

## **Adsorption of Cd(II) And Fe(II) from Aqueous Solution Using Adsorbents Prepared from Waste Polythene Sachets**

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### **Abstract**

The adsorption of Fe(II) and Cd(II) ions from aqueous solution was studied using adsorbents prepared from waste polythene sachets. The effect of initial ion concentration, contact time, pH, adsorbent dose and temperature on the removal of Fe(II) and Cd(II) ions was examined. The optimum concentration was found to be 40 ppm for Fe(II) and 50 ppm for Cd(II) ions. The equilibrium data fit the Langmuir isotherm better than the Freundlich and Temkin isotherms. The negative values of the Gibbs free energy ( $\Delta G$ ) revealed that the adsorption process is feasible and spontaneous. The adsorption of Cd(II) ion was found to be spontaneous at 323 K on sulfuric acid activated samples but not spontaneous at all on carbonized samples. The adsorption data fit well into the pseudo-second-order kinetic model and the experimental quantities of Cd(II) and Fe(II) adsorbed are relatively close to the calculated quantities adsorbed. The prepared adsorbents therefore offer an alternative for the removal of the metal ions from contaminated water.

**Keywords:** *Adsorption, Cadmium, Iron, Aqueous solution, Polythene.*

### **Introduction**

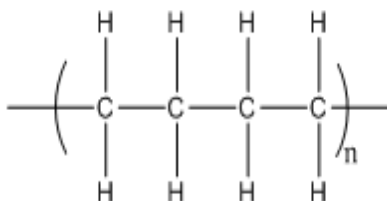
Environmental pollution and its harmful effect have been studied extensively during the last decades. The removal of pollutants from wastewater has become more challenging due to the fast increase in industrialization.<sup>[1]</sup> Several industrial operations release various metals such as lead, iron, zinc, cadmium and copper in their effluents which eventually find their ways into water bodies.<sup>[2]</sup> Bioaccumulation of these heavy metals in living organisms can result in health problems such as cancer.<sup>[3]</sup> About 80% of communicable diseases in the world are waterborne.<sup>[4]</sup> Global and local agencies have therefore established certain limits on the quantities of heavy metals being discharged into the environment.

The non-degradable thermoplastic low density polythene (LDPE) or polyethylene used for commodity goods storage and packaging purposes accounts for over 60 million tons of annual waste generated worldwide.<sup>[5]</sup> It was also reported<sup>[6]</sup> that 30% of the domestic waste in a typical Nigerian city comprises of polythene and plastic

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products in very large quantities whose disposal has continued to constitute a great environmental pollution challenge and concern in big and small cities. These polythene wastes are predominantly made up of LDPE used to package drinking water (commonly known as 'pure water' sachet). The chemical structure of polythene is shown Fig. 1.



**Fig. 1:** Chemical Structure of polythene.

Since the disposal of pure water sachets remains a major problem in Nigeria due to its non-degradability, they can better be converted into valuable adsorbents (waste to wealth) for the removal of heavy metals from polluted water. The present study aimed therefore at producing adsorbents from these pure water sachets and testing them in the removal of iron and cadmium ions. This could offer a highly effective technological means giving rise to alternative waste management and environmental conservation.

### **Materials and method**

Waste water sachets were collected from Ilorin municipal, North-Central Nigeria. The adsorbents were prepared by carbonizing the pure water sachet in a muffle furnace at 450 °C. The resulting carbon was ground and sieved with a 1.6 mm-diameter sieve. It was divided into two portions, one of which was activated with 25% H<sub>2</sub>SO<sub>4</sub>. The activated product was allowed to cool at ambient temperature and then neutralized with NaOH and washed with distilled water until the pH was constant (at pH of 6.60). It was dried in the oven at 105 °C and later removed to cool at room temperature.<sup>[7]</sup> It was then labeled as SACS and UCS for sulfuric acid activated sample and unactivated carbonized sample, respectively.

Various physico-chemical parameters were determined such as the ash content, moisture content, pH of the adsorbent, apparent bulk density and the iodine value. The carbon yield was determined by taking the initial mass of the starting raw material, weighing prior to carbonization and then after carbonization. Yield of the activated carbon was calculated as:

$$\% \text{ yield} = \frac{W_2}{W_1} \times 100$$

where  $W_1$  (g) is the initial weight of the raw material and  $W_2$  is the weight of the carbonized material.<sup>[8]</sup>

The moisture content of the prepared adsorbent was determined by weighing 0.20 g of each sample in a crucible of known weight, transferring it into an oven set at 105 °C for 3 hours, then brought out and cooled in a desiccator. The process was repeated 3 times for 15 minutes at 105 °C and re-weighed until a constant weight is obtained which gives the moisture percentage for each activated carbon sample as shown in the following equation.<sup>[8]</sup>

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

where  $W_1$  is the weight of empty crucible,  $W_2$  is the weight of crucible plus sample before oven drying and  $W_3$  is the weight of crucible plus sample after oven drying.

The apparent or bulk density was determined using ASTM D7481-09 procedure,<sup>[9]</sup> while the iodine numbers of the samples were determined following the ASTM, D4607-94 procedure.<sup>[10]</sup>

The pH of various carbon types was determined by preparing a suspension of each carbon sample in the ratio 1:2 of the carbon to distilled water. This was done by weighing 0.20 g of each carbon sample and adding 0.4 ml of distilled water in a conical flask. The mixture was agitated in a mechanical shaker for fifteen minutes to attain equilibrium. The pH of the resulting suspension was determined using a pH meter.<sup>[8]</sup>

The ash content of the sample was determined by weighing 0.20 g of the sample into a crucible and placing it in the muffle furnace at 500 °C for 3 hours until a greyish white sample was obtained. The content was allowed to cool in a desiccator before it was reweighed.

The functional groups were determined using Agilent Cary 630 FTIR Spectrophotometer, the surface morphology was characterized by scanning electron microscope using Phenom ProX SEM, and XRF was used to test for metals content.

The adsorption study was conducted in batch mode at selected pH values (2, 4, 6, 8, 10 and 12), varying thereby the contact time (35, 45, 60, 120 and 180 min) and the adsorbent dosage level (0.10, 0.20, 0.30 and 0.50 g per 20 mL of test solution). Adsorption was conducted in a 120 ml pyrex reagent bottle agitated in a mechanical orbital shaker. The concentrations of the metal ions were determined using AAS.

## **Results and discussion**

### *Physico-chemical characterization*

The carbon yield, pH, moisture content, ash content and the iodine number of the prepared adsorbents are given in Table 1 for SACS and UCS. The pH of the two samples was 6.60 and 6.80, respectively. It is worth noting that for most applications of activated carbon a pH of 6-8 is acceptable.<sup>[11]</sup> The percentage ash content of the samples, 45% for SACS and 30% for UCS, indicated a moderate mineral content in the sample materials. It was observed that SACS has a higher iodine number than

UCS. This implies that SACS has a higher surface area for adsorption because the iodine number indicates the porosity of the sample in question.

**Table 1:** Physico-chemical properties of SACS and UCS.

Adsorbents	%yield	pH	%moisture	%ash	I <sub>2</sub> No. (mg/g)	Bulk density (g/cm <sup>3</sup> )
SACS	97.88	6.60	30.00	45.00	812.16	0.28
UCS	91.75	6.80	0.00	30.00	685.26	0.25

Moreover, carbon yield with an adequate density helps also improve the filtration rate by forming an even cake on the filter surface.<sup>[12]</sup> The bulk densities of the samples are 0.28 and 0.25 g/cm<sup>3</sup> for SACS and UCS, respectively, which is acceptable according to AWWA for practical use.<sup>[13]</sup>

#### *Infra-red spectroscopic studies*

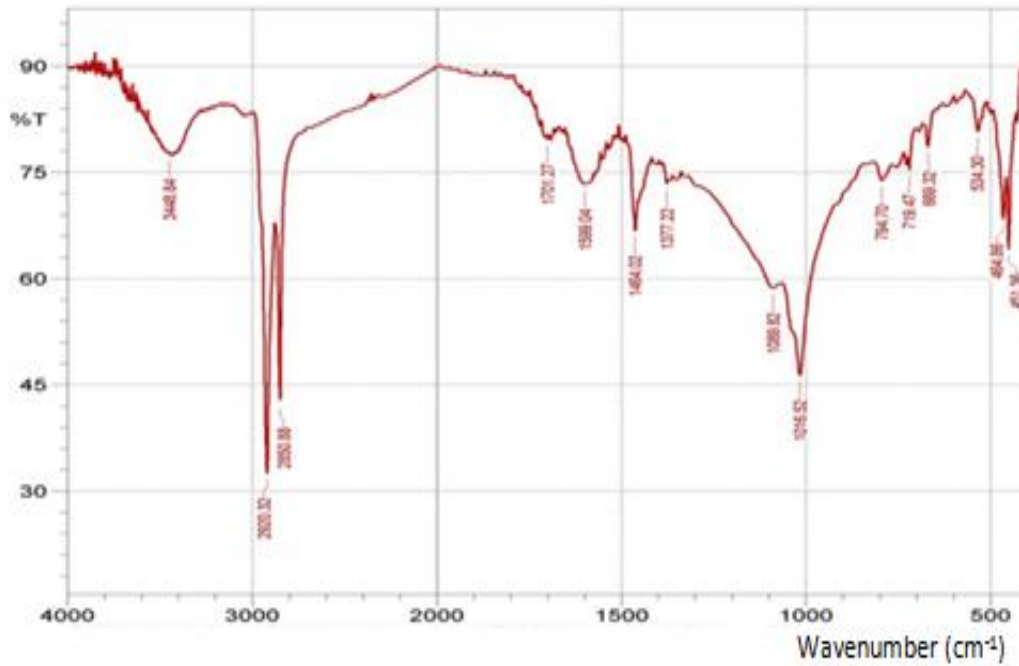
The IR spectra of SACS and UCS are presented in Figures 2a and 2b. From the spectra, the O-H stretching absorption (3397 cm<sup>-1</sup>) is due to bonded water. The C-H stretch (1377 cm<sup>-1</sup>) can be found in all samples obtained from the original polymeric material and are superimposed onto the side of the broad O-H band. The C=O band (1701 cm<sup>-1</sup>) results from the reactions taking place in the carbonization process. However, the N-H (1705 cm<sup>-1</sup>) and C-C (650- 1000 cm<sup>-1</sup>) bands come from the polymeric material, while C-S for SACS and C-N bands for the two samples appear within the range of 900-1400 cm<sup>-1</sup> and are due to the sulfuric acid used in the activation, the S=O and C=S bands fall also in this range. The C-N stretching mode shows the presence of hydroxyl and amine groups on the surface of the adsorbents.

#### *X-Ray Fluorescence (XRF)*

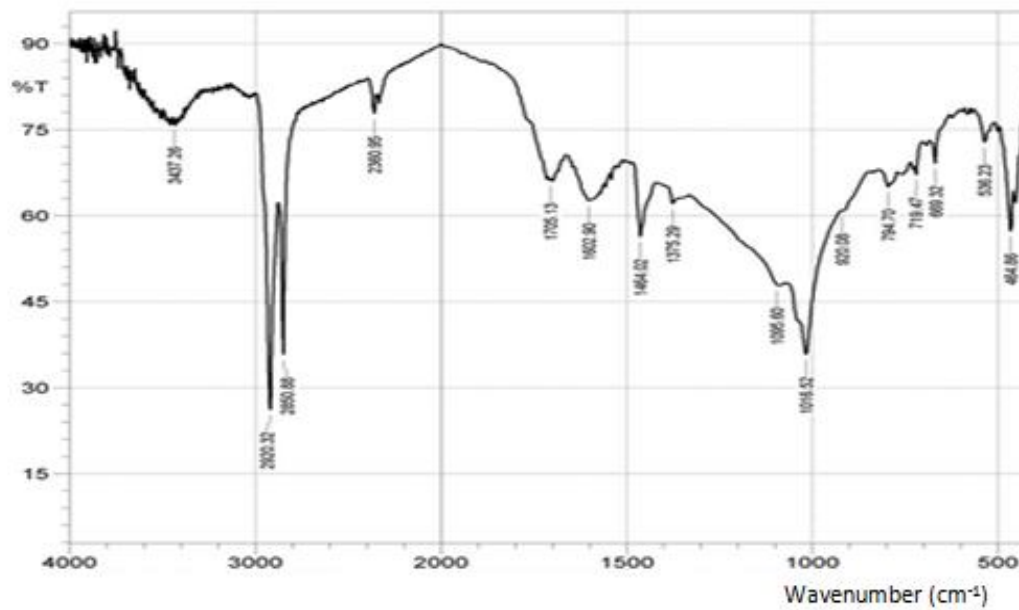
The heavy metal concentrations in SACS and UCS are listed in Table 2 as determined by XRF. The aggregation of the used pure water sachet with electronic waste at the dumping site has been suspected as the source of heavy metals contamination in the adsorbents.<sup>[14]</sup>

**Table 2:** Heavy metal concentrations in SACS and UCS.

Elements	SACS (ppm)	UCS (ppm)
K	0.0186±0.01	0.0160 ±0.01
Ca	0.0203±0.04	0.0126±0.04
Ti	3452±22.00	4781±22.00
Cr	24.1 ±8.00	27.6 ±5.00
Mn	91.8 ±5.00	100.9 ±10.00
Fe	0.4227±0.12	0.37001±0.12
Ni	31.82 ±3.00	44.7 ±4.10
Cu	64.3±12.10	86.6±10.2
Zn	101.5 ±9.3	128.1±10.1
As	22.78 ±5.8	38.2 ±7
Se	10.16 ±2	16.7 ±2.3
Zr	19.81 ±2.2	20.1 ±3
V	4.21 ±1.2	6.2 ±1.2



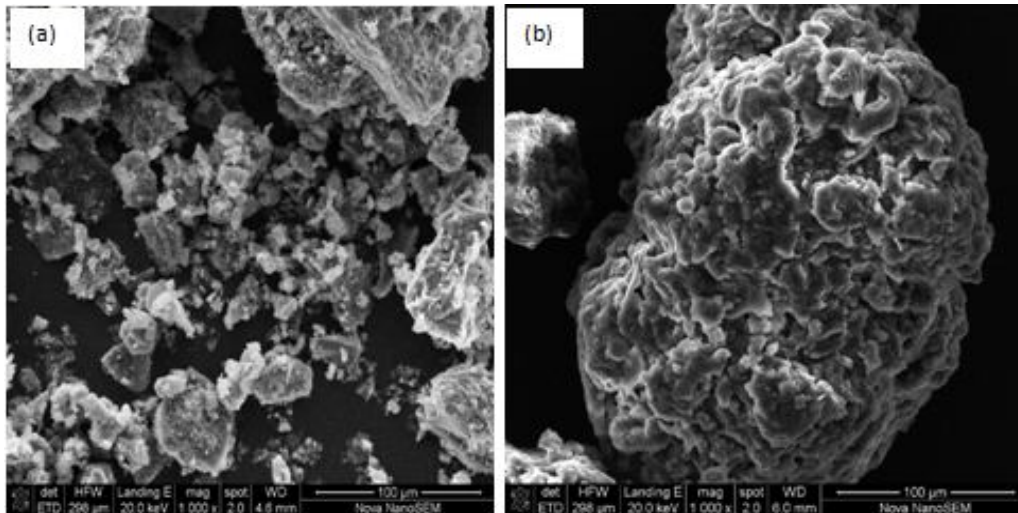
**Figure 2a:** Infrared spectrum of SACS.



**Figure 2b:** Infrared spectra of UCS.

### *Surface morphology*

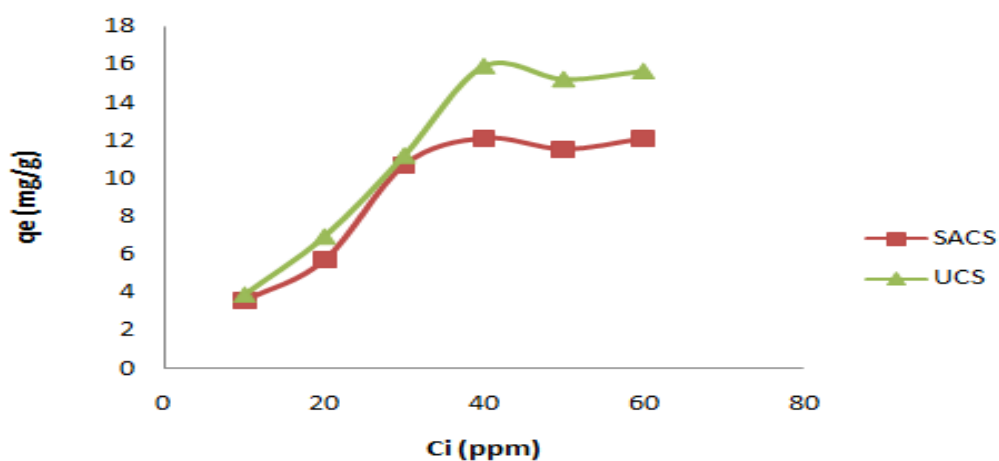
The SEM micrographs of both SACS and UCS are shown in Figures 3a and 3b, respectively. As can be seen, the size and homogeneity of particles depend on the type of the adsorbent. It can be seen that SACS in Figure 3a is stony-like while UCS in Figure 3b is coagulated and brain-like in structure which could be due to the surface interactions between the particles.



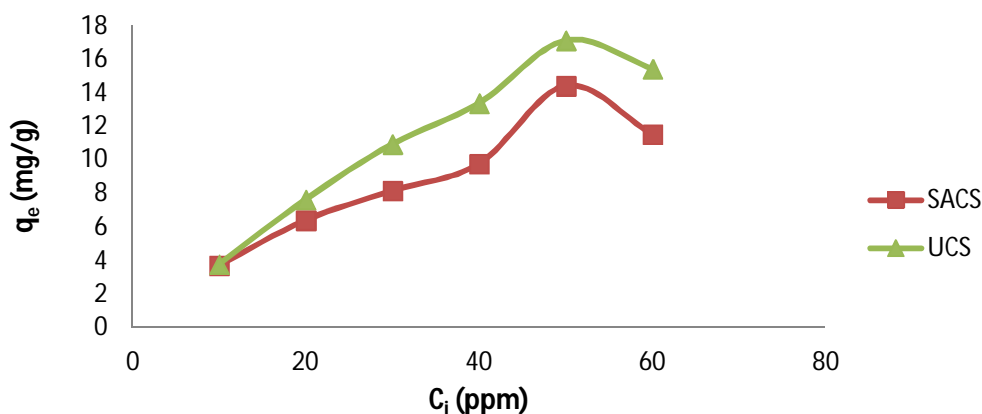
**Figure 3:** SEM micrographs of (a) SACS and (b) UCS.

#### *Effect of initial concentration of adsorbate*

To determine the optimum initial concentration of the metal ions for adsorption, the experiment was carried out with 10, 20, 30, 40, 50 and 60 ppm initial concentrations of the metal ions. A dosage of 0.10 g of the adsorbent was used at pH 6 at a temperature of 25 °C with agitation for 120 min. The effect of the initial Fe(II) and Cd(II) concentration on the removal of iron and cadmium ions is shown in Figures 4 and 5 where it can be observed that an increase in adsorbate concentration results in an increase in the amount adsorbed ( $q_e$ ) per unit weight of the adsorbent until an optimum concentration is reached after which an increase in the concentration does not show a higher adsorbate uptake. These observations are in agreement with other previous investigations.<sup>[15]</sup> Figures 4 and 5 show optimum adsorption for Fe(II) and Cd(II) initial concentrations of 40 ppm and 50 ppm, respectively.



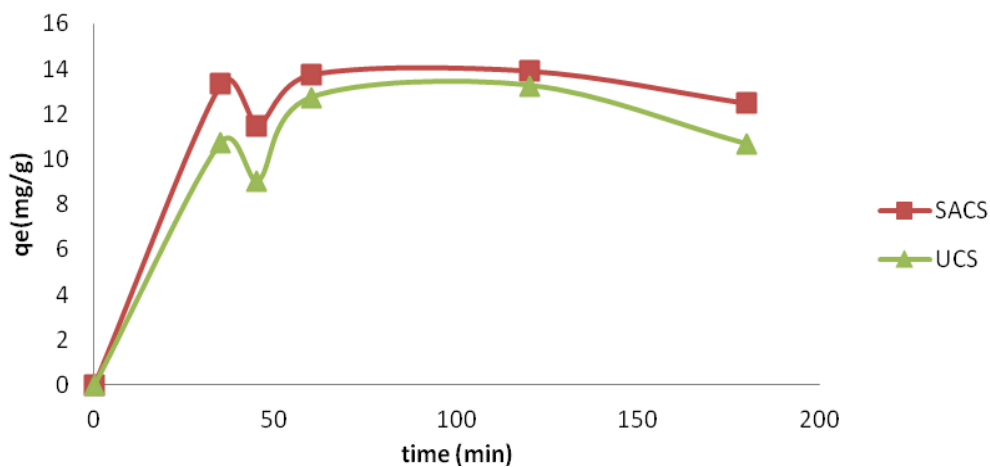
**Figure 4:** Effect of Fe(II) initial concentration on its sorption onto SACS and UCS (Conditions: pH = 6, temperature=298 K; contact time = 120 min; adsorbent dose = 0.10 g).



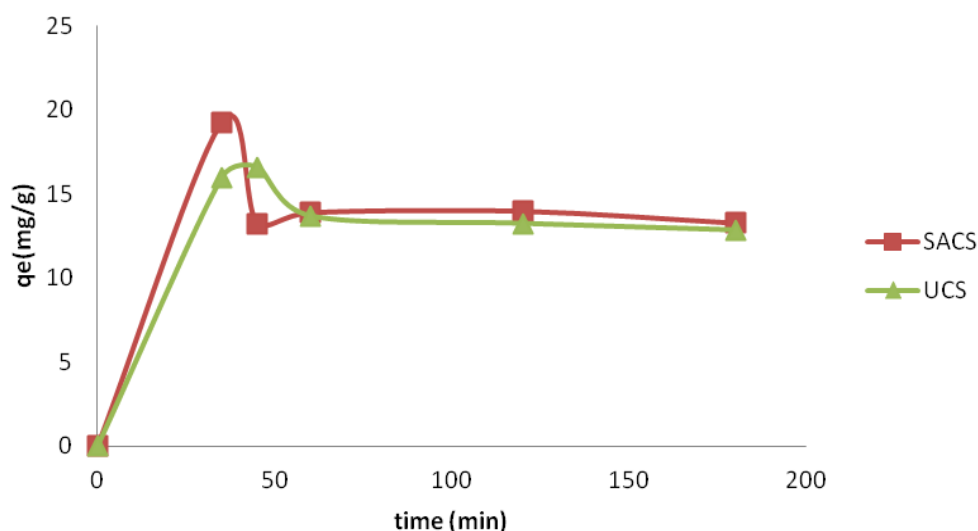
**Figure 5:** Effect of Cd(II) initial concentration on its sorption onto SACS and UCS (Conditions: pH = 6, temperature=298 K; contact time = 120 min; adsorbent dose = 0.10 g).

#### *Effect of contact time*

The effect of contact time was studied with initial concentrations of 40 ppm Fe(II) or 50 ppm Cd(II); the results are presented in Figures 6 and 7. For the sorption of Fe(II), the process was rapid at the initial stage and maximum uptake was reached in 45 minutes for the two adsorbents, SACS and UCS, with that on SACS being larger than on UCS. Beyond 45 min, the quantity adsorbed remains unchanged and a plateau is obtained. The observed behavior can be explained by the fact that in the initial stage of adsorption, there are many available active sites present in the adsorbent but after the optimum time has been reached, all the active sites have been fully utilized and there is therefore no considerable change in the amount of Fe(II) ions adsorbed with any further increase in the contact time. Similar observations have been previously reported. The sorption of Pb(II) followed similar trend but the optimum was found to be 40 minutes.



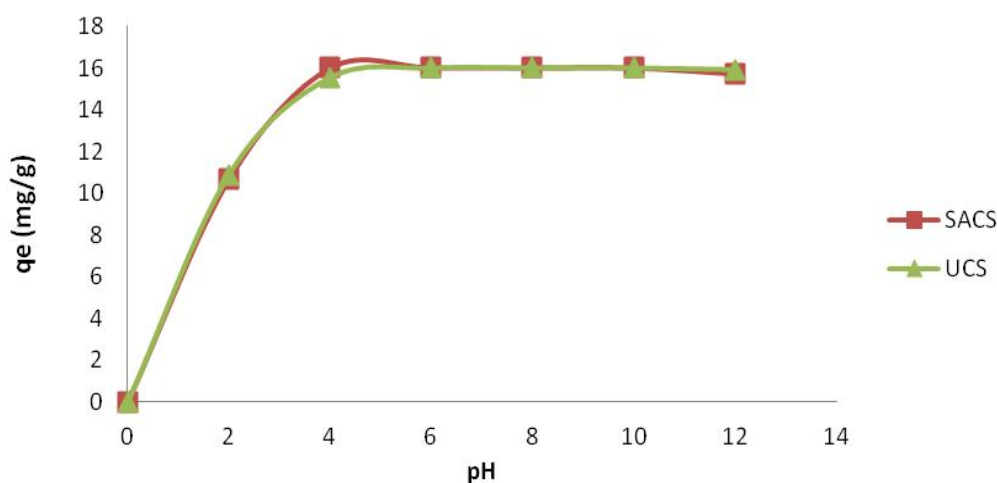
**Figure 6:** Effect of contact time on the sorption of Fe(II) onto SACS and UCS (40 ppm; pH = 6; temperature = 298 K; adsorbent dose = 0.10 g).



**Figure 7:** Effect of contact time on the sorption of Cd(II) onto SACS and UCS adsorbents (50 ppm; pH = 6; temperature = 298 K; adsorbent dose = 0.10 g).

#### Effect of pH

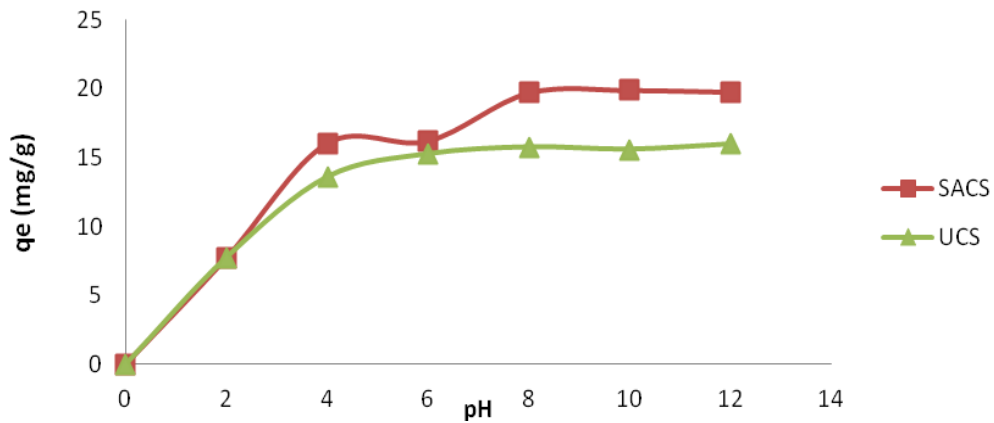
The effect of pH was studied using initial concentrations of 40 ppm Fe(II) or 50 ppm Cd(II) with a contact time of 45 min. The pH was adjusted by adding drops of 0.10 M HCl or 0.10 M NaOH accordingly. Figures 8 and 9 show the results obtained for the effect of pH on the removal of cadmium and iron ions, respectively.



**Figure 8:** Effect of pH on the sorption of Fe(II) onto SACS and UCS (40 ppm; temperature = 298 K; adsorbent dose = 0.10 g).

The pH influences both the metal binding sites as well as the metal chemistry in solution.<sup>[16]</sup> The amount adsorbed increases with increasing initial pH up to optimum values. At higher pH values, Fe(II) precipitates as hydroxide because of the high concentration of OH ions present. Hence adsorption at higher pH could not be performed. Similar result has been reported in literature.<sup>[16]</sup>



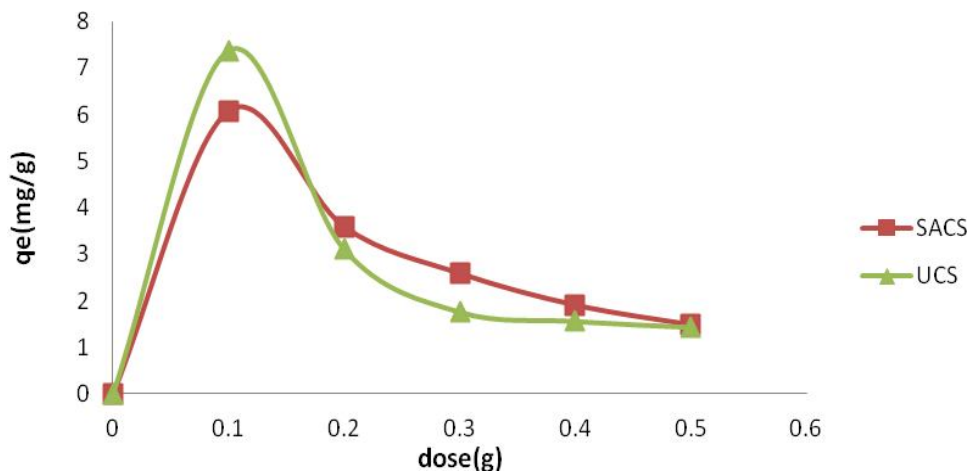


**Figure 9:** Effect of pH on the sorption of Cd(II) onto SACS and UCS (40 ppm; temperature = 298 K; adsorbent dose = 0.10 g).

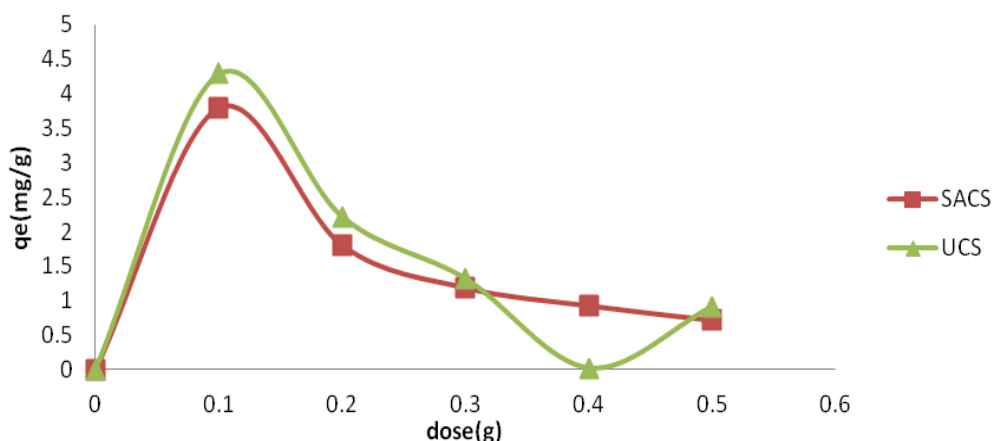
The amount of Cd(II) ions adsorbed increases with increasing pH. On increasing the pH from 2 to 4, the amount adsorbed increases until maximum uptake is reached at pH 8 and 5 for SACS and UCS, respectively. It is expected that the adsorption of metal ions decreases at low pH values because of the competition for binding sites between the cations and protons,<sup>[17]</sup> while at pH higher than 7, hydroxo species of the metals can be formed and they do not bind to the adsorption sites on the surface of the adsorbent.<sup>[18]</sup>

#### *Effect of adsorbent dose*

The doses of SACS and UCS used are 0.10, 0.20, 0.30, 0.40 and 0.50 g. The plots in Figures 10 and 11 below show the effect of adsorbent dose on the uptake of Fe(II) and Cd(II) ions, respectively.



**Figure 10:** Effect of the adsorbent dose on the sorption of Fe(II) onto SACS and UCS (40 ppm; 45 min contact time; pH 6, 298 K).

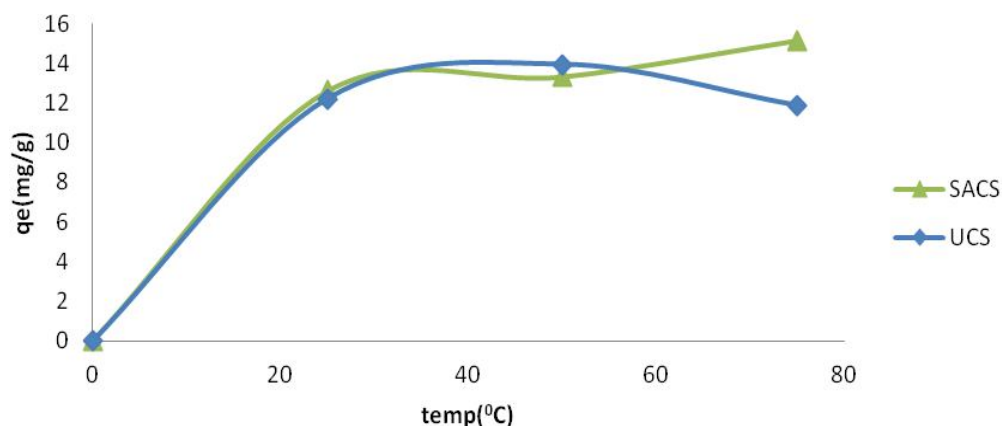


**Figure 11:** Effect of adsorbent dose on the sorption of Cd(II) onto SACS and UCS (40 ppm; 45 min contact time; pH 6, 298 K).

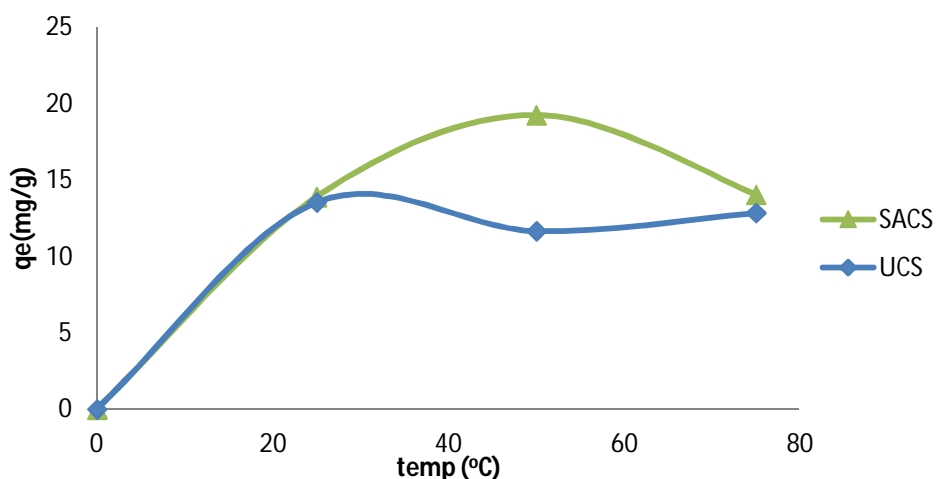
The study of adsorption of both metals at different adsorbent dosage shows that the amount adsorbed decreases with increasing the adsorbent dose for all the samples. Similar result was obtained in literature.<sup>[19]</sup> At a given initial metal concentration, the adsorbent concentration should be low to maximize the solid phase metal ion concentration at equilibrium. The results in this study are in agreement with literature report indicating lower adsorbed metal concentrations at high adsorbent concentrations.<sup>[20]</sup>

#### Effect of temperature

The effect of temperature on the adsorption of Fe(II) and Cd(II) onto SACS and UCS is shown in Figures 12 and 13, respectively. It can be seen that the amount of Fe(II) ions adsorbed on SACS increases with increasing temperature while that on UCS increases then decreases again after reaching a maximum. The amount of Cd(II) adsorbed on SACS and UCS increases with increased in temperature. Generally the amount adsorbed is expected to decrease with increasing temperature since most adsorption reactions are exothermic processes.



**Figure 12:** Effect of temperature on the sorption of Fe(II) onto SACS and UCS (40 ppm; 45 min contact time; pH 6, 0.10 g adsorbent).



**Figure 13:** Effect of temperature on the sorption of Cd(II) onto SACS and UCS.

#### Adsorption isotherms

Adsorption isotherms are basically important to describe how solutes interact with adsorbates and is critical in optimizing the use of adsorbents. For this study, Langmuir, Freundlich and Temkin adsorption isotherms were employed.

The Langmuir isotherm predicts monolayer coverage of the adsorbate on the outer surface of the adsorbent.<sup>[20]</sup> Its mathematical form is written as:

$$\frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{q_m K_L}$$

where,  $q_m$  (mg/g) is maximum monolayer coverage related to the adsorption capacity of the adsorbent, while  $K_L$  (L/mg) is the Langmuir constant related to equilibrium constant of adsorption. Both constants can be calculated from the slope and the intercept of the plot of  $C_e/q_e$  against  $C_e$ . The plots are shown in Figure 14. The parameters obtained are listed in table 3.

**Table 3:** Parameters for isotherms

Isotherms	Parameters	SACS		UCS	
		Fe(II)	Cd(II)	Fe(II)	Cd(II)
Langmuir	$q_m$ (mg/g)	12.690	16.611	16.612	16.64
	$K_L$ (L/mg)	0.570	0.431	0.761	0.76
	$R^2$	0.921	0.847	0.979	0.9883
	$R_L$	0.421	0.044	0.320	0.026
Freundlich	$K_f$ (mg/g)	4.432	4.043	8.671	6.74
	$n$	3.021	2.680	6.630	2.63
	$R^2$	0.622	0.860	0.241	0.741
Temkin	$A$ (l/g)	7.170	4.652	5743.82	10.34
	$B$ (J/mol)	2.369	2.475	1.229	3.339
	$R^2$	0.609	0.715	0.201	0.757

The Freundlich isotherm is based on multilayer adsorption on heterogeneous surfaces.<sup>[16]</sup> The linear form of Freundlich equation is:

$$\ln(q_e) = \ln(K_f) + 1/n \ln(C_e)$$

where  $K_f$  (mg/g) is the Freundlich constant indicating the adsorption capacity and  $n$  is the adsorption intensity. Both constants were calculated from the slope and the intercept of the plot of  $\ln(q_e)$  vs  $\ln(C_e)$  shown in Figure 15. The parameters obtained are listed in table 3.

The linear form of Temkin isotherm is:

$$q_e = B \ln(A) + B \ln(C_e)$$

where  $A$  (l/g) is the Temkin constant related to maximum binding energy and  $B$  (J/mol) is the Temkin constant related to the heat of sorption. The plot of  $q_e$  vs  $\ln(C_e)$  as shown in Figure 16 enables the determination of both constants. The parameters obtained are listed in table 3.

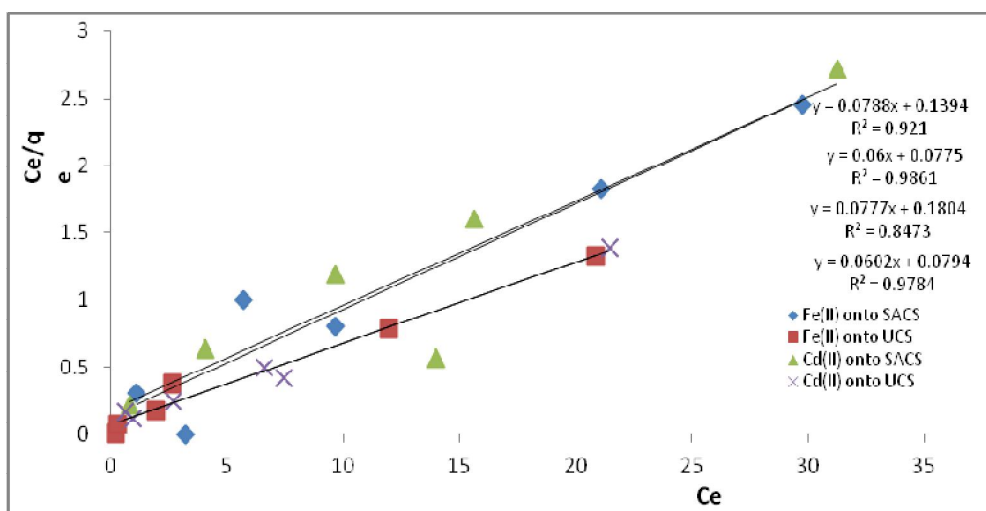


Figure 14: Langmuir isotherm plots for the sorption of Fe(II) and Cd(II) ions onto SACS and UCS.

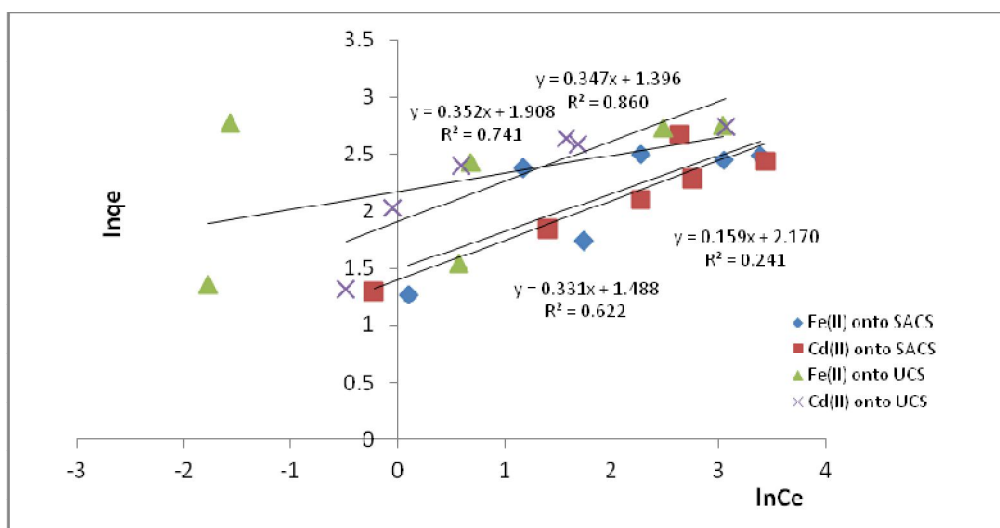
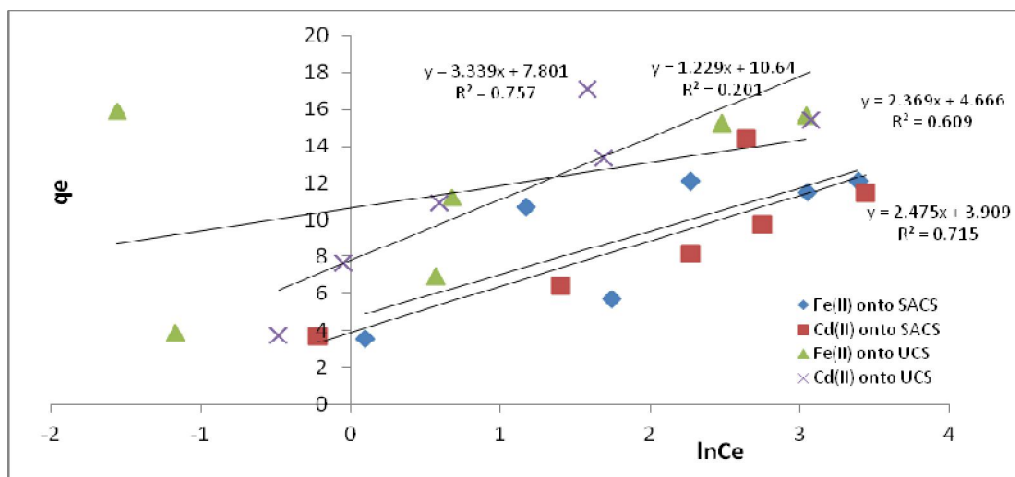


Figure 15: Freundlich isotherm plots for the sorption of Fe(II) and Cd(II) ions onto SACS and UCS.



**Figure 16:** Temkin isotherm plots for the sorption of Fe(II) and Cd(II) ions onto SACS and UCS.

The plots in Figure 14 show a linear relationship implying that the adsorption obeys the Langmuir model. The Langmuir constant are presented in Table 3. The  $R^2$  values obtained indicate that the Langmuir expression provides a better fit to the expression data of Fe(II) ion and Cd(II) ion on the adsorbents. The shape of the Langmuir isotherm was investigated by the dimensionless constant separation term ( $R_L$ ) to determine the extent of adsorption affinity;  $R_L$  is expressed as  $R_L = 1/(1+KC_0)$ . The value of  $R_L$  indicates the nature of the adsorption to be either unfavorable ( $R_L > 1$ ), linear ( $R_L = 1$ ), favorable ( $0 < R_L < 1$ ) or irreversible ( $R_L = 0$ ).<sup>[12]</sup> The  $R_L$  values obtained in this work indicate that the adsorption of both Fe(II) and Cd(II) ions are favorable processes.

The correlation coefficients obtained indicate that the adsorption of Cd(II) on SACS and UCS fit the Freundlich model more than the adsorption of Fe(II) ion on the adsorbents. The value of  $n$  shows the type of isotherm to be either favorable ( $n > 1$ ) or unfavorable ( $n < 1$ ).<sup>[21]</sup> The present study shows that  $n > 1$  indicating that the adsorption process is favorable. The linear relationship suggested by the Freundlich isotherm shows however only rather low  $R^2$  values for the adsorption of Cd(II) on both adsorbents.

From the  $R^2$  values obtained from the Temkin plots that the sorption of Fe (II) and Cd (II) onto SACS and that of Cd (II) onto UCS can be fairly explained using the Temkin adsorption model. The Temkin constant related to the heat of adsorption, which is relatively low ( $< 8$  kJ/mol), indicates that physical adsorption took place in the adsorption processes.<sup>[22]</sup>

#### *Thermodynamic parameters*

Thermodynamic parameters such as free energy change ( $\Delta G^0$ ), enthalpy change ( $\Delta H^0$ ) and entropy change ( $\Delta S^0$ ) were calculated from the variation of the thermodynamic distribution coefficient ( $K = q_e/C_e$ ) with change in temperature. The free energy change was calculated as  $\Delta G^0 = -RT \ln K$ .

Using the expression  $\ln K = \Delta S / R - \Delta H/RT$ , the values of  $\Delta H$  and  $\Delta S$  can be obtained from the slope and the intercept of the plot of  $\ln K$  vs  $1/T$ .

**Table 4:** Thermodynamic parameters of adsorption:  $\Delta G$  and  $\Delta H$  in J/mol,  $\Delta S$  in J/mol.K.

Adsorbent	Temp (K)	$\Delta G$ (Fe)	$\Delta G$ (Cd)	$\Delta S$ (Fe)	$\Delta S$ (Cd)	$\Delta H$ (Fe)	$\Delta H$ (Cd)
<b>SACS</b>	298	-236.85	53.29	-0.63	2.64	-531.34	704.73
<b>UCS</b>	298	-148.03	100.66	1.36	-0.88	157.45	-36.7

The standard Gibbs free energy was negative at all temperatures, confirming that the adsorption of Fe(II) ion onto SACS and UCS is spontaneous and thermodynamically favourable. The more negative  $\Delta G$ , the stronger is the driving force of adsorption. The standard enthalpy change was positive for UCS indicating that the adsorption of Fe(II) is an endothermic process. The positive value of entropy change may be interrelated to the increased randomness at the solid-liquid interface while the negative value of entropy change may be interrelated to the decreased randomness at the solid-liquid interface.

For Cd(II) adsorption, the process is not energy favorable as indicated by the positive values of  $\Delta G$ . The negative value of  $\Delta H$  for the sorption of Cd(II) onto UCS indicates an exothermic process.

#### *Adsorption kinetics*

The kinetics of adsorption describes the rate of metal ions uptake onto the adsorbents, this rate controls the time needed to reach equilibrium. Both Pseudo first order and pseudo second order plots were made from the experimental data for the adsorption processes.

Pseudo first order kinetics is given by the following equation:

$$\log(q_e - q_t) = \log q_e - \frac{K_{ad} t}{2.303}$$

A plot of  $\log(q_e - q_t)$  versus  $t$  was constructed as shown in Figure 17 for the adsorption of Fe(II) and Cd(II) on SACS and UCS. It can be observed that all the data of the adsorption processes fit very poorly into the pseudo first order model as evident from the  $R^2$  values of the plot. Therefore, pseudo first order kinetics does not describe well the adsorption processes.

The adsorption kinetics was also studied using the pseudo second order model given by the equation:

$$t/q_t = 1/k_2 q_e^2 + t/q_e$$

where,  $k_2$  is the second-order rate constant ( $\text{mg g}^{-1} \text{min}^{-1}$ ),  $q_t$  is the amount adsorbed at a particular time ( $\text{mg/g}$ ), while  $q_e$  is the amount adsorbed at equilibrium.

The values of  $k_2$  and  $q_e$  were calculated from the slope and the intercept of the plot  $t/q_t$  vs  $t$  as shown in Figure 18. The parameters obtained are given in Table 5.

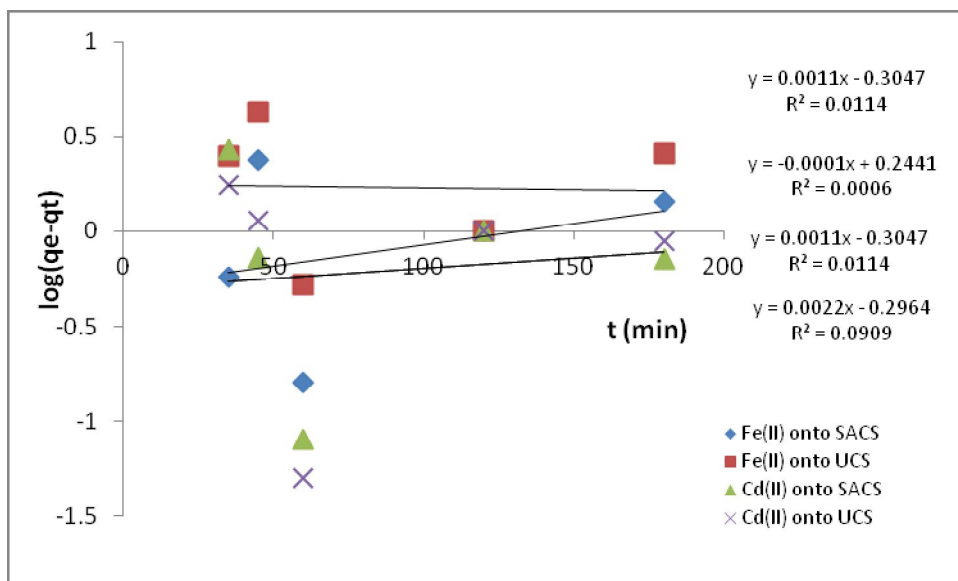


Figure 17: Adsorption kinetics analyzed by the pseudo first order kinetics model.

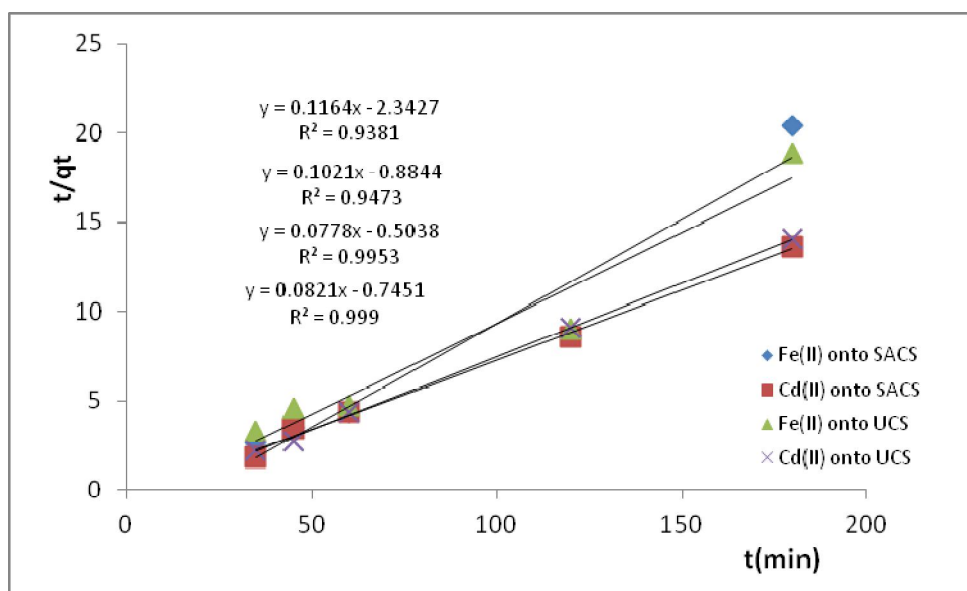


Figure 18: Adsorption kinetics analyzed by the pseudo second order kinetics model.

Table 5: Parameters for pseudo-second order kinetic model.

Parameters	SACS		UCS	
	Fe(II)	Cd(II)	Fe(II)	Cd(II)
$k_2$ ( $\text{mg g}^{-1} \text{min}^{-1}$ )	-0.006	-0.01	-0.01	-0.11
$q_e$ (calc) $\text{mg.g}^{-1}$	8.59	12.84	9.79	12.18
$R^2$	0.9381	0.9954	0.9473	0.999

From the table above, it could be observed that the rate constant ( $k_2$ ) decreases with the decrease in the equilibrium adsorption capacity ( $q_e$ ) for SACS and UCS. The

regression coefficients obtained indicated that the Pseudo-second-order model can be applied for the adsorption process. The experimental quantities of the metal ions adsorbed ( $q_e$ ) are relatively close to the quantities calculated from the pseudo second order model. For example the experimental quantity of Fe(II) ion adsorbed onto UCS was  $q_e = 12.74$  mg/g while the calculated quantity adsorbed was 12.84 mg/g. Similarly, the experimental quantity of Cd(II) ion adsorbed onto UCS was 12.83 mg/g and the calculated  $q_e$  was 12.18 mg/g. This result confirms further that the adsorption process conforms to the pseudo second order kinetics model.

## Conclusions

The present study shows that pure water sachet can be used as an effective adsorbent for the treatment of aqueous solutions containing Cd(II) and Fe(II) ions. The adsorption dynamics, isotherms, pH effect, adsorbent dosage, effect of temperature and adsorbate concentrations were examined. The metal uptake was found to increase with the increase in contact time till equilibrium has been reached. At any given contact time, the increase in initial adsorbate concentration was found to result in an increased uptake of the metal ions ( $q$ ) per unit weight of adsorbent. The effect of adsorbent dosage on the metals adsorption showed that the amount of metal adsorbed per unit weight of adsorbent decreases with increases adsorbent dosage. The optimum pH for the adsorption of Fe(II) was 4 irrespective of the adsorbent used, while that for the adsorption of Cd(II) was between pH 5-8.

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