PROCEEDINGS OF INTERNATIONAL CONFERENCE ON RESEARCH AND INNOVATIONS IN ENGINEERING

UNIVERSITY OF UYO

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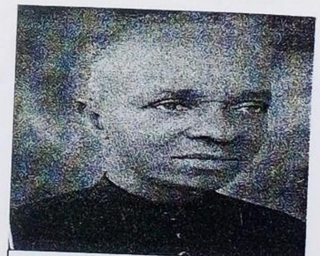

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S/No	Content(s)	Pages
1.	The use of Internet and its Effect on Administrative Functions in Non-Governmental Organization in Damaturu Metropolis **Saleh Umar and Umar Iya Girei**	1-14
2.	Modeling of Single-Phase Pulse Width Modulation (PWM) Voltage-Sourced Converters for High-Frequency Applications **Udo, E. U. and Amadi, O. A.**	15-24
3.	Numerical Study of Ni^{2-} and Cu^{2+} Ions Adsorption using Transport of Dilute Species in Porous Media (Multiple Species) Implemented in Comsol Multiphysics **Abdulkadir, M. B. and Yahya, M. D.**	25-32
4.	Production and Optimization of Fuel Oil from Used Tyre Pyrolysis **E. Zinom, M. A. Olutoye and O. A. Olanrewaju**	33-44
5.	Innovative Energy Harvesting for Low Power Devices **Usiade, Rex Ehiedum, Akwuzie, Paschal, Onoberhie, Ezeoghene Ologbo, Arugba, Iyomih Providence**	45-52
6.	Survey and Minimization of Technical Losses in the Auchi Polytechnic Power Distribution System **Peter M. Enyong and Friday Osayi**	53-72
7.	Application of Artificial Intelligence Technology as an Innovative Source of Security to Human Life in an Uncertain Future **Aminatu Maikudi and Amina Lawal**	73-80
8.	Enhanced Carbon Dioxide Adsorption using Hydroxyapatite-Embedded Activated Carbon Precursor **Inalegwu Otache, Mohammed Alhassan**	81-90
9.	Design and Construction of an Automatic Change Over Protective Circuit for Electrical Appliances **Makinde Kayode, Man Alhaji Sulaiman, Abdullahi Abubakar Yanda, Amao Enock and John Nduenso Edem**	91-106
10.	Experimental Determination and Facing of Solar Module for Proper Yield of Solar Energy Conversion in Auchi Edo North **Oshomah, Abdulai Braimah and Isah, Abdulazeez Watson**	107-118
11.	Acknowledgement Based Scheme for Securing Communication in Vehicular Ad-Hoc Network **Babangida Zubairu**	119-132
12.	Enhanced Carbon Dioxide Adsorption using Hydroxyapatite-Embedded Activated Carbon Precursor **Inalegwu Otache, Mohammed Alhassan**	133-142
13.	Design of Friction Loss Flow Measurements Apparatus for Fluid Dynamics Laboratory Experiments using Mathematical Analysis Approach **Iwenofa Sunday Ifeanyichukwu, Utu Ochuko Goodluck**	143-152

ENHANCED CARBON DIOXIDE ADSORPTION USING HYDROXYAPATITE-EMBEDDED ACTIVATED CARBON PRECURSOR

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ABSTRACT

Carbon dioxide (CO_2) has been identified as a greenhouse gas with the highest contribution to global warming. In this research, cow bone sourced from Minna abattoir was developed into activated carbon and assessed as a solid adsorbent for carbon dioxide adsorption. The performance of the adsorbent was tested by the adsorption of CO_2 onto activated cow bone using a fixed bed adsorber. The effects of contact time, bed height and temperature of the incoming CO_2 on adsorption were investigated. The rate of CO_2 adsorption was found to decrease with increase in contact time. The adsorption capacity of the adsorbent was observed to decrease with respect to increase in adsorbent dosage. Temperature increases from 25°C to 40°C, 55°C, 70°C, 85°C and 100°C witnessed a decrease in CO_2 uptake. The properties of the chemically activated precursor were studied through characterization techniques such as Scanning Electron Micrograph (SEM), Brunueur Emett and Teller (BET), Fourier Transformed and Infrared spectroscopy (FT-IR) and X-Ray Diffraction (XRD). Pseudo first-order and pseudo second-order kinetic models were used to study the kinetics of the adsorption process, in which Pseudo second-order kinetic model provided a higher value of the correlation coefficient (R^2).The value of the activation energy was 10.05 KJ/mol.

***Keywords**: Activated carbon, Adsorption, Carbon dioxide, Hydroxyapatite.*

INTRODUCTION

There has been a continuous increase in the volume of carbon dioxide in the atmosphere due to modern developmental activities. The high atmospheric concentration of CO_2 and other greenhouse gases has been identified as the primary cause of global warming and climate change (Gil et al., 2013; Susarla et al., 2015; Wu et al 2016). CO_2 is regarded as the greenhouse gas with more influence on global warming (Lee et al., 2015) because its emission comes mainly from the combustion of fossil fuels, a widely dependent energy source. In this regard, the separation of CO_2 has become a great necessity since it serves as a way of curbing global warming and its adverse effects. A number of methods of controlling the atmospheric concentration of CO_2 have been developed. These include improved energy efficiency, enhancement of natural sinks, the use of renewable energy source, and carbon dioxide capture and sequestration (CCS) (Lee et al., 2014; Wall 2007). CCS remains a vital option because it tackles CO_2 emissions from the major source, the power sector (Yang et al., 2008). Pre-combustion, post-combustion and oxy-fuel combustion are well-known technologies in carbon dioxide capture. Post combustion is considered a better alternative because it can be applied to a retrofit power plant, and does not cause alterations in combustion systems (Hammond and Spargo, 2014). Post-combustion capture is being achieved through methods such as solvent absorption using amines, membrane separation, solid adsorption and cryogenics (Lee et al., 2015). Although amine based solvent is currently the most extensively applied CO_2 capture technology, it involves high energy penalties for regeneration, water intensiveness, equipment corrosion and potential solvent degradation (Warudkar et al., 2013; Satyapal and Spargo, 2001). On this note, it is imperative to research a more tenable option. Solid adsorption technology overcomes the challenges posed by other technologies and so, it gains credence in CO_2 post-combustion separation (Xu et al., 2005; Fonwalt et al., 1996). Of the common adsorbents, activated carbon is highly promising for its low costs, easy accessibility of materials, large surface area and low sensitivity to moisture (Plaza et al., 2009). The

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MATERIALS AND METHODS

Materials

Cow bone was obtained from the local abattoir at Minna main market. The reagents and equipment for the preparation of activated carbon were available at the Department of Agricultural Engineering, Federal University of Technology, Minna. The chemicals used are of analytical grade. Distilled water was used for the preparation of 1M hydrochloric acid (HCL).

Preparation of Activated Carbon

The bone sample of Cow was collected from Minna abattoir, washed and sundried for 2 hours. The sample was then carbonized in a closed crucible at 400°C for 1 hour, with the aid of the Fischer Scientific Isotemp Muffle Furnace. The carbonized sample was crushed and sieved to various particle sizes. After the sieve analysis, the particle size of 300 µm was chosen for activation.

Activation of activated carbon

200 g of the prepared sample was impregnated with 1M hydrochloric acid in the ratio of 1:1.5. The mixture was then heated in the Muffle Furnace for 1 hour at 250°C. The sample was allowed to cool after which it was washed with distilled water to a pH of 6.8 – 7. Thereafter, it was oven dried at 105°C until a constant weight was attained.

Batch adsorption Studies

The batch adsorption study was carried out using the adsorption column with 99.8% CO_2 delivered from the gas cylinder at a constant pressure of 200 Psia a and flow rate of 1 ml/min. The effects of time, adsorbent dosage and temperature on the adsorption of pure CO_2 onto cow bone activated carbon were determined. The adsorption capacity was calçulated using the relation:

$$CO_2 \text{ adsorption} = \frac{w_t - w_0}{w_o} \quad (1)$$

Where; w_t and w_o are the weights (mg) of adsorbent after and before adsorption respectively.

Effect of contact time

The adsorption process was timed for 5, 10, 15, 20, 25, 30, 35 and 40 minutes and the respective CO_2 uptake was recorded. The CO_2 uptake decreases as the contact time increases owing to less available pore sites with time.

Effect of adsorbent dosage (bed height)

Different bed heights of 0.5 g, 1.0 g and 1.5 g were subjected to CO_2 capture for the same period of time and 1.5 g dosage being the dosage with longest saturation time (40 min) was selected for the determination of the effect of temperature on adsorption.

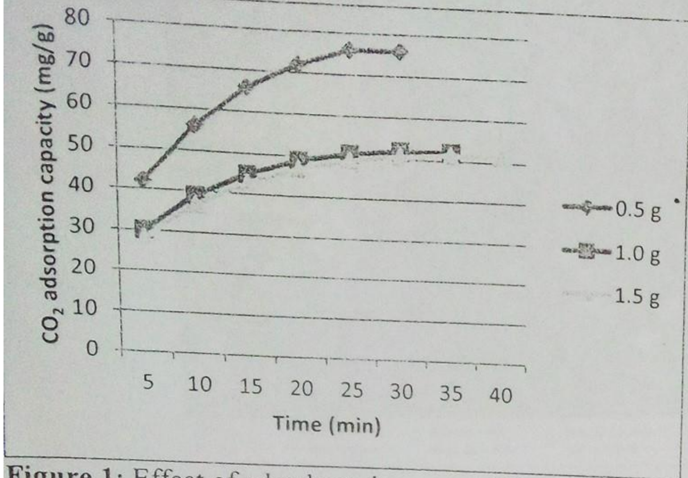
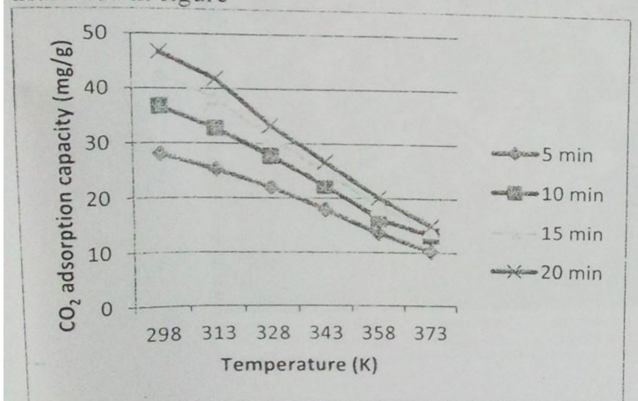


Figure 1: Effect of adsorbent dosage on CO_2 adsorption onto Cow bone activated carbon

Effect of Temperature

Adsorption was carried out on 1.5 g adsorbent under the temperatures of 25, 40, 55, 70, 85 and 100°C. The adsorption capacities were determined from the uptake and plotted against the temperatures as indicated in figure



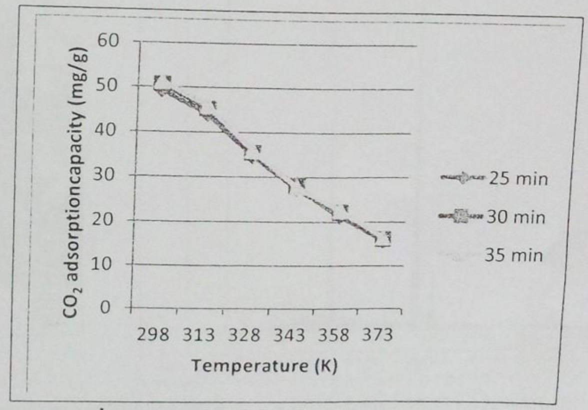


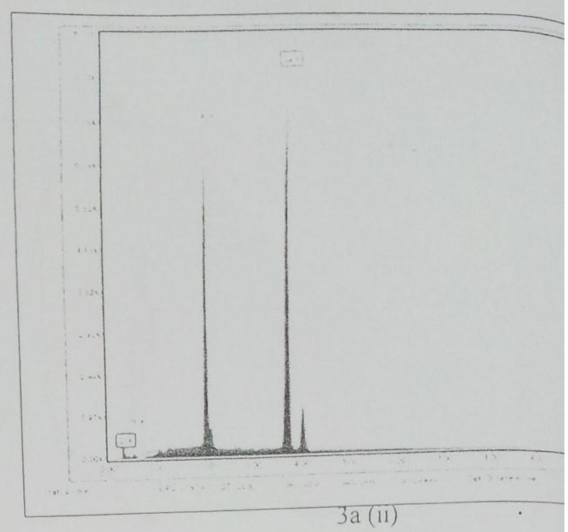
Figure 2: Graph showing the effect of temperature on CO_2 adsorption at different time intervals.

RESULTS AND DISCUSSION

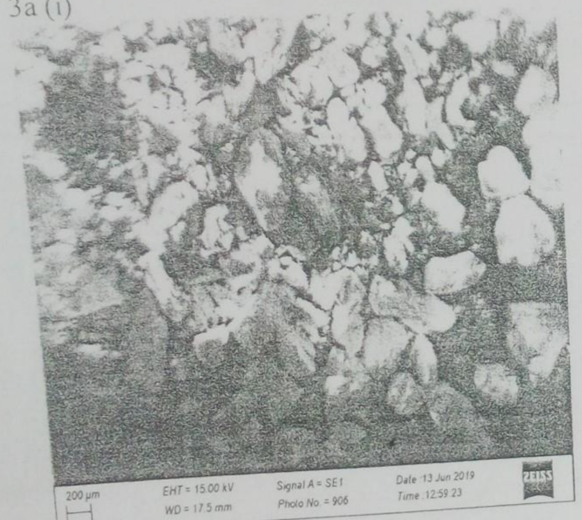
Characterization of Activated carbon

The SEM and the EDX of the activated carbon before and after adsorption were shown in figure 1a and 1b respectively. The SEM revealed irregularly shaped particles of different sizes. The pores were observed to be more opened in the sample before adsorption than after adsorption, due to the adsorption of CO_2. A quantitative analysis of the EDX showed the presence of calcium and phosphorous in a ratio 1.9 typical of that in hydroxyapatite.

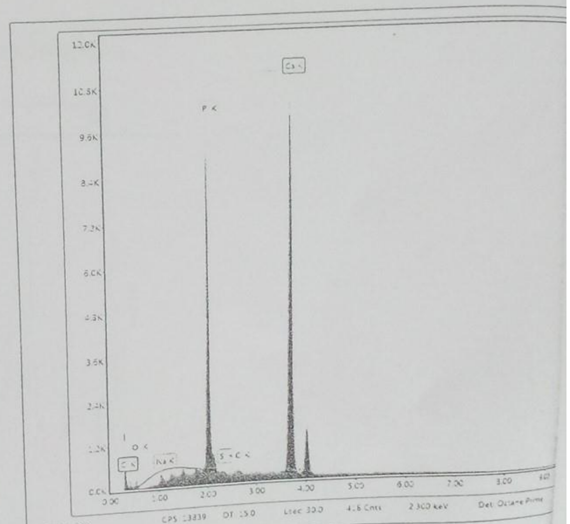
3a (i)



3a (ii)



3b (i).



(ii).

Figures 3a and 3b: SEM and EDX of cow bone activated carbon for before and after CO_2 adsorption, respectively.

Figure 2a and 2b show the FTIR spectra of the samples before and after adsorption respectively. The slight difference observed in the characteristic peaks of -OH in the before and after adsorption signifies that the adsorption of CO_2 onto cow bone activated carbon is mostly a physical adsorption process. The major peaks for Cow bone activated carbon can be assigned as follows: PO_4^{3-} [563.04, 603.58, 2361.10], adsorption of water molecule ([1636.3 cm^{-1}], CO_3^{2-} [1457], the peak at 3712 cm^{-1} in the after adsorption figure is due adsorption of CO_2 (Lambert 1998). The broad band at 3447.14-2363.07cm^{-1} and 3447.59-2361.25 cm^{-1} represent -OH for before and after adsorption respectively.

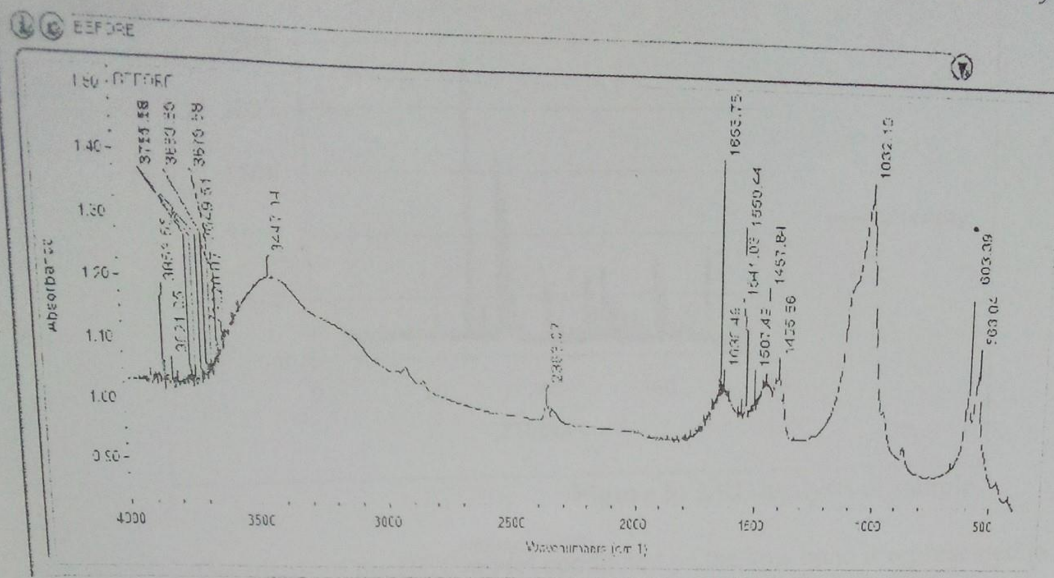


Figure 4a. FTIR of activated carbon before adsorption.

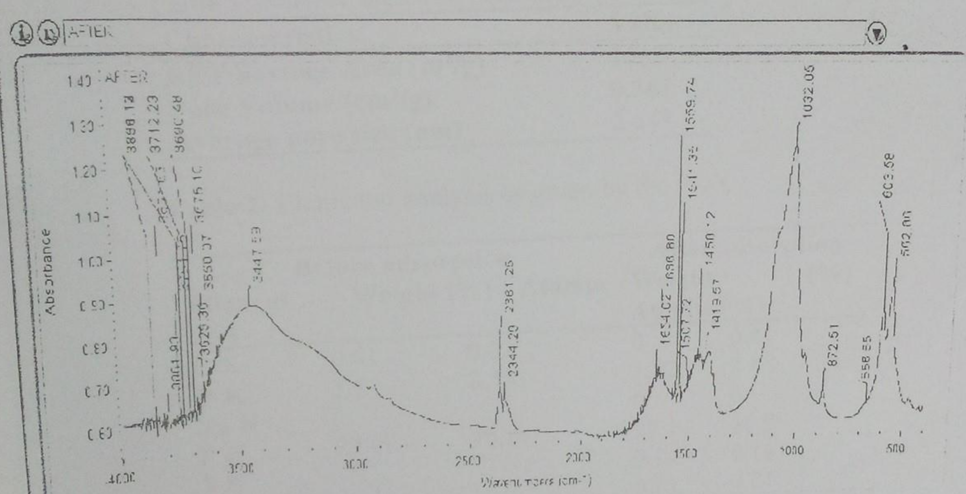


Figure 4b. FTIR of activated carbon after adsorption.

From the plots of intensity versus 2θ shown in figure 5, three sharp peaks were observed at angles of 26°, 40° and 55°. The presence of these peaks can be attributed to the presence of crystalline substances. The large area covered by non-sharp peaks signifies that the activated carbon is dominantly amorphous which is an advantage to an adsorbent in terms of performance (Kennedy et al.,2007; Pechyen et al., 2007).

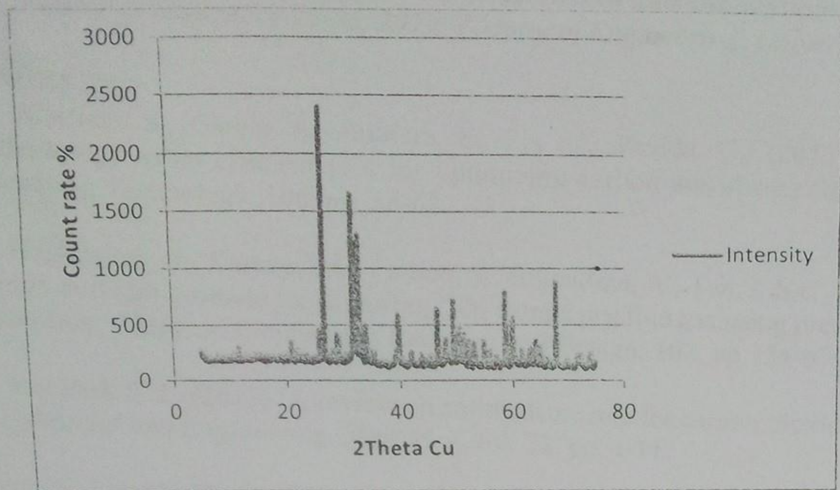


Figure 5: XRD analysis of sample.

The result of the BET model conducted on the cow bone is represented in table 1. The large specific surface area of the activated carbon contributed greatly to adsorption.

Table 1: Surface area and pore structure analysis.

Characteristics	Value
BET Surface Area (m^2/g)	1068
Pore Volume (cm^3/g)	0.381
Average pore size (nm)	2.647

Table 2: Elemental analysis as given by the EDX

Element	Before adsorption Weight (%)	Before adsorption Atomic (%)	After adsorption Weight (%)	After adsorption Atomic (%)
C K	0.01	0.02	0	0.01
O K	3.8	8.38	3.82	8.88
Na K			0	0
P K	27.07	30.81	27.17	30.9
S K			0.14	0.16
Cl K			0.21	0.21
Ca K	69.12	60.79	68.66	60.34

From table 2, the elemental analysis showed that Ca and P are present in abundance in a molar ratio of 1.97 which can be related with value of Ca/P ratio of 1.67 of pure hydroxyapatite. This implies that the dominant compound in cow bone activated carbon is hydroxyapatite.

CO_2 Adsorption and Isotherm Studies

Figures 4a and 4b show the adsorption of CO_2 onto cow bone activated carbon at temperatures of 25, 40, 55, 70 85 and 100°C. The non-linear line curve obtained was due to the fact that the rate of increase in CO_2 adsorption onto cow bone activated carbon is not in a direct proportion to increase in time. This is due to less availability of pores with increase in time. The plots of temperature versus adsorption capacity showed a decrease in the adsorption capacity of activated carbon with increase in temperature, This observation suggest that adsorption is exothermic and physical in nature in which the increase in temperature increases the desorption process (Rashidi et al, 2013).

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