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## Removal of Cadmium from Waste-water by Adsorption Using the Husk of Melon (*Citrullus lanatus*) Seed

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**Abstract-** Removal of cadmium from simulated wastewater (aqueous solution) using melon husk (an agricultural residue) modified with concentrated sulphuric acid was investigated at room temperature. Adsorption studies were carried out to determine the influence of contact time, initial cadmium ion concentration, adsorbent dosage and particle size on removal efficiency. Removal efficiency was observed to decrease with increasing initial cadmium ion concentration (2-10 mg/L), but increases with decreasing particle size (45-355  $\mu\text{m}$ ), and increasing adsorbent dosage (0.02-0.30 g). The data obtained fit into three equilibrium isotherms in the order: Freundlich > Langmuir > Temkin. Modeling of kinetics results showed that the adsorption process was best described by Pseudo-second order model with regression coefficients ( $r^2$ ) higher than 0.998.

**Key Words-** Cadmium; Melon Husk; Freundlich; Langmuir; Temkin

### 1 Introduction

Though heavy metals are natural components of the environment, their levels have undergone dramatic increase with increasing population and sophistication in human activities, especially since the beginning of industrial revolution (Nriagu, 1979). At least twenty metals have been classified as toxic, and 50% of these are being emitted into the environment in amounts that pose risks to human health (Kortenkamp *et al*, 1996). Besides their toxicity, heavy metals are of utmost concern because,

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unlike organic pollutants which are mostly biodegradable, they do not degrade into non-toxic end products. They persist in the environment and even bioaccumulate in the food chain (Ceribasi & Yetis, 2001).

Cadmium is one of the heavy metals that have been classified by the World Health Organisation (WHO) to be of serious health concern (Hundal, 1998). In fact, this metal together with Pb and Hg are referred to as “the big three” because of their significant negative impact on the environment (Volesky, 1994). Apart from the “itai-itai” disease which is a manifestation of cadmium toxicity in humans, kidney dysfunction, hepatic damage and hypertension are also other health implications of cadmium (Klaassen, 2001). It also causes cancer and genetic changes (Hill, 1984). A major source of heavy metals in the environment is the discharge of untreated industrial effluents from industries such as paints, plating, fertilizers, mining, textile dyeing and processing, automobile manufacturing and metal processing (Low & Lee, 1991; Habib-ur-Rahman *et al.*, 2006).

Several conventional methods such as coagulation/ flocculation (Sletten *et al.*, 1995; Amuda *et al.*, 2006), Oxidation process (Martinez *et al.*, 2003; Peres *et al.*, 2004) reverse osmosis, chemical precipitations, ion exchange and the use of activated charcoal (Poon, 1986) have been in use over the years for the removal of toxic heavy metals from wastewater. However, some of these technologies cannot effect complete removal of the pollutants, or are too expensive. There is therefore the need to develop more effective and economical technologies for the removal of heavy metals from effluents. This has led to the search for non-conventional low-cost materials for this purpose.

The current trend is to investigate the possibility of employing various agro-wastes and biological materials that are available in commercial quantities for wastewater remediation by adsorption (Abdel-Ghani *et al.*, 2007). This is a better alternative to the conventional techniques not only because it is cheap to process, but also because it is highly efficient and the materials are readily and abundantly available.

Various agricultural by-products in their raw and modified forms have been studied; these include sugarcane bagasse, rice husk, soybean hulls, waste tea leaves, peanut shells, and saw dust (Johns *et al.*, 1998; Ahluwalia and Goya, 2005; Taty-Costodes *et al.*, 2003; Amuda *et al.*, 2007). However, more work and investigations are still required to be carried out on some other locally available agricultural materials. This work is therefore undertaken to contribute to the search for low-cost adsorbents and the possibility of utilizing various agro-wastes, which are in many cases also pollution sources.

## **2 Materials and Methods**

### **2.1 Preparation of adsorbent**

Melon husk used in this work was collected from Aaradaa Market, a popular farm produce market in Ogbomoso, South-West Nigeria. Debris and other relatively big foreign materials were hand-picked from the husk, after which it was extensively washed with tap water to remove soil and dust. It was then thoroughly rinsed with distilled water, drained and oven-dried at 105°C for 15 h. The dried material was then ground and sieved.

Chemical treatment of the pulverized clean melon husk was carried out using concentrated sulphuric acid. The melon husk–acid mixture in ratio 1:1 (w/v) was kept in an electric oven at 150-160 °C for 24 hours. The black mass obtained was washed with distilled water, and soaked in 5% NaHCO<sub>3</sub> solution overnight to remove residual acid. This was washed again with distilled water to remove any free

NaHCO<sub>3</sub> (Habib–ur–Rehman et al., 2006; Raghuvanshi et al., 2004). It was then dried at 105°C for 24 hours, ground, sieved, stored in air–tight container and then used as acid modified melon husk, AMMH.

## 2.2 Characterisation of the adsorbent (AMMH)

The adsorbent was characterized using FTIR spectroscopy and Scanning Electron Microscopy (SEM). The IR spectrum of AMMH was recorded using Nicolet Avatar FT-IR within the range 4000 cm<sup>-1</sup> and 450 cm<sup>-1</sup>, with KBr disc as reference. The surface morphology of the adsorbent was observed on Hitachi 2300 Scanning electron microscope. Samples were coated with gold before being subjected to SEM analysis.

## 2.3 Preparation of sorbate

A stock solution (1000 mg/L) of Cd (II) was prepared by dissolving an accurately weighed analytical grade Cadmium sulphate (3CdSO<sub>4</sub>.8H<sub>2</sub>O) in de-ionised water. Working solutions of different concentrations, as required, were prepared from the stock by dilution process.

## 2.4 Batch adsorption experiments

Batch adsorption experiment were carried out in which 20 cm<sup>3</sup> of each metal ion of different concentrations was mixed with a definite mass (0.05-0.30 g) of the adsorbent in 150 cm<sup>3</sup> plastics bottles and were agitated in a horizontal mechanical shaker at 100 rpm for a pre-determined period of time and temperature at natural pH. The mixture was filtered through whatmann filter paper, and filtrate analyzed for its residual metal content using atomic absorption spectrophotometer (S- series by Thermo Electron Corporation). All experiments were carried out in duplicate and mean values determine were presented.

The amount of Cd(II) adsorbed,  $q$ , (mg/g) was evaluated thus:

$$q_e = \frac{(C_o - C_e)V}{M} \quad \dots(1)$$

$$q_t = \frac{(C_o - C_t)V}{M} \quad \dots(2)$$

$$R(\%) = \frac{C_o - C_t}{C_o} \times 100 \quad \dots(3)$$

where :  $q_e$  and  $q_t$  = the amount of dye adsorbed (mg/g) at equilibrium and at time  $t$  respectively;

$C_o$  and  $C_t$  = the initial concentration (at  $t = 0$ ) and its concentration at time  $t = t$  (mg/L);

$M$  = the mass of AMMH (g);

$V$  = the volume of Cd (II) solution (L);

$R$  = percentage of Cd (II) removed.

### 3 Results and Discussion

#### 3.1 Adsorbent Characterization

##### 3.1.1 Morphological studies

Studies on an adsorbent's surface topography could provide important information on the degree of interaction between the adsorbent particles and the dye molecules (Mas Rosemal and Kathiresan, 2009). Scanning Electron Microscope (SEM) was used to study the surface morphology of AMMH. The textural structure of the adsorbent is presented as scanning electron micrograph at x 500 magnification (Fig.1). The SEM image showed the irregular texture and porous nature of the surface of the adsorbent (Fig.1). The seemingly rough surface of the adsorbent is an indication of high surface area (Demirbas *et al.*, 2004).

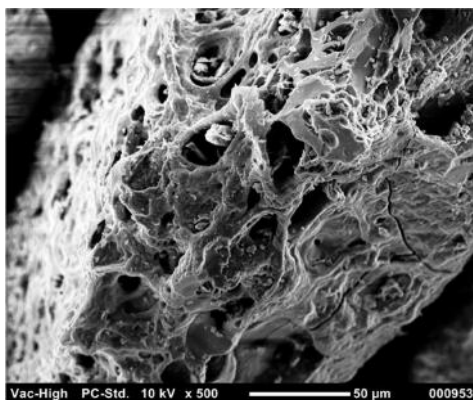


Fig.1: SEM image of AMMH (X 500)

##### 3.1.2 Infrared Spectroscopic Studies

The FTIR spectrum of AMMH before the adsorption process (Fig. 1a) displays a number of absorption peaks, indicating the complex nature of the material under study. The FTIR spectroscopic analysis indicated broad bands at  $3454\text{ cm}^{-1}$  representing -NH functional groups, while the presence of C=C and C-O-C groups are indicated by the bands at  $1624$  and  $1384\text{ cm}^{-1}$  respectively that are potential adsorption sites for cadmium ions.

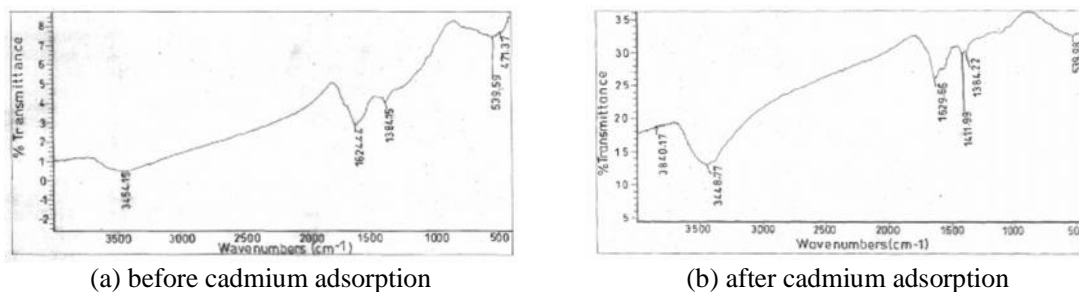


Fig.2: FTIR spectrum of Acid-treated melon husk (AMMH)

Fig. 2b is the FTIR spectrum of AMMH after the adsorption of cadmium. When compared with the FTIR spectrum of the adsorbent before any adsorption (Fig. 2a), there were slight shifts in the position of  $-NH$  and  $C=C$  bands at  $3454$  and  $1624\text{cm}^{-1}$  respectively in AMMH before adsorption to  $3448$  and  $1629\text{cm}^{-1}$  respectively after adsorption. These may be as a result of the attachment of cadmium ions to the adsorbents through these functional groups.

### 3.2 Effects of different experimental conditions

Since adsorption is affected by physical and chemical variables, the influence of initial  $\text{Cd(II)}$  concentration, adsorbent dose and contact time are investigated in this study.

#### 3.2.1 Effects of the initial concentration of cadmium (II) ions and contact time

The effect of contact time on the amount of  $\text{Cd}^{2+}$  adsorbed by AMMH was studied using three different initial concentrations (2, 5 and 10 mg/L) so as to optimize the adsorption time and to study the kinetics of the sorption process.

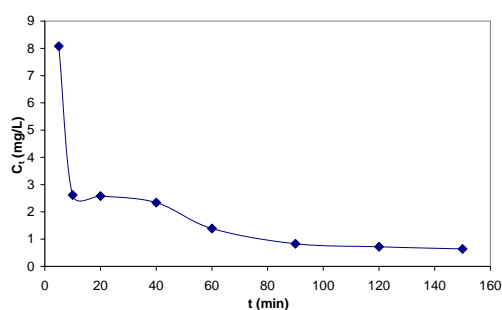


Fig.3a: Effect of contact time on the residual concentration of cadmium

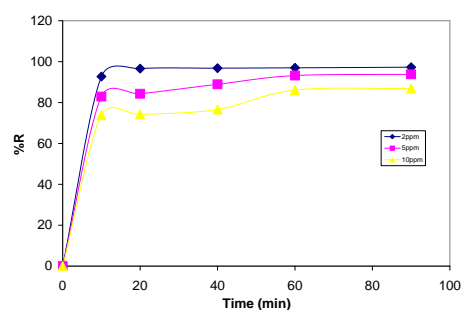


Fig. 3b: Effect of contact time on the removal of  $\text{Cd(II)}$  ions by AMMH

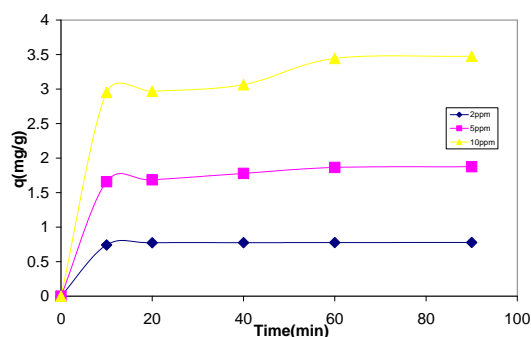


Fig. 3c: Effect of contact time on the adsorption of different concentrations of  $\text{Cd(II)}$  ions by AMMH

As contact time increases, the concentration of  $\text{Cd}^{2+}$  in the solution decreased rapidly at the beginning and later slows down until it remained constant at about 90 minutes, which was then taken as the equilibrium time (Fig.3a). This indicates that the removal of  $\text{Cd}^{2+}$  by AMMH was very rapid at the beginning. In fact, in all the initial concentrations used, over 70% removal was achieved within the first 10 min. Fig.3b depicts the time course for the percentage removal, R, for the adsorption of  $\text{Cd}^{2+}$  by AMMH. The initial rapid phase may be due to the large number of vacant sites available at the initial period of the sorption (Wong *et al.*, 2009). The amount of  $\text{Cd}^{2+}$  adsorbed per unit mass of AMMH also increases with increasing initial concentration of the metal ions. For example, the amount of  $\text{Cd}^{2+}$  removed at 40 minutes contact jumped from 0.77 mg/g at the initial concentration of 2 mg/L to 1.78 mg/g and 3.06 mg/g, at the initial concentrations of 5 and 10 mg/L respectively (Fig.3c). This may be because an increase in initial concentration enhances the interaction between the ions and the surface of the adsorbent (Rosenal *et al.*, 2009). This, however, leads to a corresponding reduction in the percentage removal of the metal ion (96.8, 88.9 and 76.6 % respectively) (Fig.3b).

Similar observation of a decrease in percentage removal with increasing initial concentration of sorbate, even though the amount adsorbed increased was reported in many works (Azhar *et al.*, 2005; Danielu & Doina, 2005). Removal efficiency (R) was higher for low concentration because of availability of unoccupied binding sites on the adsorbent. R decreased with increasing concentration because at high metal concentrations the binding sites were almost completely covered.

### 3.2.2 Effects of adsorbent dose

The dependence of adsorption of cadmium (II) ions on adsorbent dose was investigated by varying the quantity of the acid modified melon husk (AMMH) from 0.02 g to 0.30 g in 20 mL of 20 mg/L solution of the ion while keeping other parameters (contact time, agitation speed, particle size, temperature) constant.

The results shows that the adsorption capacity of AMMH decreases with increasing adsorbent concentration. However, the removal efficiency, R, of the adsorbent generally improved with increasing dose. R increased from 92.9 % to 95.6 % as the adsorbent dosage was increased from 20 mg to 300 mg (Fig.4). This can be attributed to the increase in the adsorbent pore surface areas and availability of more adsorption sites with increasing mass of adsorbent (Azhar *et al.*, 2005; Yi -Ling Lan *et al.*, 1998; Esmaeili *et al.*, 2008).

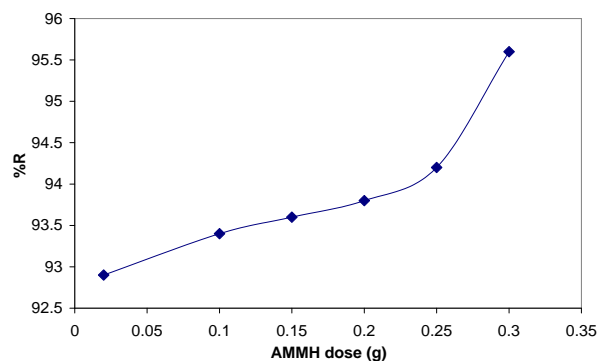


Fig.4: Effect of AMMH dose adsorption of cadmium

The increase in removal efficiency with increasing adsorbent concentration was rapid at low dosage but gradually falls and describes a typical saturation curve. This is in line with Langmuir hypothesis of increasing competition among adsorbent particles per unit volume (Converti *et al.*, 1992; Jain *et al.*, 2008; Mittal *et al.*, 2008).

### 3.2.3 Effects of adsorbent particle size

Three different particle sizes of sulphuric acid-modified melon husk (45, 125 and 355  $\mu\text{m}$ ) were investigated to study the effect of particle size on the sorption of Cd (II) by AMMH. It was observed that adsorption capacity,  $q_e$ , and removal efficiency, R increased with decreasing average particle size of AMMH. When the particle size was increased from 45  $\mu\text{m}$  to 355  $\mu\text{m}$ , R fell from 96.6% to 91.7% (Fig.5).

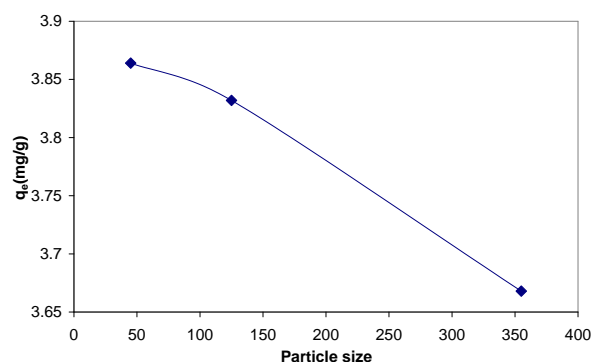


Fig.5: Effect of AMMH adsorbent particle size on the adsorption of cadmium

### 3.3 Adsorption isotherms

An adsorption isotherm model gives the equilibrium relationship between the sorbate in the fluid phase (solution) and the sorbate sorbed on the sorbent at constant temperature (Ali Riza *et al.*, 2007; Binupriya *et al.*, 2009). They are very useful for obtaining the adsorption capacity so as to facilitate the evaluation of the feasibility of the adsorption process for a given application and for selection of the most appropriate sorbent at the optimum experimental conditions (Ali Riza *et al.*, 2007; Ngada & Ghole, 2008).

In this work, adsorption isotherms were carried out at initial concentrations of 2-20 mg/L. The Langmuir, Freundlich and Temkin isotherm models were employed to interpret the sorption process in order to understand the mechanism of cadmium (II) ion adsorption on AMMH. The experimental data were fitted to the aforementioned equilibrium isotherm models. The data did not fit well into both the Temkin and Langmuir isotherms as their correlation coefficients are relatively lower than Freundlich model, which gave the best fit (Table 1).

Table 1: Isotherm model parameters for the adsorption of cadmium by AMMH

| Langmuir       |                |                | Freudlich      |                |       | Temkin         |                |        |
|----------------|----------------|----------------|----------------|----------------|-------|----------------|----------------|--------|
| R <sup>2</sup> | q <sub>m</sub> | K <sub>a</sub> | R <sup>2</sup> | K <sub>F</sub> | 1/n   | R <sup>2</sup> | K <sub>T</sub> |        |
| 0.9146         | 7.81           | 0.8997         | 0.9953         | 3.37           | 0.494 | 0.887          | 1.291          | 23.232 |

The Langmuir isotherm equation (Ho, 2005) is given as:

$$qe = \frac{q_m k_a c_e}{1 + k_a c_e} \quad \dots(4)$$

where: q<sub>e</sub> = the amount of dye adsorbed per unit mass at equilibrium (mg/g);  
q<sub>m</sub> = the maximum possible amount of dye that can be adsorbed per unit mass of adsorbent (mg/g);  
C<sub>e</sub> = concentration of sorbate (in the solution at equilibrium (mg/l);  
K<sub>a</sub> = sorption equilibrium constant.

The linearised form of equation (4) is:

$$\frac{c_e}{q_e} = \frac{1}{k_a q_m} + \frac{c_e}{q_m} \quad \dots(5)$$

A plot of  $\frac{c_e}{q_e}$  versus  $c_e$  gives a straight line, with a slope of  $\frac{1}{q_m}$  and intercept  $\frac{1}{k_a q_m}$ .

The essential characteristics of Langmuir isotherm can be expressed in terms of a dimensionless constant  $K_R$ , the separation factor or equilibrium parameter, which is defined as:

$$K_R = \frac{1}{1 + K_a C_o} \quad \dots(6)$$

Where :  $K_R$  = dimension less separation factor;  
 $K_a$  = Langmuir constant (L/mg);  
 $C_o$  = the initial concentration of Cd(II) ions (mg/L).

The shape of the isotherm is linear if  $K_R = 1$ , it is irreversible if  $K_R < 0$ , unfavourable if  $K_R > 1$  and favourable if  $0 < K_R < 1$  (46, 47).

The Freundlich isotherm is an empirical model which indicates the surface heterogeneity of the adsorbent. The equation is given as:

$$q_e = K_f C_e^{1/n} \quad \dots(7)$$



The linear form of the equation is:

$$\log q_e = \log K_f + \frac{1}{n} \log c_e \quad \dots(8)$$

where :  $q_e$  = the amount of sorbate adsorbed at equilibrium (mg/g);  
 $K_f$  (L/g) and  $n$  = Freundlich constants which indicate the adsorption capacity of the adsorbent and adsorption intensity, respectively;  
 $C_e$  = the equilibrium concentration of sorbate in the solution (mg/dm<sup>3</sup>).

A plot of  $\log q_e$  versus  $\log c_e$  gives a straight line of slope  $1/n$  and intercept  $\log K_f$  from which  $n$  and  $K_f$  can be evaluated. If  $1/n < 1$ , then the adsorption is favorable and the adsorption capacity increases with the occurrence of new adsorption sites. But if  $1/n > 1$ , the adsorption bond becomes weak and unfavorable adsorption takes place, leading to a decrease in adsorption capacity.

Temkin and Pyzhev (1940) studied the heat of adsorption and the adsorbent-adsorbate interaction of surfaces (Oladoja *et al.*, 2008). The Temkin isotherm is based on the assumption that the decrease in the heat of adsorption as a function of temperature is linear rather than logarithmic, as implied in the Freundlich equation (Pandey *et al.*, 2010). Furthermore, the model assumes that the heat of adsorption ( $\Delta H_{ads}$ ) of all molecules in the layer decreased linearly by increasing the coverage.

The isotherm is given as:

$$q_e = \frac{RT}{b} \ln k_T c_e \quad \dots(9)$$

Where :  $q_e$  = the amount of adsorbate adsorbed at equilibrium (mg/g);  
 $R$  = the universal gas constant (8.314 j/mol/k);  
 $K_T$  = the equilibrium binding constant (l/mg)

Equation (9) is linearised thus:

$$qe = B_1 \ln k_T + B_1 \ln c_e \quad \dots(10)$$

where :  $B_1$  = related to the heat of adsorption, and it is given by  $B_1 = \frac{RT}{b}$  ;  
 $T$  = temperature in Kelvin

Temkin constants are obtained from the plot of  $q_e$  versus  $\ln C_e$ .

This model takes into account the effects of indirect adsorbate/ adsorbate interactions on the adsorption process. The isotherm considers the occupation of the more energetic adsorption site first (Abdel-Ghani *et al.*, 2007), and that the adsorption process is chemisorption i.e. the particles of the adsorbate get attached to the adsorbent through valent bond formation (Lain-Chum-Jang, *et al.*, 2007). It also assumes chemical adsorption of adsorbate onto adsorbent.

### 3.4 Adsorption kinetics

The study of the adsorption kinetics of a sorption process is very important as it describes the rate of adsorbate uptake, which in turn evidently controls the residence time of the solute uptake at the solid-solution interface or the sorption reaction (Arivoli & Thenkuzhali, 2008; Igwe & Abia, 2007; Oladoja *et al.*, 2008). It is an important characteristic in defining the efficiency of sorption (Arivoli & Thenkuzhali, 2008). The data obtained from the study of adsorption dynamics are necessary to understand the variables that affect the sorption of solutes, and the rate of sorption observed can also be used to develop predictive models for column experiments (Oladoja *et al.*, 2008).

The most important thing when searching for an appropriate sorption mechanism, therefore, is to choose a mathematical model which not only fits the data with satisfactory accuracy but also complies with a reasonable sorption mechanism (Oualid & Mahdi, 2007).

Generally, sorption of adsorbate by an adsorbent consists of several steps which include:

- Transport of sorbate (solute) from the solution to the film surrounding the sorbent particles. This is called bulk diffusion.
- Diffusion of the sorbate from the film to the external surface (external diffusion).
- Diffusion from the surface to the internal sites i.e. intra-particle transport within the particle.
- Sorption of the sorbate on the interior surface of the sorbent (i.e. pore diffusion). This can involve several mechanisms including reaction kinetics at phase boundaries (Oualid & Mahdi, 2007; Malarvizhi & Sulachana, 2008; Igwe & Abia, 2007).

Various kinetic models have been proposed and used to study and describe the mechanism of a solute uptake by an adsorbent from aqueous solution (Ngada & Ghole, 2008; Oualid & Mahdi, 2007). In this study, however, the kinetic equations employed to investigate the mechanisms of cadmium ion adsorption are:

The Pseudo-first order by Lagergren (1898) given as:

$$\frac{dq}{dt} = k_1(q_e - q_t) \quad \dots(11)$$

Where :  $q_e$  and  $q_t$  = the adsorption capacities at equilibrium and at time  $t$  (mg/g) respectively;  
 $k_1$  = rate constant of pseudo-first order adsorption ( $\text{min}^{-1}$ )

After integration and applying boundary conditions  $t = 0$ , to  $t = t$ , and  $q_t = 0$  to  $q_t = q_e$ , equation (12) becomes;

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303} t \quad \dots(12)$$

where :  $q_e$  ( $\text{mg g}^{-1}$ ) = the amount of dye adsorbed at equilibrium;  
 $q_t$  ( $\text{mg g}^{-1}$ ) = the amount of metal adsorbed at time  $t$ ;  
 $k_1$  ( $\text{min}^{-1}$ ) = the rate constant of pseudo-first order adsorption.

A plot of  $(q_e - q_t)$  versus  $t$  gives the slope =  $k_1$ , and intercept =  $\log q_e$

The Lagergren first order rate constant ( $k_1$ ) and  $q_e$  determined from the model for the metals, and their respective coefficients of correlation,  $R^2$ , are shown in Table 2.

Table 2: Kinetics Parameters for the adsorption of cadmium by AMMH

| $C_0$ (mg/L) | Pseudo-First Order   |        |                     |        | Pseudo-Second Order |                     |        |      |
|--------------|----------------------|--------|---------------------|--------|---------------------|---------------------|--------|------|
|              | $q_{e, \text{expt}}$ | $R^2$  | $q_{e, \text{cal}}$ | $K_1$  | $R^2$               | $q_{e, \text{cal}}$ | $K'_2$ | $h$  |
| 2            | 0.779                | 0.9271 | 0.0287              | 0.0403 | 1                   | 0.781               | 3.33   | 2.03 |
| 5            | 1.888                | 0.9759 | 0.3803              | 0.0387 | 0.9998              | 1.922               | 0.22   | 0.82 |
| 10           | 3.488                | 0.9489 | 1.2939              | 0.0493 | 0.9984              | 3.602               | 0.07   | 0.91 |

The Pseudo-second order equation (Ho and Mckey, 1998) is given as:

$$\frac{dq}{dt} = k_2(q_e - q_t)^2 \quad \dots(13)$$

Where  $k_2$  is the rate constant of pseudo-second order adsorption ( $\text{g mg}^{-1} \text{min}^{-1}$ ), and other symbols have their usual meanings. After integration, equation (13) becomes:

$$\frac{1}{(q_e - q_t)} = \frac{1}{q_e} + k_2 \quad \dots(14)$$

Equation (14) is linearised to give:

$$\frac{t}{q_t} = \frac{1}{k_2} q_e^2 + \left(\frac{1}{q_e}\right)t \quad \dots(15)$$

if  $k_2 q_e^2 = h \quad \dots(16)$

combining equations (15) and (16) gives

$$\frac{t}{q_t} = \frac{1}{h} + \left(\frac{1}{q_e}\right)t \quad \dots(17)$$

A plot of  $t/q_t$  versus  $t$  gives a straight line.

If the sorption process follows pseudo-second order,  $h$ , is described as the initial rate constant as  $t$  approaches zero.

The correlation coefficients and adsorption capacities calculated from the kinetics models employed in the interpretation of the experimental data are given in Table 2. The pseudo-second order model give

the best description of the mechanism of cadmium adsorption onto AMMH. Apart from its having the highest  $R^2$  of 1, the adsorption capacity calculated from this model (0.781 mg/g) was very close to the experimental value (0.779 mg/g)

#### 4 Conclusion

The present study was carried out to investigate the ability of melon husk in the removal of cadmium ions from aqueous solution. The results obtained showed that the equilibrium time for the adsorption of the ions onto adsorbent was 90 minutes and the sorption process followed pseudo-second order kinetics. The data obtained fitted with Freundlich isotherm model ( $R^2 = 0.9984-1$ ). The monolayer adsorption capacity,  $q_m$ , obtained from Langmuir isotherm was 7.81 mg/g. The adsorption is highly influenced by parameters such as contact time, adsorbent dosage and initial concentration of  $Cd^{2+}$ .

The study has shown that melon husk which is abundantly available but generally considered of little or no value, has a considerable potential as an effective sorbent for the removal of cadmium ions from aqueous solutions. It can therefore have a place in the treatment of effluents from industries, thereby reducing the level of water pollution.

#### References

- Abdel-Ghani, N. T., Hefny, M., & El-Chaghaby, G.A.F. (2007). Removal of lead from aqueous solution using low cost abundantly available adsorbents. *Int. Jour. Environ. Sci. Tech.*, 4(1), 67-73.
- Aksu, Z. (2001). Equilibrium and kinetic modeling of cadmium(II) by *C. vulgaris* in a batch system: Effect of temperature. *Separa. Purif. Technol.*, 21, 285-294.
- Ali Riza, D., Yalcin, G., Nusret, K., & Elcin, G. (2007). Comparison of activated carbon and bottom ash for removal of reactive dye from aqueous solution. *Bioresour. Technol.*, 98, 834-839.
- Amuda, O. S., Amoo, I. A., Ipinmoroti, K. O., & Ajayi, O. O. (2006). Coagulation/flocculation process in the removal of trace metals present in industrial wastewater. *Jour. Appl. Sci. Environ. Mgt.*, 10(3), 159-162.
- Amuda, O. S., Giwa, A. A., & Bello, I. A. (2007). Removal of heavy metal from industrial wastewater using modified activated coconut shell carbon. *Biochem. Eng. Jour.*, 36, 174-181.
- Annadurai, G., Juang, R. S., & Lee, D. J. (2002). Use of cellulose wastes for adsorption of dyes from aqueous solutions. *Jour. Hazard. Mater.*, B92, 263-274.
- Arivoli, S., & Thenkuzhali, M. 2008. Kinetic, mechanistic, thermodynamic and equilibrium studies on the adsorption of rhodamine B by acid activated low cost carbon. *E-Jour. Chem.*, 5(2), 187-200.
- Batzias, F. A., & Sidiras, D. K. (2001). Wastewater treatment with gold recovery through adsorption by activated carbon. *Wat. Res.*, 3, 143-152.
- Batzias, F. A., & Sidiras, D. K. (2006). Dye adsorption by prehydrolysed beech sawdust in batch and fixed-bed systems. *Bioresour. Technol.*, 98, 1208-1217.
- Binupriya, A. R., Sathishkumar, M., Jung, S. H., Song, S. H., & Yun, S. I. (2009). A novel method in utilization of bok bunja seed wastes from wineries in liquid-phase sequestration of reactive blue 4. *Int. Jour. Environ. Res.*, 3(1), 1-12.
- Ceribasi, H. I., & Yetis, U. (2001). Biosorption of Ni (II) and Pb (II) by *Phanaerochate chryso sporium* from a binary metal system-kinetics. *Water SA.*, 27(1), 15-20.

- Chien, S. H., & Clayton, W. R. (1980). Application of elovich equation to the kinetics of phosphate release and sorption on soils. *Soil Sci. Soc. Ame. Jour.*, **44**, 265-268.
- Habib-Ur-Rehman, M. S., Imtiaz, A., Sher, S., & Hameedullah (2006). Sorption studies of Nickel ions onto sawdust of *Dalbergia sissoo*. *Jour. China Chem. Soc.*, **53**, 1045-1052.
- Harrison, R. M., & Laxen, D. P. H. (1980). Metals in environmental chemistry. *Chem. Br.*, **16**, 316-320.
- Hill, J. W. (1984). Chemistry for changing times. *Burgess publishing company, mineapolis*. 502-525.
- Ho, Y. S., & McKay, G. (1998). A comparison of chemisorption kinetic models applied to pollutant removal on various sorbents. *Proc. Safety Env. Prot.*, **76B**, 332-340.
- Ho, Y. S., & McKay, G. (1999). Pseudo-second order model for sorption process. *Proc. Biochem.*, **34**, 451-465.
- Ho, Y. S., Chiang, T. H., & Hsueh, Y. M. (2005). Removal of basic dye from aqueous solution using tree fern as a biosorbent. *Proc. Biochem.*, **40**, 119-124.
- Igwe, J. C., & Abia, A. A. (2007). Studies on the effects of temperature and particle size on bioremediation of As(III) from aqueous solution using modified and unmodified coconut fiber. *Global Jour. Environ. Res.*, **1(1)**, 22-26.
- John, M. M., Marshall, W. E., & Toles, C. A. (1998). Agricultural by products as granular activated carbon for adsorbing dissolved metals and organics. *Jour. Chem. Technol. Biotechnol.*, **71**, 131-140.
- Kortenkamp, A., Casadevall, M., Faux, S. P., Jenner, A., Shayer, R. O. J., Woodbridge, N. and O'Brien, P. (1996). A role for molecular oxygen in the formation of DNA damage during the reduction of the carcinogen chromium (vi) by glutathione. *Archiv. Biochem. Biophys.*, **329(2)**, 199-208.
- Lain-Chuen, J., Cheng-Cai, W., Chung-Kung, L., & Ting-Chu, H. (2007). Dyes adsorption onto organoclay and MCM-41. *Jour. Env. Eng. Manage.*, **17(1)**, 29-38.
- Langmuir, I. (1918). The adsorption of gases on plane surfaces of glass, mica and platinum. *Jour. Ame. Chem. Soc.*, **40**, 1361-1403.
- Low, K. S., & Lee, C. K. (1991). Cadmium uptake by Moss *calympe delcsertiis*. *Bioresour. Technol.*, **38**, 1-6.
- Malarvizhi, R., & Sulochana, N. (2008). Sorption isotherm and kinetic studies of methylene blue uptake onto activated carbon prepared from wood apple shell. *Jour. Env. Prot. Sci.*, **2**, 40-46.
- Martinez, N. S. S., Fernandez, J. F., Segura, X. F., & Ferrer, A. S. (2003). Pre-oxidation of an extremely polluted industrial wastewater by the fenton's reagent. *Jour. Hazard. Mat.*, **B101**, 315-322.
- McKay, G., & Poots, V. J. (1980). Kinetics and diffusion processes in colour removal from effluent using wood as an adsorbent. *Jour. Chem. Tech. Biotech.*, **30**, 279-292.
- Namasivayam, C., Radhika, R. and Suba, S. (2001). Uptake of dyes by a promising locally available agricultural solid waste, coir pith. *Wast. Manage.*, **21**: 381-387.
- Namasivayam, C. Kumar, M. D., & Begum, R. A. (2001a). Waste coir pith ; a potential biomass for the treatment of dyeing wastewaters. *Biomass. Bioener.*, **21**, 477-483.
- Nriagu, J. O. (1979). Global Inventory of natural and anthropogenic emissions of trace metals to the atmosphere. *Nature*, **278**: 409-411.
- Okiemen, F. E., & Onyenkpa, V. U. (1989). Binding of cadmium, copper, lead and nickel ions with melon (*citrullus vulgaris*) seed husk. *Biol. Waste.*, **29**, 11-16.
- Oladoja, N. A., Asia, I. O., Aboluwoye, C. O., Oladimeji, B., & Ashogbon, A. O. (2008). Studies on the sorption of basic dye by rubber (*Hevea brasiliensis*) seed shell. *Turk. Jour. Eng. Env. Sci.*, **32**, 143-152.

- Oualid, H., & Mahdi, C. (2007). Removal of methylene blue from aqueous solutions by wheat bran. *Acta. Chim. Slov.*, **54**, 407-418.
- Peres, J. A., Beltran de Heredia, J., & Dominguez, J. R. (2004). Integrated fenton's reagent ; coagulation/flocculation process for the treatment of cork processing wastewater. *Jour. Hazard. Mater.*, **107(3)**, 115-121.
- Poon, C. P. C. (1986). Removal of cadmium from wastewaters. *Cadmium in the Environ.*, **50**.
- Raghuvanshi, S. P., Singh, R., & Kaushir, C. P. (2004). Kinetics study of methylene blue dye bioadsorption on bagasse. *Appl. Eco. Env. Res.*, **2(2)**, 35-43.
- Sparks, D. L. (1986). Kinetics of reaction in pure and mixed systems in soil physical chemistry. *CRC Press*, Florida, 21-25.
- Srivastava, S. K., Tyagi, R., & Pant, N. (1989). Adsorption of heavy metal ions on carbonaceous material developed from the waste slurry generated in local fertilizer plants. *Wat. Res.*, **23**, 1161-1165.
- Taty-Costodes, V. C., Fauduet, H., Porte, C., & Delacroiz, A. (2003). Removal of Cd (II) and Pb (II) ions from aqueous and solutions by adsorption onto sawdust of *Pinus sylvestris*. *Jour. Hazard. Mat.*, **B105**, 121-142.
- Volesky, B. (1994). Advances in biosorption of metals, selection of biomass types. *FEMS Microbio. Rev.*, **14**, 291-302.
- Weber, W. J., & Morris, J. C. (1963). Kinetics of adsorption on carbon from solution. *Jour. Sanit. Eng. Div. Ame. Soc. Civ. Eng.*, **89**, 31-60.