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Removal of Cu(II) from aqueous solution using coconut *(Cocos nucifera L.)* coir dust

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ABSTRACT

The objective of this study is to assess the removal of Cu (II) from aqueous solution onto coconut Cocos nucifera L. (coir dust). The effect of various parameters has been investigated by batch adsorption techniques. The various variables studied include agitation time, pH, and particle size. The optimal time, pH, and particle size was found to be 60 mins, 7.5-8, and 50 µm respectively. The maximum uptake of copper (II) was found to be 111.11 mg of copper (II) per grams of coir dust. The equilibrium data was analyzed using Langmiur, Freundlich, Flory-Huggins and Dubinin-Radushkevich (D-R) isotherm models. Analysis of the data shows that Freundlich and Flory-Huggins described the data more appropriately than the Langmiur and Dubinin-Radushkevich isotherms. Adsorption kinetics data was tested using Pseudo-first-order, pseudo-second-order, Elovich equation and intra-particle diffusion models. Kinetic studies showed that the adsorption followed a pseudo-second-order model. Studies revealed that the intra-particle diffusion played an important role in the mechanism of Copper (II) adsorption while the Elovich equation suggests a chemisorption-ion-exchange mechanism for the adsorbate onto the coir dust.

Keywords: Adsorption, Adsorption isotherm, Coir dust, Copper (II), Ion-exchange, Kinetics.

INTRODUCTION

Heavy metal is one of the important pollutants in water and especially in wastewater, and it has become a public health concern because of its non-biodegradable and persistent nature. The toxicity of these heavy metals is enhanced through accumulation in living tissues and consequent bio magnification in the food chain [1, 2].

One of such heavy metals of concern is copper. It is present in the wastewater of several industries, such as metal cleaning and plating baths, refineries, paper and pulp, fertilizer, paints and wood preservatives industries [3].

Human body requires about 2mg/L of copper but excessive and prolonged intake of copper leads to some fatal consequences. Copper is also toxic to aquatic organisms even at very small concentrations [3]. There have been studies on the removal of heavy metals from water and wastewater using chemical precipitation, physical treatment such as ion exchange, solvent extraction, reverse osmosis and adsorption [4-6]. The application of such processes is often limited because of the technical and economic constraints [7]. As a result of these limitations of these traditional technologies, researchers have concentrated their works on low cost, unconventional absorbents (mostly agricultural products) for water and wastewater treatment.

In recent years, considerable attention has been focused on the removal of copper from aqueous solutions using absorbents derived from low cost materials. Several adsorbents such as sawdust, silica, and iron oxide, wheat shell, bagasse, fly ash, spent activated clay, natural kaolonite clay, modified goethite [8-12, 6]. The present study focuses on the removal of copper (Cu) from aqueous solution using coconut coir dust.

Coconut coir dust is one of the agricultural waste byproducts often used as adsorbent in waste water treatment. It's all year round availability and its abundance in the environment makes it a good source of adsorbent for metal ion removal from aqueous solution. It is the light, fluffy material that falls off from the thick mesocarp of coconut (Cocos nucifera L.) fruit when shredded during coir processing. The remarkable properties of coir dust that enhances its effectiveness as adsorptive / ion exchange capacities include good structural stability, high water absorptivity and high porous nature [13]. Its constituents include lignin, cellulose, hemicelluloses and extractives. These extractives contain tannins, pectins, with polyphenolic, carboxylic and hydroxyl groups. Lignins and cellulose in the coir affords its absorptive/ion exchange properties, the porous structure of the coir dust allows it to absorbs large amount of water but still, remain insoluble very much like any synthetic hydrogel [14].

The aim of this study was to explore the possibility of using coir dust for the removal of Cu(II) ions from aqueous solution. The effect of such factors as initial pH, contact time, particle size, initial concentration were investigated. The kinetics of Copper (II) adsorption by coir dust was analysed by various kinetic models. Experimental equilibrium data were fitted to the Langmuir, Freundlich, Flory-Huggins, Dubinin-Radushkevich isotherm equations to determine the best-fit isotherm model.

MATERIALS AND METHODS

2.1Materials:

2.2Adsorbent: Unground coconut (*Cocos nucifera L.*) coir dust used for the removal of Cu (II) ions from aqueous solution was procured from a local coconut processing mill in Uyo, Nigeria. It was air-dried for 24 hours and in oven at 60^0C to constant weight. The dried coir dust was separated into different particle sizes ranging from 50 – 800 μm and stored in air tight lid containers.

2.3 Adsorbate Solution

Stock solution of Cu (II) was prepared (1000 mg/L) by dissolving the desired quantity of copper sulphate hexahydrate $CuSO_4$**.** $6H_2O$ (Analytical grade) purchased from Sigma-Aldrich (Singapore). This was used as heavy metal model material without any further treatment.

2.4Characterization of Coconut Coir Dust

The coir dust was characterized for moisture, ash, lignin, cellulose contents, pH, cation exchange capacity, degree of swelling and solubility in some solvents according to standard methods.

Moisture content, cation exchange capacity (CEC) were determined using standard method of [15], Ash content was determined according to Standard method of Association of Official Analytical Chemist [16], while degree of swelling and solubility in solvents were determined using the procedure of [17] on composite cation exchangers, the presence of lignin and cellulose in the coir dust was determined using the phloroglucinol solution and Hieberman – Storch method [18] respectively.

The multimetal analysis of the coir dust was determined by digesting 0.5 g of sample in 50 ml of solution, and the elements determined using Atomic Absorption Spectrophotometer.

3.0 Adsorption Studies

3.1 Test for Agitation Time

Each 250 ml of Erlenmeyer flasks was filled with 100 ml of adsorbate (Cu) solution. Initial concentrations of samples were measured. Five hundred milligrams of adsorbent (coir dust) was measured and added to each of the conical flasks. The flasks were then agitated at 140 rpm using an Orbital shaker. They were removed from the shaker at temperature of 29.6 ^{o}C and the residual adsorbate analysis is after the other at 10, 30, 60, 90, 120 minutes. The samples were filtered and final adsorbate concentrations were measured using Atomic Absorption spectrophotometer.

3.2 Test for Optimum pH

The effect of pH on the rate of adsorption was investigated using copper concentration of 50 mg/l at constant adsorbent dosage. The pH values (pH 2-12) were adjusted with 0.1M HCl and 0.1M NaOH solutions. The adsorbent – adsorbate mixture was shaken at a temperature of 29.6 ^{o}C using agitation speed (140 rpm) for 90 mins. Then the concentration of copper ions in solution was determined using Atomic Absorption Spectrophotometer.

3.3 Test for Optimum Particle size

Adsorbent (500mg) of different particle sizes 50 – 600 μm were taken in conical flasks containing known concentration of adsorbate and shaken for 3 hours on Orbital shaker at agitation speed of 140 rpm, then the samples were filtered and final adsorbate concentrations were measured.

3.4 Sorption Equilibrium Studies

The sorption experiments for Cu (II) were carried out as follows several standard solutions concentrations, 5, 10, 25, 50, 75, 1000 and 200 mg/L were made from spectroscopic grade standard of copper sulphate hexahydrate. These metal solutions were adjusted to pH 7.0 with dil HCl and NaOH. Hundred milliliters of the metal ion was added to accurately weighed (500 ± 0.01mg) of coir dust in different flasks and agitated for three hours to ensure that equilibrium was achieved. At the end of the time, the suspension was filtered through Whatman No. 41 filter paper. The supernatant were analysed for metal ions content were determined using a Buck Scientific Atomic Spectrophotometer (FAAS) Model 300A.

RESULTS AND DISCUSSION

The important physico-chemical characteristics and the multielemental composition of coir dust are listed in Tables 1 and 2.

4.1 Characterization and multi-elemental analysis of coir dust

The content of the coir dust including moisture, cellulose lignin, ash, and extractives are listed in Table 1. Some of the data fit well with the compositional variations reported in the literature [19-21]. For coir dust the content of lignin (35.5%) is relatively high compared to other non-wood fibre species, e.g. flax (2.9%), hemp (3.0%) sisal (12.7%), jute (13.7%) and bagasse (19.9%) and comparable to hardwood (18 – 34%) and softwood (28-40%) [20], while the cellulose content (36%) is higher compared to other fibre species e.g. bagasse (28-32%), jute (16 – 22%), hardwood (19 – 26%) [21]. The carboxylate and phenolic groups of lignin, pectin and hemcellulose are known as the main sites for metal binding, resulting in bonds of more or less covalent character. Due to the structure and composition of the coir dust it is reasonable to suggest that more than one component within the network of lignin and hemicellulose is responsible for the bonding.

The multielemental content of metals native in the coir are listed in Table 2. The values are comparable to those reported in the literature [21]. The content of the light metals – Na, K, Mg, Ca is relatively higher than those for heavy metals Pb, Zn, Cd, Cu, etc. This may be partly attributed to source, growing the palm under saline conditions [23, 21].

Abad et al. [23] also reported variation is concentration of metal ions in coir dust as being related to:

i. fertilization program applied to the coconut palm.
ii. the processing of the coconut husk (“retting” process vs mechanical treatment) in the coir dust and
iii. age of the stockpiled coir dust and that of the coconut palm.

4.2 Effect of Contact Time

The absorption of Cu (II) on coir dust was also studied as a function of contact time in order to find out the equilibrium time required for maximum adsorption of Cu (II) ion on coir dust which was almost 90mins for initial concentration of 50 mg/L, (Fig. 1)

At the beginning, the Cu (II) ions were absorbed by the exterior surface of the adsorbent, and when the adsorption on the exterior surface had reached saturation, the Cu(II) ions entered into the pores of adsorbent and were adsorbed by the interior surface of the particles. This phenomenon takes relatively long contact time. The removal of metal ions by coir dust could be due to different sorption processes: – ion – exchange, adsorption (physisorption/chemisorption), co-ordination, complexation as a result of the various types of ion binding groups such as hydroxyl, carboxylic, phenolic functional groups in coir dust.

4.3 Effect of pH on Adsorption of Copper (II) ions:

The effect of pH on the adsorption of Cu II by coir dust is presented in Fig.2. The pH of the aqueous solution is an important controlling parameter in the adsorption process [24, 25]. At lower pH value, the H^+ ions compete with metal cations for the exchange sites in the system thereby partially releasing the latter. The heavy metal cations are completely released in extreme acidic conditions [8]. The present adsorption is minimum (69.88%) at pH 2 and increases as the pH is increased (Fig.2). The maximum adsorption occurs at pH 7-8 (91%) but adsorption decreases, when pH is increased further. The minimum adsorption at low pH (pH 2) may be due to the fact the high concentration and high mobility of H^+ ions, the hydrogen ions are preferentially adsorbed compared to Cu (II) ions by the coir dust.

4.4 Effect of Particle Size

It is evident from Fig. 3 that the amounts of Cu (II) ions adsorbed increased with a decrease in the particle size of the coir dust, showing that increasing sorption rate at small particle dimension. The high sorption of metal ions by the adsorbent with smaller particle size is due to the availability of more specific area on the coir dust [26]. The amount of adsorbate adsorbed following the order of particle sizes in microns of 50>63>150>300>425>600 respectively. Hence particle size of 50 µm was used throughout the study.

4.5 Studies of adsorption Isotherms

Four two-parameter equations – the Langmuir, Freundlich, Dubinin - Radushkevich and Flory-Huggins isotherms were examined for their ability to model the equilibrium data.

4.5.1 Langmuir Isotherm

The Langmuir sorption isotherm is widey used for the sorption of pollutants from a liquid solution assuming that the sorption takes place at specific homogeneous sites within the adsorbent. It is then assumed that once an adsorbate molecule occupies a site, no further adsorption can take place at that site. Therefore saturation value is reached beyond where no further adsorption can take place. The linear form of Langmuir equation is represented as:

$$\frac{Ce}{qe}=\frac{1}{Q_o b}+\frac{Ce}{Q_o} \qquad (1)$$

C_e is the equilibrium concentration (mg/L), q_e the amount of adsorbate adsorbed at equilibrium (mg/g), Q_o the monolayer capacity (mg/g) and b is the sorption equilibrium constant (L/mg). By plotting C_e/q_e versus C_e (Fig.4), the adsorption coefficient, could be calculated. The Q_o and b thus determined from the Langmiur isotherm were 111.11mg/g and 0.16364 L/mg, respectively, at 29.6 ^oC with R^2 of 0.796 (Table 3). According to Hall [27], the essential features of the Langmiur isotherm can be expressed in terms of a dimensionless constant (R_L) :

$$R_L=\frac{1}{1+bC_o} \qquad (2)$$

The value indicates the shape of the isotherm as follows:

R_L value	Type of Isotherm
$R_L > 1$	Unfavourable
$R_L = 1$	Linear
$0 < R_L < 1$	Favourable
RL = 0	Irreversible

where b is the Langmuir constant and C_o is the initial Cu (II) ion concentration (mg/L). The value of R_L indicates the types of the isotherm to be either unfavourable, RL > 1, linear, $R_L = 1$, favourable, $0< R_L < 1$, or irreversible, $R_L = 0$. The values of R_L for adsorption of Cu (II) onto coir dust at 29.6 ^oC are shown in Table 4. The dimensionless constant, R_L lies within the favourable limit. High values of b indicate high adsorption affinity and from the findings, adsorption of Cu (II) by coir dust occurs at lower concentrations of the metal ions.

4.5.2 Freundlich Isotherm

Freundlich is another important isotherm used in the analysis of equilibrium studies of copper (II) ions removal from aqueous solution. The empirical Freundlich isotherm is based on the equilibrium relationship between heterogeneous surfaces. This isotherm is derived from the assumption that the adsorption sites are distributed exponentially with respect to the heat of adsorption. The logarithmic linear form of Freundlich isotherm may be represented as follows:

$$Log\ q_e = log\ K_F + 1/n\ log\ C_e \qquad (3)$$

where K_F and n are the Freundlich constants that point to relative capacity and adsorption intensity respectively, the constants can be determined from the slope and intercept of the Freundlich isotherm plot (Fig. 5). The values of K_F and n were determined to be 5.296 (mg/g) and 1.65260 respectively. From Table 3 the value of n is greater than unity, indicating that Cu (II) ions was favourably adsorbed on coconut coir dust at the temperature studied.

4.5.3 Flory – Huggins Isotherm

The Flory – Huggins model accounts for the degree of surface coverage characteristics of adsorbate on the adsorbent and the linear form of the Flory –Huggins equation is expressed as:

$$log\ (\theta/C) = log\ K_{FH} + \alpha_{FH}\ log\ (1-\theta) \qquad (4)$$

where θ is the surface coverage of the adsorbent by adsorbate ($\theta = (1-C_e/C_o)$),
C_o and C_e are the initial and equilibrium Cu (II) ion concentrations respectively. K_{FH} and α_{FH} are the Flory – Huggins constants. These constants can be obtained from the plot of log (θ/C) versus log (I-θ) and are determined from Fig. 6. The equilibrium constants K_{FH} and α_{FH} are shown in Table 3, to be 3.767 and 0.252 respectively for Cu (II) adsorption by coir dust at the temperature under investigation. Furthermore the equilibrium constant K_{FH}, obtained from the Flory – Huggins isotherm model is used to compute the Gibbs free energy for the adsorption process. The Gibbs free energy is related to equilibrium constant as follows:

$$\Delta G^0 = -RT/In\ K_{FH} \qquad (5)$$

where R is universal gas constant 8.314 J/K/mol, T is absolute temperature (K) and K_{FH} is equilibrium constant from Flory-Huggins isotherm equation.
The ΔG^0 for this study was computed to be -33.334 kJ/mol. The negative value of ΔG^0 indicates that the sorption process is spontaneous in nature.

4.5.4 Dubinin-Radushkevich

The Dubinin – Radushkevich model was chosen to estimate the characteristic porosity and the apparent free energy of adsorption. The model assumed that the characteristics of the sorption curves are related to the porosity of the adsorbent. The linear form of the isotherm can be expressed as follows:

$$\ln q_e = \ln q_D - B_D(RT \ln(1+1/C_e) \qquad (6)$$

Where q_D is the theoretical maximum capacity (mol/g) B_D is the D – R model constant (mol^2/KJ) or the porosity factor which can be obtained from the slope of the plot of $\text{In}q_e$ verses ε and $\varepsilon = RT\text{In}\ (1 + 1/Ce)$, (Fig7, Table 3), ε being the Polanyi potential. The mean sorption energy of sorption, E_s (kJ/mol) was calculated using the following equation:

$$E = \frac{1}{\sqrt{2B_D}} \qquad (7)$$

and this energy value which was calculated to be 0.917 KJ/mol was found to be in the energy range of physical adsorption reaction. Physisorption processes have adsorption energies less than 8 KJ mol^{-1} and the energy of 0.917 KJ/mol for Cu (II) ions sorption on coir dust indicates that the sorption process is physisorption and the positive value of energy (E), of sorption indicates that the sorption process is endothermic and that higher solution temperature will favour the sorption process. Other authors have reported both endothermic and exothermic adsorption for Pb (II) onto activated carbon prepared from coconut shell and coconut copra meal as adsorbent [28, 29] respectively.

4.6 Adsorption Kinetics

Sorption kinetic mechanics can be based on diffusion mass transfer processes or chemical reaction kinetics. The sorption kinetics of a sorbent depend on the property of the sorbate, experimental conditions, temperature and pH value. Each combination of sorbent and sorbate has a unique metal ion – sorbent interaction. In this study, three different reaction kinetic models (pseudo-first order equation, pseudo-second order equation and Elovich equation) were applied to determine the reaction order and rate constant of the adsorption/ion exchange between coir dust and Cu(II) ions in solution.

4.6.1 The Pseudo-first-Order Equation

The pseudo-first order reaction equation for solid-liquid sorption system was proposed by Lagergren [30]. This equation has been traditionally the most conventional model often used for liquid sorption modelling. The pseudo-first-order kinetic model can be represented by the following Lagergren equation:

$$\log(qe - qt) = \log qe - k_1 \frac{t}{2.303} \qquad (8)$$

Where q_e and q_t are the amounts of adsorbate adsorbed (mg/g) at equilibrium and at contact time t (min), respectively and k_1 is the pseudo-first order rate constant (min^{-1}). The values of q_e and k_1 for pseudo-first – order kinetic model were determined from the intercepts and slopes of the plots of log ($q_{e\,-}\,q_t$) versus t (fig. not shown) The value of k_1 , correlation coefficient and q_e are shown in Table 5 as 3.556, 0.544 and 26.77 (mg/g) respectively. The low value of correlation coefficient suggest that the kinetics of Cu (II) adsorption on coir dust did not follow the pseudo – first order kinetic model and hence a diffusion – controlled phenomena.

4.6.2 Pseudo–second–order kinetic model.

The pseudo-second-order kinetic model can be represented in the following form:

$$\frac{t}{q_t} = \frac{1}{k_2 qe^2} + \frac{1}{q_e t} \qquad (9)$$

where k_2 is the rate constant of the pseudo-second-order adsorption (g/(mg min). The plot of t/qt versus t is a straight line as shown in Fig. 8. The k_2 and q_e values determined from the slope and intercept of the plot are presented in Table 5 along with the corresponding correlation coefficients. This procedure is more likely to predict the behaviour over a whole range of adsorption. The high value of the correlation coefficient (R^2) of 0.972, indicate the applicability of the pseudo-second-order kinetic model to describe the adsorption process of Cu (II) on coconut coir dust. It suggested that the adsorption process was controlled by chemisorption [31]. The pseudo-second-order kinetic parameters obtained could be used to determine the equilibrium sorption capacity, percentage of the removal of Cu (II) ions, rate constants and initial sorption rate for a reactor design.

4.6.3. Elovich Equation

The Elovich equation is one of the most useful models for describing chemisorption which is expressed as follows:

$$q_t = 1/\beta\, In(\alpha\beta) + 1/\beta\, In\,(t) \qquad (10)$$

where α is the initial adsorption rate (mg/(g min) and β is the adsorption constant related to the extent of surface coverage and activation energy for chemisorption (g/mg). The parameters (1/β) and (1/β)In(αβ) can be calculated from the slope and intercept of the linear plots of q_t versus Int. (Fig. 9). The parameters β, α and the correlation factor calculated are shown in Table 5 to be 8.621 (g/mg), 5.840 (mg/g min), and 0.919 respectively. The parameter 1/β is related to the number of sites available for adsorption while (1/β)In(αβ) is the adsorption quantity when *In t* is equal to zero, i.e. the adsorption quantity when t is 1min. This value is helpful in understanding the adsorption behaviour of first step of sorption process [31]. The high correlation value R^2 = 0.919 also suggested that chemisorption may also be involved in the adsorption of copper(II) ions onto coconut coir dust as this adsorbent possess different types of functional groups.

4.6.4 Intraparticle diffusion

The adsorbate transport from the solution phase to the surface of the adsorbent particles occurs in several steps. The overall adsorption process may be controlled either by one or more steps, e.g. film or external diffusion, pore diffusion, surface diffusion and adsorption on the pore surface, or a combination of more than one step. The rate parameter of intraparticle diffusion can be defined as [32]:

$$qt = k_{id}\, t^{1/2} + C \qquad (11)$$

where k_{id} is the intraparticle diffusion rate constant (mg/g $min^{1/2}$) and C is the intercept, qt is the amount of Cu (II) ions adsorbed at time t. If the mechanism of adsorption follows the intraparticle diffusion, the plot of qt versus $t^{1/2}$ would be a straight line and k_{id} and C can be calculated from the slope and intercept of the plot. Values of C give an idea about the thickness of boundary layer, i.e. the larger the intercept, the greater the contribution of the surface sorption in the rate controlling step [33]. The value of k_{id} and C can be determined from the slope and intercept of plot of q_t versus $t^{1/2}$ (Fig. 10). The regression was linear, but the plot did not pass through the origin, suggesting that adsorption involved intraparticle diffusion, but that, that was not the only rate-controlling step, that some other mechanisms might be involved [34]. The k_{id} value and C values calculated were 0.116 (mg/g $min^{1/2}$) and 16.48 respectively.

4.7 Fractional Attainment of Equilibrium

The fraction attainment of equilibrium (α) is the ratio of the amounts of metal ion removed when sorption equilibrium is attained. Vinod and Anirudhan [35] using the equation:

$$\ln(I - \alpha) = K_a t \qquad (12)$$

where α - the fractional attainment of the equilibrium
K_a - the overall rate constant
t - time

observed that the fractional attainment of equilibrium (α) which can be calculated from the equation is an important parameter usually obtained from kinetic studies. The rate of attainment of equilibrium may either be film diffusion or particle diffusion controlled; however, these two different mechanism cannot be sharply demarcated. Using this equation, a linear relationship indicates a particle diffusion controlled sorption and the diffusivity of the metal ions onto the biomass surface is independent of the extent of sorption.

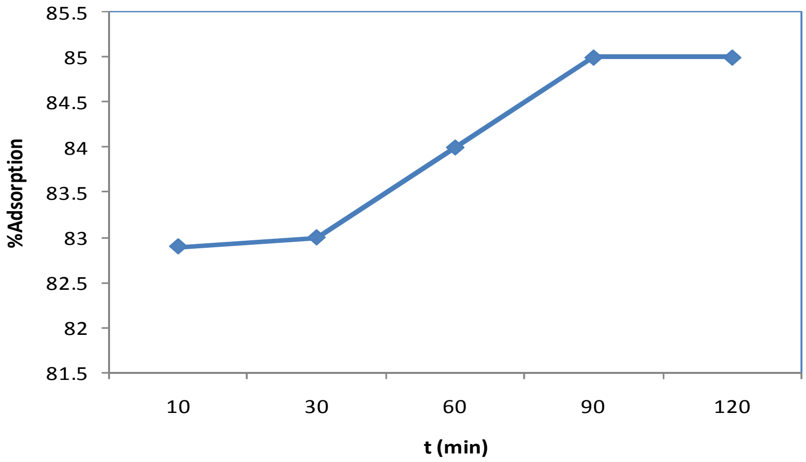

Fig. 1. Plot of % adsorption versus time for Cu(II) adsorption onto coir dust

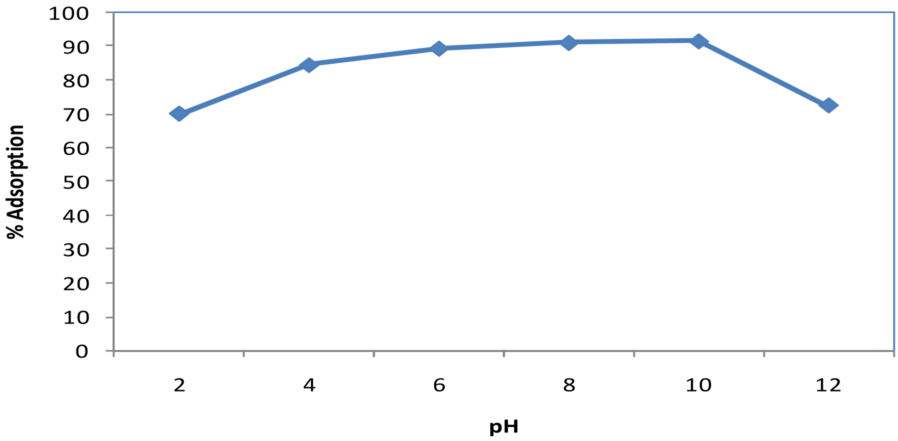

Fig. 2. Plot of % adsorption versus pH for Cu(II) adsorption onto coir dust.

However, a non-linear plot indicates that the diffusion of the ions onto the adsorbent surface is film – diffusion controlled. From Fig 11, it can be seen that the relationship between metal ion diffusivity, In (1-α), and time is linear one, and therefore a diffusion-controled sorptions process is suggested for the adsorption of Cu(II) ions onto coir dust.

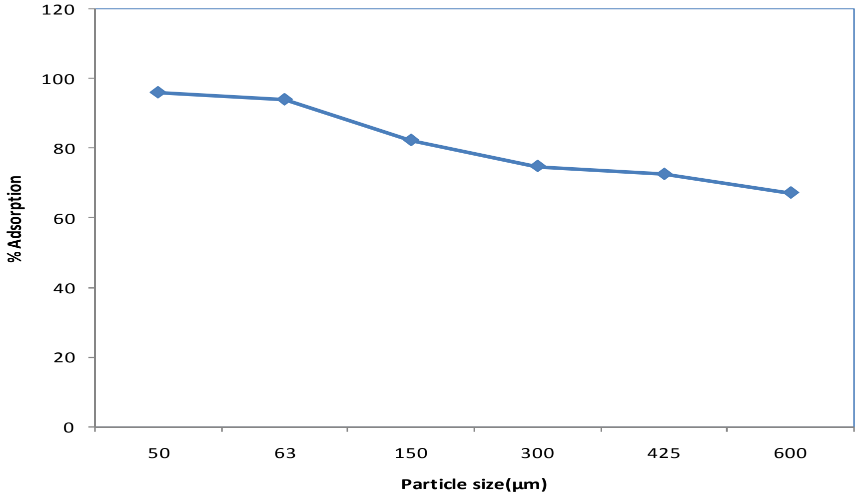

Fig. 3. Plot of % adsorption versus particle size for Cu(II) adsorption onto coir dust.

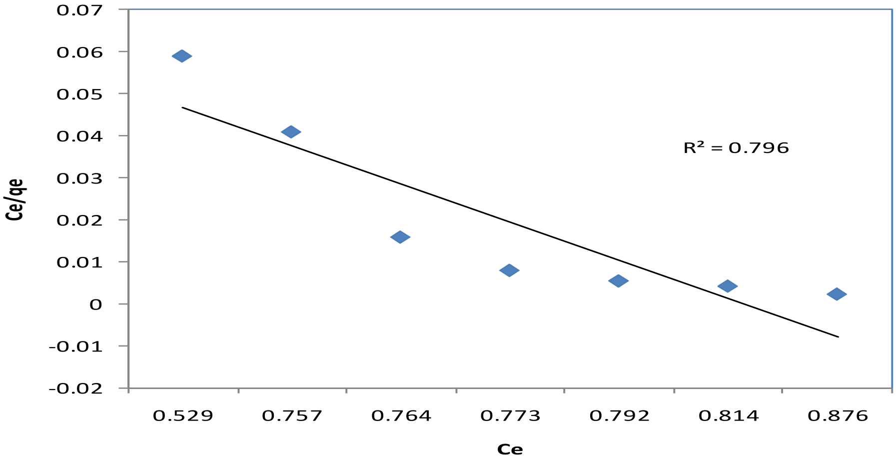

Fig. 4. Langmuir isotherm plot for Cu(II) adsorption onto coir dust.

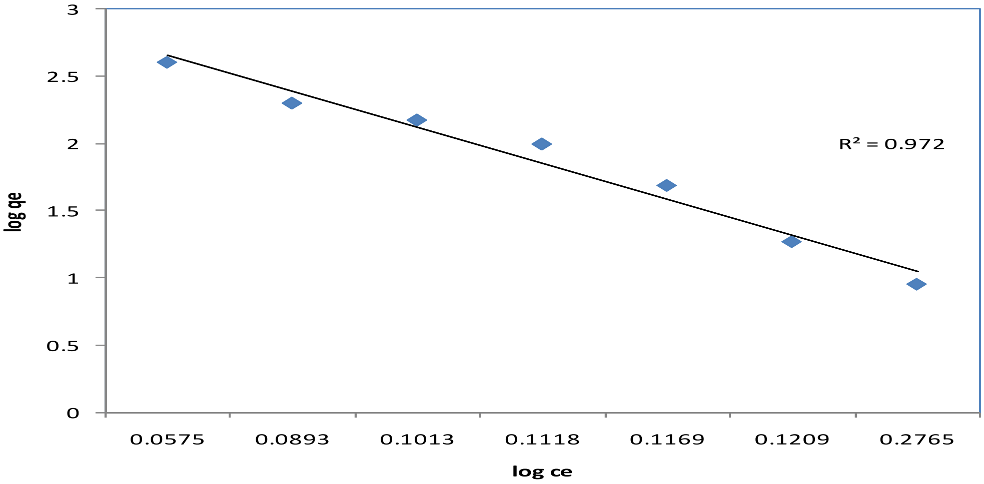

Fig. 5. Freundlich isotherm plot for Cu(II) adsorption onto coir dust.

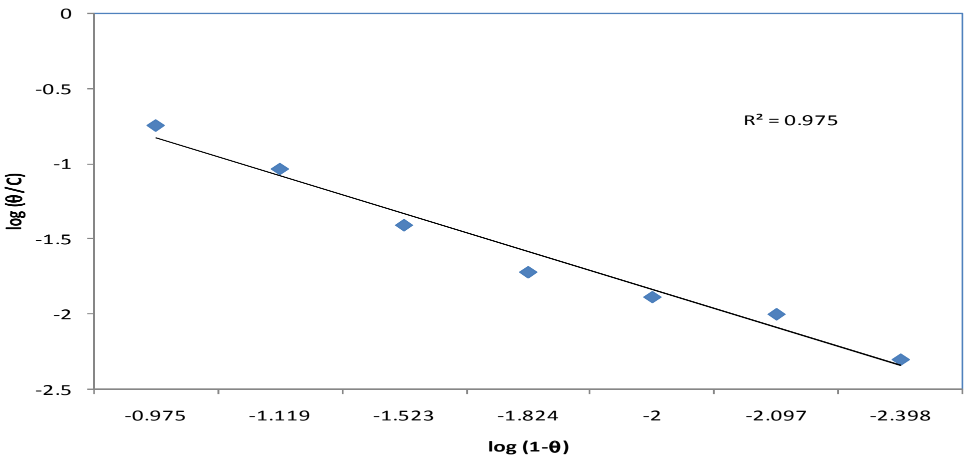

Fig. 6. Flory- Huggins isotherm plot for Cu(II) adsorption onto coir dust.

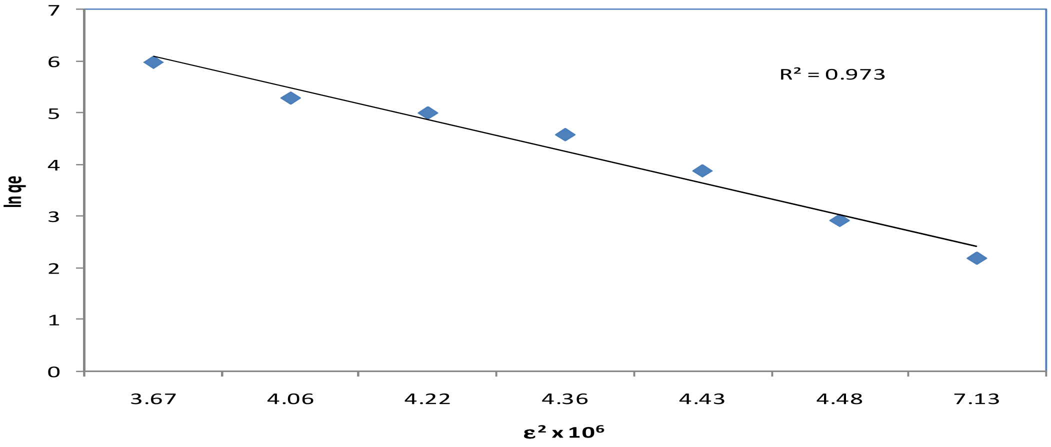

Fig. 7. Dubinin-Radushkevic (D-R) isotherm plot for Cu(II) adsorption onto coir dust.

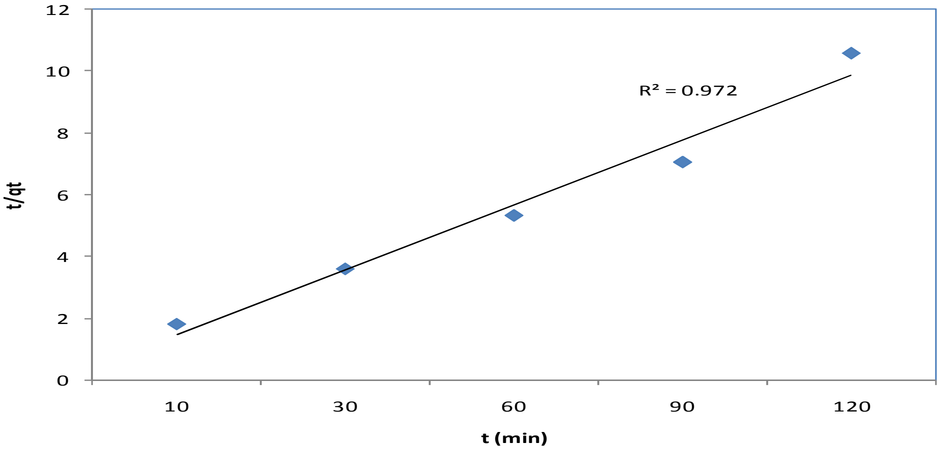

Fig. 8. Pseudo-second-order kinetic plot for the adsorption of Cu(II) onto coir dust.

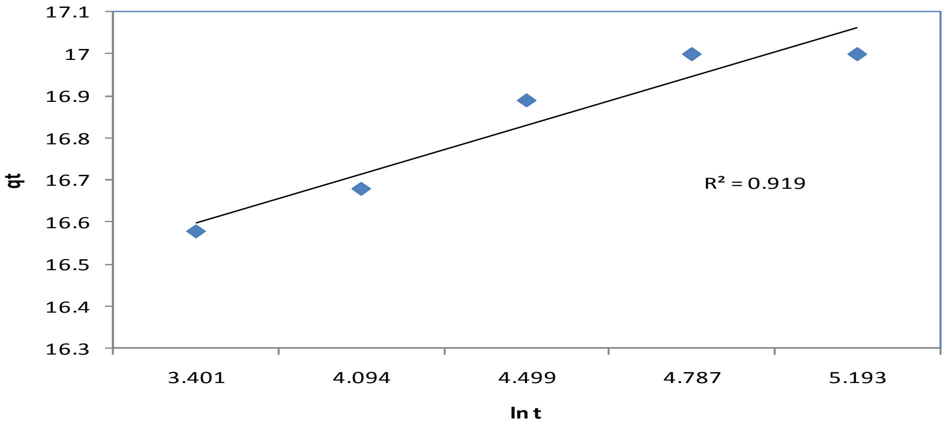

Fig. 9. Elovich kinetic plot for the adsorption of Cu(II) onto coir dust.

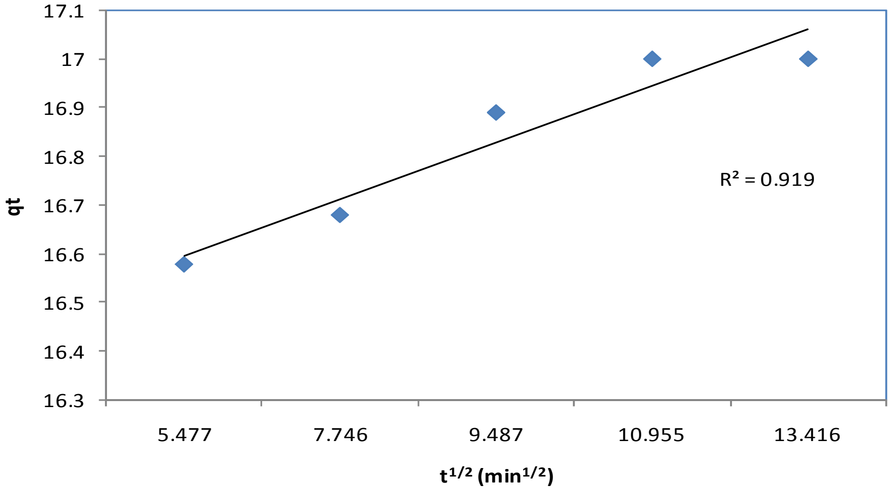

Fig. 10. Intraparticle diffusion model plot for the adsorption of Cu(II) onto coir dust.

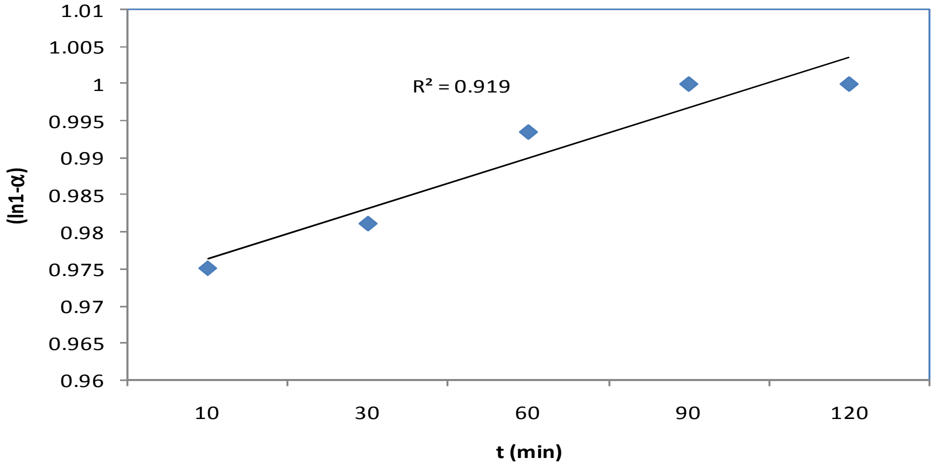

Fig. 11. Fractional attainment of equilibrium for adsorption of Cu(II) on coir dust.

Table 1: Characteristics of Coconut Coir Dust

Parameter	**% Content**
Moisture content	25.5
Ash	9.0
Water Extractive	28.2
Acid (dil HCl Extractive)	41.3
Swelling in H_20	
1 hour	65.7
5 hour	70.8
10 hours	77.7
24 hours	85.7
Swelling in Acetone	0.934
Swelling in dil HCl	3.229
pH of coir dust in H_20	6.4
Cellulose	35.99
Lignin	35.50
Alkali soluble (18% NaOH solution)	*41.3*
Cation exchange capacity (mmolg^{-1})	*2.39*

Table 2: Multielemental contents in the Coir (based on air dried weight)

Metal	**µ metal/g coir dust Present Study**	**Literature value µ metal/g coir dust (Conrad and Hansen, 2007)**
Na	463.20	861.0
K	711.60	3630
Ca	227.40	564
Mg	172.0	474
Pb	0.180	0.175
Cu	1.60	3.12
Cd	0.04	0.020
Cr	0.20	0.238
Zn	4.286	4.32
Fe	285.20	121.0
Mn	1.094	5.94
Mo	0.020	0.035
Co	0.060	0.054
Ni	1.00	0.715
As	ND	ND
Hg	ND	ND
V	ND	ND

pH = 7.0 Temp. = 29.6 °C, dose 0.5 g. ND = not detected
Particle size = 50 µm. Colour of coir dust = brown to light brown.

Table 3: Isotherm constants for adsorption studies

METAL	**MODEL**	**MODEL PARAMETERS**			
Cu(II)	Langmuir	Q_o(mg/g)	b(L/mg)	R^2	
		111.11	0.164	0.796	
	Freundlich	K_F (mg/g)	1/n	R^2	n
		5.29	0.615	0.972	1.626

Flory-Huggins	K_{FH} (mg/g)	α	R^2	
	3.296	0.252	0.975	
D-R (model)	β_D	q_D	R^2	E(kJ/mol)
	0.615	832.0	0.973	0.917

Table 4: Analysis of langmiur isotherm for Cu (II) adsorption. $R_L = 1/1+bC_o$

Initial Conc.(mg/g) of Cu(II)	R_L
5	0.5499
10	0.3739
25	0.1964
50	0.1089
75	0.0753
100	0.0576
200	0.0296

Time: 90 mins, pH: 7, Temp.: 29.6 °C, Particle size: 50 µm, Dosage: 0.5 g, Shaking rate: 140 rpm.

Table 5: Kinetic model values for adsorption of Cu(II) onto coir dust

METAL	**KINETIC MODEL**	**MODEL PARAMETERS**			
Cu(II)					
	Pseudo- first- order	$q_{e.exp}$	k_1 (g/mg min)	$q_{e.cal.}$	R^2
		17.00	3.56	26.90	0.544
	Pseudo-second-order	$q_{e.exp}$	k_2 (g/mg min)	$q_{e.cal.}$	R^2
		17.00	35.98	0.47	0.972
	Elovich kinetic model	β(g/mg)	1/β(mg/g)	α (mg/g min)	R^2
		8.62	0.12	5.84	0.919

Time: 90 mins, pH: 7, Temp.: 29.6 °C, Particle size: 50 µm, Dosage: 0.5 g, Shaking rate: 140 rpm.

CONCLUSION

This study shows that coconut coir dust was effective as low cost adsorbent/ion-exchanger for the removal of Cu(II) ions from aqueous solution. The adsorption was found to be dependent on contact time, pH, and particle size. The maximum adsorption of Cu(II) ions was found to be at 90 mins, pH of 7.5-8 and particle size of 50 µm. The experimental results were analysed using four two-parameters adsorption isotherm models- the Langmuir, Freundlich, Flory-Huggins, and

Dubinin-Radushkevich isotherms. Analysis of the data showed that the Fruendlich and Flory-Huggins isotherm described the data more appropriately than the Langmiur and Dubinin-Radushkevich isotherms. Adsorption parameters were substituted to four Kinetic models-pseudo-first-order, pseudo-second-order, Elovich equation and Intra-particle diffusion models. Kinetic studies showed that the sorption of Copper metals ions can best be described by the pseudo-second-order and Elovich equation. The Elovich equation is the most applicable model for chemisorption ion-exchange mechanism process. Studies also revealed that the Intra-particle diffusion played an important role in the mechanism of Copper (II) adsorption. The negative value of ΔG^0 signifies that the adsorption reaction was a spontaneous process. Coconut coir dust is a renewable, low cost natural abundant adsorbent material and it may be an alternative to more costly adsorbent materials.

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