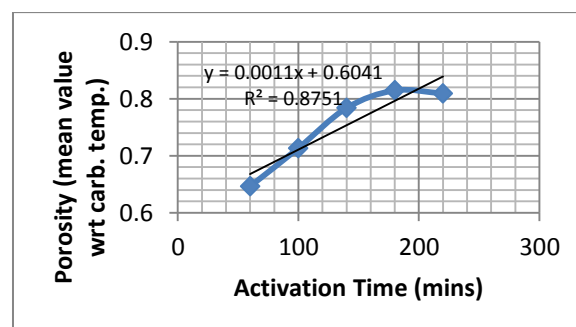


Fig. 4 Graphical relationship between Mean values of porosity (with respect to carbonization temperature) and activation time.

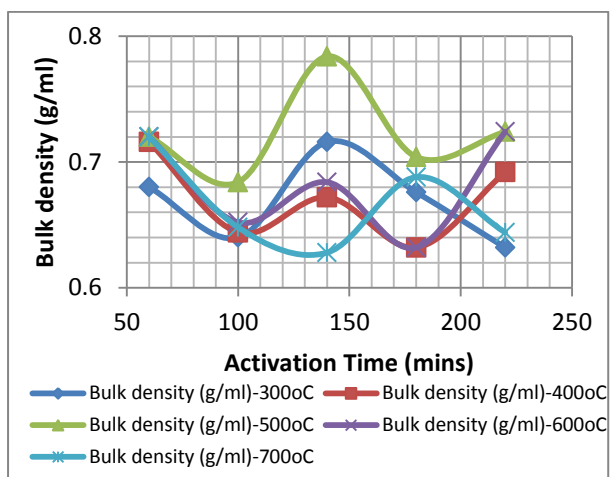


Fig. 5 Graphical representation of effect of produced Coconut Shell Activated Carbons on Bulk density

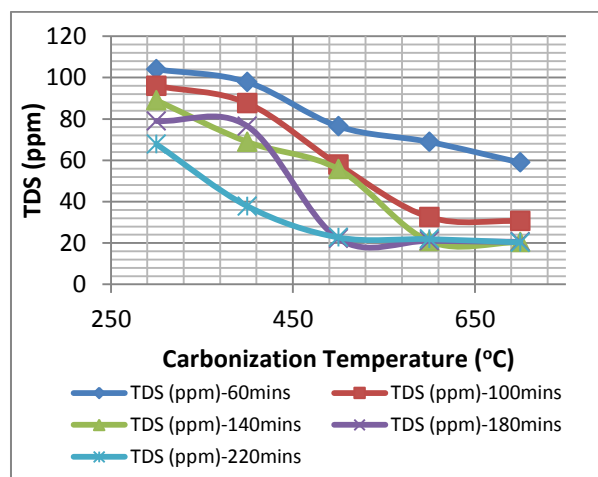


Fig. 6 Graphical representation of effect of produced Coconut Shell Activated Carbons on TDS.

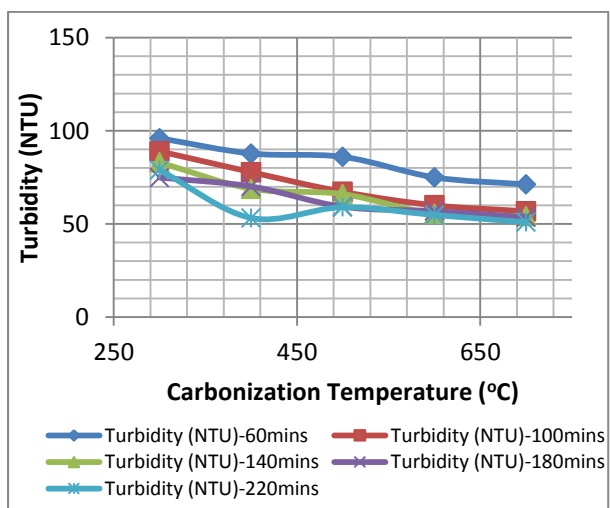


Fig. 7 Graphical representation of effect of produced Coconut Shell Activated Carbons on Turbidity.

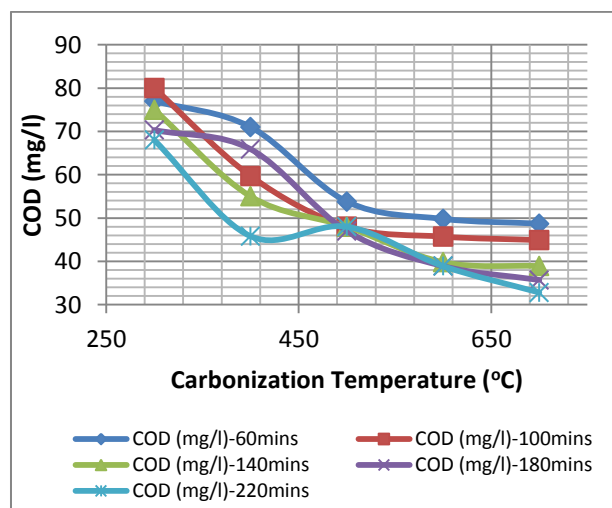


Fig. 8 Graphical representation of effect of produced Coconut Shell Activated Carbons on COD.

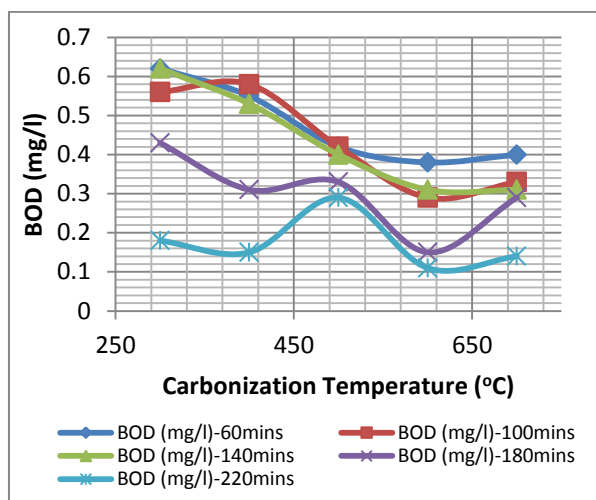


Fig. 9 Graphical representation of effect of produced Coconut Shell Activated Carbons on BOD.

5. DISCUSSION

In Table 1, it was observed that the percentage yield decreased with increase in carbonization temperature. On the other hand, the weight loss increased with increase in temperature. This shows that more volatile matter is consumed with increase in carbonization temperature and vice-versa. Graphical representation of the relationship between percentage yield and carbonization temperature in fig. 1 as well as weight loss and carbonization temperature in fig. 2 showed that from 300°C to about 420°C there was a rapid reduction in the percentage yield and increase in weight loss (shown by the steep slope), after which the slope is very gentle, that is from 420°C to 600°C. At 600°C the trend stabilizes till it gets to 700°C. This is an indication that between 300°C and 420°C at the carbonization timing of 2 hours, there is a rapid expulsion of volatile matter (in which most of the volatile matter would be expelled), after which the rate reduces. The trend indicates that at 600°C all volatile matter would have been consumed. In relation to the established result of Yusufu et. al. (2012) that maximum increase in weight loss for carbon samples occur at carbonization time of 2hrs, it can be stated from this experiment that for coconut shell, the maximum increase in weight loss occurs at carbonization time of 2hrs and temperature of 600°C. The Ash content (Table 2) was discovered to reduce with increase in temperature. It was also discovered that the ash content generally reduced with increase in activation time, having highest value of 13% (at 300°C carbonization temperature; 60mins activation time) and a least value of 4% (at 700°C carbonization temperature; 180mins and 220mins activation times). This shows clearly that ash content reduces with increase in carbonization temperature (at uniform carbonization time) and activation time (at uniform activation temperature). This result tallies with the findings of Gumus and Okpeku (2015) that increase in carbonization temperature reduces the ash content.

The porosity which is directly related to pore volume and surface area was found to increase steadily with increase in carbonization temperature. The steady increase was noticed when the mean value of each group was determined and compared with the other groups. The Mean values of porosity were compared to carbonization temperature and the mean values of porosity were compared to activation time. Graphically, the relationships showed that porosity increased and got to a peak at 460°C with a mean value of 0.8, after which it began to decrease with a very gentle slope till 565°C where the porosity reduced rapidly (fig 3). This shows that as carbonization temperature increases, there is a further breakdown of the carbon chains. When this occurs, the pore spaces decrease. Also, fig. 4 showed an increase in porosity which peaked at 185 minutes with a mean value of 0.82 after which it also reduced. The above findings indicate that porosity also increases with carbonization temperature and activation time, although to a certain extent after which it reduces. Also, for

coconut shell carbonized for two hours, the porosity is highest between 460°C to 500°C and at an activation time of 185 minutes (or within 180 to 200 minutes).

The emergence of characteristics of carbon indicated that the bulk density of carbon prepared from different processes were close to each other as shown in fig. 5. No major deviations were noticed in bulk density values. The bulk density had a least value of 0.628 g/ml (at 700°C carbonization temperature; 140 mins activation time) and a highest value of 0.784 g/ml (at 500°C carbonization temperature; 140 mins activation time). The activated carbon produced with 140mins activation time undulated with peak value of 0.784mg/l at 500°C after which it declined. It was noticed that for each activation time, the bulk density was highest at 500°C.

There was a significant reduction in the Total Dissolved Solids (TDS) as shown in fig. 6. The TDS of the raw water was 149ppm and results showed a highest value of 104ppm for 300°C; 60 mins activated carbon and least value of 20.3ppm for 700°C; 220 mins activated carbon. The values of TDS reduced with increase in carbonization temperature and also with increase in activation time. It was discovered that the activated carbon produced at 500°C carbonization temperature and 180 mins activation time had TDS value of 22.1ppm which is just a little higher than the least value of TDS in the test results (20.3ppm) and even less than that of the commercially produced activated carbon with 25.6ppm.

The turbidity also reduced significantly after treatment with the produced coconut shell activated carbons (fig. 7). The raw water sample had a turbidity value of 150NTU and after treatment the highest value was 96NTU for 300°C; 60 mins activated carbon and the least value was 50.9NTU for 700°C; 220 mins activated carbon. The turbidity also reduced with increase in carbonization temperature and activation time. 500°C; 180 mins activated carbon had 59.2NTU which was again less than the commercially produced activated carbon with 60.3NTU.

The Chemical Oxygen Demand (COD) also reduced remarkably after treatment with the produced activated carbons (fig. 8). A steady decrease was also noted with increase in carbonization temperature and activation time. The raw water had a COD value of 142mg/l and after treatment the highest value was 80mg/l for 300°C; 100 mins activated carbon and the least value was 32.8mg/l for 700°C; 220 mins activated carbon. This insinuates that as carbonization temperature and activation time increase, the adsorption capacity of the activated carbon also increases.

The Biochemical Oxygen Demand (BOD) also generally reduced with increase in carbonization temperature and activation time as indicated in fig. 9. The raw water had BOD of 2.49mg/l and after treatment with the produced coconut shell activated carbons, the highest value was 0.62mg/l for 300°C; 60 mins and 300°C; 100 mins activated carbons (both had the same value). The least value was 0.11mg/l for 600°C; 220 mins activated carbon.

In consideration of the above results, the activated carbon produced at 500°C carbonization temperature and 180 minutes activation time, proved to be more effective in water treatment.

6. CONCLUSION

The results of this study show that it is very possible and economical to produce activated carbon (having well developed pore structure and adsorption capacity) from coconut shell (which is an abundant agricultural waste in Nigeria) for water treatment. Experimental results show that increase in carbonization temperature and activation time resulted in better activation as demonstrated by the characterization and water analysis conducted.

Results show that the optimum carbonization temperature/time is 500°C/2hrs and activation temperature/time is 800°C/180 minutes (3hrs). Characteristics of activated carbon produced under this condition were; yield of 30.579 %, bulk density of 0.704 g/ml, ash content of 7 % and pore volume of 0.64ml. The results obtained in this study further showed that produced activated carbon from coconut shell can be used for contaminated surface water treatment, achieving 66.9% COD removal efficiency, 86.7% BOD removal efficiency and 85.17% TDS removal efficiency at a carbon dosage of 0.2g/60ml of contaminated surface water. This would be of immense benefit to the water treatment industry and also in the aspect of renewable energy.

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