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Preparation and Characterisation of Activated Carbon from Agrowastes Peanut Seed (African Canarium) and Palm Kernel Shell

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Abstract:
Two agro wastes were selected and carbonized at 600^{o}C for 45min and 800^{o}C for 30min and each was portioned into three different parts. Each portion was activated with HCl, H_2SO_4 and H_3PO_4 as activating agents. The activated carbons were characterized for some important parameters such as pH, ash content, nitrogen, carbon content, sulphur, fat, fibre, protein, moisture content, carbohydrate, oxygen, hydrogen, sodium, potassium and pore volume. Wastewater from battery industry was collected and treated with the activated carbons with a view to determining the extent of the heavy metal adsorption ability. The results of the characterization shows pH of 6.31 for Peanut Seed activated carbon and 7.23 for Palm Kernel shell carbon, while the pore volume ranged from 3.8 X 10^{-5} to 2.3 X $10^{-5}m^3/g$. The percentage yield of activated carbon before activation is 28.01% and 32.61 for Peanut Seed carbonized 800^{o}C and 600^{o}C respectively, while that for Palm kernel shell is 32.19% and 34.58% for that carbonized at 800^{o}C and 600^{o}C respectively. The FTIR result shows a surface reorganization of the activated carbon with a formation of new functional groups after chemical activation. The trend in the adsorption capacity of the activated carbons was PNAC > PKAC. The adsorption data generated fitted well into the Freundlich isotherm model since most values of the determination coefficient (R^2) >0.500 indicating a heterogeneous adsorption of heavy metals from aqueous solution. It was observed also that those carbon activated with H_3PO_4 were better adsorbents in most of the activated carbons produced irrespective of the heavy metals, followed by those activated with HCl while those activated with H_2SO_4 were the least. The ANOVA indicates that there exist a positive significance relationship between the reliability factor (R^2) and the Langmuir constants in almost all the activated carbon types produced. So also it was for Freundlich isotherm constants except few of them. There was a great effect of the chemical activation process on the pore development in virtually all the activated carbon types produced as shown by the pore volumes of the activated carbons indicated by both before and after activation. This study has shown that activated carbon produced from Peanut Seed and Palm kernel shell can confidently be used as adsorbents in place of the traditional activated carbons used in treating industrial waste especially from battery industries using HCL, H_2SO_4 and H_3PO_4 as activating agents.

***Keywords**: adsorption, activated, carbon, heavy metals, treatment*

1. Introduction

Heavy metals are widely distributed in the environment and are ecologically important due to their high toxicity for living organisms including human beings (Volesky, 2001). Several industrial activities are important sources of environmental pollution due to their high content of several heavy metal ions. In particular, Pb^{2+} is a common metal ions found in effluents of a large number of industries like the Battery industry.

The toxicological profile of this pollutant has been well documented in literature and its presence in water and wastewaters is a potential risk for the environment and public health (Bhattacharya, et al., 2006, Mishra, et al., 2009). Therefore, it is necessary to design feasible processes to minimize the pollution caused by Pb^{2+} discharges and to reduce the risks associated to its presence in the environment. A wide range of various treatment techniques such as ion exchange, biodegradation, oxidation, solvent extraction and adsorption have been reported to be used for removal of heavy metal ions from industrial effluents (Subramanyam, 2009). However, adsorption has been universally accepted as one of the most effective pollutant removal process, with low cost, ease in handling, low consumption of reagents, as well as scope for recovery of value added components through desorption and regeneration of adsorbent (Igwe, et al., 2006, Abdel-Ghani, et al., 2007). A notable and growing trend is to evaluate the feasibility and suitability of natural, viable, renewable and low-cost materials which will be used as adsorbent to combat the menace of heavy metal pollution. The aforesaid growing trend is the main objective of this research via the modification of Peanut Seed and Palm Kernel shell and evaluation of the equilibrium sorption data using the notable adsorption isotherms such as Langmuir and Freundlich isotherms.

Peanut Seed is an agricultural waste material, a hard Seed from African elemi tree. Palm Kernel Shell as well as Peanut Seed are used in-place of gravel in building slab and flooring of surface in some African countries like Nigeria.

2. Materials and Methods

2.1. List of Apparatus

The following apparatus was used in the course of the research: Digital pH meter (Labtech 4620), Weighing balance (Metler MP301), Digital Muffle furnace (Labtech 201), Burette, retort stand**,** Sample bottles, Beakers, Pestle and Crucible, Platinium Crucible, 1.18mm Mesh, Dessicator, Thermometer, Filter paper, Fume Cupboard, Funnels, FTIR (Buck 530 FTIR), SEM (Aspex 3020 PSEM2), stop watch, kjehdal flask, Measuring cylinder, Petri dish

2.2. List of Reagents

Hydrochloric acid (HCl), Phosphoric acid (H_3P0_4), Sulphuric acid (H_2SO_4), sodium hydroxide (NaOH), Deionized water, Barium Chloride ($BaCl_2$), Cadmium chloride monohydrate ($CdCl_2.H_2O$), manganese sulphate monohydrate ($MnSO_4.H_2O$), Nickel Chloride hexahydrate ($NiCl_2.6H_2O$), Lead Nitrate ($Pb(NO_3)_2$), Selenium powder and Perchloric acid $HClO_4$.

2.3. Sampling and Pre-sample Treatments

Today, one promising approach for the production of cheap and efficient activated carbon is the reuse of agricultural waste produced at Rural, Municipal or Industrial activities. The usage of waste materials is especially important due to its mass production and waste reuse so as to make our environment safer. Two types of agricultural wastes were chosen for this research. African elemi or Canarium seed (Ube Mgba in Imo state, Ube Okpoko in Enugu State, Nigeria) and Palm Kernel shell. The Palm Kernel shell and African Canarium seed were collected from Obollo Afor in Enugu State Dirt was removed from the samples after which they were washed and sun dried.

African elemi (Canarium schweinfurthii) is one of the tropical trees whose fruits contain oils in its pulp and seed kernel. The tree is grown widely in the tropics and is abundantly available in Sub-Sahara Africa, including Nigeria (Burkill, 1994; Keay, 1989; Orwa et al., 2009, Hafchinson and Dalziel, 1954). The pulp is commonly eaten raw or cooked; it is also usually processed for the constituent oil which is popularly referred to as atile oil in some parts of northern Nigeria. The seed (stone) which contains the kernel oil is either thrown away or used as local beads for feet (Burkill, 1994).

Figure 1: African Canarium (African Elemi) Fruit

Figure 2: African Canarium (African Elemi) Seed

Figure 3: Smashed African Canarium Fruit seed

Figure 4: Carbonized African Canarium Fruit Seed

Figure 5: Palm Kernel shell

2.4. Carbonization and Activation

The procedure by Grigis, et al., (1999) with slight modifications was used. The Shell was removed, washed, dreid and crushed using locally made grinder. This was sieved to 1.18mm and carbonized at 800^0C for 30mins and 600^0C for 45mins. 75g of the carbonized sample was mixed with 20% of three different activating agents (H_2S0_4, HCl and H_3P0_4) at a ratio of 1:1 (Acid: char). This impregnation at 80^0C was done with continuous stirring for 2hours. After that, the sample was then filtered, washed with deionized water and dried overnight at 120^0C in oven. Activated carbons were gradually cooled to room temperature. It was washed severally using deionized water until the washing deionized water had a pH of 7.0. The prepared activated carbons were dried at 120^0C overnight, cooled and stored for further studies.

2.5. Determination of the Carbonization Yield

The carbonization yield was determined as follows: Yield (%) = weight of carbon produced/weight of raw sample used x 100

2.6. Carbon Content Determination (AOAC, 1984)

Procedure:

- Empty Platinum Crucible was washed, dried and the weight was noted.
- Exactly 2g of wet sample was weighed into the Platinum Crucible and placed in a Muffle Furnace at 850^0C for 3hours.
- The sample was cooled in a Dessicator after burning and weighed.

Calculations:

$$\% \text{ Ash content} = \frac{W_3 - W_1}{W_2 - W_1} \times \frac{100}{1}$$

Where

W_1 = weight of empty Platinum Crucible

W_2 = weight of Platinum Crucible and sample before burning

W_3 = weight of Platinum and carbon.

2.7. Nitrogen Content Determination (AOAC, 1984)

Principle: the method is the digestion of sample with hot concentrated sulphuric acid in the presence of a metallic catalyst (Selenium powder). Organic nitrogen in the sample is reduced to ammonia. This is retained in the solution as ammonium sulphate. The solution is made alkaline, and then distilled to release the ammonia. The ammonia is trapped in dilute acid and then titrated.

2.8. Procedure:

- Exactly 1g of each sample was weighed into a 30ml kjehdal flask (this was gently done to prevent the sample from touching the walls of the Flask) and then the flasks were closed (stoppered) and shaken. Then 1g of the kjedahl catalyst mixture was added. The mixture was heated in a digestion rack under fire until a clear solution was seen.
- The clear solution was then allowed to stand for 30 minutes in order for it to cool. After cooling about 100ml of deionized water was added to avoid caking and then transferred to the kjedahl digestion apparatus.
- A 500ml receiver flask containing 5ml of boric acid indicator was placed under a condenser of the distillation apparatus so that the tap was about 20cm inside the solution. The 10ml of 40% sodium hydroxide was added to the digested sample in the apparatus and distillation commenced immediately until distillation reaches the 35ml mark of the receiver flask, after which it was titrated to pink colour using 0.01N Hydrochloric acid.

Calculation:

% Nitrogen = Titre value x 0.01 x atomic mass of Nitrogen x 4

Where 0.01 = normality of the acid.

2.9. Sulphur Content Determination (Adrian, 1973)

2.9.1. Digestion of Samples

1. 10g of the dried sample was Weighed into a digestion flask and 20ml of the acid mixture (650ml of concentrated HNO_3; 80ml Perchloric acid; 20ml concentrated H_2SO_4) was added
2. The flask was heated until a clear digest was obtained.
3. The digest was then diluted with distilled water to the 250ml mark.
4. Appropriate dilutions were then made for each element to be determined.

Sulphate was analyzed according to APHA standard method (APHA; 1998)

2.9.2. Procedure

A 250cm^3 of the sample was evaporated to dryness on a dish. The residue was moistened with a few drops of Conc. HCl and 30cm^3 distilled water. The mixture was boiled and then filtered. The dish was rinsed and the filter paper washed with distilled water severally and both filterate and washings added together. This was heated to boiling and then 10cm^3 of 10% $BaCl_2$ solution was added, drop by drop with constant stirring. The mixture was digested for about 30minutes, filtered and the filter paper washed with warm distilled water. It was then ignited, cooled and weighed in a pre-weighed crucible.

Calculation: mg/dm^{3}Sulphur$^-$ = mg $BaS0_4$ x 411.5cm^3 of water sample

2.9.3. Determination of Heavy Metal Concentration

Heavy metal concentration was carried out using Varian AA240 Atomic Absorption Spectrophometer. The samples were prepared for AAS analysis according to Adrian, 1973.

1. 2g of the dried sample was weigh into a digestion flask and 20ml of the acid mixture (650ml conc HNO_3; 80ml perchloric acid; 20ml conc H_2SO_4) was added.
2. It was heated until a clear digest was obtained.
3. The digest was diluted to the 100ml mark with deionized water.

3. Proximate Analysis Methods Moisture Content

Procedure:

A petridish was washed and dried in the oven

- Exactly 2g of the sample was weighed into the petri dish
- The weight of the petridish and sample was recorded before drying in the oven
- The petridish and sample were put in the oven for 30minutes and the weight was noted
- The drying procedure was continued until a constant weight was obtained

$$\% \text{ moisture content} = \frac{W_1 - W_2}{\text{Weight of sample (2g)}} \times 100$$

Where w_1 = weight of petridish and sample before drying

W_2 = weight of petridish and sample after drying.

3.1. Carbohydrate Determination (Differential Method)

100 – (%Protein + %Moisture + %Ash + %Fat + % Fibre)

Ash Content (AOAC, 1984)

The ash content of sample is the inorganic residue remaining after the organic matter has been burnt off.

Procedure:

- Empty Platinum Crucible was washed, dried and the weight was recorded.
- Exactly 2g of the wet sample was weighed into the Platinum Crucible and placed in the Muffle Furnace at 500^0C for 3hours.
- The sample was cooled in a Dessicator after burning and it was weighed and weight recorded.

. Calculations:

$$\% \text{ Ash content} = \frac{W_3 - W_1}{W_2 - W_1} \times \frac{100}{1}$$

Where:

W_1 = weight of empty platinum crucible
W_2 = weight of platinum crucible and sample before burning
W_3 = weight of platinum and ash.

3.2. Determination of the Percent fixed carbon

Percentage fixed carbon = 100 - % ash content

Crude Fibre Determination

- 2g of sample was de-fat with petroleum ether (this is done if the fat content is more than 10%)
- It was boiled under reflux for 30 minutes with 200ml of a solution containing 1.25g of H_2SO_4 per 100ml of solution
- The solution was filtered through linen on a fluted funnel
- It was washed with boiling water until the washings were no longer acid.
- The residue was then transfer to a beaker and boiled for 30minutes with 200ml of a solution containing 1.25g of Carbonate free NaOH per 100ml
- The final residue was filtered through a thin but close pad of washed and ignited asbestos in a Gooch crucible
- The Gooch crucible was dried in an electric oven and weighed
- It was incinerated, cooled and then weighed.

The loss in weight after incineration x 100 is the percentage of crude fibre.

$$\% \text{ crude fibre} = \frac{\text{weight of fibre}}{\text{weight of sample}} \times 100$$

3.3. Determination of Crude Fat (Soxhlet Fat Extraction Method)

This method is carried out by continuously extracting a sample with non-polar organic solvent such as petroleum ether for about 1hour or more.

Procedure:

- A 250ml clean boiling flasks was dried in oven at 105 - 110^0c for about 30minutes.
- It was transferred into a Dessicator and allow to cool
- It was labeled and weighed
- The boiling flasks was filled with about 300ml of petroleum ether (boiling point 40 - 60^0c)
- The extraction thimble was plugged lightly with cotton wool
- The soxhlet apparatus was assembled and allowed to reflux for about 6hours
- The thimble was removed with care and petroleum ether was collected draining into a container for re-use.
- The flask was removed and dried when the flask were almost free of petroleum ether at 105^0c - 110^0c for 1hour.
- It was transferred from the oven into a dessicator and allowed to cool, then weighed.
- $\% \text{ Fat} = \dfrac{\text{weight of flask + oil – weight of flask x 100}}{\text{Weight of sample}}$
-

3.4. Determination of Crude Proteins (AOAC, 1984)

Principle: The method is the digestion of sample with hot concentrated sulphuric acid in the presence of a metallic catalyst. Organic nitrogen in the sample is reduced to ammonia. This is retained in the solution as ammonium sulphate. The solution is made alkaline, and then distilled to release the ammonia. The ammonia is trapped in dilute acid and then titrated.

Procedure:

- Exactly 1g of sample was weighed into a 30ml kjehdal flask (gently to prevent the sample from touching the walls of the flask) and then the flasks were stoppered and shaken. Then 1g of the kjedahl catalyst mixture was added. The mixture was heated cautiously in a digestion rack under fire until a clear solution was seen.
- The clear solution was then allowed to stand for 30minutes and allowed to cool. After cooling, about 100ml of deionized water was added to avoid caking and then 50ml was transferred to the kjedahl distillation apparatus.
- A 100ml receiver flask containing 5ml of 2% boric acid and indicator mixture containing 5 drops of Bromocresol blue and 1 drop of methylene blue was placed under a condenser of the distillation apparatus so that the tap was about 20cm inside the solution. 5ml of 40% sodium hydroxide was added to the digested sample in the apparatus and distillation commenced immediately until 50 drops gets into the receiver flask, after which it was titrated to pink colour using 0.01N Hydrochloric acid.

Calculations

% Nitrogen = Titre value x 0.01 x 14 x 4
% Protein = % Nitrogen x 6.25

3.5. Determination of the Adsorption Efficiency

Stock solution of heavy metals was prepared by dissolving required quantity of Analar grade salts in deionized water. The salts used are cadmium chloride monohydrate ($CdCl_2.H_2O$), manganese sulphate monohydrate ($MnSO_4.H_2O$), nickel Chloride hexahydrate ($NiCl_2.6H_2O$), lead nitrate ($Pb(NO_3)_2$), for Cd(II), Mn(II), Ni(II) and Pb(II), respectively, for the preparation of stock solution. The stock solution was further diluted with deionized water to desired concentration for obtaining the test solutions. NaOH was used for pH adjustments.

The method by Grigis, et al., (1999) with slight modification was used to study the adsorption capacity of each activated carbon prepared at different temperature and time from each of the agro waste. Dose of Activated Carbon was 2g, Volume of Aqueous Solution used 10ml, Different Initial Heavy Metal Concentration were prepared for different metal ranging from 35mg/l to 150mg/l, pH 7, Temperature was about room temperature, Contact Time 24h, Agitation Speed 120rpm

Adsorption Efficiency = $C_0 – C/C_0$ x 100
C = concentration at equilibrium heavy metal
Co = initial concentration of the heavy metal

3.6. Isotherm Studies (Freundlich and Langmuir Isotherms)

The batch technique was selected to obtain equilibrium data because of its simplicity. Batch adsorption was performed at the same temperatures and initial Heavy Metal (HM) concentrations to obtain equilibrium isotherms. For isotherm studies, adsorption experiments was carried out by shaking 1g of activated carbon samples with 100ml flasks filled with 10ml of HM solution at a concentration range 35mg/l to 150mg/L at a fixed temperature in a thermostated shaker bath for a known period of time. After equilibrium the suspension was filtered and the metal solution was then analyzed using AAS (Varian AA240). In order to obtain the adsorption capacity, the amount of ions adsorbed per mass unit of activated carbon sample (mg/g) was evaluated using the following expression:

$q_e= (C_0− C_e)V/m$

where q_e is the amount adsorbed at equilibrium (mg/g), C_0 is the initial metal ions concentration (mg/L), C_e is the equilibrium metal ions concentration (mg/L), V is the volume of the aqueous phase (L), and m is the amount of the activated carbon used.

3.7. Determination of Pore Volume

1g of each activated carbons was immersed in water and boiled for 15minutes in order to displace air from the pores of the activated carbons. The samples were superficially dried and reweighed. The pore volume was calculated from the difference in weight (dw) divided by the density of water (e) at room temperature.

Pore Volume = dw/e_{t25}

4. Results and Discussion

The proximate analysis of the samples was carried out (table 1), and it was observed that the pH values of the samples is 6.31 for Peanut Seed and 7.23 for Palm Kernel shell, indicating slightly acidic to neutral samples. It was also observed that Palm Kernel shell had a high sulphur content (382.695mg/g), while the sulphur content of Peanut was relatively low. Also, the percentage ash, fat, fibre, nitrogen and protein contents were relatively low for all the samples which are comparable to literature values as found in Daud and Ali, (2004), Ademiluyi, et al., (2012).

S/N	Sample	pH	Sulphur (Mg/g)	%Ash	%fat	%fibre	% N_2	% protein	% moisture	% C
1	Peanut seed	6.31	41.15	5.00	7.00	3.50	0.616	3.85	5.5	75.15
2	Palm Kernel Shell	7.23	382.695	3.5	8.00	6.5	0.448	2.80	13.5	65.7

Table 1: The Proximate Analysis of the Samples

Parameter / Sample	Peanut	Palm Kernel
Carbon (%)	18.3	17.2
Hydrogen (mg/g)	14.33	12.66
Oxygen (mg/g)	29.33	17.42
Sodium (ppm)	0.00	20.01
Potassium (ppm)	18.882	15.351

Table 2: The Elemental Analysis of the Samples

Sample	800 ^{O}C for 30Min (%)	600 ^{O}C for 45Min (%)
Peanut Seed	28.01	32.61
Palm kernel shell	32.19	34.58

Table 3: Percentage Yield after Carbonization

From table 3, percentage yield after carbonization, we observe that all the samples had a low percentage yield after carbonization having recorded their percentage yield below 35%,

This is in line with that reported by Abechi, et al., (2013). It can also be observed that the percentage yield at a higher temperature is lower than that at lower temperature even when carbonized at a longer period. This is because increase in temperature resulted in more volatile components of the precursor materials being lost, and hence a decreasing percentage yield. This was also noted by Abechi, et al., (2013).

Sample	800^{O}C/30Min (%)			600^{O}C/45Min (%)		
	H_2SO_4	HCl	H_3PO_4	H_2SO_4	HCl	H_3PO_4
Peanut Seed	70.27	76.93	92.40	77.74	76.86	83.90
Palm Kernel shell	76.61	89.67	95.31	82.88	71.74	89.28

Table 4: Percentage Yield after Chemical Activation

After chemical activation, the percentage yield (table 4) was very high in all the samples and at the temperatures used, though it was better for H_3PO_4, in both conditions. The activation time does not influence the yield remarkably, relative to the activation temperature. The percentage yield of Palm Kernel activated at 800^{o}C with H_3PO_4 and $ZnCl_2$ using activating agent as reported by Abechi, et al., (2013) is 46.33%.

Activated Carbon Type	Initial Pb Conc. (mg/g)	Amount Adsorbed (mg/g)
PNAC/600^{0}C/HCl	17.95	0.95
PNAC/600^{0}C/H_2SO_4	17.95	1.17
PNAC/600^{0}C/H_3PO_4	17.95	1.99
PNAC/800^{0}C/HCl	17.95	6.75
PNAC/800^{0}C/H_2SO4	17.95	8.08
PNAC/800^{0}C/H_3PO_4	17.95	1.35
PKAC/600^{0}C/HCl	17.95	0.39
PKAC/600^{0}C/H_2SO_4	17.95	0.81
PKAC/600^{0}C/H_3PO_4	17.95	1.44
PKAC/800^{0}C/HCl	17.95	3.56
PKAC/800^{0}C/H_2SO_4	17.95	5.79
PKAC/800^{0}C/H_3PO_4	17.95	2.67

Table 5: Heavy Metal Concentration in Waste Water Samples from Ibeto Battery Industries and its treatment with Activated Carbons Prepared

The waste water collected from Ibeto Battery factory (Nnewi) was analyzed for Pb concentration. The waste water was also treated with the various type of activated carbons produced and the result is as shown in table 5. From the result it could be deduced that all the prepared activated carbons were good Pb adsorbents. The PNAC adsorption capacity ranged from 0.95 to 8.08mg/g with PNAC/800^{0}C/H_2SO_4 recording the highest adsorbed Pb concentration, while that of PKAC was 0.39 to 5.79.

4.1. Surface Chemistry Study

The type and net charge of functional groups bonded to the carbon surface is important in understanding the mechanism of adsorption of ionic adsorbates on activated carbons (Nale, et al., 2012). The adsorption capacity of activated carbon is influenced by functional groups on the carbon surface. The functional groups on the surface of activated carbon analysed by the FTIR demonstrated the existence of carboxyl, hydroxyl, amine groups, amide groups, alkyl, aromatic C = C, Nitrile, Phenol and carboxylic groups (table 6 and 7). The FTIR spectra of the carbonised and activated carbons showed some differences from each other. This demonstrates that after the activation, shifting occurred both to higher and lower wave numbers. This shifting indicated that there were binding processes taking place on the surfaces of the activated carbons during activation. FTIR spectra were obtained on a JASCO FTIR-3500 spectrometer. The analysis conditions used were 16 scans at a resolution of 4cm^{-1} measured between 400 and 4000cm^{-1}.

Functional groups are formed during activation by interaction of free radicals on the carbon surface with atoms such as oxygen and nitrogen, both from within the precursor and from the atmosphere (Zawadski, 1989). The functional groups render the surface of activated carbon chemically reactive and influence its adsorptive properties (McEnaney and Mays, 1989). Surface oxidation is an inherent feature of activated carbon production. It results in hydroxyl (-OH), carbonyl (=CO), and carboxylic (-COOH) groups that impart an amphoteric character to the activated carbon. So it can be either acidic or basic.

In the FTIR analysis of PKAC, there were peaks observed before activation and after activation as well. The peaks observed after chemical activation was more than that observed before chemical activation. This also indicates a reorganization of the chemical bonds on the surfaces of the activated carbons prepared. There was shifting of peaks on the activated carbon surfaces. It can also be deduced from table 7 that more peaks were observed with the activating agents H_2SO_4 and H_3PO_4 in all the activated carbon types prepared. This may be attributed to the presence of the oxygen atoms as earlier mentioned. The O – H stretch of the carboxylic, phenol and alcohol group shifted from around 2544.58cm^{-1} to around 3000 – 2500cm^{-1}. So also it was for several other observed functional groups. This is in line with the observation made by Abechi et al., 2013.

A similar observation was also made for the PNAC prepared (table 6). There was reorganization of the surface oxides on subjection to chemical activation of the carbonized peanut seed. There was also shifting of observed peaks as a result of the activation. For instance, the O – H stretch of COOH, Phenol and Alcohol groups observed at 2671.554cm^{-1} in the inactivated peanut seed carbon shifted to around 3000 – 2500cm^{-1} in the chemical activated PNAC prepared. So also it was for Amine N – H stretch, but the Alkyl C – H stretch disappeared on subjection of the carbon to chemical activation. African Canarium or African elemi (Peanut seed) is known to contain phenolic group, carboxylic as well as saponins and terpenes (Mogana & Wiart, 2011).

From table 8 which is the percentage adsorption of Ni by PNAC, Ni adsorption by those activated with HCl and carbonized at 600^{0}C were better adsorbent, so also it was for those activated with H_2SO_4 and H_3PO_4 except for few of them.

HCl 600^{O}c E%	**HCl 800^{o}c E%**	**H_2SO_4 600^{O}c E%**	**H_2SO_4 800^{o}c E%**	**H_3PO_4 600^{O}c E%**	**H_3PO_4 800^{o}c E%**
60.7	57.5	57.7	21.6	51.0	60.6
63.2	62.1	59.6	58.9	57.6	47.0
60.1	36.3	46.5	58.1	45.7	49.1
40.6	11.8	46.3	27.0	17.8	27.8
1.74	68.1	42.1	33.7	8.2	36.2

Table 6: Percentage Adsorption of Ni by PNAC

PNAC = Peanut Seed Activated Carbon

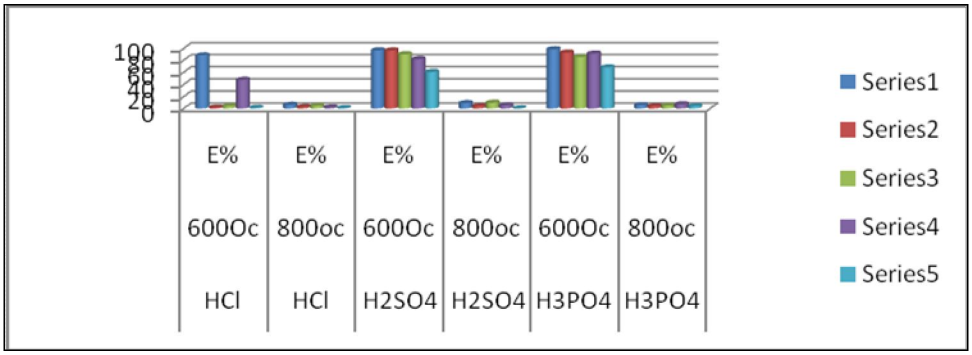

Figure 6: Percentage Adsorption of Ni by PNAC

Table 9 shows the percentage adsorption of Pb by peanut seed activated carbon. It can be deduced that those carbonized at 600^{o}C were better adsorbent than their counterpart except for few that were carbonized at 800^{o}C. This can easily be seen in figure 7.

HCl/600^{O}c/E%	**HCl/800^{o}c/E%**	**H_2SO_4/600^{O}c/E%**	**H_2SO_4/800^{o}c/E%**	**H_3PO_4/600^{O}c/E%**	**H_3PO_4/800^{o}c/E%**
98.4	87.5	97.6	77.8	98.6	75.0
92.9	93.6	97.7	65.7	96.9	49.0
89.1	98.8	98.7	38.9	98.1	34.1
99.0	98.9	90.9	41.0	94.0	33.8
95.8	98.8	95.4	27.4	91.5	30.1

Table 7: Percentage Adsorption of Pb by PNAC

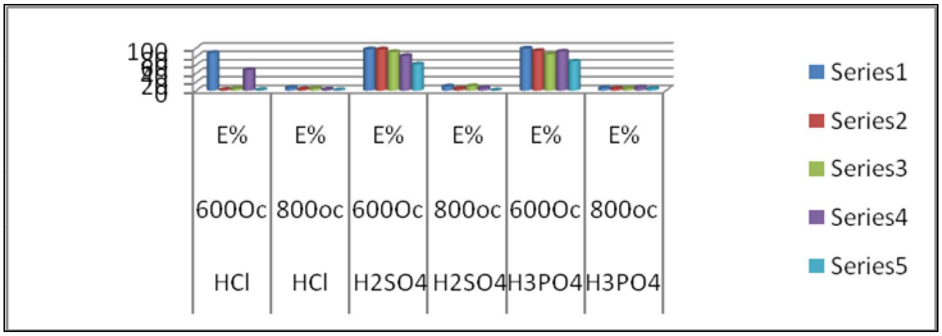

Figure 7: Percentage Adsorption of Pb by PNAC

In the adsorption of Cd by the Peanut seed activated carbon, those carbonized at 800°C and activated with H_2SO_4 and H_3PO_4 were better adsorbents in most of the produced activated carbon. Generally they all had low percentage of adsorption (table 10 and figure 8).

HCl 600^{O}c E%	**HCl 800^{o}c E%**	**H_2SO_4 600^{O}c E%**	**H_2SO_4 800^{o}c E%**	**H_3PO_4 600^{O}c E%**	**H_3PO_4 800^{o}c E%**
62.1	61.7	35.1	47.1	36.0	39.2
46.1	56.6	32.9	31.8	41.0	24.0
33.0	47.8	32.3	89.4	43.4	27.3
9.7	10.9	10.9	40.4	11.9	16.1
3.7	3.4	19.9	44.0	4.2	27.0

Table 8: Percentage Adsorption of Cd by PNAC

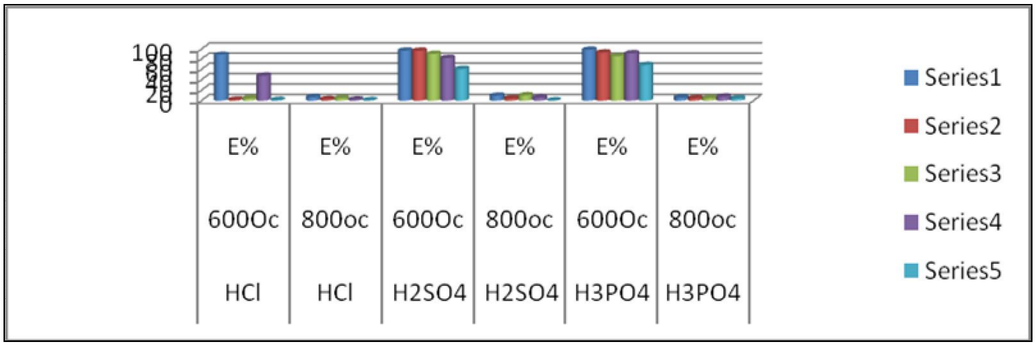

Figure 8: Percentage Adsorption of Cd by PNAC

The percentage Mn adsorption by PNAC as shown in table 11 and figure 9 indicates that those carbonized at 800°C were mostly better than their counterpart except in few of them. In general, their overall adsorptions were of average.

HCl 600^{O}c E%	**HCl 800^{o}c E%**	**H_2SO_4 600^{O}c E%**	**H_2SO_4 800^{o}c E%**	**H_3PO_4 600^{O}c E%**	**H_3PO_4 800^{o}c E%**
60.0	59.8	50.4	84.8	59.9	71.1
69.8	59.5	48.3	80.6	40.9	62.9
64.0	43.6	32.5	64.6	49.2	46.4
50.4	8.9	11.8	41.7	1.6	18.8
52.6	7.3	20.9	7.1	19.6	12.3

Table 9: Percentage Adsorption of Mn by PNAC

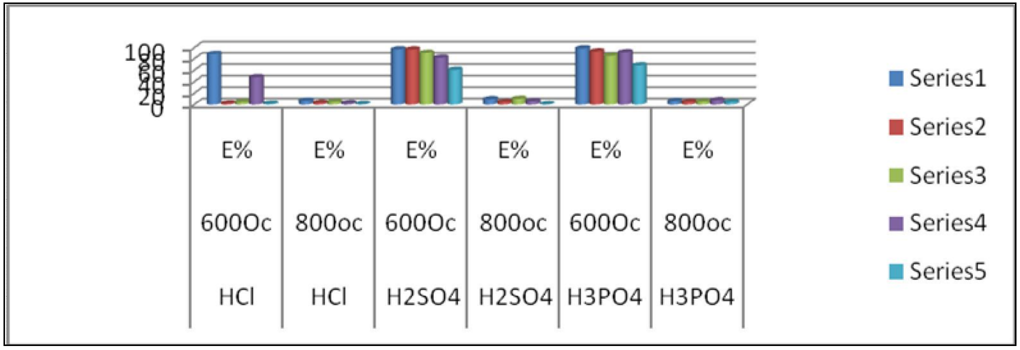

Figure 9: Percentage Adsorption of Mn by PNAC

The adsorption by palm Kernel shell activated carbon where generally of average and those carbonized at 800^{o}C had a better percentage adsorption especially for the H_2SO_4 and HCl (table 12, figure 10).]

HCl 600^{O}c E%	HCl 800^{o}c E%	H_2SO_4 600^{O}c E%	H_2SO_4 800^{o}c E%	H_3PO_4 600^{O}c E%	H_3PO_4 800^{o}c E%
41.2	53.9	23.7	77.7	61.6	47.9
36.2	45.0	24.4	77.3	69.3	50.2
39.9	48.7	17.6	75.6	87.9	50.9
19.8	23.5	18.3	50.8	72.6	21.9
9.2	3.96	11.9	16.2	31.5	19.4

Table 10: Percentage Adsorption of Ni by PKAC
PKAC = Palm Kernel Shell Activated Carbon

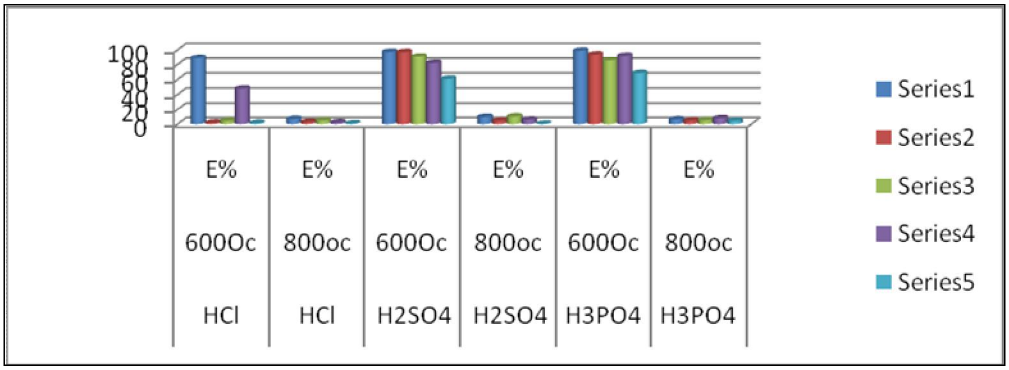

Figure 10: Percentage Adsorption of Ni by PKAC

From table 11 and figure 11, the PKAC activated with HCl and carbonized at 600^{o}C were better adsorbent of Pb but for those activated with H_2SO_4 and H_3PO_4, those carbonized at 800^{o}c were better adsorbents. Generally, they all had a high percentage of adsorption except for few.

HCl 600^{O}c E%	HCl 800^{o}c E%	H_2SO_4 600^{O}c E%	H_2SO_4 800^{o}c E%	H_3PO_4 600^{O}c E%	H_3PO_4 800^{o}c E%
98.6	88.0	83.7	89.8	54.3	86.6
97.7	84.4	80.9	81.9	40.7	95.8
96.2	74.0	63.1	68.3	36.4	84.1
88.9	65.0	40.0	41.2	33.3	75.1
87.6	67.3	43.7	34.6	37.9	70.8

Table 11: Percentage Adsorption of Pb by PKAC

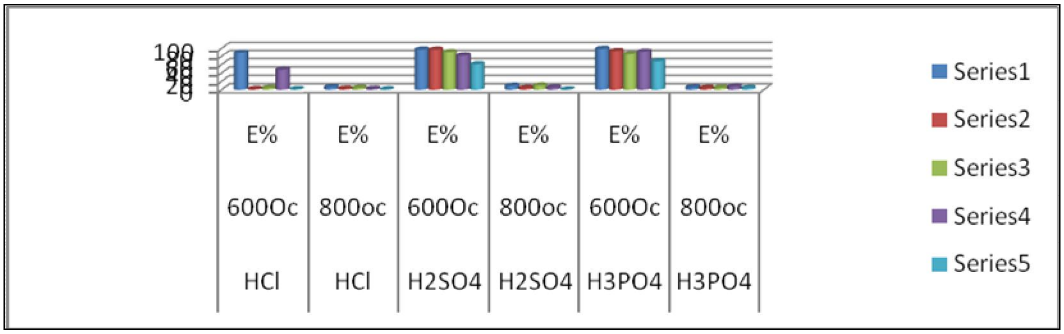

Figure 11: Percentage Adsorption of Pb by PKAC

In the adsorption of Cd by PKAC, those carbonized at 600°C had a better percentage adsorption in all except for few of them. Also the percentage adsorption of the Cd was generally high (table 12 and figure 12).

HCl 600°c E%	**HCl 800°c E%**	**H_2SO_4 600°c E%**	**H_2SO_4 800°c E%**	**H_3PO_4 600°c E%**	**H_3PO_4 800°c E%**
49.4	45.6	88.6	83.2	95.5	90.1
46.1	42.2	89.2	83.4	95.6	87.2
43.9	40.5	83.3	86.4	53.9	84.9
12.7	11.8	72.8	91.9	88.4	83.6
3.30	3.70	69.7	5.80	65.4	72.7

Table 12: Percentage Adsorption of Cd by PKAC

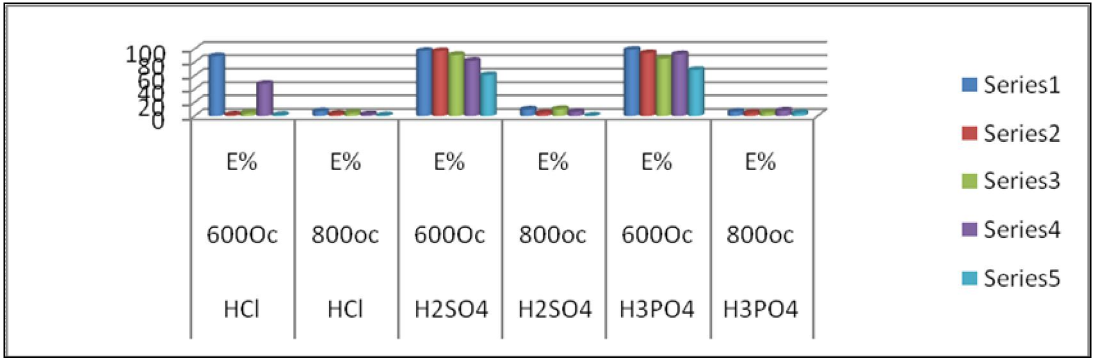

Figure 12: Percentage Adsorption of Cd by PKAC

The palm kernel AC had a high percentage adsorption of Mn almost in all, but those carbonized at 600oC was better (table 13, figure 13).

HCl 600°c E%	**HCl 800°c E%**	**H_2SO_4 600°c E%**	**H_2SO_4 800°c E%**	**H_3PO_4 600°c E%**	**H_3PO_4 800°c E%**
99.1	29.8	83.4	75.0	62.5	50.1
85.9	22.0	85.3	64.7	41.8	53.3
79.0	11.0	61.9	45.8	35.9	31.6
71.9	68.9	40.5	60.1	37.2	19.7
73.5	95.7	29.9	6.8	32.3	20.3

Table 13: Percentage Adsorption of Mn by PKAC

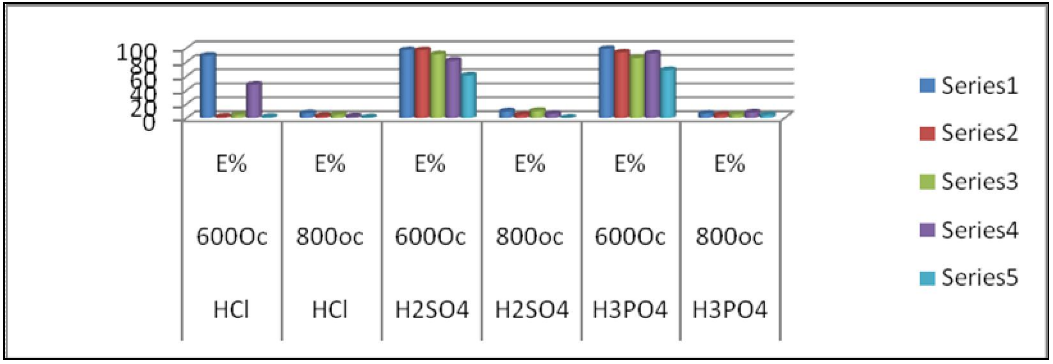

Figure 13: Percentage Adsorption of Mn by PKAC

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	$\log q_e$	$\log C_e$	$1/q_e$	$1/C_e$
55.47	21.81	0.34	60.7	-0.47	1.34	2.94	0.0459
52.67	19.38	0.33	63.2	-0.48	1.29	3.03	0.0516
59.35	23.654	0.36	60.1	-0.44	1.37	2.78	0.0423
64.96	38.590	0.26	40.6	-0.59	1.59	3.85	0.0257
66.797	65.631	0.01	1.74	-0.82	1.82	100.0	0.0152

Table 15: Ni Adsorption by Pea nut Carbonized at 600°C and Activated with HCl

Considering the R^2 values of the Freundlich Ni adsorption isotherm by PNAC carbonised at 600°C and 800°C, there was a good fit in all the type of activated Peanut seed carbons as R^2 ranged from 0.596 to 0.924. Also, the Freundlich adsorption intensities as well as the Freundlich adsorption capacities were all relatively high which ranged between 0.61 to 5.56 and 1.8 to 61.9 respectively. The PNAC carbonized 600°C had better values for the Freundlich constants (n and K_f)

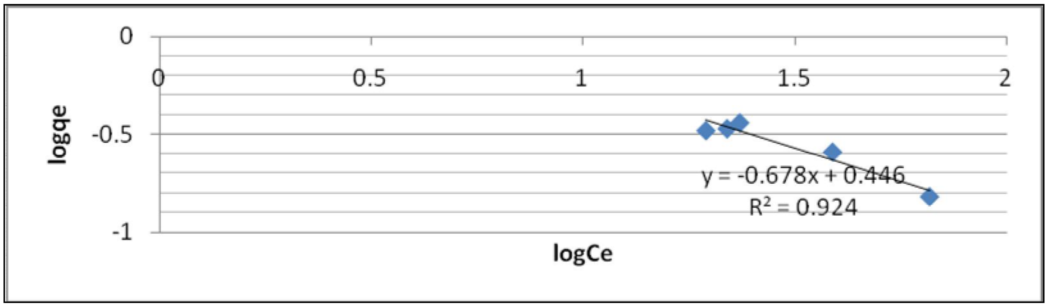

Figure 14: Freundlich isotherm plot for Ni onto PNAC Carbonized at 600°C & activated with HCl

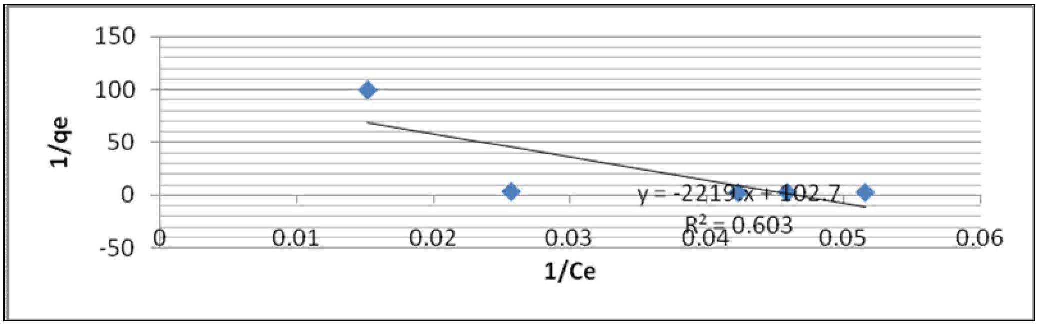

Figure 15: Langmuir isotherm plot for Ni onto PNAC Carbonized at 600°C & activated with HCl

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	$\log q_e$	$\log C_e$	$1/q_e$	$1/C_e$
55.47	27.13	0.28	51.0	-0.55	1.43	3.57	0.0369
52.67	22.33	0.30	57.6	-0.52	1.35	3.33	0.0448
59.352	32.198	0.27	45.7	-0.57	1.51	3.70	0.0311
64.96	53.406	0.12	17.8	-0.92	1.73	8.33	0.0187
66.797	61.350	0.05	8.2	-1.30	1.79	20.0	0.0162

Table 16: Ni Adsorption by Pea nut Carbonized at 600°C and Activated with H_3PO_4

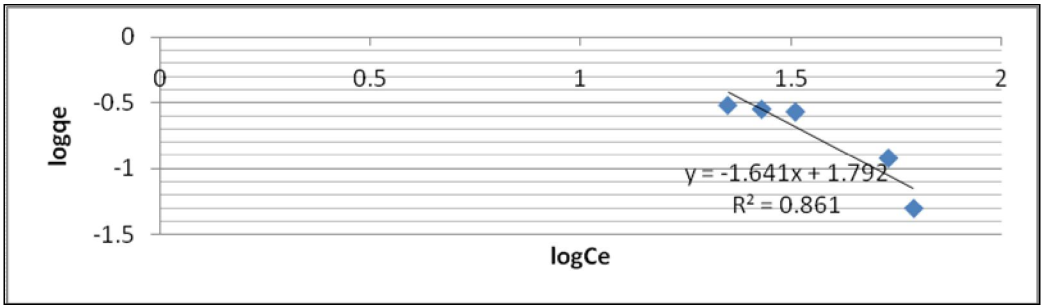

Figure 16: Freundlich isotherm plot for Ni onto PNAC Carbonized at 600^{o}C & activated with H_3PO_4

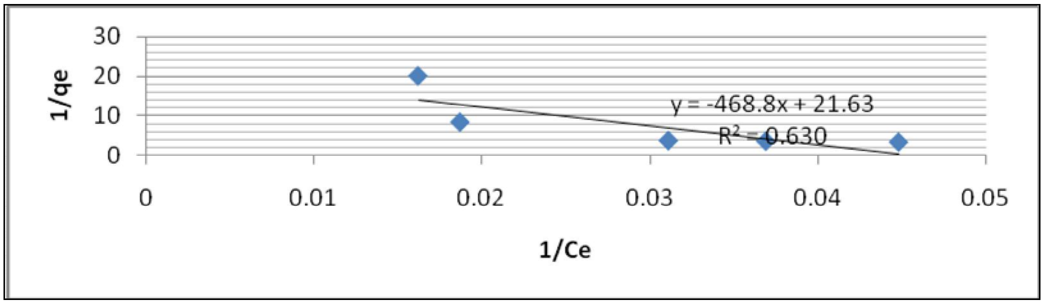

Figure 17: Langmuir isotherm plot for Ni onto PNAC Carbonized at 600^{o}C & activated with H_3PO_4

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
55.47	23.46	0.32	57.7	-0.49	1.37	3.125	0.0426
52.67	21.29	0.31	59.6	-0.51	1.33	3.226	0.0470
59.352	31.78	0.28	46.5	-0.55	1.50	3.571	0.0315
64.96	34.91	0.30	46.3	-0.52	1.54	3.333	0.0286
66.797	38.67	0.28	42.1	-0.55	1.59	3.571	0.0259

Table 17: Ni Adsorption by Pea nut Carbonized at 600^{o}C and Activated with H_2SO_4

The equation of plot for the Freundlich and Langmuir adsorption isotherm is as summarized in tables 64, 65, 66 and 67.

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
55.47	23.56	0.32	57.5	-0.4949	1.3722	3.1250	0.0424
52.67	19.91	0.33	62.1	-0.4815	1.2991	3.0303	0.0502
59.352	37.799	0.23	36.3	-0.6383	1.5775	4.3478	0.0265
64.96	57.357	0.08	11.8	-1.0969	1.7586	12.5000	0.0174
66.797	21.296	0.46	68.1	-0.3372	1.3282	2.1739	0.0470

Table 18: Ni Adsorption by Pea nut Carbonized at 800^{o}C and Activated with HCl

The determination coefficient for the Langmuir model of the experimental data obtained for the adsorption of Ni on PNAC was relatively high and so there was a good fit for the types of Peanut seed activated carbon prepared. R^2 ranged from 0.603 to 0.898. Though the model had a good fit, the Q^o was not high but the adsorption energy term was high and it ranges from 4.4 to 21.7.

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
55.47	21.86	0.34	60.6	-0.4685	1.3397	2.9412	0.0457
52.67	27.91	0.25	47.0	-0.6021	1.4458	4.0000	0.0358
59.352	30.18	0.29	49.1	-0.5376	1.4797	3.4483	0.0331
64.96	46.88	0.18	27.8	-0.7447	1.6710	5.5556	0.0213
66.797	42.61	0.24	36.2	-0.6198	1.6295	4.1667	0.0235

Table 19: Ni Adsorption by Pea nut Carbonized at 800^{o}C and Activated with H_3PO_4

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
55.47	27.8	0.28	21.6	-0.5528	1.4440	3.5714	0.0360
52.67	21.67	0.31	58.9	-0.5086	1.3359	3.2258	0.0461

59.352	24.9	0.34	58.1	-0.4685	1.3962	2.9412	0.0402
64.96	47.36	0.18	27.0	-0.7447	1.6754	5.5556	0.0211
66.797	44.31	0.22	33.7	-0.6576	1.6465	4.5455	0.0226

Table 20: Ni Adsorption by Pea nut Carbonized at 800^{o}C and Activated with H_2SO_4

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
35.7	0.57	0.35	98.4	-0.46	-0.24	2.86	1.75
37.6	2.05	0.36	92.9	-0.44	0.31	2.78	0.49
43.9	4.77	0.39	89.1	-0.41	0.68	2.56	0.21
57.2	0.56	0.57	99.0	-0.24	-0.25	1.75	1.79
57.4	2.42	0.55	95.8	-0.26	0.38	1.82	0.41

Table 21: Pb Adsorption by Pea nut Carbonized at 600^{o}C and Activated with HCl

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
35.7	0.50	0.35	98.6	-0.46	-0.30	2.86	2.00
37.6	1.16	0.36	96.9	-0.44	0.06	2.78	0.86
43.9	0.83	0.43	98.1	-0.37	-0.08	2.33	1.20
57.2	3.43	0.54	94.0	-0.27	0.54	1.85	0.29
57.4	4.87	0.53	91.5	-0.28	0.69	1.89	0.21

Table 22: Pb Adsorption by Pea nut Carbonized at 600^{o}C and Activated with H_3PO_4

The plot of Freundlich adsorption isotherm fitted well on the Pb adsorption by PNAC carbonized at 600^{o}C and 800^{o}C except for that carbonized at 600^{o}C and activated with HCl which had low R^2 of 0.021. The range of the determination coefficients is 0.021 TO 0.820. Looking at the adsorption intensity values for both carbonization temperatures, it can be observed that they all had high adsorption intensities though those of 600^{o}C where better. In the same way, the Freundlich adsorption capacity constant (K_f) were all high and it ranged from 2.3 to 28.0.

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
35.7	0.86	0.35	97.6	-0.45	-0.07	2.86	1.16
37.6	0.87	0.37	97.7	-0.43	-0.06	2.70	1.15
43.9	0.58	0.43	98.7	-0.37	-0.24	2.33	1.72
57.2	5.23	0.52	90.9	-0.28	0.72	1.92	0.19
57.4	2.64	0.55	95.4	-0.26	0.42	1.82	0.38

Table 23: Pb Adsorption by Pea nut Carbonized at 600^{o}C and Activated with H_2SO_4

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
35.7	4.26	0.31	87.5	-0.5086	0.6294	3.2258	0.2347
37.6	2.38	0.35	93.6	-0.4559	0.3766	2.8571	0.4202
43.9	0.49	0.43	98.8	-0.3665	-0.3098	2.3256	2.0408
57.2	0.58	0.57	98.9	-0.2441	-0.2366	1.7544	1.7241
57.4	0.71	0.57	98.8	-0.2441	-0.1487	1.7544	1.4058

Table 24: Pb Adsorption by Pea nut Carbonized at 800^{o}C and Activated with HCl

For the Langmuir isotherm plot of the experimental data generated from the adsorption of Pb by PNAC, the determination coefficient (R^2), were all high and so the model had a good fit. R^2 ranged from 0.464 to 0.726. The Q^o ranged from 0.037 to 2.0 while the b ranged from 0.2 to 4.0.

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
35.7	8.91	0.27	75.0	-0.5528	0.9499	3.5714	0.1122
37.6	19.16	0.18	49.0	-0.7447	1.2824	5.5556	0.0522
43.9	28.90	0.15	34.1	-0.8239	1.4609	6.6667	0.0346
57.2	37.89	0.19	33.8	-0.7212	1.5785	5.2632	0.0264
57.4	40.10	0.17	30.1	-0.7696	1.6031	5.8824	0.0249

Table 25: Pb Adsorption by Pea nut Carbonized at 800^{o}C and Activated with H_3PO_4

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	$\log q_e$	$\log C_e$	$1/q_e$	$1/C_e$
35.7	7.89	0.27	77.8	-0.5686	0.8971	3.7037	0.1267
37.6	12.91	0.25	65.7	-0.6021	1.1109	4.0000	0.0775
43.9	26.80	0.17	38.9	-0.7696	1.4281	5.8824	0.0373
57.2	33.70	0.24	41.0	-0.6198	1.5276	4.1667	0.0297
57.4	41.66	0.16	27.4	-0.7959	1.6199	6.2500	0.0240

Table 26: Pb Adsorption by Pea nut Carbonized at 800^{o}C and Activated with H_2SO_4

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	$\log q_e$	$\log C_e$	$1/q_e$	$1/C_e$
53.66	20.32	0.33	62.1	-0.4815	1.3079	3.0303	0.0492
53.06	28.59	0.24	46.1	-0.6198	1.4562	4.1667	0.0350
53.90	36.118	0.18	33.0	-0.7447	1.5577	5.5556	0.0277
55.70	50.32	0.05	9.7	-1.3010	1.7017	20.0000	0.0199
57.47	55.37	0.02	3.7	-1.6990	1.7433	50.0000	0.0181

Table 27: Cd Adsorption by Pea nut Carbonized at 600^{o}C and Activated with HCl

For the adsorption of Cd by PNAC, the Freundlich adsorption isotherm plot fitted well with R^2 ranging from 0.816 to 0.985, though those carbonized at 600^{o}C were better off. So also it was for their respective Freundlich adsorption intensities (n) which ranged from 0.27 to 2.14. Unlike the adsorption intensity, the adsorption capacities of those carbonized at 800^{o}C were better off. The K_f values ranged from 1.1 to 7.2 x 10^3.

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	$\log q_e$	$\log C_e$	$1/q_e$	$1/C_e$
53.66	34.38	0.19	36.0	-0.7212	1.5363	5.2632	0.0291
53.06	31.30	0.22	41.0	-0.6576	1.4955	4.5455	0.0319
53.90	30.5	0.23	43.4	-0.6383	1.4843	4.3478	0.0328
55.70	49.06	0.07	11.9	-1.1549	1.6907	14.2857	0.0204
57.47	55.03	0.02	4.2	-1.6889	1.7406	50.0000	0.0182

Table 28: Cd Adsorption by Pea nut Carbonized at 600^{o}C and Activated with H_3PO_4

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	$\log q_e$	$\log C_e$	$1/q_e$	$1/C_e$
53.66	34.8	0.19	35.1	-0.7212	1.5416	5.2632	0.0287
53.06	35.6	0.17	32.9	-0.7696	1.5515	5.8824	0.0281
53.90	36.5	0.17	32.3	-0.7696	1.5623	5.8824	0.0274
55.70	49.66	0.06	10.9	-1.2218	1.6960	16.6667	0.0201
57.47	50.03	0.07	19.9	-1.1549	1.6992	14.2857	0.0199

Table 29: Cd Adsorption by Pea nut Carbonized at 600^{o}C and Activated with H_2SO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	$\log q_e$	$\log C_e$	$1/q_e$	$1/C_e$
53.66	20.56	0.33	61.7	-0.4815	1.3130	3.0303	0.0486
53.06	23.01	0.30	56.6	-0.5229	1.3619	3.3333	0.0435
53.90	28.10	0.26	47.8	-0.5850	1.4487	3.8462	0.0356
55.70	49.60	0.06	10.9	-1.2218	1.6955	16.6667	0.0202
57.47	55.50	0.02	3.4	-1.6990	1.7443	50.0000	0.0180

Table 30: Cd Adsorption by Pea nut Carbonized at 800^{o}C and Activated with HCl

Just like the Langmuir model plot for Pb, the Langmuir plot for Cd adsorption by PNAC had a good R^2 values and so were fitted well. The range of the values of R^2 is 0.521 to 0.966. The Q^o values were very low and so there was a very low adsorption capacity of the activated carbon prepared from the Peanut seed. But the b values were relatively high indicating good adsorption energy for Cd adsorption onto PNAC.

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	$\log q_e$	$\log C_e$	$1/q_e$	$1/C_e$
53.66	32.61	0.21	39.2	-0.6778	1.5134	4.7619	0.0307
53.06	40.30	0.13	24.0	-0.8861	1.6053	7.6923	0.0248
53.90	39.16	0.15	27.3	-0.8239	1.5928	6.6667	0.0255
55.70	46.70	0.09	16.1	-1.0458	1.6693	11.1111	0.0214
57.47	41.90	0.16	27.0	-0.7959	1.6222	6.2500	0.0239

Table 31: Cd Adsorption by Pea nut Carbonized at 800^{o}C and Activated with H_3PO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
53.66	28.36	0.25	47.1	-0.6021	1.4527	4.0000	0.0353
53.06	36.20	0.17	31.8	-0.7696	1.5587	5.8824	0.0276
53.90	5.69	0.49	89.4	-0.3098	0.7551	2.0408	0.1757
55.70	33.16	0.23	40.4	-0.6383	1.5206	4.3478	0.0302
57.47	32.14	0.25	44.0	-0.6021	1.5070	4.0000	0.0311

Table 32: Cd Adsorption by Pea nut Carbonized at 800°C and Activated with H_2SO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	30.03	0.45	60.0	-0.3468	1.4776	2.2222	0.0333
114.69	34.65	0.80	69.8	-0.0969	1.5397	1.2500	0.0289
135.2	48.68	0.86	64.0	-0.0655	1.6874	1.1628	0.0205
145.14	71.92	0.73	50.4	-0.1367	1.8568	1.3699	0.0139
147.28	69.7	0.78	52.6	-0.1079	1.8432	1.2821	0.0143

Table 33: Mn Adsorption by Pea nut Carbonized at 600°C and Activated with HCl

The range of the determination coefficient (R^2) for the Freundlich adsorption isotherm of Mn adsorption on PNAC is 0.006 to 0.639. The PNAC carbonized at 600°C and activated with H_2SO_4 had the least value (0.006), which means it is the least fitted Freundlich isotherm plot for the adsorption of Mn on PNAC, unlike others that were relatively well fitted. The highest R^2 value (0.639) was recorded by the PNAC carbonised at 800°C and activated with HCl. The adsorption intensities were relatively high (0.004 to 2.82). So also it was for the Freundlich adsorption capacities for the PNAC irrespective of the temperature of carbonization and the activating agents used.

x

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	37.19	0.38	50.4	-0.4202	1.5704	2.6316	0.0269
114.69	59.25	0.55	48.3	-0.2596	1.7727	1.8182	0.0169
135.2	91.25	0.44	32.5	-0.3565	1.9602	2.2727	0.0110
145.14	128.0	0.17	11.8	-0.7696	2.1072	5.8824	0.0078
147.28	116.56	0.31	20.9	-0.5086	2.0665	3.2258	0.0086

Table 34: Mn Adsorption by Pea nut Carbonized at 600°C and Activated with HCl

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	30.05	0.45	59.9	-0.3468	1.4780	2.2222	0.0333
114.69	67.81	0.47	40.9	-0.3279	1.8313	2.1277	0.0147
135.2	68.66	0.67	49.2	-01739	1.8367	1.4925	0.0146
145.14	142.75	0.24	1.6	-0.6198	2.1546	4.1667	0.0070
147.28	118.40	0.29	19.6	-0.5376	2.0734	3.4483	0.0084

Table 35: Mn Adsorption by Pea nut Carbonized at 600°C and Activated with H_3PO_4

C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	30.162	0.45	59.8	-0.3468	1.4795	2.2222	0.0332
114.69	46.61	0.68	59.5	-0.1675	1.6685	1.4706	0.0215
135.2	76.34	0.59	43.6	-0.2291	1.8828	1.6949	0.01310
145.14	132.2	0.13	8.9	-0.8861	2.1212	7.6923	0.0076
147.28	136.6	0.11	7.3	-0.9586	2.1355	9.0910	0.0073

Table 36: Mn Adsorption by Pea nut Carbonized at 800°C and Activated with HCl

The determination coefficient for the Langmuir plot of Mn adsorption on PNAC were low and so the model had poor fit for almost all the type of activated carbon prepared from Peanut seed. R^2 ranged from 0.201 to 0.509, and Q^o was also low but b had high values which in turn indicate good adsorption energy values for Mn adsorption onto PNAC.

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	21.67	0.53	71.1	-0.2757	1.3359	1.8868	0.0461
114.69	42.6	0.72	62.9	-0.1427	1.6294	1.6294	0.0235
135.2	72.5	0.63	46.4	-0.2007	1.8603	1.8603	0.0138
145.14	117.9	0.27	18.8	-0.5686	2.0715	3.0715	0.0085

147.28	129.6	0.18	12.3	-0.7447	2.1126	5.1126	0.0077

Table 37: Mn Adsorption by Pea nut Carbonized at 800^{o}C and Activated with H_3PO_4

C$_o$(mg/l)	**C$_e$ (mg/l)**	**q$_e$ (mg/g)**	**E (%)**	**logq$_e$**	**logC$_e$**	**1/q$_e$**	**1/C$_e$**
75.05	11.35	0.64	84.8	-0.1938	1.0550	1.5625	0.0881
114.69	22.29	0.92	80.6	-0.0362	1.3481	1.0870	0.0449
135.2	47.9	0.87	64.6	-0.0605	1.6803	1.1494	0.0209
145.14	84.6	0.61	41.7	-0.2147	1.9274	1.6393	0.0118
147.28	136.8	0.10	7.1	-1.0000	2.1361	10.0000	0.0073

Table 38: Mn Adsorption by Pea nut Carbonized at 800^{o}C and Activated with H_2SO_4

C$_o$(mg/l)	**C$_e$ (mg/l)**	**q$_e$ (mg/g)**	**E (%)**	**logq$_e$**	**logC$_e$**	**1/q$_e$**	**1/C$_e$**
55.47	32.60	0.23	41.2	-0.6383	1.5132	4.3478	0.0307
52.67	33.56	0.19	36.2	-0.7212	1.5258	5.2632	0.0298
59.35	35.62	0.24	39.9	-0.6198	1.5517	4.1667	0.0281
64.96	52.08	0.13	19.8	-0.8861	1.7167	7.6923	0.0192
66.79	60.64	0.06	9.2	-1.2218	1.7828	16.6667	0.0165

Table 39: Ni Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with HCl

The Freundlich model for the adsorption of Ni on PKAC data fitted well for both activation temperatures except for that carbonized at 600˚C and activated with H_2SO_4 which recorded a low R^2 value, 0.276. The R^2 values ranged from 0.276 to 0.945. The range for the freundlich adsorption intensity is 0.30 to 2.05, while that for the K_f ranged from 1.5 to 2.3 x10¯4. Both Freundlich isotherm constants were generally high and they have an inverse relationship.

C$_o$(mg/l)	**C$_e$ (mg/l)**	**q$_e$ (mg/g)**	**E (%)**	**logq$_e$**	**logC$_e$**	**1/q$_e$**	**1/C$_e$**
55.47	21.31	0.34	61.6	-0.4685	1.3285	2.9412	0.0469
52.67	16.16	0.37	69.3	-0.4318	1.20844	2.7027	0.0619
59.35	7.15	0.52	87.9	-0.2840	0.8543	1.9231	0.1399
64.96	17.79	0.47	72.6	-0.3279	1.2502	2.1277	0.0562
66.79	45.74	0.21	31.5	-0.6778	1.6603	4.7619	0.0219

Table 40: Ni Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with H_3PO_4

C$_o$(mg/l)	**C$_e$ (mg/l)**	**q$_e$ (mg/g)**	**E (%)**	**logq$_e$**	**logC$_e$**	**1/q$_e$**	**1/C$_e$**
55.47	42.30	0.13	23.7	-0.8861	1.6263	7.6923	0.0236
52.67	39.81	0.13	24.4	-0.8861	1.5999	7.6923	0.0251
59.35	48.90	0.10	17.6	-1.0000	1.6893	10.0000	0.0204
64.96	53.08	0.12	18.3	-1.9208	1.7249	8.3333	0.0188
66.79	58.80	0.08	11.9	-1.0969	1.7694	12.5000	0.0170

Table 41: Ni Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with H_2SO_4

C$_o$(mg/l)	**C$_e$ (mg/l)**	**q$_e$ (mg/g)**	**E (%)**	**logq$_e$**	**logC$_e$**	**1/q$_e$**	**1/C$_e$**
55.47	25.56	0.30	53.9	-0.5229	1.4076	3.3333	0.0346
52.67	28.96	0.24	45.0	-0.6198	1.4618	4.1667	0.0381
59.35	30.44	0.29	48.7	-0.5376	1.4834	3.4483	0.0343
64.96	49.68	0.15	23.5	-0.8239	1.6962	6.6667	0.0197
66.79	64.15	0.03	3.96	-1.5229	1.8072	33.3333	0.0186

Table 42: Ni Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with HCl

Ni adsorption data on PKAC prepared relatively fitted well onto Langmuir isotherm model as the values of R^2 ranged from 0.497 to 0.941. Q^o ranged from 0.0010 to 0.054, while b ranged from 4.5 to 27.9 (tables 64, 65, 66 and 67).

C$_o$(mg/l)	**C$_e$ (mg/l)**	**q$_e$ (mg/g)**	**E (%)**	**logq$_e$**	**logC$_e$**	**1/q$_e$**	**1/C$_e$**
55.47	28.90	0.27	47.9	-0.5686	1.4609	3.7037	0.0346
52.67	26.22	0.26	50.2	-0.5850	1.4186	3.8462	0.0381
59.35	29.12	0.30	50.9	-0.5229	1.4642	3.3333	0.0343
64.96	50.77	0.14	21.9	-0.8539	1.7056	7.1429	0.0197
66.79	53.81	0.13	19.4	-0.8861	1.7309	7.6923	0.0186

Table 43: Ni Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with H_3PO_4

C_o(mg/l)	**C_e (mg/l)**	**q_e (mg/g)**	**E (%)**	**logq_e**	**logC_e**	**1/q_e**	**1/C_e**
55.47	12.38	0.43	77.7	-0.3665	1.0927	2.3256	0.0808
52.67	11.96	0.41	77.3	-0.3872	1.0777	2.4390	0.0836
59.35	14.49	0.45	75.6	-0.5468	1.1611	2.2222	0.0690
64.96	31.95	0.33	50.8	-0.4815	1.5044	3.0303	0.0313
66.79	55.99	0.11	16.2	-0.9586	1.7481	9.0909	0.0179

Table 44: Ni Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with H_2SO_4

C_o(mg/l)	**C_e(mg/l)**	**q_e (mg/g)**	**E (%)**	**logq_e**	**logC_e**	**1/q_e**	**1/C_e**
35.7	0.50	0.35	98.6	-0.4559	-0.3010	2.8571	2.0000
37.6	0.88	0.37	97.7	-0.4318	-0.0522	2.7027	1.1364
43.9	1.67	0.42	96.2	-0.3768	0.2227	2.3809	0.5988
57.2	6.32	0.51	88.9	-0.2924	0.8070	1.9608	0.1582
57.4	7.10	0.50	87.6	-0.3010	0.8513	2.0000	0.1408

Table 45: Pb Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with HCl

In the adsorption of Pb by the PKAC carbonized at both 600˚C and 800˚C, the data did not fit well into Freundlich adsorption isotherm model. The R^2 values were low except for Pb/PKAC/600˚C/HCl, Pb/PKAC/800˚C/HCl and Pb/PKAC/800˚C/H_2SO_4. The n for the adsorption of Pb by PKAC ranged from 5.59 to 28.6 indicating a high value for all the types of activated carbon produced with Palm kernel shell. Also, the range for the K_f values was 2.3 to 9.4.

C_o(mg/l)	**C_e (mg/l)**	**q_e (mg/g)**	**E (%)**	**logq_e**	**logC_e**	**1/q_e**	**1/C_e**
35.7	16.34	0.19	54.3	-0.7212	1.2133	5.2632	0.0612
37.6	22.3	0.15	40.7	-0.8239	1.3483	6.6667	0.0448
43.9	27.9	0.16	36.4	-0.7959	1.4456	6.2500	0.0358
57.2	38.11	0.19	33.3	-0.7212	1.5810	5.2632	0.0262
57.4	35.6	0.22	37.9	-0.6576	1.5515	4.5455	0.0281

Table 46: Pb Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with H_3PO_4

C_o(mg/l)	**C_e (mg/l)**	**q_e (mg/g)**	**E (%)**	**logq_e**	**logC_e**	**1/q_e**	**1/C_e**
35.7	5.81	0.29	83.7	-0.5376	0.7642	3.4483	0.1721
37.6	7.15	0.30	80.9	-0.5229	0.8543	3.3333	0.1399
43.9	16.2	0.28	63.1	-0.5528	1.2095	3.5714	0.0617
57.2	29.7	0.27	40.0	-0.5686	1.4728	3.7037	0.0337
57.4	28.3	0.29	43.7	-0.5376	1.4518	3.4483	0.0353

Table 47: Pb Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with H_2SO_4

C_o(mg/l)	**C_e (mg/l)**	**q_e (mg/g)**	**E (%)**	**logq_e**	**logC_e**	**1/q_e**	**1/C_e**
35.7	4.28	0.31	88.0	-0.5086	0.6314	3.2258	0.2336
37.6	5.87	0.32	84.4	-0.4949	0.7686	3.1250	0.1704
43.9	11.38	0.33	74.0	-0.4815	1.0561	3.0303	0.0879
57.2	19.98	0.37	65.0	-0.4318	1.3006	2.7027	0.0501
57.4	18.77	0.39	67.3	-0.4089	1.2735	2.5641	0.0533

Table 48: Pb Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with HCl

R^2 ranged from 0.141 to 0.906 for the adsorption of Pb onto PKAC and so the experimental data generated did fit well on most of the activated carbon types prepared from Palm Kernel shell. Only few of them had poor fit and the Langmuir constants (Q^O and b) were low in their respective values and so indicated poor adsorption capacity and adsorption energy for the Pb onto PKAC.

C_o(mg/l)	**C_e (mg/l)**	**q_e (mg/g)**	**E (%)**	**logq_e**	**logC_e**	**1/q_e**	**1/C_e**
35.7	4.78	0.31	86.6	-0.5086	0.6794	3.2259	0.2092
37.6	1.59	0.36	95.8	-0.4437	0.2014	2.7778	0.6289
43.9	6.96	0.37	84.1	-0.4318	0.8426	2.7027	0.1437
57.2	14.20	0.43	75.1	-0.3665	1.1523	2.3256	0.0704
57.4	16.77	041.	70.8	-0.3872	1.2245	2.4390	0.0596

Table 49: Pb Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with H_3PO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
35.7	3.66	0.32	89.8	-0.4949	0.5635	3.1250	0.2732
37.6	6.81	0.31	81.9	-0.5086	0.8331	3.2258	0.1468
43.9	13.90	0.30	68.3	-0.5229	1.1430	3.3333	0.0719
57.2	33.60	0.24	41.2	-0.6198	1.5263	4.1667	0.0298
57.4	37.50	0.20	34.6	-0.6990	1.5740	5.0000	0.0267

Table 50: Pb Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with H_2SO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
53.66	27.11	0.27	49.4	-0.5686	1.4331	3.7037	0.0369
53.06	28.56	0.24	46.1	-0.6198	1.4558	4.1667	0.0350
53.93	30.27	0.24	43.9	-0.6198	1.4810	4.1667	0.0330
55.73	48.61	0.07	12.7	-1.1549	1.6867	14.2857	0.0206
57.47	55.57	0.02	3.3	-1.6990	1.7448	50.0000	0.0180

Table 51: Cd Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with HCl

The Freundlich adsorption isotherm fitted well with the adsorption of Cd on PKAC in this study. The determination coefficient (R^2) ranged from 0.136 to 0.976. Only that carbonized at 800˚C and activated with HCl had a low R^2 value of 0.146 and indicated a poor fit. The Freundlich adsorption intensity and the adsorption capacity parameters for the Cd adsorption on PKAC were all high. They ranged from 0.31 to 6.33 and 1.7 to 15135.6 respectively.

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
53.66	2.41	0.51	95.5	-0.2924	0.3820	1.9608	0.4149
53.06	2.36	0.51	95.6	-0.2924	0.3729	1.9608	0.4237
53.93	1.14	0.53	53.9	-0.2757	0.0569	1.8868	0.8772
55.73	6.46	0.49	88.4	-0.3098	0.8102	2.0408	0.1548
57.47	19.84	0.38	65.4	-0.4202	1.2975	2.6316	0.0504

Table 52: Cd Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with H_3PO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
53.66	6.11	0.48	88.6	-0.3188	0.7860	2.0833	0.1637
53.06	5.72	0.47	89.2	-0.3279	0.7574	2.1277	0.1748
53.93	8.99	0.45	83.3	-0.3467	0.9538	2.2222	0.1112
55.73	15.12	0.41	72.8	-0.3872	1.1796	2.4390	0.0661
57.47	17.36	0.40	69.7	-0.3979	1.2395	2.5000	0.0576

Table 53: Cd Adsorption by Palm Kernel shell Carbonized at 600^{o}C and Activated with H_2SO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
53.66	29.15	0.25	45.6	-0.6021	1.4646	4.0000	0.0343
53.06	30.66	0.22	42.2	-0.6576	1.4866	4.5455	0.0326
53.93	32.07	0.22	40.5	-0.6576	1.5061	4.5455	0.0312
55.73	49.14	0.66	11.8	-0.1805	1.6914	1.5152	0.0204
57.47	55.34	0.02	3.7	-0.6990	1.7430	50.000	0.0181

Table 54: Cd Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with HCl

The experimental data for the adsorption of Cd on PKAC fitted well on the Langmuir isotherm model plot. R^2 ranged from 0.417 to 0.935. Those carbonised at 600^{o}C had a better fit than their counter parts. The Q^o ranged from 0.00053 to 1.5 while the b ranged from0.3 to 27.8.

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
53.66	5.28	0.48	90.1	-0.3188	0.7226	2.0833	0.1894
53.06	6.77	0.46	87.2	-0.3372	0.8306	2.1739	0.1477
53.93	8.10	0.46	84.9	-0.3372	0.9085	2.1739	0.1235
55.73	9.10	0.47	83.6	-0.3279	0.9590	2.1277	0.1099
57.47	15.67	0.42	72.7	-0.3768	1.1951	2.3810	0.0638

Table 55: Cd Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with H_3PO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
53.66	9.10	0.45	83.2	-0.3468	0.9590	2.2222	0.1099
53.06	8.76	0.44	83.4	-0.3565	0.9425	2.2727	0.1142
53.93	7.32	0.47	86.4	-0.3279	0.8645	2.1277	0.1366
55.73	4.49	0.51	91.9	-0.2757	0.6522	1.9608	0.2227
57.47	4.14	0.03	5.8	-1.5229	1.7335	33.3333	0.0185

Table 56: Cd Adsorption by Palm Kernel shell Carbonized at 800^oC and Activated with H_2SO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	0.67	0.74	99.1	-0.1308	-0.1739	1.3514	1.4925
114.69	16.16	0.99	85.9	-0.0044	1.2084	1.0101	0.0619
135.2	28.30	1.07	79.0	0.0294	1.4518	0.9346	0.0353
145.14	40.65	1.04	71.9	0.0170	1.6091	0.9615	0.0246
147.28	38.91	1.08	73.5	0.0334	1.5901	0.9259	0.0257

Table 57: Mn Adsorption by Palm Kernel shell Carbonized at 600^oC and Activated with HCl

The adsorption data for Mn adsorption by PKAC were poorly fitted on the Freundlich adsorption isotherm model. The values ranged from 0.177 to 0.980. It was only that carbonized at 600˚C and activated with HCl that had a good fit (R^2=0.980). The values of the Freundlich adsorption intensities and adsorption capacities were generally high and ranged from 2.11 to 20.41 and 1.1 to 17.3 respectively.

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	28.12	0.47	62.5	-0.3279	1.4490	2.1277	0.0356
114.69	66.79	0.48	41.8	-0.3188	1.8247	2.0833	0.0150
135.2	86.79	0.48	35.9	-0.3188	1.9385	2.0833	0.0115
145.14	91.14	0.54	37.2	-0.2676	1.9597	1.8519	0.0110
147.28	99.6	0.48	32.3	-0.3188	1.9983	2.0833	0.0100

Table 58: Mn Adsorption by Palm Kernel shell Carbonized at 600^oC and Activated with H_3PO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	12.4	0.63	83.4	-0.2007	1.0934	1.5873	0.0806
114.69	16.8	0.98	85.3	-0.0088	1.2253	1.0204	0.0595
135.2	51.4	0.84	61.9	-0.0757	1.7110	1.1905	0.0195
145.14	86.3	0.59	40.5	-0.2291	1.1963	1.6949	0.0116
147.28	103.2	0.44	29.9	-0.3565	2.0137	2.2727	0.0097

Table 59: Mn Adsorption by Palm Kernel shell Carbonized at 600^oC and Activated with H_2SO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	56.65	0.22	29.8	-0.6576	1.7214	4.5455	0.0190
114.69	89.39	0.25	22.0	-0.6021	1.9513	4.0000	0.0112
135.2	120.30	0.15	11.0	-0.8239	2.0803	6.6667	0.0083
145.14	44.92	0.00	68.9	-0.0000	1.6524	0.0000	0.0223
147.28	6.28	0.41	95.7	-0.1492	0.7980	0.7092	0.1592

Table 60: Mn Adsorption by Palm Kernel shell Carbonized at 800^oC and Activated with HCl

The adsorption data of Mn by PKAC did not fit well on the Langmuir isotherm model. This can easily be seen by looking at the R^2 values which ranged from 0.122 to 0.972, so also it was for Q^o but b was relatively high (0.3 to 19.0).

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	37.46	0.38	50.1	-0.4202	1.5736	2.6316	0.0267
114.69	53.48	0.61	53.3	-0.2147	1.7282	1.6393	0.0187
135.2	92.44	0.43	31.6	-0.3665	1.9659	2.3256	0.0108
145.14	116.55	0.29	19.7	-0.5376	2.0665	2.0665	0.0086
147.28	117.26	0.30	20.3	-0.5229	2.0691	2.0691	0.0085

Table 61: Mn Adsorption by Palm Kernel shell Carbonized at 800^oC and Activated with H_3PO_4

C_o(mg/l)	C_e (mg/l)	q_e (mg/g)	E (%)	logq_e	logC_e	1/q_e	1/C_e
75.05	18.76	0.56	75.0	-0.2518	1.2732	1.7857	0.0533
114.69	40.49	0.74	64.7	-0.1308	1.6073	1.3514	0.0247
135.2	73.31	0.62	45.8	-0.2076	1.8652	1.6129	0.0136
145.14	136.14	0.09	60.1	-1.0458	2.1340	11.1111	0.0073
147.28	137.27	0.10	6.8	-1.0000	2.1376	10.0000	0.0073

Table 62: Mn Adsorption by Palm Kernel shell Carbonized at 800^{o}C and Activated with H_2SO_4

Freundlich adsorption capacities for Activated carbon produced from Peanut seed ranged from 1.1 to 7.2x10^4 (table 64). For Mn/PNAC/600^{0}C/H_3PO_4, the K_f value tends towards infinity but looking at the determination coefficient (0.006), it shows that the Freundlich isotherm did not have a good fit and so it gave a doubtful value for the K_f. This shows that it is better to use more than a single error measurement to confirm the goodness of fit between the data and the Freundlich Isotherm model, as there are instances where one parameter indicates a poor fit and the other indicates a good fit (Coles, et al., 2006). The goodness of fit of an experimental data is measured by the determination coefficients (R^2) (Zaid and Mohammed, 2008). The R^2 for the isotherm studied are as summarized in table 64, and it could be deduced from the table that the Freundlich model showed a better fit for all the Peanut seed activated carbon except for Pb/PNAC/600^{0}C/HCl, Mn/PNAC/600^{0}C/HCl, Mn/PNAC/800^{0}C/H_2SO_4, Mn/PNAC/600^{0}C/H_2SO_4 and Mn/PNAC/600^{0}C/H_3PO_4.

The value of n is a function of the strength of the adsorbent materials used. When the value of n is high, it showed the adsorption bond is weak and when n > 1, the absorption coefficient increases with increasing concentration of the solution which lead to an increase in the surface characteristic after monolayer adsorption. When the value of n < 1, K_f decreases with concentration in most of the activated carbon types. This is also in line with Hamidi et al., (2003) observation.

S/N	AC Type	Equation	R^2	n	K_f
1	Ni PNAC 600^{0}C HCl	Y =-0.678x+0.446	0.924	1.47	2.8
2	Ni PNAC 600^{0}C H_2SO_4	Y =-0.180x-0.259	0.596	5.56	1.8
3	Ni PNAC 600^{0}C H_3PO_4	Y =-1.641x+1.792	0.861	0.61	61.9
4	Ni PNAC 800^{0}C HCl	Y =-1.402x+1.447	0.883	0.71	28.0
5	Ni PNAC 800^{0}C H_2SO_4	Y =-0.699x+0.462	0.888	1.43	2.9
6	Ni OBAC 800^{0}C H_3PO_4	Y =-0.672+0.423	0.792	1.49	2.6
7	Pb PNAC 600^{0}C HCl	Y =0.037x-0.355	0.021	27.0	2.3
8	Pb PNAC 600^{0}C H_2SO_4	Y =0.172x-0.384	0.650	5.81	2.4
9	Pb PNAC 600^{0}C H_3PO_4	Y =0.190x-0.398	0.820	5.26	2.5
10	Pb PNAC 800^{0}C HCl	Y =-0.247x-0.348	0.727	4.05	2.2
11	Pb PNAC 800^{0}C H_2SO_4	Y =-0.259x-0.329	0.571	3.86	2.1
12	Pb PNAC 800^{0}C H_3PO_4	Y =-0.307x-0.299	0.657	3.26	2.0
13	Cd PNAC 600^{0}C HCl	Y =-2.664x+3.17	0.861	0.38	1.4x10^3
14	Cd PNAC 600^{0}C H_2SO_4	Y =-2.972x+3.858	0.985	0.34	7.2x10^3
15	Cd PNAC 600^{0}C H_3PO_4	Y =-3.670x+4.862	0.916	0.27	7.2x10^4
16	Cd PNAC 800^{0}C HCl	Y =-2.630x+3.076	0.918	0.38	1.1x10^3
17	Cd PNAC 800^{0}C H_2SO_4	Y =-0.467x+0.051	0.891	2.14	1.1
18	Cd PNAC 800^{0}C H_3PO_4	Y =-2.149x+2.594	0.816	0.47	392.6
19	Mn PNAC 600^{0}C HCl	Y =0.356x-0.749	0.297	2.81	5.6
20	Mn PNAC 600^{0}C H_2SO_4	Y =-0.526x+0.534	0.366	1.90	3.4
21	Mn PNAC 600^{0}C H_3PO_4	Y =237.4x-793.2	0.006	0.004	∞
22	Mn PNAC 800^{0}C HCl	Y =-1.052x+1.437	0.639	0.95	27.4
23	Mn PNAC 800^{0}C H_2SO_4	Y =-0.597x+0.672	0.425	1.68	4.7
24	Mn PNAC 800^{0}C H_3PO_4	Y =-0.579x+0.658	0.526	1.73	4.5

Table 63: Freundlich Adsorption Isotherm Constants for Peanut Activated Carbon

S/N	AC Type	Equation	R^2	n	K_f
1	Ni PKAC 600^{0}C HCl	Y = -1.878x+2.221	0.862	0.53	166
2	Ni PKAC 600^{0}C H_3PO_4	Y = -0.487x+0.176	0.837	2.05	1.5
3	Ni PKAC 600^{0}C H_2SO_4	Y = -3.287x+4.371	0.276	0.30	2.3x10^4
4	Ni PKAC 800^{0}C HCl	Y = -2.222x+2.686	0.829	0.45	485.3
5	Ni PKAC 800^{0}C H_3PO_4	Y = -1.121x+1.061	0.945	0.89	11.5
6	Ni PKAC 800^{0}C H_2SO_4	Y = -0.691x+0.362	0.727	1.45	2.3
7	Pb PKAC 600^{0}C HCl	Y = 0.143x-0.415	0.989	6.99	2.6
8	Pb PKAC 600^{0}C H_3PO_4	Y = 0.161x-0.973	0.134	6.21	9.4

9	Pb PKAC 600^0C H_2SO_4	Y = -0.035x-0.503	0.441	28.6	3.2
10	Pb PKAC 800^0C HCl	Y = 0.132x-0.598	0.858	7.58	4.0
11	Pb PKAC 800^0C H_3PO_4	Y = 0.085x-0.497	0.405	11.8	3.1
12	Pb PKAC 800^0C H_2SO_4	Y = -0.179x-0.366	0.801	5.59	2.3
13	Cd PKAC 600^0C HCl	Y = -3.276x+4.180	0.928	0.31	$1.5x10^4$
14	Cd PKAC 600^0C H_3PO_4	Y = -0.112x-0.252	0.859	8.93	1.8
15	Cd PKAC 600^0C H_2SO_4	Y = -0.158x-0.200	0.976	6.33	1.6
16	Cd PKAC 800^0C HCl	Y = 0.614x-1.528	0.135	1.63	33.7
17	Cd PKAC 800^0C H_3PO_4	Y = -0.113x-0.234	0.817	8.85	1.7
18	Cd PKAC 800^0C H_2SO_4	Y = -1.263x+0.735	0.941	0.79	5.4
19	Mn PKAC 600^0C HCl	Y = 0.090x-0.113	0.980	11.1	1.3
20	Mn PKAC 600^0C H_3PO_4	Y = 0.049x-0.400	0.208	20.41	2.5
21	Mn PKAC 600^0C H_2SO_4	Y = -0.144x+0.035	0.177	6.94	1.1
22	Mn PKAC 800^0C HCl	Y = -0.473x+0.330	0.452	2.11	2.1
23	Mn PKAC 800^0C H_3PO_4	Y = 10.348x+0.243	0.342	2.87	1.7
24	Mn PKAC 800^0C H_2SO_4	Y = -0.98x+1.240	0.631	10.2	17.3

Table 64: Freundlich Adsorption Isotherm Constants for Palm Kernel Activated Carbon

The Freundlich isotherm model showed a good fit for virtually all the type of activated carbon produced from Palm kernel shell except for Ni/PKAC/600^0C/H_2SO_4, Pb/PKAC/600^0C/H_3PO_4, Pb/PKAC/600^0C/H_2SO_4, Cd/PKAC/800^0C/HCl, Mn/PKAC/600^0C/H_3PO_4, Mn/PKAC/600^0C/H_2SO_4, Mn/PKAC/800^0C/HCl, Mn/PKAC/800^0C/H_3PO_4. R^2 ranged from 0.134 to 0.989. The adsorption intensity parameter ranged from 0.30 to 28.6. n being greater than 0ne is also an indication of the favourability of heavy metal adsorption (Gupta, et al., 1999). This shows relative high adsorption intensities for the Palm kernel activated carbons. Similar observation was obtained for the Freundlich adsorption capacity parameter which had a range of 1.1 to $2.3x10^4$ (Table 65).

The extent of adsorption of Ni, Pb, Cd and Mn on the prepared Peanut Seed activated carbon which was tested by the essential feature of the Langmuir isotherm model, showed that their adsorption were all favourable ($0 < R_L < 1$). The Langmuir energy of adsorption (b) from table shows good adsorption energy for most of the activated carbon types. A confirmation of of the fitness of experiment data into the Langmuir isotherm model indicates the homogeneous nature of the adsorbent surface. The result also demonstrates the formation of monolayer coverage of Ni, Pb, Cd and Mn ions at the outer layer of the adsorbents (Hameed et al., 2006).

Considering the determination coefficients for the Peanut activated carbons prepared, it shows that the Langmuir isotherm had a better fit when compared with that of the PKAC (table 66).

S/N	**AC Type**	**Equation**	**R^2**	**Q^o**	**b (l/mg)**	**R_L**
1	Ni PNAC 600^0C HCL	Y=-2219x+102.7	0.603	0.00045	21.60	0.0007
2	Ni PNAC 600^0C H_3PO_4	Y=-468.8x+21.63	0.630	0.02100	21.70	0.0007
3	Ni PNAC 600^0C H_2SO_4	Y=-17.42x+3.977	0.629	0.05700	4.400	0.003
4	Ni PNAC 800^0C HCL	Y=-256.4x+14.44	0.727	0.00390	17.80	0.0008
5	Ni PNAC 800^0C H_3PO_4	Y=-85.02x+6.733	0.728	0.01200	12.60	0.001
6	Ni PNAC 800^0C H_2SO_4	Y=-89.63x+6.943	0.838	0.01100	12.90	0.001
7	Pb PNAC 600^0C HCL	Y=0.540x+1.849	0.691	1.90000	0.290	0.057
8	Pb PNAC 600^0C H_3PO_4	Y=0.540x+1.849	0.691	1.90000	0.290	0.057
9	Pb PNAC 600^0C H_2SO_4	Y=0.499x+1.866	0.464	2.00000	0.270	0.061
10	Pb PNAC 800^0C HCL	Y=-0.660x+3.153	0.646	1.50000	0.200	0.080
11	Pb PNAC 800^0C H_3PO_4	Y=-26.76x+6.727	0.726	0.03700	4.000	0.0043
12	Pb PNAC 800^0C H_2SO_4	Y=-19.34x+5.942	0.507	0.05200	3.300	0.0053
13	Cd PNAC 600^0C HCL	Y=1134x+50.56	0.521	0.00088	22.40	0.0008
14	Cd PNAC 600^0C H_3PO_4	Y=-2393x+39.49	0.966	0.00042	30.30	0.0006
15	Cd PNAC 600^0C H_2SO_4	Y=1203x+39.49	0.966	0.00083	30.50	0.0006
16	Cd PNAC 800^0C HCL	Y=-1181x+54.57	0.641	0.00085	21.60	0.0008
17	Cd PNAC 800^0C H_3PO_4	Y=-588.3x+22.15	0.713	0.00170	26.60	0.0007
18	Cd PNAC 800^0C H_2SO_4	Y=-17.77x+5.120	0.707	0.05600	3.500	0.0049
19	Mn PNAC 600^0C HCL	Y=32.12x+0.744	0.414	0.03100	43.20	0.0002
20	Mn PNAC $600^0CH_2SO_4$	Y=-100.6x+4.6	0.247	0.00990	21.90	0.0003
21	Mn PNAC 600^0C H_3PO_4	Y=-56.10x+3.566	0.293	0.01800	15.70	0.0004
22	Mn PNAC 800^0C HCL	Y=-238.4x+8.378	0.509	0.00420	28.50	0.0002
23	Mn PNAC $800^0CH_3PO_4$	Y=-52.89x+3.765	0.335	0.01900	14.00	0.0005
24	Mn PNAC $800^0CH_2SO_4$	Y=-52.32x+4.898	0.201	0.01900	10.70	0.0006

Table 65: Langmuir Adsorption Isotherm Constants for Peanut Seed Activated Carbon

The Langmuir isotherm constants determined from the slopes and intercepts of the respective plot for PKAC are summarized in table 67. Although the constants are specific to test conditions and adsorption types, the results indicates they all had a favourable separation factor ($0<R_L<1$). The Langmuir adsorption energy was also favourable having recorded high values. So also it was for the determination coefficients of the respective activated carbon types prepared.

S/N	**AC Type**	**Equation**	**R^2**	**Q^o**	**b (l/mg)**	**R_L**
1	Ni PKAC 600^{0}C HCL	Y=-690.2x+24.78	0.740	0.00140	27.90	0.0005
2	Ni PKAC 600^{0}C H_3PO_4	y=-488.5x+19.49	0.635	0.00200	25.10	0.003
3	Ni PKAC 600^{0}C H_2SO_4	Y=-18.61x+4.108	0.540	0.05400	4.500	0.0006
4	Ni PKAC 800^{0}C HCL	Y=-999.9x+39.24	0.497	0.00100	25.50	0.0006
5	Ni PKAC 800^{0}C H_3PO_4	Y=-221.3x+11.57	0.941	0.00450	19.10	0.0008
6	Ni PKAC 800^{0}C H_2SO_4	Y=-76.88x+8.167	0.607	0.01300	19.10	0.002
7	Pb PKAC 600^{0}C HCL	Y=0.492x+1.983	0.906	2.03000	0.200	0.080
8	Pb PKAC 600^{0}C H_3PO_4	Y=15.18x+5.002	0.065	0.06600	3.000	0.005
9	Pb PKAC 600^{0}C H_2SO_4	Y=-1.434x+3.628	0.417	0.70000	0.400	0.041
10	Pb PKAC 800^{0}C HCL	Y=3.119x+2.558	0.782	0.30000	1.200	0.012
11	Pb PKAC 800^{0}C H_3PO_4	Y=0.559x+2.569	0.141	1.80000	0.200	0.080
12	Pb PKAC 800^{0}C H_2SO_4	Y=-5.674x+4.392	0.535	0.20000	1.300	0.013
13	Cd PKAC 600^{0}C HCL	Y=-1885x+69.39	0.684	0.00053	27.20	0.0006
14	Cd PKAC 600^{0}C H_3PO_4	Y=0.0680x+2.357	0.512	1.50000	0.300	0.055
15	Cd PKAC 600^{0}C H_2SO_4	Y=-3.337x+2.657	0.935	0.30000	1.300	0.013
16	Cd PKAC 800^{0}C HCL	Y=-1789x+61.89	0.417	0.00056	27.80	0.0006
17	Cd PKAC 800^{0}C H_3PO_4	Y=-2.081x+2.452	0.714	0.50000	0.800	0.021
18	Cd PKAC 800^{0}C H_2SO_4	Y=-150.4x+26.49	0.618	0.00660	5.700	0.0030
19	Mn PKAC 600^{0}C HCL	Y=0.271x+0.947	0.972	3.70000	0.300	0.022
20	Mn PKAC 600^{0}C H_3PO_4	Y=4.614x+1.969	0.203	0.20000	2.300	0.0029
21	Mn PKAC 600^{0}C H_2SO_4	Y=-6.68x=1.794	0.191	0.10000	3.700	0.0018
22	Mn PKAC 800^{0}C HCL	Y=-23.99x+4.240	0.311	0.04000	5.700	0.0012
23	Mn PKAC 800^{0}C H_3PO_4	Y=16.19x+1.909	0.122	0.06000	8.500	0.0007
24	Mn PKAC 800^{0}C H_2SO_4	Y=-164.5x+8.667	0.413	0.00600	19.00	0.0004

Table 66: Langmuir Adsorption Isotherm Constants for Palm Kernel shell Activated Carbon

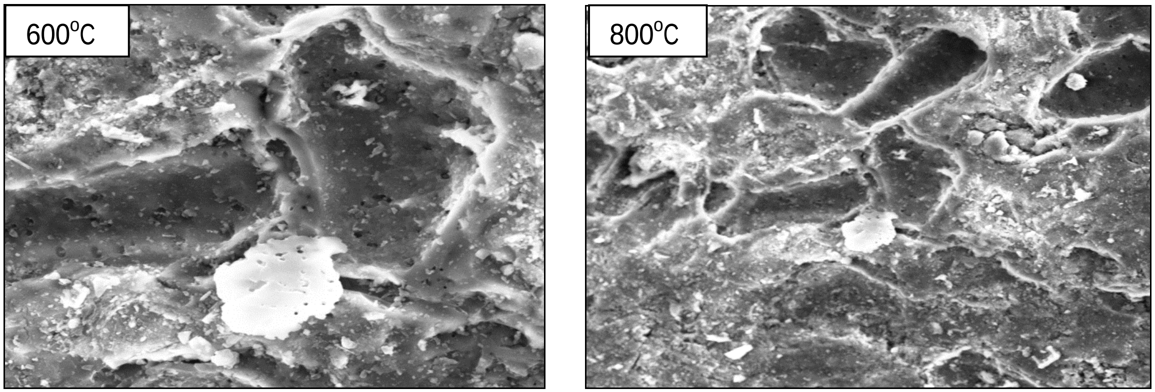

Figure 18: SEM image of Paim Kernel Carbonised at 600^{o}C and 800^{o}C
15.0kv. mag =5000x. 20µm. wd = 16.0mm

For Palm Kernel carbons produced, there was a poor pore development before activation but after activation, there were several pores developed by the chemical activation process (figure 19). This may be as a result of the lack of impurities like tars that could clog the pores. The pores developed were not evenly distributed and was of macro and micro sizes. Looking at figure 19, we can deduce that that carbonized at 800^{o}C had a better pores that its counterpart.

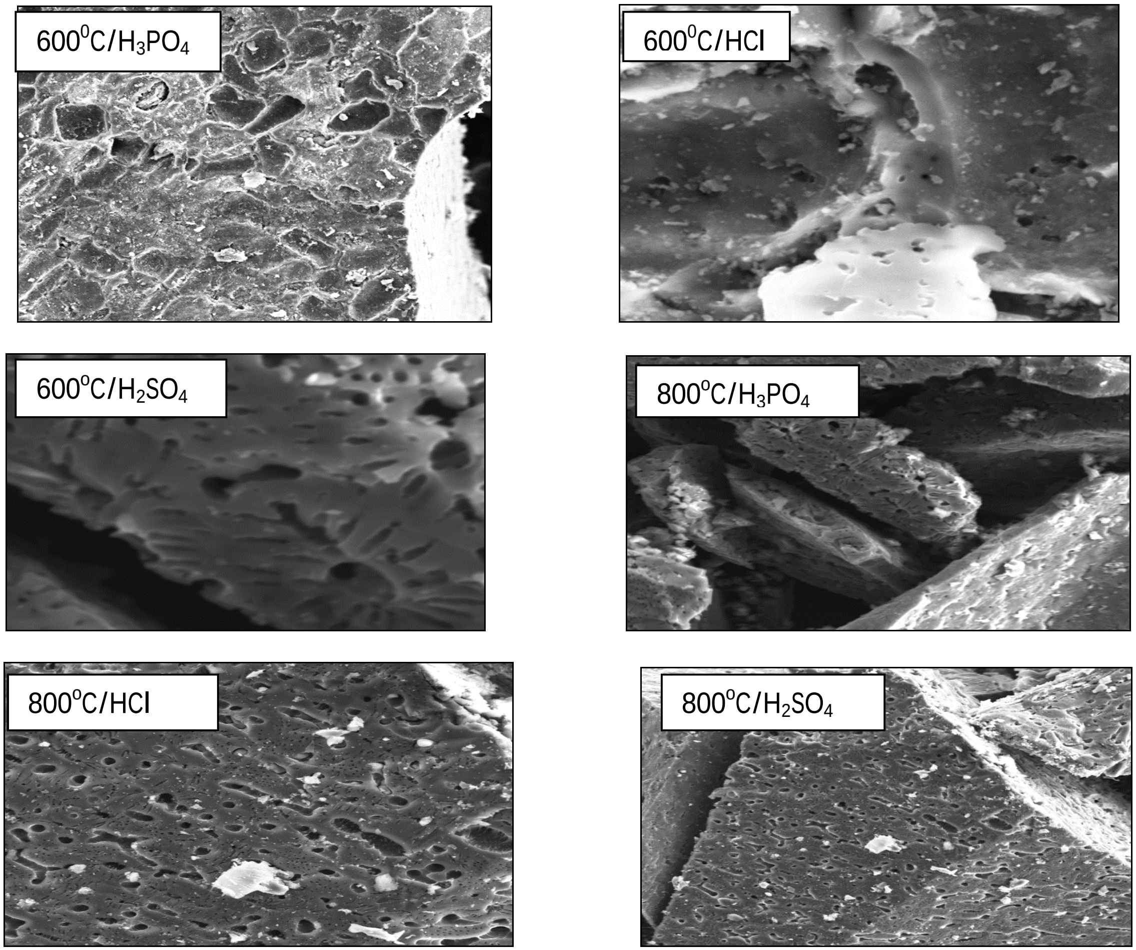

Figure 19: SEM image of Paim Kernel Carbonised at 600^{o}C & 800^{o}C and Activated with acids
15.0kv. mag =5000x. 20µm. wd = 16.0mm

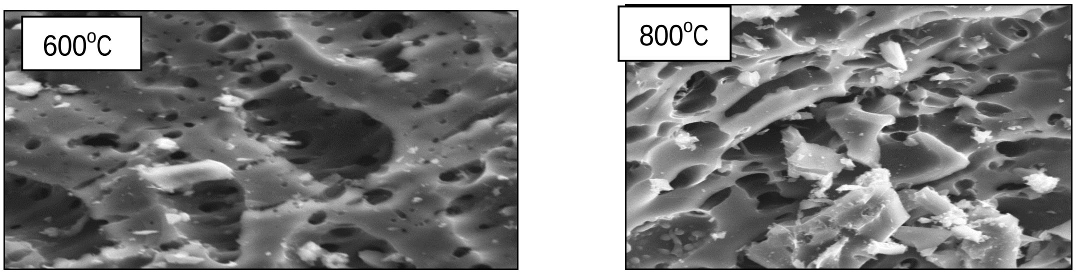

Figure 20: SEM image of Peanut Seed Carbonised at 600^{o}C and 800^{o}C
15.0kv. mag =5000x. 20µm. wd = 16.0mm

The morphological structure of the peanut seed activated carbon has honeycomb-like structures as shown in figure 20 and 21. The SEM photograph is characterised by a rough surface with many non orderly pores developed. The pores on the activated carbon were finely structured unlike that inactivated carbon produced from Peanut seed. There was not much physical difference between the different types of activated carbons produced. This indicates that there adsorption capacity will be somewhat close to each other. Those activated with H_2SO_4 irrespective of the carbonization temperatures showed better and larger pores than others.