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ADSORPTION OF NICKEL(II) IONS FROM AQUEOUS SOLUTION USING BANANA PEEL AND COCONUT SHELL

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ABSTRACT

This work investigates the comparative adsorptive removal of Ni (II) ions from aqueous solution using coconut shell and banana peel. Optimum conditions for adsorption were determined by experimental design, while Analysis of Variance (ANOVA) and Bonferroni-Holm Posthoc significance statistical tests on operational parameters were also conducted. The parametric effect of adsorbate dose, adsorbent dose, pH, contact time, particle size and temperature were varied individually, and their effect on the percentage of Ni (II) ion removal was estimated. The maximum percentage removal was achieved at a pH of 8.0 by both adsorbents. The optimum conditions obtained for both adsorbents were 4.5 g adsorbent dose, 30 min contact time and 25 ^oC for coconut shell, and 4.5 g adsorbent dose, 120 mins and 25 ^oC for banana peel. The Langmuir isotherm best described the adsorption, with correlation coefficient (R^2) values of 0.9821 and 0.9744 for banana peel and coconut shell respectively. The mean free energy from the Dubinin-Radushkevich isotherm suggested chemisorption, and the adsorption mechanism was found to fit the second order.

Keywords: Adsorption; ANOVA; Banana peel; Coconut shell; Nickel (II) ions

1. INTRODUCTION

Coconut shell and banana peel are low cost adsorbents usually regarded as agricultural waste. Various studies have analyzed their adsorbing characteristics using different adsorbates and conditions. In various capacities, adsorption depends on the characteristics of the individual adsorbent, the extent of surface modification, and the initial concentration of the adsorbate, temperature, pH, adsorbent dosage and size, among other variables. Annadurai *et al*. (2002) worked on the adsorption of heavy metals from water using banana and orange peel. At 30 ^oC, adsorption capacity decreased in the order Pb^{2+}> Ni^{2+} >Zn^{2+}>Cu^{2+} >Co^{2+} for both adsorbents, and rose with increasing pH. Song *et al*. (2013) described the removal of Pb^{2+} ions from aqueous solution using coconut shell, activated with KOH. The Freundlich isotherm described the adsorption data, while kinetics indicated a pseudo-second order kinetic model. In addition, Olayinka *et al*. (2009) investigated the removal of Cr (VI) and Ni (II) from industrial waste effluents using adsorption. The adsorption mechanism was found to fit the pseudo second order after evaluation with pseudo first order and second order kinetics. Abbasi *et al*. (2013) carried out a study on the adsorptive removal of Co^{2+} and Ni^{2+} by banana peel from aqueous solution. The maximum amounts of Co^{2+} and Ni^{2+} adsorbed (q_m), from the Langmuir isotherm were 9.02 and 8.91 mg per gram of banana peel, respectively.

Abbas *et al*., (2013) also studied the potentiality of banana peel to remove cyanide ion pollutant

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from waste water using an adsorption process by simulating a synthetic aquatic solution; maximum removal efficiency was 95.65% for cyanide ion removal. Okafor *et al*. (2012) explored the adsorption capacity of coconut shell for the removal of Pb^{2+}, Cu^{2+}, Cd^{2+} and As^{3+} from aqueous solutions. Adsorption capacity followed the trend $Pb^{2+} > Cu^{2+} > Cd^{2+} > As^{3+}$ and the kinetic treatment gave a pseudo second order type, while the Freundlich adsorption isotherm best described the adsorption. Soco and Kalembkiewicz (2013) worked on the adsorption of Ni^{2+} and Cu^{2+} ions from aqueous solution using coal fly ash. Optimum conditions of adsorption of Cu and Ni ions in the systems were established and the coefficient of adsorption was obtained using the Freundlich and Langmuir equations. Divakaran *et al*. (2012) also studied the adsorption of Ni (II) ions and Cr (VI) ions by chitin and chitosan when both ions were present together. The adsorption of Cr (VI) ions was much lower than that of Ni (II) ions.

Garba *et al*. (2016) reported on the ideal conditions for the adsorption of Ni (II) and Cd (II) ions onto Modified Plantain Peel (MPP) from aqueous solution. The Langmuir model and pseudo second order kinetics best described the two adsorption processes. The factors, effects and mechanisms of the adsorption of Hg (II), Cd (II) and Ni (II) on charged liposomes was reported by Gong *et al*. (2018). Attention was paid to the effect of pH, ionic strength and particle size of the liposomes on sorption. The mutual effects between graphene oxide and Ni (II) ions with regard to their adsorption and co-adsorption on two minerals (goethite and hematite) in aqueous phase have been reported (Sheng *et al*., 2018). A pseudo second order kinetic model with chemisorption was reported by Rao and Khan (2017) in the adsorption of Ni (II) on alkali-treated pineapple residue in batch and column studies. The influence of metal ion concentration and pH was investigated by Pino *et al*. (2006) in the biosorption of cadmium by green coconut shell powder. In another useful account of agricultural waste, banana peel particles have been effectively used as a replacement for asbestos in brake pad manufacture (Idris *et al*., 2015).

This present work is focused on the separate removal of nickel (II) ions from an aqueous solution using coconut shell and banana peel, to study the comparative effect of various parameters such as pH, contact time, adsorbent dose, adsorbate dose, particle size and temperature. Further investigations of this present work include fitting the adsorption process with suitable isotherms such as those of Langmuir, Freundlich, Temkin and Dubinin-Radushkevich, and to establish the kinetics of the adsorption process, as well as to optimize the adsorption process and statistically correlate and justify the importance of the process parameters.

2. MATERIALS AND METHODS

2.1. Materials

Banana peel (*Musa Acuminata*) was collected from the local market in Bariga, Lagos, while coconut shell (*Cocos nucifera L.*) was obtained from Badagry, Lagos, Nigeria.

2.1.1. Adsorbent preparation

The banana peel was prepared by adopting the method of Abbasi *et al*., (2013) and Taimur *et al*. (2012). It was washed thoroughly with distilled water to remove dust and soil, dried in sunlight for 5 days and kept in an oven at 70 ^{o}C. The dried peel was then cut into small pieces, after which it was ground. The coconut shell was prepared based on the method used by Ayub and Khorasgani (2014) and Tharannum *et al*. (2015). After collection it was sun dried for 2 days, crushed with a hammer mill, sieved and pre-treated with 0.1 M NaOH for 3 hours, then washed with distilled water to remove dust, soil and NaOH traces. The adsorbent was sieved and dried again at 50 ^{o}C in an oven. It was then stored in desiccators for use.

2.1.2. The adsorbate

Nickel(II) nitrate hexahydrate was used as the adsorbate and was obtained from Finlab, Ikorodu Road, Lagos. It was prepared according to the method adopted by Gonen and Serin (2012). Ni(II) ions were prepared by diluting 1000 mg/L of $Ni(NO_3)_2.6H_2O$ stock solution with distilled water to a desired concentration range of between 10 and 200 mg/L.

2.1.3. Apparatus and reagents used

The following apparatus and reagents were used: analytical grade nitric acid (HNO_3); analytical grade sodium hydroxide (NaOH); analytical grade nickel(II) nitrate hexahydrate salt [Ni $(NO_3)_2.6H_2O$]; a mesh sieve B.S.S (200); Buck atomic absorption spectrophotometer (AAS); hammer mill; electric water bath; electric oven; electric water bath; graduated beakers and cylinders; Whatman filter paper; electronic weighing balance; electronic pH meter; furnace; funnels; stopwatch and distilled water.

2.2. Experimental Procedure

The initial pH of the solutions was adjusted by 0.1 M NaOH or 0.1 M HNO_3. All the experiments were carried out at room temperature, and the initial and final metal ion concentrations were determined using the AAS. All runs were conducted three times, with averages taken. The % removal of the Ni(II) ion and the amount of (q_e) adsorbed on the coconut shell and banana peel were calculated using Equations 1 and 2, respectively:

$$\text{Removal (\%)} = \frac{100\ (C_0 - C_e)}{C_0} \tag{1}$$

$$q_e = \frac{C_0\ V_0\ -\ C_e V_e}{m} \tag{2}$$

where C_e is the equilibrium concentration of the mixture in mg/L; C_0 is the initial concentration of the mixture in mg/L; m is the mass of the adsorbent in grams; q_e is the amount of solute removed or adsorbed at equilibrium in mg/g; V_o is the initial volume of simulated oil spill in L; and V_e is the final volume of simulated oil spill at equilibrium in L.

2.2.1. Effect of temperature on adsorption

Exactly 50 ml of 100 mg/L of the Ni solution was prepared from the stock solution using distilled water. About 50 ml of the prepared adsorbate was placed into separate 250 ml beakers and 2.5 g of each adsorbent (banana peel and coconut shell) was added to the beakers. The beakers were placed in a water bath shaker for 20 minutes at 120 rpm. This step was then repeated with temperature ranges from 20 to 60^{o}C. The adsorbents were filtered out with filter paper and funnels, while the filtrate concentrations were determined by the AAS. Average ambient temperature was at 27^{o}C.

2.2.2. Effect of pH

Exactly 50 ml of 100 mg/L Ni solution and 2.5 g of the adsorbents were poured into separate glass beakers, and the pH of each solution was adjusted using 0.1 M NaOH. The beakers were placed in an electric water bath shaker for 20 minutes at 120 rpm. This was done for pH values of 1.0–8.0. The resulting solutions were filtered and the concentrations determined using the AAS.

2.2.3. Effect of adsorbent dose on adsorption

Up to 50 ml of 100 mg/L prepared adsorbate was poured into separate beakers and various weighed amounts of the adsorbents (0.2–1.4 g) were added to each of the beakers. The beakers were placed in an electric water bath shaker for 20 minutes at 120 rpm. The resulting filtered concentrations were measured with the AAS.

2.2.4. Effect of adsorbate dose on adsorption

A 50 ml of 100 mg/L adsorbate was prepared using distilled water in two 250 ml beakers and 2.5 g of both adsorbents were placed into the adsorbate solutions. The beakers were placed in an electric water bath shaker for 20 minutes at 120 rpm. This step was carried out at adsorbate concentrations of 20–100 mg/L. The final concentrations of the filtrates were determined with the AAS.

2.2.5. Effect of contact time on adsorption

Exactly 50 ml of 100 mg/L adsorbate was poured into separate glass beakers. Up to 2.5 g of the adsorbents were added into the beakers containing the adsorbate, and the beakers were placed in the electric water bath shaker at 120 rpm for 5 minutes. This step was made at varying contact times, from 5 to 60 minutes. The resulting mixtures were filtered and placed in the AAS to measure their concentrations.

2.2.6. Effect of particle size on adsorption

Exactly 50 ml of 100 mg/L of the adsorbate solution was poured into separate glass beakers. Exactly 2.5 g and 53 microns of each adsorbent were then mixed with the adsorbate, and the beakers were placed in an electric water bath shaker for 20 minutes at 120 rpm. This step was made for varying particle sizes, up to 250 microns. The final filtrate concentrations were determined with the AAS.

3. RESULTS AND DISCUSSION

3.1. Effect of Adsorbent Dose on Adsorption

From Figure 1, it can be seen that the percentage removal of each adsorbent rose with increasing adsorbent dosage, but tended to remain constant at about 1.3 g. This may be due to overlapping of the adsorption sites as a result of overcrowding of the adsorbent particles. A similar explanation was given by Suresha and Deepa (2014) for the biosorption of Ni(II) ions from aqueous solution using Araucaria cookie leaves.

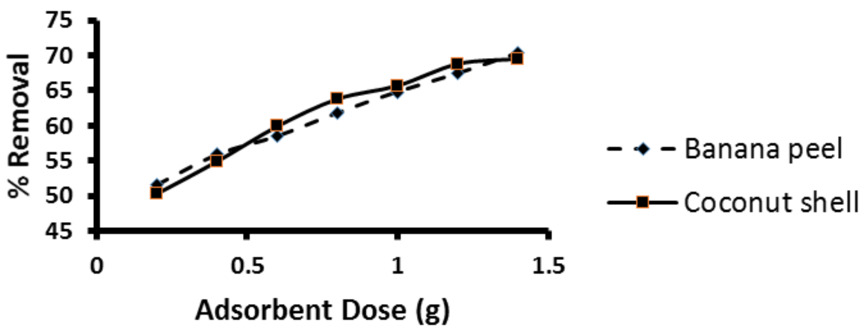


Figure1 Effect of varying adsorbent doses on adsorption

3.2. Effect of pH on Adsorption

Figure 2 shows that increments in pH resulted in a high percentage removal, and remained constant for pH values of about 6 to 8. This is due to the fact that pH has a significant effect on adsorption because it affects the solubility of metal ions, the concentration of counter ions on the functional group of the adsorbent, and the degree of ionization of the adsorbate during the reaction. Sorption does not seem to occur in highly acidic and alkaline conditions because hydrogen ions and hydroxyl ions compete for active sites on the adsorbent surface, as reported by Shah *et al*. (2016).

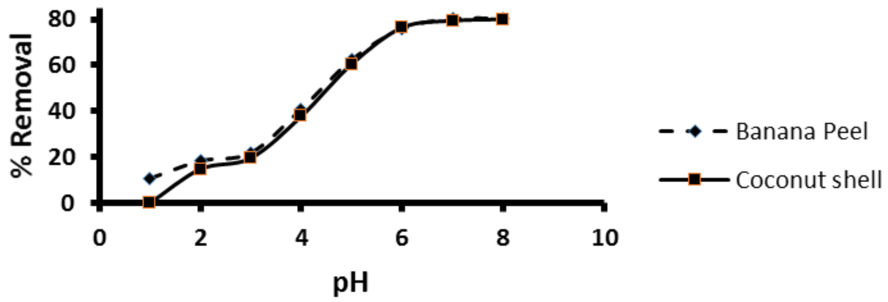


Figure 2 Effect of varying pH on adsorption

3.3. Effect of Contact Time on Adsorption

It is evident from Figure 3 that an increase in contact time favors only adsorption using banana peel as the adsorbent. Decreasing the contact time between the solution and coconut shell would improve the percentage removal. It seems that banana peel has more capacity than coconut shell for adsorption. Increases in time are expected to enhance sorption until saturation at equilibrium. From the observed phenomenon, the optimized maximum uptake of banana peel compared to coconut shell seems to be higher, as reported separately by Annadurai *et al*., (2002) and Aziz *et al*. (2005).

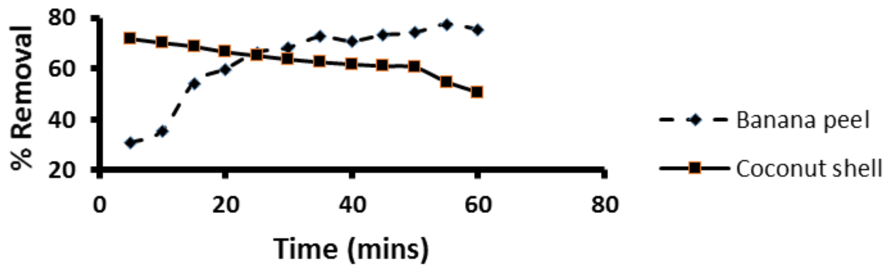


Figure 3 Effect of contact time on adsorption

3.4. Effect of Temperature on Adsorption

As shown in Figure 4, with an increase in temperature the percentage removal decreases as a result of the desorption taking place; that is, the nickel ions do not attach themselves properly to the adsorbent as the temperature is increased over time. Naturally, temperature increases the kinetic energy of the ions and molecules in solution, which has an adverse effect on the adsorption. Similar accounts were given by Matouq *et al*. (2015) for the sorption of nickel onto moringa pods, and by Hannachi *et al*. (2014) for the adsorption of nitrate ions onto a membrane.

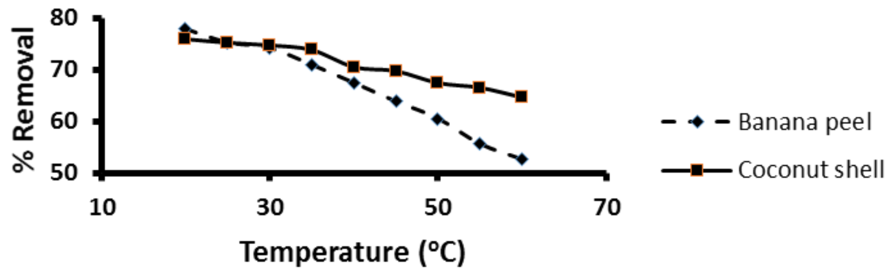


Figure 4 Effect of temperature on adsorption

3.5. Effect of Adsorbate Concentration on Adsorption

Increasing the adsorbate concentration slightly reduced the percentage removal for banana, while it appeared constant for coconut shell, as shown in Figure 5. Increasing adsorbate concentration presented a situation whereby more ions were provided to be adsorbed, without increasing the adsorbent quantity. This led to supersaturation of the active sites available for adsorption. Matouq *et al*. (2015) and Khelifi *et al*. (2016) similarly reported that as the initial concentration for metal ions increases, the removal percentage decreases for a fixed adsorbent dose and contact time. This behavior was also explained by the limited active site on the adsorbent surface.

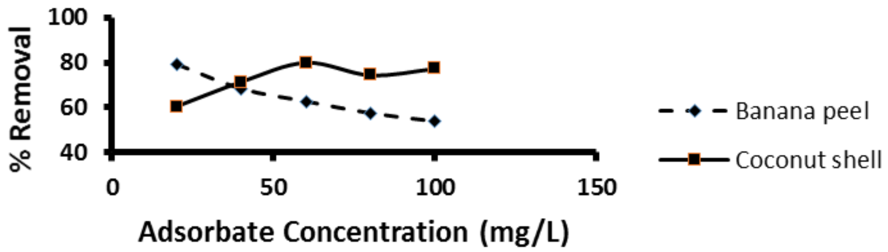


Figure5 Effect of adsorbate concentration

3.6. Effect of Particle Size on Adsorption

As shown in Figure 6, the percentage removal by adsorption fell with increased particle size. This could be explained from the fact that as the particle size increased, the active available surface area decreased, which hindered adsorption for both adsorbents. The same parametric observation was made by Hossain *et al*. (2012).

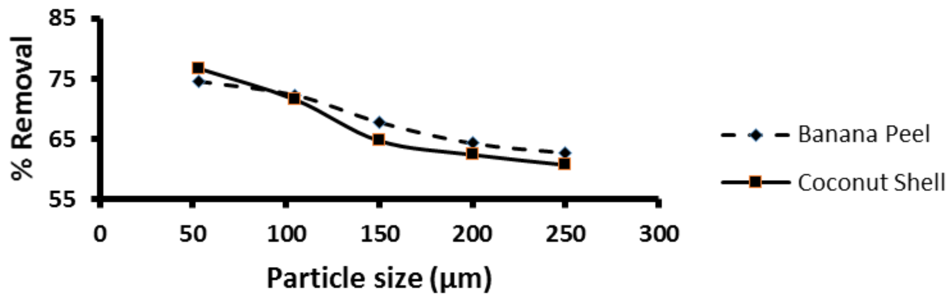


Figure 6 Percentage Removal with Varying Particle Size

3.7. Theoretical Statistical Experiment Design

Design Expert 9 was used to design the experiment. It was employed to check for the interdependence of more than one factor by identifying their overall effect. A full factorial experiment design was used. Subsequently, the percentage removal was calculated.

3.7.1. Full factorial design

The main factors (adsorbent dose, temperature and contact time) were selected, as well as their factor levels, coded as –1 (low) and +1 (high), as seen in Table 1. A full $\mathbf{2^3}$ factorial design was employed and a matrix generated. The factor levels were coded as –1 (low) and +1 (high), as seen in the Table. The percentage removal results obtained are presented in Table 2.

Table 1 High and low values for the main factors

Factors	Low (−1)	High (+1)
Adsorbent dose	0.5 g	4.5 g
Contact time	30 mins	120 mins
Temperature	25ºC	65ºC

Table 2 Percentage removal obtained

Run		1	2	3	4	5	6	7	8
% Removal	Banana peel	40.42	47.23	55.89	61.02	68.45	74.53	78.16	80.1
	Coconut shell	41.80	44.40	50.70	56.90	67.20	72.50	70.30	68.4

As previously observed, banana peel seems to be a better adsorbent for nickel under similar conditions, which is confirmed by the findings of Annadurai *et al*. (2002) and Aziz *et al*., (2005).

3.8. Analysis of Variance and Parametric Statistical Significance

The ANOVA and Bonferroni-Holm Posthoc significance test results for Nickel (II) ion adsorption by banana peel and coconut shell with varying parameters are given in Table 3. The statistical computation presented was carried out with the aid of Daniel's XL Toolbox Version 6.70 © 2008–2013 software.

Table 3 Bonferroni-holm posthoc significance test and analysis of variance (ANOVA) for Nickel (II) ion adsorption with banana peel and coconut shell, using varying parameters

Group 1	Group 2	Bonferroni-Holm Posthoc Significance Test			Analysis of Variance (ANOVA) Test					
		P_C	P	Significant	S_{SB}	S_{SW}	D_{FB}	D_{FW}	F	P
W_B	P_R	0.0167	1.449E-11	Yes	17283.91	573.67	2	18	271.15	3.64
W_C	P_R	0.0250	3.712E-11	Yes						
pH_B	P_R	0.0167	0.000846	Yes	9841.02	13391.79	2	21	7.72	0.0031
pH_C	P_R	0.0250	0.002678	Yes						
t_B	P_R	0.0167	1.35E-05	Yes	7503.19	6658.63	2	33	18.59	3.91E-06
t_C	P_R	0.0250	0.000198	Yes						
T_B	P_R	0.0167	7.59E-06	Yes	5025.17	2275.82	2	24	26.50	8.42E-07
T_C	P_R	0.0250	0.000176	Yes						
C_{AB}	P_R	0.0250	0.409121	No	414.70	4623.60	2	12	0.54	0.60
C_{AC}	P_R	0.0500	0.780217	No						
S_B	P_R	0.0167	0.041120	No	23428.15	24204.77	2	12	5.81	0.0172
S_C	P_R	0.0250	0.043023	No						

where C_A is the adsorbate concentration (mg/L), C_{AB} is the adsorbate concentration with banana peel (mg/L), C_{AC} is the adsorbate concentration with coconut shell (mg/L), D_{FB} is the degrees of freedom between groups, D_{FW} is the degrees of freedom within groups, F is Fisher's ratio, P is the probability factor, P_C is the critical probability factor, pH_B is the measured pH with respect to banana peel, pH_C is the measured pH with respect to coconut shell, P_R is the percentage removal of ions (% removal), S_B is the banana peel particle size (µm), S_C is the coconut shell particle size (µm), S_{SB} is the sum of squares between the groups, S_{SW} is the sum of squares within the groups, t is the mixing time (min), t_B is the time with respect to banana peel (min), t_C is the time with respect to coconut shell (min), T is the temperature (K), T_B is the temperature with respect to banana peel (ºC), T_C is the temperature with respect to coconut shell (ºC), W is the weight of the adsorbent (g), W_B is the adsorbent dose for banana peel (g); and W_C is the adsorbent dose for coconut shell (g).

The parameters investigated show the actual values of the sum of squares within and between the groups. There exists a statistically wide variation between the individually investigated parameters and the percentage removal of Nickel (II) ion groups at the 95% confidence interval, as the F and P values are mostly within the expected ranges. Fisher's F is a ratio of the variance between groups to the variance within groups, and P is a probability factor that must be less than 0.05 in the ANOVA analysis.

The degree of freedom between the groups was 2, while the degree of freedom within them varied from 12 to 33. The F and P values implied a strong dependence of P_R on the various parameters investigated. The Bonferroni-Holm Posthoc parametric significance test for various parameters investigated showed a strong dependence or significance on each other, except for the relationships between P_R and C_{AB}, C_{AC}, S_B and S_C with P values greater than the P_C values in the 95% confidence interval. In comparison with previous literature, the parametric variables that furnished the maximum percentage removal of ions with similar adsorbent or adsorbate systems conformed with the work of Chaudhari (2009) and Abbasi *et al*., (2013). In agreement with the statistical Bonferroni-Holm Posthoc parametric significance test in Table 3, none were obtained under adsorbate nor particle size variation. In conformity with the results obtained from this work, similarities between them can be drawn, as the maximum percentage removal obtained from the use of banana peel was 80.3%, and from coconut shell it was 80%, under the same conditions of pH variation.

3.8.1. Adsorption isotherms

The Langmuir isotherm was expressed using Equation 3 below:

$$\frac{C_e}{q_e} = \frac{1}{Q_0\, b} + \frac{C_e}{Q_0} \quad (3)$$

Q_0 is the Langmuir constant for maximum adsorption capacity, and b is the Langmuir constant. The essential characteristics of the Langmuir isotherm can be expressed in terms of a dimensionless constant separation factor or equilibrium parameter, R_L, which is defined in Equation 4 by:

$$R_L = \frac{1}{1+bC_0} \quad (4)$$

where C_o is the initial concentration.

The Freundlich isotherm is often expressed in Equation 5 as:

$$\text{Log}\, q_e = \text{Log}\, K_f + \frac{1}{n}\, \text{Log} C_e \quad (5)$$

where K_F and n are the Freundlich constants.

The Langmuir and Freundlich adsorption isotherm constants are given in Table 4, while the Temkin and Dubinin-Radushkevich adsorption isotherm constants are presented in Table 5. A_T is the Temkin isotherm equilibrium binding constant (L/mg); B is the Temkin constant related to heat of adsorption; b_T is the Temkin isotherm constant (J/mol); E is the Dubinin–Radushkevich isotherm parameter; K_{ad} is the Dubinin–Radushkevich isotherm constant (mol^2/kJ^2); q_s is the theoretical isotherm saturation capacity (mg/g); R is the Universal Gas Constant (8.314 J/mol K); R^2 is the Coefficient of Regression; and T is Temperature (K).

Table 4 Langmuir and Freundlich adsorption isotherm constants

Adsorbent	Langmuir Constants				Freundlich Constants		
	Q_o(mg/g)	b (L/mg)	R^2	R_L	K_F (L/mg)	n	R^2
Banana Peel	1.47	0.018	0.9821	0.356	0.004	0.263	0.9202
Coconut Shell	2.57	0.016	0.9744	0.384	0.016	0.33	0.9619

Table 5 Temkin and Dubinin-Radushkevich adsorption isotherm constants

Adsorbent	Temkin Constants				Dubinin-RadushkevichConstants			
	B (J/mol)	A_T (L/g)	B	R^2	K_{ads}(mol^2/kJ^2)	q_s (mg/g)	R^2	E_D (kJ/mol)
Banana Peel	19.308	0.034	117.55	0.7312	0.0005	23.96	0.8338	44.72
Coconut Shell	17.513	0.036	129.6	0.8355	0.0004	22.21	0.9087	50

From Table 4, it can be seen that the Langmuir isotherm for banana peel gave the best fit for the adsorption operation, similar to the observations of Amer *et al*., (2015). Favorable adsorption was achieved as a result of the fact that $0<R_L< 1$. In Table 5,the Temkin and Dubinin-Radushkevich adsorption isotherms also gave good R^2 values, but are not as high as those of the Langmuir isotherm obtained for banana peel, as shown in Table 4.

The Temkin and Dubinin-Radushkevich constants were both accounted for in order to estimate certain energy adsorption related parameters. The Dubinin-Radushkevich isotherm is more general than that of Langmuir because its deviations are not based on ideal assumptions, such as the equipotential of sorption sites, absence of steric hindrances between sorbed and incoming particles, and surface homogeneity at the microscopic level. The isotherm with the highest R^2 value proves to be a better choice in explaining sorption energies. From Table 5, the mean free energy obtained, $E_{D,}$ was greater than 8 kJ/mol, which is an indication from Dubinin-Radushkevicht hat the operation suggested chemisorptions. Rao and Khan (2017) suggest close observations.

3.8.2. Kinetic studies

The pseudo first order kinetic model is given in Equation 6 as:

$$\log (q_e-q_t) = \log q_e - (K_1/2.303)t \qquad (6)$$

The pseudo second order kinetic model is given in Equation 7 as:

$$\frac{t}{q_t} = \frac{1}{h} + \frac{1}{q_e t} \qquad (7)$$

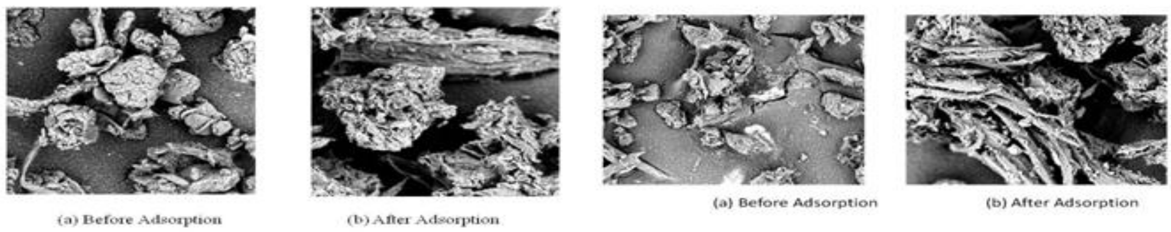
where, q_t is the amount of solute adsorbed at time t in mg/g, h and $K_1$are constants.

The constants from the plots of the pseudo first and second order kinetics are given in Table 6. It can be seen that the pseudo second order kinetics gave a better fit for the two adsorbents, which is similar to the reports of Amer *et al*. (2015) and Ajayi-Banji *et al*. (2016) for the biosorption of contaminated wastewater with coconut shell husk.

Table 6 Pseudo first and second order kinetic constants

Adsorbent	Pseudo First Order Constants			Pseudo Second Order Constants		
	K (min^{-1})	R^2	q_e (mg/g)	h ($gmg^{-1}min^{-1}$)	q_e (mg/g)	R^2
Banana Peel	0.044	0.1106	0.663	0.047	0.0140	0.8537
Coconut Shell	0.025	0.0387	0.196	0.047	0.0099	0.7628

Figures 7a and 7b give the Scanning Electron Microscope (SEM) images of banana peel and coconut shell before and after adsorption at 671 microns (×400 magnification), respectively. In both cases, the swelling of the adsorbents and site occupation of sorbent active sites are noticeable.



(a) Banana Peel (b) Coconut Shell

Figure 7 Scanning electron microscope images of banana peel and coconut shell before and after adsorption at 671 microns (×400 Magnification)

4. CONCLUSION

It has been shown that banana peel and coconut shell are both good adsorbents for the retrieval of Ni (II) ions with consideration of the six parameters, but that banana peel has a higher percentage removal for most of the factors. The ideal pH for obtaining the maximum amount of Ni (II) ion uptake by the adsorbents was 8, so this can be considered to be the optimum dosage in specific conditions. A very good comparative percentage, similar to existing works, was also obtained in this study. From the experimental approach design, the highest percentage removal for banana peel suggested an adsorbent dose of 4.5 g, contact time of 120 mins and temperature of 25°C, while the conditions for the maximum Ni (II) ion uptake using coconut shell are 4.5 g adsorbent dose, 30 min contact time and temperature of 25°C. The percentage removal of Ni (II) ions was found to decrease with increasing temperature for both adsorbents, which indicated the exothermic nature of the process. The adsorption operation was in close agreement with the Langmuir isotherm for both adsorbents, indicating a monolayer adsorption process. The constants obtained from the Langmiur and Freundlich adsorption isotherms had similar values to those of Chaudhari (2009). The statistical test with ANOVA and Bonferroni-Holm Posthoc parametric significance test gave good insight into the significance and interdependencies of variables, or the parameters needed for improved and more focused future operations. Lastly, banana peel and coconut shell are effective adsorbents for the removal of Nickel(II) ions from their aqueous solution, with the highest removal for coconut shell obtained at 75.9%, and at 77.8% for banana peel, at 20 °C.These adsorbents are cost effective and could be considered for the treatment of heavy metals present in industrial wastewater.

5. ACKNOWLEDGEMENT

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