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BIOSORPTION OF Cd^{2+}, Cr^{3+}, Pb^{2+}, Hg^{2+}, and Ni^{2+} FROM AQUEOUS SOLUTIONS USING BEANS HUSK (BH)

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ABSTRACT

The adsorption capacity of beans husk (Vigna Unguiculatae) towards metal ions such as Cd^{2+}, Pb^{2+}, Hg^{2+}, Cr^{3+}, and Ni^{2+} were studied. The adsorption capacity was investigated using batch experiments under different experimental conditions such as pH, contact time, adsorbent dosage, adsorbent temperature and metal ion concentration to identify the optimum conditions. The effects of these parameters on the adsorption capacity were studied. The adsorption data were modeled using both the Langmuir and Freundlich adsorption isotherms. The results showed that the removal of ion percentages increased with increase in sorbent temperature (298^0K-343^0K). The effect of metal ion concentration was studied at six different concentrations (40 -140 ppm) and the results showed that the removal percentages increased as pH increased (pH 4-14). The fitness of experimental data to equilibrium isotherm models was tested and thermodynamic parameters were equally calculated. The values of the separation factor (R_L) for beans husk were in the range of 0.463-0.373 which indicated favourable biosorption. The biosorption process of the metal ions onto BH was favoured by Freundlich model. Results showed that the Pseudo-Second order equation provided the best model for the biosorption process of the metal ions onto BH. Thermodynamics parameter evaluation for all the metal ions gave a positive value of ΔH^o. ΔH^o for BH were 31.37KJ/mol, 38.63KJ/mol, 29.99KJ/mol, 12.06KJ/mol, 1.29KJ/mol for Cd^{2+}, Pb^{2+}, Hg^{2+}, Cr^{3+}, and Ni^{2+} respectively. The negative values of the Gibbs free energy at all the temperatures (298k-343k) showed that the adsorption process was spontaneous while the positive values of ΔS^o (0.105,0.141,0.129,0.042,0.009KJ/mol) for Cd^{2+}, Pb^{2+}, Hg^{2+}, Cr^{3+}, and Ni^{2+} respectively reflected good affinity of the metal ions towards the beans husk. The results have established that BH has a good potential to be used as biosorbent for the removal of cadmium, chromium, nickel, mercury and lead from waste water.

Keywords: Biosorption, Beans Husk; Metal ions, Isotherms; Kinetics.

INTRODUCTION

The term heavy metal is commonly used to describe the group of dense metals or their related compounds, usually associated with environmental pollution or toxicity. Heavy metal is a term used to denote a metal that is toxic to human and aquatic life[1,2]. Broad definition of heavy metals may be applied to toxic metalloids, like arsenic, as well as nutritionally-essential trace minerals with potential toxicities at elevated intake or exposure (eg, iron, zinc, copper, nickel, mercury)[1]. Unlike organic pollutant, the majority of which are susceptible to biological degradation, heavy metal ions do not degrade into harmless end products.

Cadmium is biopersistent and once absorbed by an organism, remains resident for many years (over decades for humans) although it is eventually excreted[4=5].

Lead

Lead affects almost every organ system in the human body. Its sources include pesticides used on fruits and vegetables, tap water, cigarette smoke, hair dyes, paints, inks, glazes, pesticide residues and occupational exposure in battery manufacture and other industries[4=5].

Mercury

Mercury is a heavy metal occurring in several forms, all of which can produce toxic effects in high enough doses.

It is a toxic substance which has no known function in human biochemistry or physiology and does not occur naturally in living organisms[5].

Chromium

Low-level exposure can irritate the skin and cause ulceration. Long-term exposure can cause kidney and liver damage, and damage circulatory and nerve tissue. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium[11].

Nickel

In small quantities nickel is essential, but when the uptake is too high it can be a danger to human health. It is found in large quantities, sadly in some older hydrogenated oils (margarine, commercial peanut butter and shortening), shellfish, air pollution, cigarette smoke, plating and occupational exposure[7].

Cowpeas are one of the most important food legume crops in the semi-arid tropics covering Asia, Africa, southern Europe and Central and South America. A drought-tolerant and warm-weather crop, cowpea is well-adapted to the drier regions of the tropics, where other food legumes do not perform well. It also has the useful ability to fix atmospheric nitrogen through its root nodules, and it grows well in poor soils with more than 85% sand, less than 0.2% organic matter and low levels of phosphorus[8]. In addition, it is shade tolerant, so is compatible as an intercrop with maize, millet, sorghum, sugarcane, and cotton. This makes cowpea an important component of traditional intercropping systems, especially in the complex and elegant subsistence farming systems of the dry savannas in sub-Saharan Africa. Note that beans husk is a waste.

This study is to know how the heavy metal ions such as Cd^{2+}, Cr^{3+}, Pb^{2+}, Hg^{2+} and Ni^{2+} can be removed from aqueous solutions using beans husk (BH).

EXPERIMENTAL

Adsorbent Materials

The Beans Husk (BH) used in this research was collected from Amansea in Awka North Local government of Anambra State. The beans husk was oven dried for 24 hours at 300^{0}C and ground severally into powdered form and was sieved into six different particle sizes of 0.075µm, 0.10µm, 0.25µm, 0.5µm, 0.71µm and 1µm.

Chemical Activation of the Adsorbents

The adsorbent was boiled with 0.04M HNO_3 for 1 hour to activate it. It was then washed several times with distilled water, dried, ground again and sieved into six different particle sizes.

Stock solutions of the following metal ions were prepared in deionised water:

i. 1000 *ppm* solution of Pb(II) ion was prepared by dissolving 1.5999g of $Pb(NO_3)_2$ in deionised water and the volume was made up to the mark in a 1000 ml volumetric flask.

ii. 1000 *ppm* solution of Cd(II) ion solution was prepared by dissolving 2.774g of $Cd(NO_3).4H_2O$ in deionised water and the volume was made up to the mark in a 1000 ml volumetric flask.

iii. 1000 *ppm* solution of Ni(II) ion was prepared by dissolving 4.951g of $Ni(NO_3)_2.6H_2O$ in deionised water and the volume was made up to mark in a 1000 ml volumetric flask.

iv. 1000 *ppm* solution of Cr(III) ion was prepared by dissolving 3.73g of K_2CrO_4 in deionized water and the volume was made up to mark in a 1000 mL volumetric flask.

v. 1000 *ppm* solution of Hg(II) ion was prepared by dissolving 1.59g of $Hg(CH_3COO)_2$ in deionized water and the volume was made up to mark in a 1000 ml volumetric flask.

All solutions used in this study were prepared by serial dilution of the standard solutions using deionized water. All the salts used were of analytical grade.

Characterization of the Adsorbent

The beans husk was characterized for its moisture content, ash content, pH, surface area, specific gravity and bulk density.

The batch adsorption process of the metal ions was carried out to determine the effect of adsorbent dosage, effect of pH of the solution, initial concentrations and contact time on the adsorption of metal ions on the BH.

The metal ions uptake (Adsorption capacity) at a particular time q_t and the uptake percentage (% removal of metal ion) was determined by mass balance, as follows: $q_t = \frac{(C_o - C_t)\,V}{W}$ (1)

Uptake percentage =

$$\frac{(C_o - C_t)}{C_o} \text{ X } \frac{100}{1} \quad (2)$$

Where $q_t =$ the amount of metal ion adsorbed (mg per g of sorbent) at time "t", "V" was the volume of the sample solution, "W" denoted the weight of sorbent (g), "C_o" and "C_t" are the initial metal concentration in the aqueous solution (mg/l) and metal concentration at time t, respectively. Metal ion uptake (adsorption capacity) at equilibrium q_e was determined by mass balance using Equation 3:

$$q_e = \frac{(C_o - C_e)V}{w} \quad (3)$$

Where:

q_e is the equilibrium adsorption capacity (mg/g), c_o and c_e are the initial and equilibrium metal concentrations in the water (mg/L), respectively

V is the Volume of used solution (l)

W is the weight of used adsorbent (g).

These equations were used to obtain the percentage removal or percentage adsorption of the metal ions and the quantity of metal ions adsorbed at a time t and at equilibrium.

All studies were carried out in triplicate, and the mean values are reported.

Determination of Effects of Adsorbent Dosage on the Adsorbent

The amount of Cd^{2+}, Cr^{3+}, Hg^{2+}, Ni^{2+} and Pb^{2+} ions adsorbed by beans husk was studied at different adsorbent doses at a fixed concentration (150mgL^{-1}) of the metal ions. To aliquots (20mL) of the metal ions in separate conical flasks, the required amount (0.2g, 0.4g, 0.6g, 0.8g, 1g and 2g) of the adsorbent was added. Each flask was corked and shaken on an electrical shaker for 30 mins with a constant agitation speed of 500 rpm and then filtered. The metal ion contents of these filtrates were determined using Atomic Absorption Spectrometer (AA 240 FS). The amount of metal ion sorbed at equilibrium q_e(mg/g) and percentage adsorbed was calculated .

Determination of the Effect of contact time on Adsorption of Metal Ions by BH

By keeping all other variable constant, the effect of contact time on the amount of removal of metal ions from the solution were obtained by contacting 20mL of 150mg/L of the metal solutions with 2g of the adsorbents at the optimum pH and room temperature. The sample was agitated for the time of 20 to 120 mins respectively in plastic tube at 200rpm and at room temperature. Then the sample was filtered with Whatmann filter paper no. 1 and the concentrations of the filtrate solutions at each time were analyzed using Atomic Absorption Spectrometer (AA 240 FS). The amount of metal sorbed at equilibrium q_e(mg/g) and percentage adsorbed was calculated with equations 1-3.

Determination of the Effect of pH on the Adsorption of Metal Ions by BH

The effect of pH on the amount of Metal ions removal was analyzed over the pH range of 4 to 14. 20mL of the metal solutions of 150mg/L was taken in plastic tube and was agitated with 2g of BH at 200rpm for 2hrs at room temperature.

The sample was filtered using Whatmann filter paper no 1 and the concentrations of the metal ion solutions were analyzed using Atomic Absorption Spectrophotometer (AA 240 FS). The amount of metal sorbed at equilibrium q_e(mg/g) and percentage adsorbed was calculated with equations 1-3.

Determination of the Effect of metal ion concentration on the Adsorbent

Different metal ion concentrations were used ranging from (40-140ppm).The beans husk (2g) was dispersed into 20 mL of the separate metal ion solutions. Each mixture was shaken mechanically on a shaker for 90 mins at room temperature (30^0C) and filtered. The residual concentration of metal ions in the filtrate was determined using AAS (AA 240 FS). The amount of metal sorbed at equilibrium q_e(mg/g) and percentage adsorbed was calculated with equations 1-3.

Determination of the Effects of Temperatures on the Adsorbent

The sorption experiments for the adsorption of metal ion system were carried out using 20ml of 150mg/L of metal ion concentration on the adsorbent (BH).The metal solutions were adjusted to pH 8.0 and agitated manually on a magnetic stirrer for 60 mins. This was carried out at different temperatures of 25^0C to 70^0C. At the end of the time, the suspension was filtered through what man No.41 filter paper. The filtrates were analyzed using Atomic Absorption spectrophotometer (AA 240 FS). The amount of metal sorbed at equilibrium q_e(mg/g) and percentage adsorbed was calculated with equations 1-3.

Determination of the Effect of particle size on the Adsorbent

2g of 0.075µm adsorbent was introduced into a beaker containing 20mL of 150mg/L of metal ion solutions with the pH and temperature (pH14 and 70^0C) respectively. The mixture of the solution was shaken manually on the magnetic stirrer for 1 hr and was filtered. The filtrate was used to determine the metal ions using AAS. The same procedure was used for other adsorbent particle sizes. The amount of metal sorbed at equilibrium q_e(mg/g) and percentage adsorbed was calculated with equations 1-3.

RESULTS AND DISCUSSION

Physico-Chemical Characterization of the adsorbent

The physico-chemical characteristics of BH are shown in Table 1. From the analysis it can be observed that the BH has low moisture content, ash content, pH, specific gravity, bulk density and high surface area.

Table 1: *Physical Characteristics of BH Composition BH*

Parameter	BH
Moisture content (%)	3.00
Ash content (%)	4.00
pH	5.05
Surface Area (m^2/g)	1191
Specific Gravity	0.01
Density (g/cm^3)	0.01

Effect of Adsorbent Dosage

The biosorbent dosage is an important parameter because this determines the capacity of a biosorbent for a given initial concentration.

Fig 1 shows the adsorption capacity of Cd (II) as a function of adsorbent dosage. It is clear from fig 1 that cadmium adsorption was found to increase with increasing adsorbent dose (other ions followed similar trend).

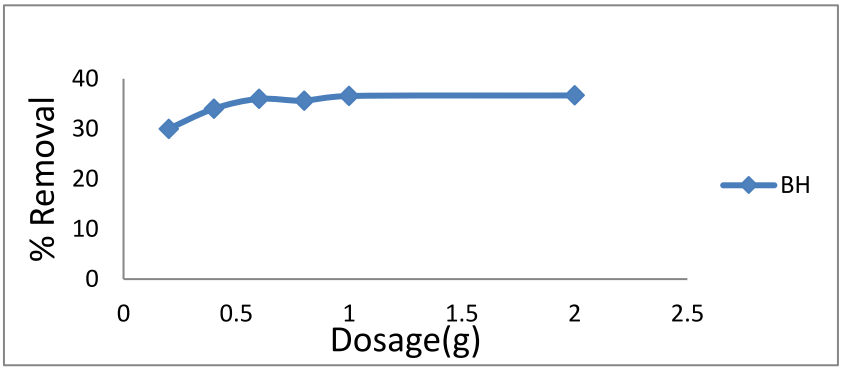

Fig. 1. Effect of Adsorbent Dosage on BH for Cd (II)

EFFECT OF pH ON THE ADSORPTION OF CADMIUM ION FOR BH

pH is one of the most important controlling parameters in all adsorption processes. The pH of the solution affects the extent of adsorption because the distribution of surface charge of the adsorbent can change (because of the composition of raw materials and the technique of activation) thus varying the extent of adsorption according to the adsorbate functional groups[8].

Fig 2 showed the adsorption capacity of Pb(II) as a function of the adsorbate at fixed adsorbent dose, fixed agitation time, fixed adsorbate concentration at room temperature. It was clear that the metal adsorption was found to increase with increasing pH of the solution within the range studied. Other ions Cd (II), Hg (II), Cr (III) and Ni (II) followed similar trend.

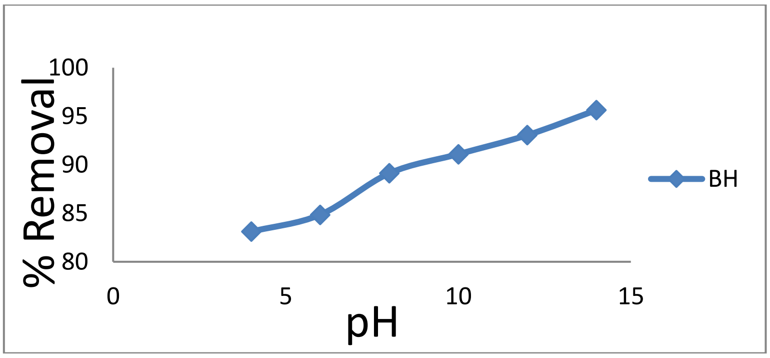

Fig. 2. Effect of pH on BH for Pb (II)

EFFECT OF CONTACT TIME ON THE ADSORPTION OF MERCURY ION FOR BH

The rate of biosorption is important for designing batch biosorption experiments. The required agitation time for sorption to be completed is important to give insight into a sorption process. This also provides information on the minimum time required for considerable adsorption to take place, and also the possible diffusion controlled mechanism between the adsorbate[8].

The effect of agitation time on Hg (II) Removal (%) at fixed adsorbent dosage, fixed pH and fixed adsorbate concentration at room temperature is presented in Fig. 3. From the figure the minimum amount of time required for considerable adsorption to take place is 20 min; further increase resulted in slight increase in percentage of Mercury removed.

Based on the results obtained from this study the agitation for further experiment were maintained at 120min to ensure that equilibrium was attained.

From the fig 3, it could be seen that as the time increases, the % removal also increases. This is also the case for other ions studied.

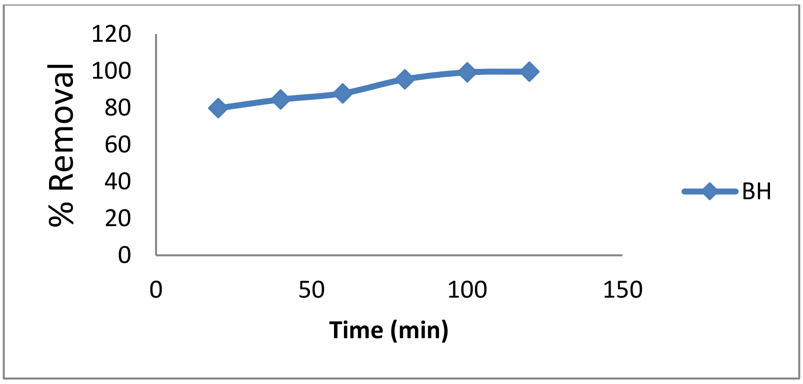

Fig. 3. Effect of contact time on BH for Hg (II)

EFFECT OF METAL ION CONCENTRATION *ON THE ADSORPTION OF CHROMIUM ION FOR BH*

The effect of metal ions concentration on amount of Chromium adsorbed (mg/g) are presented in figure 4. As the Concentration of the metal ions was increased the percentage removal of the metal ions decreased as shown in Fig 4. This according to Sao and Pederson[8] is due to the fact that at high-level concentrations, the available sites of adsorption become fewer and therefore the rate of adsorption decreases. The amount of adsorbate in the solid phase with lower initial concentration of adsorbate was smaller than the amount when higher concentrations were used, although not in a linear relationship. The metal uptake mechanism is particularly dependent on the initial heavy metal concentration: at low concentrations, metals are adsorbed by specific active sites, while at higher concentrations; lower adsorption yield is due to the saturation of adsorption sites[9]. Other ions followed similar trend.

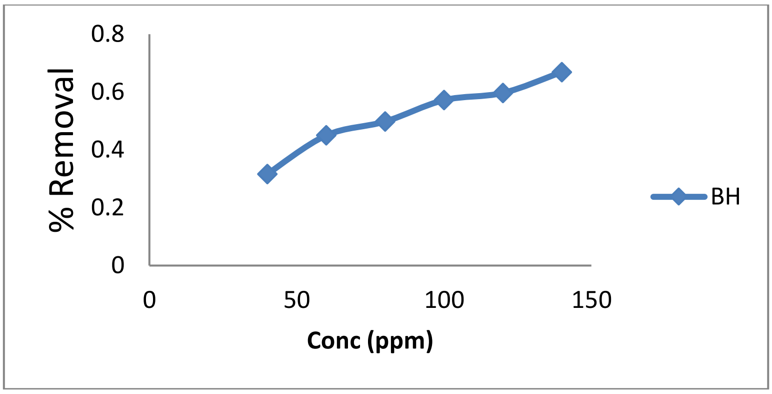

Fig. 4. Effect of metal ion concentration on BH for Cr (III)

Biosorption Isotherms

Adsorption isotherms or capacity studies are of fundamental importance in the design of adsorption systems since they indicate how the metal ions are partitioned between the adsorbent and liquid phase at equilibrium as a function of increasing metal concentration. When an adsorbent and metal ion solution is placed in contact, the concentration of metal ions on the adsorbent will increase until a dynamic equilibrium is reached; at this point, there is a defined distribution of metal ions between the solid and liquid phases. In order to optimize the design of a sorption system to remove Cd (II), Pb (II), Hg (II), Ni (II) and Cr (III) from waste water, it is important to establish the most appropriate correlation for the equilibrium curve. Two isotherm equations were tested in this work namely; Langmuir and Freundlich.

Langmuir Adsorption Isotherm

The values of Langmuir parameters q_{max} and K_L were calculated from the slope and intercept of the linear plot of C_e/q_e versus C_e as shown in figure 5 as example. Values of q_{max}, K_L and coefficient correlation R^2 for BH are given in Table 2.

$$R_L = \frac{1}{(1+K_LC_i)} \qquad (4)$$

Table 2 Langmuir Isotherm Constant for the adsorption of the metal ions onto BH

Adsorbent	**Metal ions**	**Isotherm model**			**Parameters**		
			R^2	q_{max}(mg/l)	n	K_F	K_L
BH	Cd(II)	Langmuir	0.843	1.835			0.029
		Freundlich	0.979		1.621	0.103	
	Pb(II)	Langmuir	0.898	0.990			0.081
		Freundlich	0.908		3.185	0.229	
	Hg(II)	Langmuir	0.967	0.720			0.049
		Freundlich	0.980		2.941	0.130	
	Cr(III)	Langmuir	0.988	0.750			0.081
		Freundlich	0.942		2.066	0.109	
	Ni(II)	Langmuir	0.968	0.902			0.012
		Freundlich	0.978		1.534	0.025	

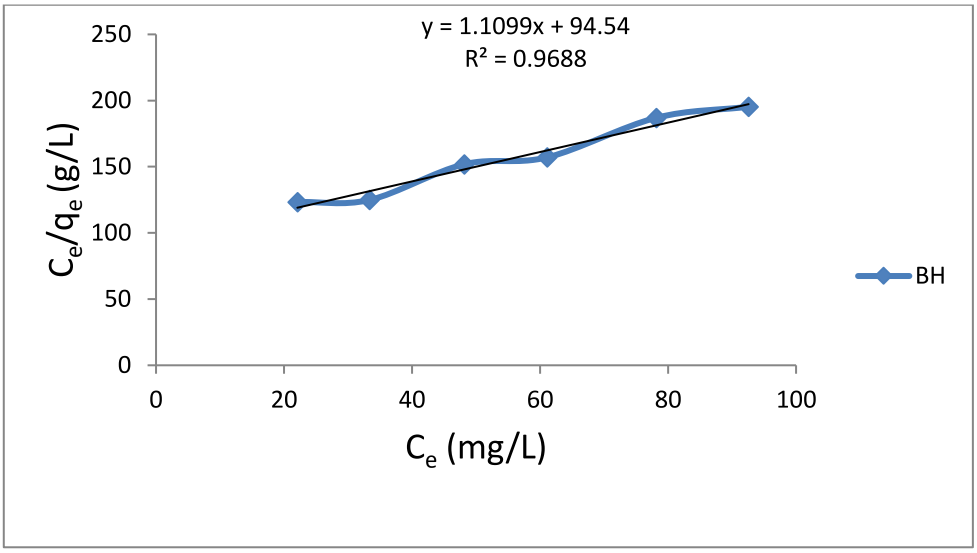

Fig 5: Langmuir isotherms for adsorption on Ni (II)

Freundlich Isotherm

Freundlich equilibrium constant were determined from the plot of log q_e versus log C_e, Fig 6 on the basis of the linear of Freundlich equation (5) as examplified on that of Ni(II) ions.

$$\log q_e = \log k_F + \frac{1}{n} \log C_e \qquad (5)$$

The values of Freundlich parameters n and K_F were calculated from the slope and intercept of log q_e versus log C_e as shown in fig 6. Values of n, K_F and coefficient correlation R2 for BH are shown in Table 3.

Table 3 Freundlich Isotherm Constant for the adsorption of the metal ions onto BH

Adsorbents	**Metal ions**	**Kinetic model**	**Parameters**				
			R^2	**K_1**	**K_2**	**q_e(exp)**	**q_e(cal)**
BH	Cd(II)	First Order	0.851	0.048		0.525	0.290
		Second Order	0.999		0.578	0.525	0.537
	Pb(II)	First Order	0.856	0.046		1.363	0.782
		Second Order	0.999		0.277	1.363	1.387
	Hg(II)	First Order	0.887	0.046		1.495	1.403
		Second Order	0.999		0.248	1.495	1.445
	Cr(III)	First Order	0.821	0.039		0.829	0.292
		Second Order	0.999		0.541	0.829	0.841
	Ni(II)	First Order	0.813	0.037		1.015	0.372
		Second Order	0.996		0.358	1.015	1.032

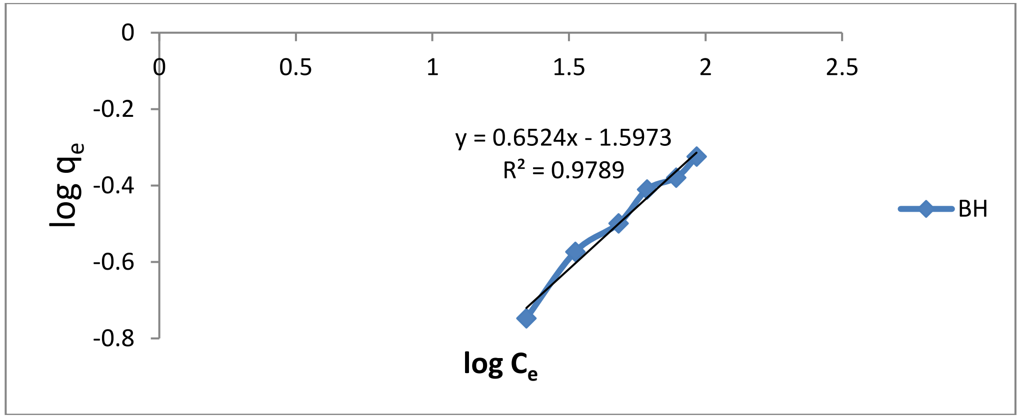

Fig 6: Freundlich isotherms for adsorption of metal ion on Ni (II)

SORPTION REACTION MODELS

In order to instigate the biosorption process of Cd (II), Pb (II), Hg (II), Cr (III) and Ni (II) on BH, Pseudo-first order of Lagergren rate equation and Pseudo-second order model were used to find the best fit kinetic model for the adsorption of Cd (II), Pb (II), Hg (II), Cr (III) and Ni (II) onto BH.

The Lagergren rate equation is the most widely used rate equation for sorption of a solute from a liquid solution[10]. The Pseudo first order rate constant of Lagergren rate equation is obtained from the slope of plot between log (q_e – q_t) against time t. Figure 7 showed the Lagergren pseudo-first order kinetic plot for the adsorption of Cd^{2+} onto BH powder. The calculated values and their corresponding linear regression correlation coefficient values are shown in Table 4.This showed that this model cannot be applied to predict the adsorption kinetic model. Also the values of calculated adsorption capacities (q_e), calculated were far much lower than experimental ones (q_e) experimental suggesting that the adsorption process did not fit the pseudo- first order model. The same result was obtained by some workers[11].

Adsorbents	**Metal ions**	**Kinetic model**	**Parameters**				
			$\mathbf{R^2}$	$\mathbf{K_1}$	$\mathbf{K_2}$	$\mathbf{q_e}$**(exp)**	$\mathbf{q_e}$**(cal)**
BH	Cd(II)	First Order	0.851	0.048		0.525	0.290
		Second Order	0.999		0.578	0.525	0.537
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	Hg(II)	First Order	0.887	0.046		1.495	1.403
		Second Order	0.999		0.248	1.495	1.445
	Cr(III)	First Order	0.821	0.039		0.829	0.292
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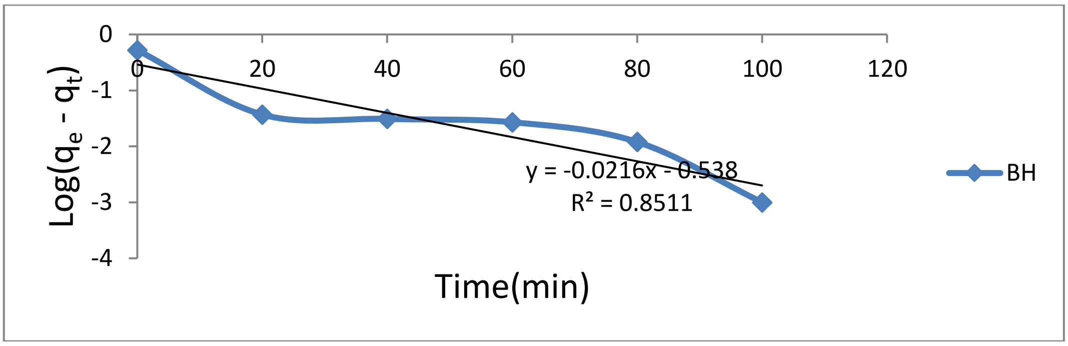

Fig 7: The pseudo first order for adsorption on Cd (II)

Figure 8 showed the pseudo-second order kinetic plot for the adsorption of Cd (II) onto BH powder, from which q_e and rate constant were determined from the slope and intercept. From Tables 4, the results for the linear regression coefficient correlation R^2 values for BH are higher than the pseudo first order kinetics. The higher values confirmed that the adsorption data are well represented by Pseudo-second order kinetics[12]. The calculated maximum adsorption capacity values of q_e, calculated are quite close to the experimental values, q_e, experimental for adsorption of Cd (II), Pb (II), Hg (II), Cr (III) and Ni (II) onto BH; this indicated that the pseudo second order model fitted the kinetic data very well. Similar results were obtained by Ho and Mckay[11].

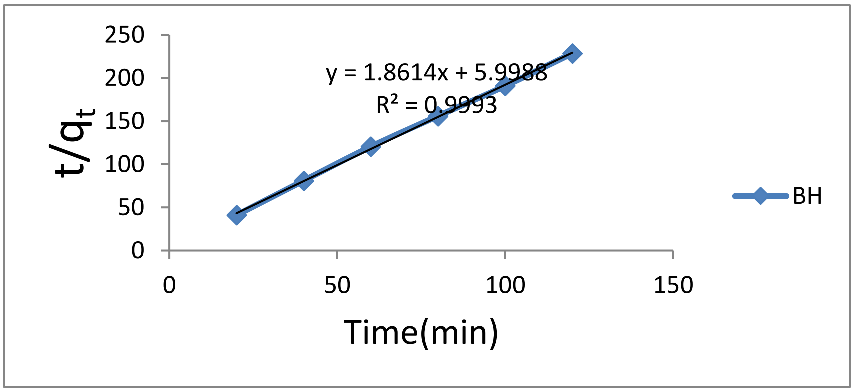

Fig 8 shows the pseudo second order for adsorption on Cd (II)

Van't Hoff Plots

From the Van't Hoff plot shown in Fig 9, it could be observed that as the temperature increases, lnK_C decreased for the adsorbents.

Thermodynamic parameters associated with the adsorption, viz standard free energy change(ΔG^O), standard enthalpy change(ΔH^O), and standard entropy change(ΔS^O) were calculated and the results are shown in Table 5.The free energy of adsorption process considering the adsorption equilibrium constant K_C is given by the equation 6.

$$K_c = \frac{C_{ae}}{C_e} \qquad (6)$$

The values of enthalpy change(ΔH^O), and entropy change(ΔS^O) were calculated from the slope and intercept of the plot of $ln\, K_c$ vs.$1/T$. The calculated values of thermodynamic parameters, ΔG^o, ΔH^o and ΔS^o for the biosorption of Cd^{2+},Pb^{2+},Hg^{2+},Cr^{3+},and Ni^{2+} onto BH powder are reported in Table 5. Positive values of ΔH^o for BH 31.37KJ/mol, 38.63KJ/mol, 29.99KJ/mol, 12.06KJ/mol, 1.29KJ/mol for Cd^{2+}, Pb^{2+}, Hg^{2+}, Cr^{3+}, and Ni^{2+} respectively. This indicated the endothermic nature of the process .Negative values of the free energy ΔG^o for BH at all temperatures indicated the process to be feasible and the spontaneous nature of the biosorption process. The same result was obtained by some workers[11,12].

TABLE 5. Thermodynamic Parameters of Adsorption of Cd (II) on BH

		BH	
T(K)	**ΔG^O(KJ/MOL)**	**ΔH^O(KJ/MOL)**	**ΔS^O(KJ/MOL)**
298	-106.54		
303	-430.77		
313	-1171.03	31.37	0.105
323	-1869.05		
333	-3053.72		
343	-3761.39		

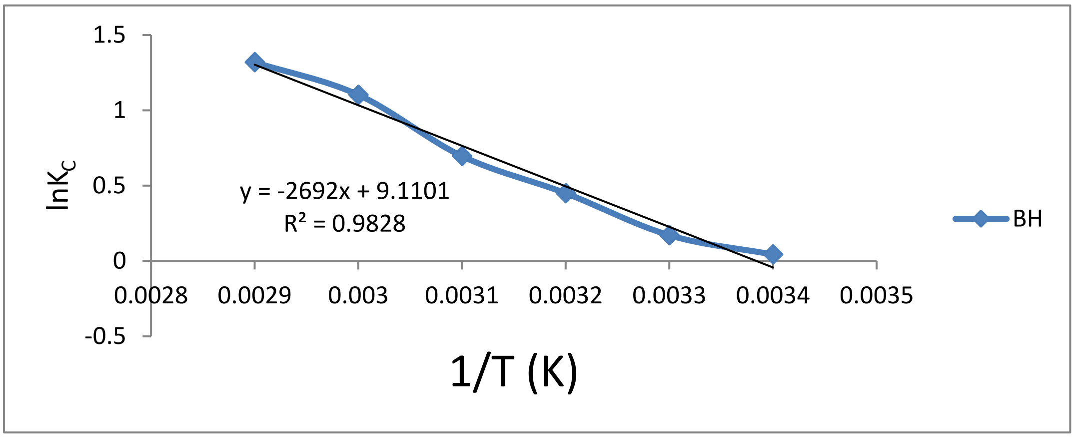

Fig 9. Van't Hoff plot for Adsorption of Cd (II) on BH

CONCLUSION

From results and discussion, it has been concluded that: Adsorption of Cd^{2+}, Cr^{3+}, Hg^{2+}, Ni^{2+} and Pb^{2+} onto BH are dependent on pH of the solution, agitation time, initial metal concentration and temperature of adsorption.

On the basis of Correlation factor R^2 the equilibrium data showed that Freundlich models described the biosorption process of Cd^{2+}, Cr^{3+}, Hg^{2+}, Ni^{2+} and Pb^{2+} onto BH.

The value of separation parameter (R_L) for BH is less than 1 which indicated favourable biosorption.

The n values for BH is greater than 1, indicating that the biosorption of Cr^{3+}, Hg^{2+}, Ni^{2+} and Pb^{2+} onto BH is a physical process with the exception of Cd^{2+} onto BH where the n value was less than 1 which showed that it was a chemical process. The pseudo second order kinetic model fitted the adsorption of Cd^{2+}, Cr^{3+}, Hg^{2+}, Ni^{2+} and Pb^{2+} onto BH favourably.

Thermodynamic study showed that the adsorption process was spontaneous having negative Gibbs free energy values at all the temperatures. ΔS^o values for BH were 0.105KJ/mol, 0.141 KJ/mol, 0.129 KJ/mol, 0.042 KJ/mol and 0.009 KJ/mol for Cd^{2+}, Pb^{2+} Hg^{2+}, Cr^{3+}, and Ni^{2+} respectively. ΔH^o values for BH were 31.37KJ/mol, 38.63KJ/mol, 29.99KJ/mol, 12.06KJ/mol, and 1.29KJ/mol for Cd^{2+}, Pb^{2+} Hg^{2+}, Cr^{3+}, and Ni^{2+} respectively. These values showed increased randomness and that adsorption process was endothermic.

This work has shown that Beans Husk is effective biosorbent for the removal of heavy metal ions (Cd^{2+}, Cr^{3+}, Hg^{2+}, Ni^{2+} and Pb^{2+}) from aqueous solutions. The major advantages in their use are that the materials are cheap and readily available hence they are very suitable for water purification. BH can therefore be used in the treatment of effluents from industries, thereby reducing the level of water pollution

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