

THE USE OF SELECTED CARBONIZED AGRICULTURAL WASTE AS A LOW COST SCRUBBER IN AIR POLLUTION CONTROL.

Tunde Oloriegbe (MSC, MTL): Principal Transport Technology Officer, Nigerian Institute of Transport Technology, Zaria, Kaduna State. Nigeria. oloriegbetunde@yahoo.com

Okofu C.A (Prof.): Water Resources and Environmental Engineering Department, Ahamdu Bello University, Zaria, Kaduna State. Nigeria.

Ibrahim F.B (PhD): Water Resources and Environmental Engineering Department, Ahamdu Bello University, Zaria, Kaduna State. Nigeria. FBibrahim@yahoo.com

Abstract

The production of activated carbon from agricultural waste is one of the most environmental friendly solutions of transforming less valuable into more valuable materials and it is also a way of converting waste to wealth. Rice husks, maize cobs and coconut shells were individually used to prepare activated carbon under the same experimental conditions of 500°C carbonization temperature, impregnation ratio of 10:1 under 1hr activation time using chemical activation method with ZnCl_2 as the activation agent. After being subjected to carbonization and chemical activation, the farm residues were examined for their surface areas, pHs, conductivities, specific gravities, bulk densities and moisture contents. Elemental composition of each of the waste at carbonized stage, when chemically activated, when used to trap air pollutants and when reactivated were also determined. The adsorptive capacities of these activated carbons were investigated and compared by loading each of them in an adsorption column of 1.5m tall, 0.98m diameter with four openings at height 0m (input), 0.5m, 1.0m, 1.5m (output). A 0.85kva generator was connected to the column and the concentrations of some selected primary pollutants (HC , CO , CO_2 , NO_x) were determined at the input was analyzed and compared to the concentrations at different heights in the column, as the fumes passed through. Optimization studies were also carried out to investigate the adsorptive efficacies of blends of the activated carbons, at different ratios and proportions. When the three activated carbons were mixed at same ratio and proportion, the adsorptive capacity was found to be less than when compared to the efficiencies of the individual activated carbons. Activated carbon produced from coconut shells was experimentally found to have the highest adsorptive capacity followed by that produced from maize cobs and rice husks. The adsorptive capacity was experimentally found to be dependent on adsorbate dosage, contact time and concentration of the adsorbate. CO and CO_2 were found to be easily absorbed by all the three activated carbons. Some recommendations have been made.

Key words: Activated carbon, rice husk, maize cobs, coconut shell, Adsorption, pollutants: HC , NO_x , CO , CO_2

1. INTRODUCTION.

As a common practice, direct combustion of agricultural waste biomass results in air pollution thereby it poses a risk to human and ecological health. Hence, improper management of agricultural waste biomass is contributing to climate change, water and soil contamination, and air pollution. (UNEP, 2009)

Apart from posing health risks to humans and to the ecosystem in general, governments at various levels, in both developed and developing nations, spend huge sums of money in managing and disposing agricultural wastes yearly. Report from USEPA 2000, had it that the government of the United States spends millions of dollars yearly in managing and disposing her agricultural wastes apart from money spent by farmers and other stakeholders.

Although there is an emerging trend in the utilization of biomass conversion technologies from the combustion of rice husk and sugarcane bagasse to the gasification of other agricultural residues, biomass is still largely underutilized and often left to rot or openly burnt in fields, especially in developing countries that do not have strong regulatory instruments to control such pollutive practices. (UNEP, 2009)

Biomass is a renewable resource that causes problems when not used. The challenge, therefore, is to convert biomass to energy and other productive uses. Biomass is a renewable resource that has a steady and abundant supply, especially those biomass resources that are by-products of agricultural activities. Biomass wastes include agricultural wastes, such as corn stalks, straw, sugarcane leavings, bagasse, nutshells, manure from cattle, poultry, and hogs; forestry residues, such as wood chips, bark, sawdust, timber slash, and mill scrap; municipal wastes, such as waste paper and yard clippings.

Globally, 140 billion metric tons of biomass waste is generated every year from agriculture. This quantity of biomass can be converted to an enormous amount of energy and serves as raw materials to manufacturing industries. (UNEP, 2009)

Considerable efforts are being made by many Governments and by other agencies in order to manage waste agricultural biomass and to convert it to a resource. However, there are still major gaps to be filled. There is a lack of awareness and capacity to convert most of the wastes to useful materials and in energy recovery. This would reduce the costs of waste disposal and would generate revenue from the sale of the recovered materials and energy. Biomass can provide added income to farmers without compromising the production of main food and even non-food crops. This would make it possible for the waste to be converted to wealth.

One critical and important area where the potential of agricultural waste biomass is yet to be fully utilized is in the production of activated carbon. In this research, there has been an attempt to produce activated carbon from selected agricultural wastes and these activated carbons were used as adsorbents in trapping primary pollutants from fumes emissions emanating from the exhaust of 0.85kVa electricity generating set, popularly called “I pass my neighbor” in Nigeria contest.

However, the high cost and non-renewable source of commercially available ACs limits their use as adsorbents in developing countries. Agricultural wastes are potential precursors because of the abundant supply and low cost. Moreover, transforming agricultural wastes into valuable end products may help to increase crop yields and production efficiency as well as to reduce solid wastes disposal problems. (Mohamed et al, 2010)

The market for activated carbon has been expanding as a consequence of environmental issues, especially water and air purification. Furthermore, as more and more countries are becoming industrialized, the need for activated carbon to comply with environmental regulations will grow at a faster rate. The technology of managing agricultural waste and to convert it to wealth or material resources remains a challenge and has created a gap to be filled by scientist, researchers and engineers.

Clean air is the basis for a healthy life, and it is considered to be a basic requirement for human health and well-being. The present-day atmosphere is quite different from the natural atmosphere that existed before the industrial revolution in terms of its chemical composition. (WHO, 2008) If the natural atmosphere is considered to be “clean” it then means that “clean air” cannot be found anywhere in today’s atmosphere. (WHO, 2008)

Poor air quality threatens human health and contributes to environmental damage. The air around us is a mixture of gases, mainly nitrogen and oxygen, but containing much more smaller amounts of water vapor, methane, hydrogen, ozone, argon, carbon dioxide and very small amounts of other gases. Air also contains suspended dust, spores and bacteria. Clean air is air that has 78% of nitrogen, 21% of oxygen, 1% of inert gases and 0.03% of carbon dioxide (Gouveins et al, 2000)

Air pollution continues to be a significant threat to health around the world today. Industrial activities, motor vehicles and even burning of coal at home contribute a lot to air pollution. For more than two centuries, severe air pollution incidents in mega cities have shown that breathing dirty air can be dangerous and, at times, deadly. Air quality therefore is a global issue. (Mateen, 2011)

Some industrialized countries have lowered the levels of these pollutants in many of their cities through the adoption of Ambient Air Quality Standards (AAQS) to protect the public against the most common and damaging pollutants. They have even invested large sums of money in pollution control, but poor air quality is still a major concern throughout the industrialized world.

Polluted air contains many kinds of toxic chemicals, such as sulphur oxides, particulate matter, ground-level ozone, nitrogen oxides, carbon monoxide etc. These air pollutants have been found to cause diseases, such as, asthma, respiratory illness, cardiovascular disease and lung cancer, which can increase the chances of death in vulnerable groups. WHO (2002) pointed out that air pollution is sixth-leading cause of death, causing over 2.4 million premature deaths worldwide per year.

In this research, three agricultural wastes, maize cobs, coconut shells and rice husks were used to produce activated carbon. These wastes are readily available, inexpensive, have high carbon and low inorganic content. A number of researches have been reported in literature about the production of activated carbon using coconut shells and rice husks as raw materials but much has not been done with the use of maize cobs.

Recently, researches have been focused more on the removal of heavy metal ions such as copper, zinc, cadmium, chromium and mercury from waste streams and only few researches have been done on the use of activated carbon sourced from agricultural wastes to adsorb primary pollutants especially carbon dioxide, carbon monoxide, oxides of nitrogen, oxides of sulphur, hydrocarbons, heavy metals and the likes from “engines and machines” exhaust fumes. This fact prompted this research.

2. METHODOLOGY.

Agricultural waste sourcing.

Rice husks and maize cobs were sourced from Nigerian Seed Research Council (NSRC) North –West Zonal office, Zaria. Coconut shells on the other hand, were sourced from Gaskiya Market, Zaria.

Pre-treatment of samples of agricultural wastes

The materials, Rice husks, Maize cobs and Coconut shells were washed thoroughly with distilled water to remove residues and sun dried for 1 week to reduce moisture.

3.2.3 Preparation of activated carbon from agricultural waste.

3.2.4 Carbonization.

After drying, coconut shells were placed on a tray-like plate made from mild steel and placed into the Gemco furnace for carbonization. The temperature regulator was then set at the desired temperature of 600°C. Once the desired carbonization temperature was attained, the heated samples were held isothermally at the set point for 1 h before it was allowed to cool down to room temperature. The materials were harvested and stored in a neat bag. This procedure was repeated for other batches of the dried coconut shells until the required quantity was obtained.

The same procedure was repeated for rice husks and maize cobs.

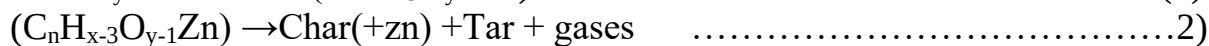
3.2.5 Carbon activation

The dried material (shell of coconut) was well soaked with ZnCl₂ solution for a period of 24 hours at an impregnation ratio of 10:1. At the end of 24 hours after impregnation, the excess ZnCl₂ solution was decanted and air-dried. The materials were then placed in the Gemco furnace kept at 800 °C for a period of 60 minutes. After activation, the carbon materials obtained were sufficiently washed with large volumes of water to remove the free ZnCl₂ solution. Then the obtained materials were washed, dried and reduced to a desired particle size by grinding.

Char obtained from rice husks and maize cobs were subjected to the same experimental procedure described for char of coconut shell as above.

Activated carbon produced from the three agricultural waste were stored separately in clean bags and kept in a safe store until needed.

The following reactions occurred during impregnation and activation process



Char usually contains 75-80% carbon; some oxygen, (15-17%) and some hydrogen, (<3%)

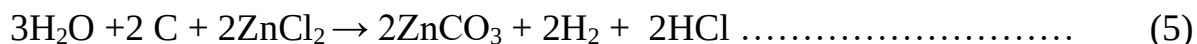
Tars consists of phenols, CH₃COOH, CH₃OH, (CH₃)₂CO, and other high molecular weight hydrocarbons. The gaseous components include among others H₂O, HCl CO₂, CO. The following reaction occurred during the activation.

(according to Colins et al, 2006)





Zinc intercalated with the carbon matrix during activation, resulting in the widening and formation of new pores. Secondary reaction that could possibly take place is given below:



Zinc carbonate is known to prevent excessive sample burn-off, as such, a well-developed porosity and high yield resulted. The structure of the carbonaceous material became reorganized in a fashion characterized by large internal surface through the activation process. (Colins et al 2006)



Prepared Activated Carbon

Characterization of the Activated Carbons Produced.

3.2.6.1 Determination of the Ultimate Composition: Ultimate analysis gives the elemental composition of the activated carbon in weight percentage of carbon, hydrogen and oxygen (the major components) as well as sulphur and nitrogen if any.

(A) Percentage Carbon

1 g of each of the activated carbon was weighed into 250 ml Erlenmeyer flask

- (a) 5 ml of K_2CrO_7 was added to each of the activated carbon in the Erlenmeyer flask using a pipette, and each flask was swirl gently to disperse the activated carbon.
- (b) 10ml of concentrated sulphuric acid was added to each of the solution in (b) above and swirling followed suit for 1 minute.
- (c) Each of the flask was allowed to stand on asbestos sheets for 30 minutes
- (d) 100 ml of distilled water was added to the each of the flask and allowed to cool.
- (e) 5 drops of indicator (phenophtalein) was added to each of the flask
- (f) Each of the solution was titrated with ammonium ferrous sulphate solution with a white background.
- (g) A color change from blue –green was observed in each of the titration for each of the sample.
- (h) A blank experiment was repeated without the activated carbon.

$$\text{Organic carbon \%} = \frac{(\text{blank titre} - \text{actual titre}) \times 0.3 \times M \times F}{\text{weight of activated carbon}} \dots \dots \dots 6$$

M = Concentration of ferrous ammonium sulphate

F= Correction factor (1.724)

(B) Nitrogen Determination

- (a) 1 g of each of the activated carbon was weighed in 500 ml digestion tubes.
- (b) A few drops of water was added to each of the activated carbon in the digestion tubes
- (c) 5 g of kjeldahl catalyst was added to each of the mixture.
- (d) 200 ml of concentrated sulphuric acid was added to each of the mixture.
- (e) Each of the flasks was heated on a digestion block until frothing ceased.
- (f) The temperature was increased until digest cleared for another 2hrs
- (g) Each of the flasks was cooled, little water was added to each of the flask and the content in each flask was washed into a 100 ml volumetric flask, allowed to cool and then made to mark.
- (h) 10 ml from each of the digest was pipette into a distillation flask.
- (i) 20 ml 2% boric acid was introduced into each of the flasks and 3 drops of indicator (methyl red) was added to each of the flask.
- (j) 10 ml of 10 M NaOH was added to 10 ml each of the mixture of the three activated carbon in the distilling flask.
- (k) The distilling unit was immediately introduced and the digest was distilled off.

(l) 50 ml of the distillates in each case was collected and titrated against 0.01 M H₂SO₄.

(m) A color change from green to purple end point was obtained in each case.

$$\% \text{ Nitrogen} = \frac{0.014 \times (T - B) \times NA \times \text{vol. of digest} \times 100}{\text{weight of activated carbon}} \dots\dots\dots 7$$

T= Actual titre value

NA= Number of moles of acid used.

B= Blank titre value

(C) Determination of P^H and Conductivity.

10 g of each activated carbon was weighed and transferred into a 250 ml beaker and 100 ml of distilled water was added and stirred for 1 hour. Samples were allowed to stabilize and then pH measured using an electronic pH/Conductivity meter.

(D) Moisture content Determination.

Each AC sample (2 g) was weighed and dried in a furnace continuously. The drying sample was constantly reweighed at a 10 minute interval until a constant weight (W_p) was obtained. The crucible and its content was retrieved and cooled in desiccators. The difference in weight (∂W) was recorded and the moisture content (MC) calculated from equation...4 as loss in weight on drying divided by initial weight of carbon multiplied by 100.

$$MC = \frac{(2 - W_p)}{W_o} \times 100 \dots\dots\dots 8$$

Where W_p = weight of Carbon retrieved from the furnace and W_{oi} = initial dry weight of the AC sample.

(a) Carbon Yield Determination

The total yields were determined after sample processing in terms of raw material mass. The dried weight, W_o of each pre-treated sample was determined using Metler balance and the carbon yield calculated as

$$Y_{ch} = \frac{W}{W_o} \times 100 \dots\dots\dots 9$$

(E) Bulk Density and Porosity Determination

A cylinder and an aluminium plates were each weighed. A sample of activated carbon was placed into the cylinder, reweighed and transferred onto the aluminium plate and then oven dried to a constant weight at a temperature of 105°C for 60 minutes.

The weight of dry sample was recorded after drying. A cleaned, dried well-cooked density bottle was weighed. A small quantity of sample of activated carbon was taken and grounded to powder; sieved using 110 µm mesh size, and gradually put into the density bottle with a little amount of water added and weighed. The volume of void (Vv) was obtained by first determining the total volume of the cylinder ($V = \pi r^2 h$) used for the experiment and also determining the volume of the AC used: Where r = radius of cylinder, h = height of cylinder, Ms = mass of cylinder, Gs = specific gravity,

$$V_s = \frac{M_s}{G_s P_w} \dots \dots \dots 10$$

Pw = density of water. The volume of void (Vv) was obtained as

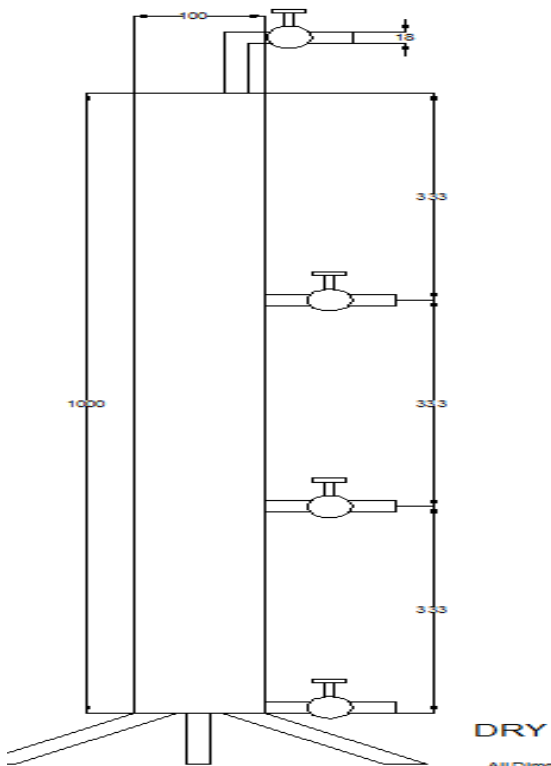
The bulk density and porosity were calculated as

$$\text{Bulk density (B.d)} = \frac{\text{mass of carbon sample}}{\text{volume}} \dots \dots \dots 11$$

$$\text{Porosity } (\eta) = \frac{\text{Volume of void}}{\text{Total volume}} \dots \dots \dots 12$$

CONSTRUCTION OF ADSORPTION COLUMN

The materials for construction were procured. Galvanized pipe was used for the fabrication. Work was given close monitoring in order to ensure it was done according to specifications. The construction was done by Design and Fabrication unit of Transport Technology Centre of Nigerian Institute of Transport Technology, Zaria as shown below



All dimensions in (mm) **ADSORPTION COLUMN
THAT WAS FABRICATED**

Test running of the Adsorption column

The required batch dosage of the activated carbon from rice husk was fed into the adsorption column. The generator was turned on and allowed to stabilize for 30 min. The generator flue gas emission point was connected to gas inlet point of the adsorption column. Flue gas through the adsorption column was analyzed at point A, B, C and D. Readings were taken and recorded. The same procedure was carried out for the activated carbon produced from maize cobs and coconut shells respectively. The gas analyzer was connected to gas outlet points of the adsorption column. Results of gas compositions on gas analyzer in each case were taken and recorded.





RESULTS AND DISCUSSION.

1. Ultimate Analysis.

Table 1 below shows the result of the elemental composition of the agricultural waste at the raw stage, char stage, activated stage and after use for rice husk, coconut shell and maize cob.

Ultimate Composition of Agricultural Wastes (%) as they undergo Metamorphoses.

	RICE HUSK				COCONUT SHELL				MAIZE COB			
	Raw	Char	Act	Used	Raw	Char	Act	used	Raw	Char	Act	used
C	47.5	62.0	75.4	43.6	46.8	66.3	79.3	46.2	44.9	60.2	77.4	39.8
H	4.8	2.30	1.4	2.4	4.4	2.4	1.65	1.9	5.4	2.9	1.7	2.0
N	0.9	1.30	1.5	1.5	1.5	1.90	2.03	1.6	1.1	1.5	1.7	1.8
O	46.8	34.4	21.8	62.5	47.3	29.5	16.9	50.5	48.6	35.4	19.1	56.4
	100	100	100	100	100	100	100	100	100	100	100	100

The percentage composition of carbon (**C**) of the three agricultural wastes under consideration increases as the wastes transform from raw to char and increases further as it transform from char to activated carbon. While that of hydrogen (**H**), Nitrogen (**N**) and (**O**) reduces as the agricultural wastes went through transformation. These results when compare closely with the findings of Mohd Iqbalidin et al (2013) and Muthadhi et al (2007) are in agreement.

The percentage increase in carbon content from raw stage to activated stage across the agricultural waste; Rice husk, Coconut shell and Maize cobs respectively are: 5873%, 69.4% and 68.9%. Coconut shell therefore had the highest percentage of carbon content follow closely by Maize cobs with rice husk having the least.

The percentage decrease in carbon contents across the activated carbons produced from the three agricultural wastes; Rice husk, Coconut shell and Maize cob respectively after being subjected to trap pollutants from fumes of generating set are: 72.9%, 71.64% and 94.47%. Coconut shell activated carbon had the lowest decrease followed closely by maize cob activated carbon. Rice husk activated carbon has the highest percentage decrease in carbon content.

Contrary to what was observed in the contents of carbon across the three activated carbon under consideration; Rice husk, Coconut shell and maize cob, Hydrogen, Nitrogen and Oxygen experienced a percentage increase. Coconut shell activate carbon also proved to be more efficient and effective in this regard followed closely by maize cob, leaving rice husk activated carbon last.

Results of Physico-chemical and Proximate Analysis of Activated Carbons

Table 2 below shows the results of the physico-chemical analyses carried out on each of the activated carbon produced from these agricultural wastes. This results are in-line with findings of Sivakumar et al (2012) Abechi at al (2013)

Table 2: Physico-chemical and Proximate Analysis of Activated Carbons

PARAMETERS	RICE HUSK	COCONUT	MAIZE
p^H	7.23	6.90	6.98
Conductivity(mS/cm)	0.74	0.22	0.31
Specific gravity	0.98	1.61	1.52
Bulk density (g/ml)	0.63	0.84	0.73
MoistureContent(%)	4.13	3.86	3.17
Surface Area (m²/g)	688	882	786

FUME ANALYSIS

Table 3: Analysis of the Exhaust fumes from the Generator at the Intake of the Adsorption Column.

S/NO	Gas Constituents	Composition
1	Hydrocarbon (HC) (ppm)	706.00
2	Oxides of Nitrogen (NO _x)(ppm)	404.00
3	Carbon Monoxide (CO) (%)	3.98
4	Carbondioxide (CO ₂) (%)	4.70

Table 3 above shows the results of the concentrations of pollutants as they were being discharged from the exhaust of the generator. Gas constituents under consideration are hydrocarbon (HC), oxides of nitrogen (NO_x) carbon monoxide (CO) and carbon dioxide (CO₂). 706.00 ppm was obtained as the record value of (HC), 404.00 ppm for (NO_x), 3.98% for (CO) and 4.70% for (CO₂). These concentrations were assumed to be the concentrations of pollutants that entered the adsorption column through the input manifold and it is with these concentrations that emission analyses carried out in this study were based.

Table 4: Analysis of the Fumes in the Adsorption Column at Varying Height.

	RICE HUSK			COCONUT SHELL			MAIZE COB		
	0.5m	1.0m	1.5m	0.5m	1.0m	1.5m	0.5m	1.0m	1.5m
HC	601	403	313	557	377	264	582	398	285
NO _x	338	296	224	304	249	194	319	273	207
CO	2.16	1.49	0.35	1.85	1.97	0.22	2.09	2.48	0.27
CO ₂	4.03	2.70	1.73	3.65	1.90	1.35	3.89	2.46	1.52

Table 4 shows the result of concentrations of pollutants discharged at varying heights of the adsorption column as read by the emission gas analyser for each of the activated carbon. From the results at height 0.5m, for rice husks activated carbon, 601 ppm concentration of hydrocarbon was released as compared to 706 ppm that entered through the input manifold. 338 ppm concentration of oxides of nitrogen was released as compared to 404ppm that entered through. 2.16% of carbon monoxide was released as compared to 3.98% that entered and for carbon dioxide, 4.03% concentration was released as

compared 4.70% that entered. Activated carbons produced from coconut shells and maize cobs followed the same adsorptive pattern as earlier discussed for activated carbon produced from rice husks.

At height 1.0m of the adsorption column as read by the emission gas analyser for each of the activated carbon. 403 ppm hydrocarbon was released when rice husks activated carbon was used; 377ppm was released for coconut shell activated carbon and 398 ppm for maize cobs activated carbon. It can therefore be said that the adsorptive capacities of these activated carbons increase as the amount of adsorbents increases. And this observation was correct for the three activated carbons under study. This trend was also observed at height 1.5m of the adsorption column. Coconut shells activated carbon was found to have the best adsorption capacity, followed by maize cobs activated carbon and rice husks activated carbon had the least adsorption strength. This observation was also found to be in line with the results obtained at height 0.5m and 1.0m.

PERCENTAGE POLLUTANT REMOVAL

Table 5: Percentage Pollutants Removal at Varying Heights og the Adsorption Column

	RICE HUSK			COCONUT SHELL			MAIZE COB		
	0.5m	1.0m	1.5m	0.5m	1.0m	1.5m	0.5m	1.0m	1.5m
HC (%)	14.87	42.91	55.65	21.10	46.60	62.60	17.56	43.62	59.63
NOX (%)	16.33	26.73	44.55	24.70	38.36	51.98	21.03	32.42	48.63
CO (%)	27.51	50.00	88.25	37.90	65.77	92.61	29.99	58.72	90.01
CO₂ (%)	14.25	42.55	63.19	22.34	58.08	71.27	17.23	47.23	67.65

Table 5 shows the result of percentage pollutants removal at height 0.5 m of the adsorption column for each of the activated carbon. From the results, as earlier discussed, coconut shells activated carbon had the best percentage pollutants removal followed by maize cobs activated carbon while rice husks activated carbon was last on the array. This observation agreed with results obtained when these activated carbons were characterized for their physico-chemical properties. Coconut shells activated carbon had the best surface area and

the degree of its particle compartment had the strongest force of attraction when compared to the surface areas and particle compartments of activated carbon produced from rice husks and maize cobs.

3. CONCLUSIONS

- Results of the study revealed that low-cost activated carbon can be produced conveniently and economically from coconut (*Cocos nucifera*) shells; maize (*Zea mays*) cobs and rice (*Oryza sativa*) husks and these activated carbons have been used as adsorbents in trapping air pollutants from generator fumes.
- Activated carbon produced from coconut shells was found to have the highest adsorptive capacity followed by that produced from maize cobs and rice husk activated carbon in that order.
- The adsorptive capacities of the carbon samples were found to be dependent on adsorbent dosage, contact time and concentration of the adsorbate.
- Carbon dioxide (CO₂) and Carbon monoxide (CO) were found to be easily adsorbed using all the three activated carbon compared to Hydrocarbons (HC) and Nitrogen oxide (NO_x) under same conditions.
- Adsorption Column was successfully constructed and it played a key role during the comparative study of agricultural wastes. It aided the height variation study.
- Result of this study could provide activated carbon consumers with cost effective and environmentally friendly alternative sources from agricultural wastes.

Recommendations.

- Activated carbon has several industrial applications depending on its porous structure and adsorption capacity. To increase the surface area value of the activated carbon produced from agricultural wastes, it is recommended to carry out experiments with different experimental parameters. Some of the most critical parameters are the impregnation ratio, heating rate, carbonization temperature and carbonization time.
- This research should be repeated using other carbon rich agricultural wastes like palm kernel shells, mango seeds, date seeds, sugarcane bagasse, bone char etc
- This research should be repeated using physical method of activation to give bases for comparison with chemical activation process.

- The future efforts in this field should include the investigation of the effect of other chemical agents like acids and alkalis in the production of activated carbon.
- Studies should be carried out on fluidized bed to compare performance with fixed bed.

REFERENCES

- [1] Abechi S.E., Gimba C.E, Uzairu A, Dallatu Y.A. (2013). Preparation and Characterization of Activated Carbon from Palm Kernel Shell by Chemical Activation. *Research Journal of Chemical Sciences*. Vol. 3(7), 54-61,
- [2] Collins J.C., Zain M.F.H. and Dek F.S.,(2006) Treatment of landfill leachate in Kayumadang, sabah: textural and physical characterization (Part I), *Malaysia Journal of Analytical Science*, 10(1),
- [3] Gouveins N and Fletcher T (2000) Time series analysis of air pollution and mortality: effects by cause, age and socioeconomic status. *Journal of Epidemiology and Community Health*, 54:750–755.
- [4] Mateen, F. J.; Brook, R. D. (2011). "Air Pollution as an Emerging Global Risk Factor for Stroke". *JAMA* **305** (12): 1240–1241
- [5] Mohamed, A. R., Mohammadi, M. and Darzi, G.N. (2010). Preparation of carbon molecular sieve from lignocellulosic biomass: A review. *Renewable and Sustainable Energy Reviews*, Vol. 14, No. 6, (August 2010), pp. (1591-1599), ISSN 1364-0321
- [6] Mohd kamal N.L and Nuruddin M.F, (2008) Interfacial bond strength: influence of microwave incinerated rice husk ash. *Bioresource Technology* 99 704-711
- [7] Mohd Iqbaldin MN , I Khudzir, MI Mohd Azlan1, AG Zaidi B Surani Z Zubri (2013) Properties of Coconut Shell Activated Carbon. *Journal of Tropical Forest Science* 25(4): 497–503
- [8] United Nation Environmental Protection Agency (UNEP) (2009). Air Quality Criteria for oxides of nitrogen Vol. 3. 1993, Washington DC: Office of Research and Development. U.S. Environmental Protection Agency. EPA600/8-91/049c
- [9] United States Environmental Protection Agency U.S. EPA (2000) Air Quality Criteria for Carbon Monoxide. 2000, Washington DC: Office of Research
- [10] United States Environmental Protection Agency (U.S. EPA) (2000) Air Quality Criteria for Carbon Monoxide. 2000, Washington DC: Office of Research and Development. U.S. Environmental Protection Agency. EPA 600/P-99/001F

- [11] United State Department of Health and Human Services. (2006). The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. Atlanta, GA.
- [12] United States Environmental Protection Agency (USEPA) (2006) Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information, Report No. EPA-452/R-96-013 (USEPA, Washington, D.C., 2006), pp. V-2-V-24, V-27-V-28, V-71
- [13] United States Environmental Protection Agency (USEPA), (2006) Air Quality Criteria for Ozone and Related Photochemical Oxidants. Vol. 1. 2006, Washington DC: Office of Research and Development. U.S. Environmental Protection Agency. EPA 600/R-05/004aF, .
- [14] United States Environmental Protection Agency (USEPA,) (2009) Air Quality Criteria for Ozone and Related Photochemical Oxidants. Vol. 2.
- [15] World Health Organization WHO, (2000) Air Quality Guidelines for Europe. 2nd ed. 2000, Copenhagen: World Health Organisation: Regional Office for Europe
- [16] World Health Organization (WHO), (2002) The World Health Report, Annex Table 9, http://www.who.int/whr/2002/en/whr2002annex9_10.pdf
- [17] World Health Organization (WHO) (2004) Health aspects of air pollution : Results from WHO project systematic review of health aspects of air pollution.
- [18] World Health Organization (WHO) (2004).Indoor Smoke from solid fuel; assessing the environmental burden of disease. Environmental burden of diseases series No. 4 World Health Organization Publication Geneva pp 1-2
- [19] World Health Organization (WHO) (2005) Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Summary of risk assessment. 2006b, World Health Organization