



## Direct investigation of the adsorption capacities of coconut, date palm and palm kernel shell charcoals commonly found in some North Central States, Nigeria

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### ABSTRACT

Adsorption capacities of three charcoals were investigated using flame atomic absorption spectrophotometer. Results showed that Palm kernel shell charcoal has the highest adsorption capacity followed by the Date palm and Coconut shell charcoals. For the metals adsorption studied, recoveries ranged from 80.99 - 83.98% for Cu, 99.10 - 99.17% for Mg and 99.96 - 100% for Pb. It was also observed that longer contact time may lead to desorption.

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### INTRODUCTION

Adsorption is the process by which organic molecules are attracted to the surface of an adsorbent. Adsorbents include activated carbon, silica gel, zeolites and polymers. The most common and widely used adsorbent is activated carbon. The requirement of a good adsorbent is for it to have a high surface area to mass ratio. This will assure the availability of several sites where molecules can attach themselves onto the surface of the adsorbent. Adsorption capacity is the accumulation of solute molecules at the surface of a solid. This capacity is directly proportional to the area of the surface exposed and is dependent on the solute partial pressure and the temperature.

Several research works have tried to prepare activated carbon from bio-waste materials and explored their adsorption capacities (Rifaqat and Fouzia, 2010; Rifaqat et al., 2010). One of the reasons is that adsorption properties of the wastes and bio-waste materials available in a particular locality will be helpful for solving the metal contamination problem in a more economical way (Mehmet, 2010). Various adsorbents have been prepared with varying degrees of adsorption capacities for both laboratory and industrial use (Dončo, 2004; Peiyuan et al., 2008; Chien et al., 2004; Linqi et al., 1999; Mizota, 1999; Xu et al., 2003; Wang et al., 2005). Several kinds of adsorbents have been reported for the removal of H<sub>2</sub>S from the flue

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gas, natural gas and coal-derived gas (Slimane and Abbasian, 2000). There are reports on the use of transition metals such as Ni, Cu, Co or in some cases noble metals (Pt and Pd) supported on Al<sub>2</sub>O<sub>3</sub>, SiO<sub>3</sub>, ZnO or mixture thereof (Velu et al., 2002). Adsorbent have been applied for the treatment of waste water (Hsing-Cheng et al., 2002) and dye removed from solutions (Yavus and Aydin, 2006).

Coconut, date palm and palm trees are grown in the savannah and forest regions of Nigeria. The shells are usually disposable wastes after obtaining probably the more useful endosperm from coconut, the juicy epicarp of the date palm or kernel of the Palm kernel. The vast availability of these agricultural wastes in Nigeria makes them a veritable alternative source of generating activated carbon, and which can save the country scarce foreign exchange on the importation of activated carbon considering its wide use and applications.

In undertaking the research project on direct investigation of adsorption capacities of coconut, date palm and palm kernel shell charcoals, what has been attempted is to establish a possible local source for the production of activated carbon since the adsorption capacity of the primary material for an activated carbon play a major part in determining the ability of the final product to adsorb certain molecular species (Yao et al., 2010; Jung-Nan et al., 2007; Inukai et al., 2004).

The aim of this research is to investigate the adsorption capacities of coconut shell charcoal, date palm shell charcoal, and palm kernel shell charcoal and determine the best suitable and reliable locally source material for the production of a activated carbon as an alternative to the imported products.

## **MATERIALS AND METHODS**

### **Material**

The coconut shells were obtained from Rubochi in the Federal Capital Territory (FCT)- Abuja, Nigeria. The date palm shell was obtained from Keffi in Nassarawa State

while the palm kernel shells were obtained from Ugbokolo in Benue State, Nigeria. Sampling period spans May-July 2004. The samples were sun dried and stored in plastic containers.

The respective samples were burnt in air tight containers for one hour each to obtain the corresponding charcoal. These were then stored in separate plastic containers. Each of the charcoal was ground in a mortar to powdered form and the resulting carbon sieved to obtain a particle size of <124 microns.

All reagents used in this research are of analytical grades. Pye Unicam 969 Flame Atomic Absorption Spectrophotometer, Mettler PC 400 weighing machine. Standard solutions of Cu, Mg and Pb were prepared in the laboratory with concentration of 2 g/100 cm<sup>3</sup> each.

### **Method**

A 5.00 g each of the charcoals (adsorbent) was weighed and placed in three separate beakers and labeled. A 25 mL of each of the standard solution prepared was pipetted into each of the adsorbents with thorough stirring and allowed for a contact time of 6 hours. It was then filtered and the filtrates collected into clean plastic containers and stored. Room temperature and pressure conditions were employed. The procedure was repeated, but the contact time was adjusted to 2 hours at room temperature and pressure. The filtrate was then subjected to analysis by flame atomic absorption spectrophotometer. To ensure reproducibility of results, the analysis was carried out in triplicates.

## **RESULTS AND DISCUSSION**

The results of the analysis of the filtrate by FAAS for Cu, Mg, and Pb at a contact time of 6 hours and 2 hours are shown in Tables 1 and 2 respectively. The amount of Cu, Mg and Pb adsorbed was obtained from the difference in the filtrate and standard samples. This is recorded in Tables 3 and 4 for 6 hours and 2 hours contact time respectively.

From the results as shown in Tables 5 and 6 above, the percentage recoveries for Cu are 80.99%, 82.26% and 83.06% for coconut shell charcoal, date palm shell charcoal and palm kernel shell charcoal respectively. In comparison to the % recovery in Table 6, the recovery was higher for Cu with a contact time of 2 hours than at 6 hours. The reasons may be attributed to temperature fluctuations since room temperature was employed in the adsorption process (Inukai et al., 2004). Thermal stability plays an important role in the adsorption process. The observed % recoveries are 82.72%, 83.35% and 83.98% respectively for coconut shell charcoal, date palm shell charcoal and palm kernel shell charcoal. This result also indicates that the palm kernel shell charcoal had the highest adsorption for Cu followed by the date palm shell charcoal and the coconut shell charcoal.

For Mg adsorption, the % recoveries in Table 5 are 99.10%, 99.11% and 99.11% for coconut shell charcoal, date palm shell charcoal and palm kernel shell charcoal respectively. The observed recoveries in Table 6 (contact time of 2 hours) are 99.16%, 99.16% and 99.17% for coconut shell

charcoal, date palm shell charcoal and palm kernel shell charcoal respectively. This however represents a higher recovery than that in Table 5. Pore spaces, particle size and thermal stability may be responsible for this variation. It was also observed that palm kernel shell charcoal had a higher percentage recovery than the coconut and date palm shell charcoals.

Adsorption of Pb on the three charcoals was higher than that of Cu and Mg. In Table 5 the observed % recovery are 99.96%, 99.98% and 100% respectively for coconut, date palm and palm kernel shell charcoals. The result in Table 6 is similar to that in Table 5 with recoveries of 99.99%, 99.98% and 100% respectively for coconut, date palm and palm kernel shell charcoals. However, a contact time of 2 hours showed a higher percentage recovery than a contact time of 6 hours. Factors such as molecular size of Pb, Pore sizes and variations in tropical temperature and pressure may plausibly be responsible for these high recoveries.

The results of the statistical analysis are shown in Tables 7, 8 and 9.

**Table 1:** Results of filtrate analysis for a contact time of 6 hours.

Sample	Parameters (ppm)		
	Cu	Mg	Pb
Coconut shell charcoal	3801.857±0.003	181.167±0.001	8.825±0.002
Date palm shell charcoal	3548.262±0.001	179.410±0.001	4.674±0.002
Palm kernel shell charcoal	3388.984±0.006	179.488±0.003	1.136±0.003

**Table 2:** Results of filtrate analysis for a contact time of 2 hours.

Sample	Parameters (ppm)		
	Cu	Mg	Pb
Coconut shell charcoal	3457.380±0.006	168.909±0.001	2.183±0.001
Date palm shell charcoal	3329.946±0.001	168.844±0.003	3.924±0.003
Palm kernel shell charcoal	3204.120±0.004	167.538±0.001	0.557±0.001

**Table 3:** Amount of Cu, Mg and Pb adsorbed for a contact time of 6 hours.

Sample	Parameters (g/100 cm <sup>3</sup> )		
	Cu	Mg	Pb
Coconut shell charcoal	1.6198	1.9819	1.9991
Date palm shell charcoal	1.6452	1.9821	1.9995
Palm kernel shell charcoal	1.6611	1.9821	1.9999

**Table 4:** Amount of Cu, Mg and Pb adsorbed for a contact time of 2 hours.

Sample	Parameters (g/100 cm <sup>3</sup> )		
	Cu	Mg	Pb
Coconut shell charcoal	1.6543	1.9831	1.9997
Date palm shell charcoal	1.6670	1.9831	1.9996
Palm kernel shell charcoal	1.6796	1.9833	1.9999

**Table 5:** Percent (%) recovery for a contact time of 6 hours.

Sample	Percent (%) recovery		
	Cu	Mg	Pb
Coconut shell charcoal	80.99	99.10	99.96
Date palm shell charcoal	82.26	99.11	99.98
Palm kernel shell charcoal	83.06	99.11	100

**Table 6:** Percent (%) recovery for a contact time of 2 hours

Sample	Percent (%) recovery		
	Cu	Mg	Pb
Coconut shell charcoal	82.72	99.16	99.99
Date palm shell charcoal	83.35	99.16	99.98
Palm kernel shell charcoal	83.98	99.17	100

**Table 7:** Paired Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Cu analysis for a contact time of 2 hours	1.642033E0	3	.0208313	.0120270
	Cu analysis for a contact time of 6 hours	1.666967E0	3	.0126500	.0073035
Pair 2	Mg analysis for a contact time of 2 hours	1.982033E0	3	.0001155	.0000667
	Mg analysis for a contact time of 6 hours	1.983167E0	3	.0001155	.0000667
Pair 3	Pb analysis for a contact time of 2 hours	1.999500E0	3	.0004000	.0002309
	Pb analysis for a contact time of 6 hours	1.999733E0	3	.0001528	.0000882

**Table 8:** Paired Samples Correlations.

		N	Correlation	Sig.
Pair 1	Cu analysis for a contact time of 2 hours & Cu analysis for a contact time of 6 hours	3	.992	.083
Pair 2	Mg analysis for a contact time of 2 hours & Mg analysis for a contact time of 6 hours	3	.500	.667
Pair 3	Pb analysis for a contact time of 2 hours & Pb analysis for a contact time of 6 hours	3	.655	.546

**Table 9:** Paired Samples Test.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Cu analysis for a contact time of 2 hours - Cu analysis for a contact time of 6 hours	-2.493333E-2	.0084477	.0048773	.0459185	.0039481	-5.112	2	.036
Pair 2	Mg analysis for a contact time of 2 hours - Mg analysis for a contact time of 6 hours	-1.133333E-3	.0001155	.0000667	-.0014202	-.0008465	17.000	2	.003
Pair 3	Pb analysis for a contact time of 2 hours - Pb analysis for a contact time of 6 hours	-2.333333E-4	.0003215	.0001856	-.0010319	.0005652	-1.257	2	.336

## Conclusion

It can be deduced from this work that palm kernel shell charcoal has a higher adsorption capacity than the coconut shell and date palm shell charcoals. The metals studied had various percentage recoveries in the three different charcoals. This variation was

attributed to differences in their molecular size, thermal stability, pore sizes and surface area. It is a known fact that all these charcoals are waste products from their respective processing factories, thus palm kernel charcoal without further treatment and preparation may be utilized effectively in

heavy metal recovery from industrial effluents. This however may serve as alternative to activated carbon.

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