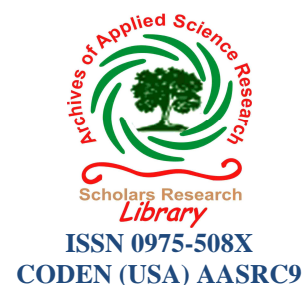




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Absorption approach for recovery and removal of Cd (II) from aqueous solution using coir dust

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ABSTRACT

Removal of cadmium, Cd (II) from aqueous solution was studied using Coir Dust, Carboxylated Toluene and Sulphonated Toluene Resins. The experiment was performed as a function of solute concentration and contact time. The effect of Cd (II) on adsorption was then examined. The effect of resins on adsorption showed that the quantity of metals adsorbed from solution rise with increase in time and attain equilibrium at 60mins for Coir Dust and Sulphonated Toluene Resins and at 90mins for Carboxylated Toluene Resine. Different isotherms were employed to study the effect of time and concentration. The data showed that Coir Dust is efficient in the recovery and removal of Cd (II) from aqueous solutions.

Keywords: Adsorption, Cadmium II, Coir Dust, Aqueous Solution, Isotherm Models.

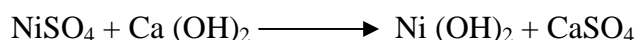
INTRODUCTION

The presence of heavy metals in both surface and underground water has led to increase environmental concern by both scientists and engineers. One of such heavy metals is Cd (II) which is non-essential for human consumption. Cadmium, Cd (II) has an extremely long biological half life (greater than 20 years) and is listed as one of the 126 priority contaminants known as 'carcinogen' by the International Agency for Research on Cancer. Cadmium is released through natural processes such as volcanic activity. Its release meets water bodies directly through the effluent of industries causing a mark increase in its concentration. Metals such as silver, mercury, cadmium and copper are markly more toxic even at low levels [1]. Due to the toxicity of these metals resulting in bad health, there is need for their recovery and removal. Several methods such as precipitation, ion exchange reaction, solvent extraction, reverse osmosis and adsorption are used for the recovery and removal of metal ions from solutions.

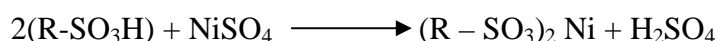
Adsorption (surface reaction) which could be physical or chemical is the ability of the adsorbate to adhere to adsorbent. The force associated with physical nature is relatively weak and of important with the surface reaction of the adsorbed. Chemical force is considerably stronger; the adsorbed molecules are held to the surface by valence force. The heat evolved is of the order 10 to 100 Kcal per mole, compared to physical adsorption which has less than 5 Kcal per mole. Ion exchanged describes the process as water flows through a bed of ion composite materials. The undesirable ions are removed and replaced with less objectable ones. Demineralization simply replaced all cations with hydrogen ions (H^+) and all anions with hydroxide ions (HO^-). Ion exchange processes are capable of removing selected ions almost completely [2].

A reversible chemical reaction wherein an ion (an atom or molecule) that has lost or gained an electron thus acquired an electrical charge/form solution is exchanged for a similarly charged ion attached to an immobile solid particle. These solid ion exchange particles are either naturally occurring inorganic zeolites or synthetically produced organic resins. The synthetic organic resins are predominant type used today because their characteristics can be tailored to specific applications. An organic ion exchange resin is composed of high-molecular-weight polyelectrolytes that can exchange their mobile ions for ions of similar charge from surrounding medium. Each resin has a distinct number of mobile ion sites that set the maximum quantity of exchange per unit resin.

In a water deionization process, the resins exchange hydrogen ions (H^+) for a positively charged ions (such as nikel, copper and sodium) and hydroxyl ions (OH^-) for negatively charged such as sulfates, chromates and chlorides. Because the quantity of H^+ and OH^- ions are balanced, the result of ion exchange treatment is relatively pure, neutral water. Ion exchange reactions are stoichiometric and reversible and in that way they are similar to other solutions phase reaction for example:



In this reaction, the nikel ions of nikel sulfate ($NiSO_4$) are exchanged for the calcium ions of calcium hydroxide ($Ca(OH)_2$) molecule. Similarly, a resin with hydrogen ions available for exchange will exchange those ions for nikel ions from solution. The reaction can be written as follows:



R indicates the organic portion of the resin and SO_3 is the immobile portion of the ion active group [3].

Coir Dust (CD) is the spongy peat-like residue from the processing of coconut cocopeat. It consists of short fibres of about 2 to 13 percent of the total cork-like particles ranging in size from granules to fine dust. Coir Dust strongly absorbs liquids and gases, due to the honey-comb-like structure of the mesocarp tissue which gives it a high surface area per unit volume. Coconut Coir Dust (CCD) is a lignocellulosic material of plant origin, having a combination of cellulose and hemicellulose content: lignin, pectin and waxes which acts as binders. One of the most important attributes of CCD is its ease of wetting, unlike the peat which becomes increasingly difficult to rewet as it dries or becomes hydrophobic in nature [4]. Coir Dust has an acceptable pH, cation exchange capacity and electrical conductivity. These properties make it a viable alternative plant growing medium. Coconut CD and other organic media are biologically active in providing conducive environment for plant roots. They also support fast populations of microbes. Various applications of CD are medium for the production of flower feeds, carpets, saw dust blushes, filters, ropes, mats, car seat covers and adsorbent pads [5].

Adsorptive recovery and removal of heavy metals from aqueous solution is achieved by using activated carbon or activated alumina. Activated carbon is a porous material with an extremely large surface area and intrinsic adsorption of chemicals. Polymer resins that can form complexes with heavy metal ions are the best adsorbents [6]. These are called conventional adsorption and many others have been reported to include silica and zeolite [7]. These conventional adsorbents are employed in many processes for the recovery and removal of heavy metals from waste water such as chemical precipitation, chemical oxidation or reduction, electrochemical treatment, ion exchange and membrane technologies. These processes may be ineffective or expensive [8], especially when the heavy metal ions are in solutions containing in the order of 1 – 100mg dissolved heavy metal ions L⁻¹ as a result of these biological methods such as biosorption for the removal of heavy metal ions may provide an attractive alternative to physico-chemical methods [9]. Biosorbents of plants origin are mainly agricultural by product such as maize cob and husk, cassava waste, wile cocoyam, saw dust, coconut fibre.

The pH of the aqueous solution is an important controlling parameter in the adsorption process. According to [10], the recovery and removal of Cd (II) from waste water increased as the pH is increased. In acidic medium (lower pH) hydrogen ions compete with metal ions as a result active sites (negatively charged) become protonated resulting in the prevention of metal ion adsorption on the more negative charge surface of adsorbent. However, with increase in pH, more and more negative charged surface of the adsorbent became available and hence uptake of metal ion increased. This was observed in the removal of cadmium, Cd (II) from waste water using *parthenium hysterophorous weed*. According to [11], removal of Cd (II) by modified lawny grass cellulose adsorbent, the adsorption capacity of Cd (II) was very little at lower pH but sharply increasing the pH, Cd (II) uptake became higher. This is because, at low pH, the concentration of H⁺ is high which competes with cadmium ions for the surface active sites.

In adsorption of metals, the effect of time was studied at different time intervals in the range of 2 to 240 minutes. It was observed that equilibrium adsorption was established rapidly within 30 minutes indicating that the initial adsorption was very fast and maximum uptake was reached with 30 minutes for Pb(II), Cd(II), Ni(II) and Cu(II). Thereafter, the amount of adsorption remained almost constant. This is due to the decrease of adsorption sites on the clay which gradually interacted with the metal ions [12]. The adsorption of cadmium by *Hydrilla verticillata* was very high. Most of the metal biosorption occurred during the first 3 – 5 minutes. Equilibrium was attained within a short period of 30 minutes [13]. The effect of initial concentration was studied in the adsorption of metal ions on Kaolinite clay and was observed to be increasing as the concentration of metal in solution was increased from 10 to 15mgL⁻¹. With each increasing metal ion concentration, there was an increase in the amount of metal ion adsorbed due to increase driving force of the metal ions towards the active sites on the adsorbent. The percentage of ions remaining also increased because of the increscent initial concentration. It indicated a decrease in the active sites on the sorbents as more metals were adsorbed [14].

The initial concentration of cadmium was taken as 50mgL⁻¹ in its adsorption using *parthenium hysterophorous weed* whose dosage was varied from 0.1g to 1.0g at a constant temperature (20°C). The percentage adsorption increases from 92.2 percent to 99 percent when adsorbent dose was increased. This is as a result of more adsorptive sites. According to [15], the adsorption of Cd (II) on activated carbon from 70°C to 50°C, the maximum is from 30 – 40°C but after 40°C, the adsorption of adsorbate increases leading to a net decrease in adsorption. This may be due to the weakening of adsorptive forces between the active sites of the adsorbents and the adsorbate species and also between the adjacent molecules of adsorbed phase. Cadmium is a chemical element with symbol Cd and atomic number 48. It has atomic weight of 112.411

atomic mass unit (amu) with melting point of 320.9°C. It has boiling point of 765.0°C. The number of protons/electrons in cadmium is 48 and the number of neutrons is 64. It is classed as a transition element with crystal structure, hexagonal. The density of cadmium is 8.65gcm⁻³ at 20°C. Cadmium is silvery in colour [16].

MATERIALS AND METHODS

The equipments used in this study include rotary flask, electrical shaker and bulk scientific atomic adsorption spectrometer (model 200A), drying oven (Gallenkamp plus II) pH meter and thermostated water bath.

Coconut Coir Dust was obtained from a local processing mill in Akwa Ibom State, Nigeria. It was air dried for 24 hours and in oven at 60°C to constant weight. The dried Coir Dust was separated into different particle sizes and stored in air tight lid containers.

Reagent: Acetone, Cadmium Nitrate – Cd(NO₃)₂.6H₂O, Toluene Diisocyanate (TDI), Sodium Hydroxide, Phenol-4-sulphonic acid and 4-hydroxybenzoic acid.

Extraction: Coconut Coir Dust of a mass 100g was taken in the thimble of the soxhlet extractor fitted to the ground bottom flask containing acetone on a heating mantle. The extraction was completed when the solution in arm of the soxhlet extractor turn colourless. The extract was removed by distillation of the acetone mixture, and was separated into different particle sizes. The sulphonated acid cation exchange resin based on acetone coir extract, was first dissolved in a minimum quantity of acetone in a beaker on a hot plate and magnetically stirred until completely homogenized, followed by addition of phenol-4-sulphonic acid (0.65 mls/mole). 1.45mls (2 moles) of toluene diisocyanate (TDI) was added drop wise. The stirring was allowed to continue and the brownish foaming mixture evolving heat becomes more viscous slowing down the speed of the magnetic stirrer. The brownish solid was allowed to air dry over night. The dried Sulphonated Toluene Diisocyanate coir resin was separated into different particle sizes and stored in air tight lid containers.

The synthetic carboxylic acid cation exchange resin based on acetone coir extract was first dissolved in a minimum quantity of acetone in a beaker of hot plate, continuously stirred until the mixture was completely homogenised. Four-hydroxybenzoic acid dissolved in acetone was added, followed by drop wise addition of 2 moles of Toluene Diisocyanate (TDI). The mixture foamed while becoming viscous with evolution of heat. The light brown solid formed was allowed to air dry over night. The air dried solid was separated into different particle sizes and stored in air tight lid containers.

Stock solutions of Cd(II) of different concentrations were prepared by dissolving Cd (NO₃).6H₂O in deionizer water and the volume made up to mark in 1000cm³ volumetric flask with demonized water. The adsorption study was carried out by placing the (Coir Dust, Carboxylated Toluene Resin (CTR) and Sulphonated Toluene Resin (STR)) in beakers containing 30ml of the cadmium solution of 10ppm concentration and shaken at different time rates, then the adsorbents were placed in beakers containing same volume of different concentrations of Cd (II) solution and shaken. After each time interval, the content of the beakers were filtered and were analysed for cadmium metal ion using the Buck Scientific Atomic Adsorption/Emission Spectrophotometer 200A. The percentage adsorption of metal ion on the resins was calculated by the formula [17]:

$$\% \text{ adsorption} = \frac{\text{initial concentration} - \text{concentration of filtrate}}{\text{final concentration} - \text{non-filtrated concentration}} \times \frac{100}{1} \quad (1)$$

Quantity adsorbed by the resins

$$q_t = \frac{C_o - C_f}{m} \times \frac{V}{1000}$$

m is the mass of the resin of 0.2000g placed in the beaker containing 30ml of the solution, V is the volume of the solution, C_o represent the final concentration and C_f is the initial concentration.

The following factors we deeply considered; contact time, initial concentration, the final concentration, temperature, dosage and particle size.

Time ranges 0.5, 5, 10, 30, 60, 90 and 120 minutes were employed in the study of Cd (II) adsorption using Coir Dust. This was done using a constant concentration of 10mgL^{-1} of solution containing Cd (II). During the first procedure, a constant concentration of 10mgL^{-1} of solution containing Cd (II) was used to study the rate of cadmium uptake. On a later procedure, different concentrations of Cd (II) solution ranging from 2mgL^{-1} to 15mgL^{-1} was employed to investigate cadmium uptake using Coir Dust. A constant temperature of 40°C was used to study the rate at which metal (cadmium) would be sorped from the aqueous solution by coir dust. Particle size of $(100 - 106)\mu\text{m}$ and 0.2g of Coir Dust was used during the experiment to study cadmium uptake from stock solution [18].

RESULTS AND DISCUSSION

The result of adsorption of Cd (II) ion on CD, CTR and STR as a function of initial concentration at a temperature of 40°C by varying the concentration of the initial aqueous solution from 2mgL^{-1} to 15mgL^{-1} while keeping all other parameters constant is represented in Table 4.1. This reveals that the percentage adsorption of Cd (II) on CD fluctuated between 2-10 mgL^{-1} but had a steady rise from 10mgL^{-1} to 15mgL^{-1} while for CTR and STR, the percentage adsorption had a steady rise.

Table 4.1: Percentage adsorption of Cd (II) on CD, CTR and STR

	$C_o \text{ mgL}^{-1}$	$C_e \text{ mgL}^{-1}$	$X_e \text{ mgL}^{-1}$	Adsorption (%)
CD	2	0.05	1.95	97.5
	4	0.47	3.53	88.25
	8	0.17	7.83	97.875
	10	0.93	9.07	90.7
	15	0.64	14.36	95.73
CTR	2	1.77	0.23	11.5
	4	2.23	1.77	44.25
	8	2.65	5.35	66.875
	10	3.38	6.62	66.2
	15	4.42	10.58	70.5
STR	2	1.77	0.23	11.5
	4	3.32	0.68	17.75
	8	2.26	5.74	71.75
	10	3.48	6.52	65.2
	15	4.42	10.58	70.5

The sorption data were subjected to sorption models namely langmiur, Freundlich, Flory-Huggins and Dubinin-Radush Kevich models which help to describe the adsorption processes

and mechanisms. The data for metal ions over the concentration of $2\text{mgL}^{-1} - 15\text{mgL}^{-1}$ at 40°C have been correlated with the Langmiur Isotherm and the result presented in Table 4.2.

Table 4.2: Data for Metal Ions Over the Concentration of Coir Dust Using Langmiur Isotherm Model

	$C_o \text{ mgL}^{-1}$	$C_e \text{ mgL}^{-1}$	$X_e \text{ mgL}^{-1}$	Adsorption (%)
CD	2	0.05	1.95	0.1709
	4	0.47	3.53	0.8876
	8	0.17	7.83	0.1447
	10	0.93	9.07	0.6836
	15	0.64	14.36	0.2971
CTR	2	1.77	0.23	51.3043
	4	2.23	1.77	8.3992
	8	2.65	5.35	3.3022
	10	3.38	6.62	3.4038
	15	4.42	10.58	2.7851
STR	2	1.77	0.23	51.3043
	4	3.32	0.68	32.5490
	8	2.26	5.74	2.6249
	10	3.48	6.52	3.5583
	15	4.42	10.58	2.7851

The relationship for the langmiur isotherm is shown in the equation (3):

$$\frac{C_e}{q_e} - \frac{1}{Q_0 b} + \frac{C_e}{Q_0}$$

C_e is the equilibrium concentration of metal ion in solution, q_e is the equilibrium quantity of metal ions adsorbed unto the adsorbents, Q_0 and b are Langmiur constant related to sorption capacity and sorption energy respectively.

The Langmiur model parameters and the statistical fit of the sorption data to this equation are given in figure 4.1, 4.2 and 4.3 for CD, CTR and STR respectively.

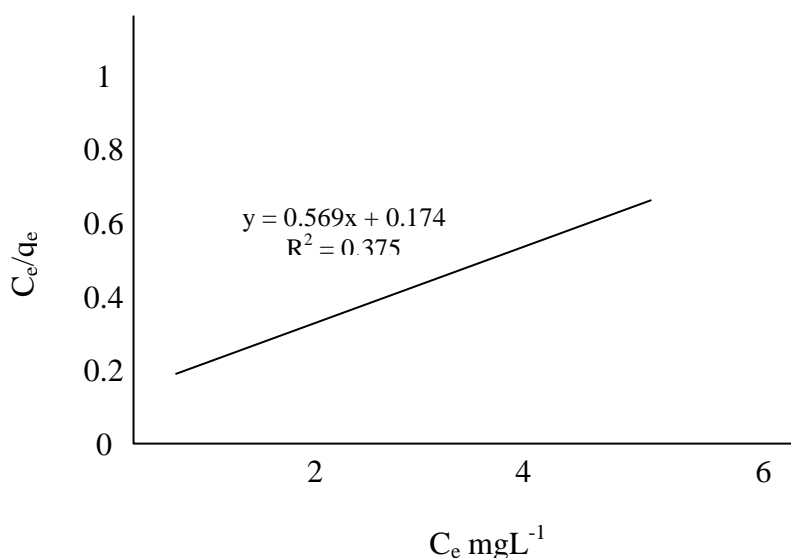


Fig. 4.1: Langmiur Plot of C_e/q_e Versus C_e of Cd (11) ions on Coir Dust (CD) at 40°C

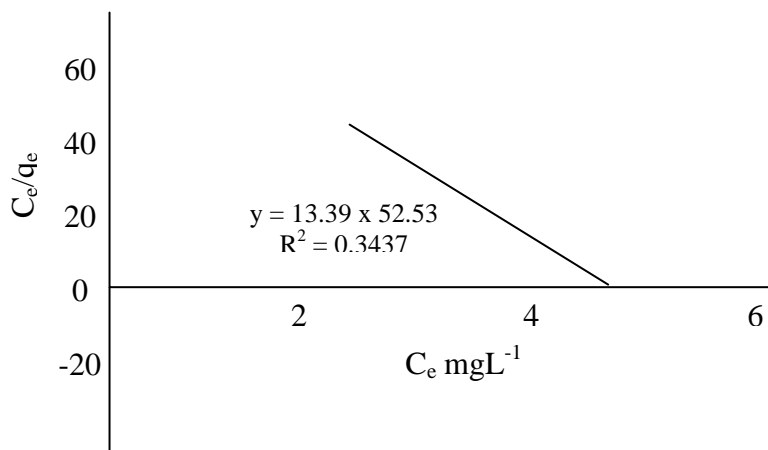


Fig. 4.2: Langmuir Plot of C_e/q_e Versus C_e of Cd (II) ion onto Carboxylated Toluene Resin (CTR) at 40°C

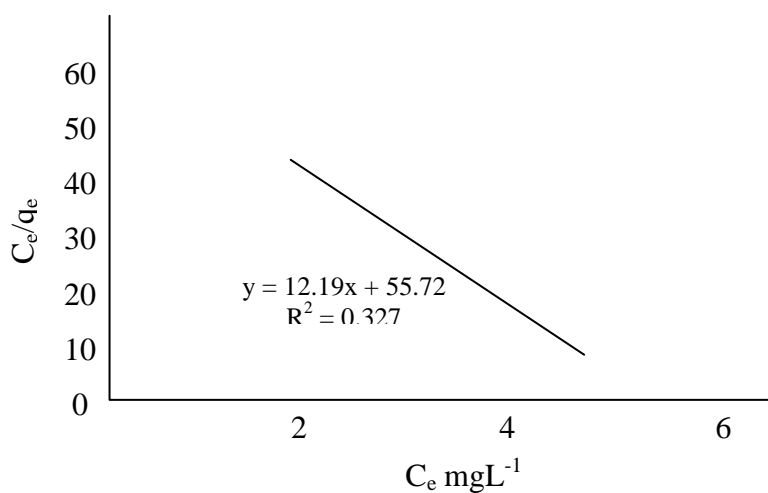


Fig. 4.3: Langmuir Plot of C_e/q_e Versus C_e of Cd (II) Ions on Sulphonated Toluene Resin (STR) at 40°C

Table 4.3: Data for Metal Ions Over the Concentration of Coir Dust Using Freundlich Isotherm Model

	C_0 mgL ⁻¹	C_e mgL ⁻¹	X_e mgL ⁻¹	Adsorption (%)
CD	2	0.05	0.2925	-1.3010
	4	0.47	0.5295	-0.3279
	8	0.17	1.1745	-0.7696
	10	0.93	1.3605	-0.0315
	15	0.64	2.154	-0.1938
CTR	2	1.77	0.0345	0.2480
	4	2.23	0.2655	0.3483
	8	2.65	0.8025	0.4232
	10	3.38	0.993	0.5289
	15	4.42	1.587	0.645
STR	2	1.77	0.0345	0.2480
	4	3.32	0.102	0.5211
	8	2.28	0.861	0.3541
	10	3.48	0.998	0.5416
	15	4.42	1.587	0.6454

The Langmuir model did not effectively described the sorption data as the correlation coefficient value of R^2 for CD, CRT and STR are 0.375, 0.434 and 0.327 respectively and thus suggest the sorption process involves multiplayer coverage of adsorbate and the adsorbents.

The Freundlich isotherm is mathematical description which usually fits the experimental data over a wide range of concentration [19]. This Isotherm gives an expression encompassing the surface heterogeneity and the exponential distribution of action sites and their energies. Table 4.3 shows the Freundlich data for the sorption of Cd (II) ion on CD, CTR and STR.

The Freundlich model equation for the removal of Cd (II) ions from aqueous solution can be expressed as follows:

$$\text{Log } q_e = \log K_F + \frac{1}{n} \log C_e \quad (4)$$

By this equation, the low correlation values of R^2 for CD and STR are 0.505 and 0.452 respectively indicating that the adsorption process cannot be effectively described by the Freundlich isotherm but the high value of R^2 for CTR, 0.842 indicates that the adsorption process can be effectively described by the Freundlich isotherm. The constant K and n are calculated for the metal ion from the slope and intercept of $\log q_e$ and $\log C_e$. The numerical value $1/n < 1$ indicates that sorption capacity is suppressed at lower concentration for CD and predicts insaturation of Cd(II) by the sorbate and also indicates multiplayer adsorption. Conversely $n > 1$ for CTR and STR indicates that sorption capacity has been exceeded at higher concentration and therefore predicts saturation by the sorbate and also indicates multiplayer adsorption and finite surface coverage by the adsorbate on the adsorbent.

The Flory-Huggins Isotherm is given by the relationship

$$(\theta/C_o) = \log K_{FH} + n \log (1 - \theta) \quad (5)$$

Where θ is the degree of surface coverage, n is the number of metal ion concentration. A plot of $\log (\theta/C_o)$ against $\log (1 - \theta)$ yields a straight line. K_{FH} and n are determined from the intercept and slope respectively.

Table 4.4: Data for Ion Exchange Reaction on CD, CTR and STR Using Flory-Huggin Isotherm Model

	$C_o \text{ mgL}^{-1}$	$C_e \text{ mgL}^{-1}$	θ	$\text{Log } \theta/C_o$	$\text{Log } (1 - \theta)$
CD	2	0.05	0.975	-0.3120	-1.6021
	4	0.47	0.8825	-0.6563	-0.9300
	8	0.17	0.9787	-0.9398	-1.6726
	10	0.93	0.907	-1.0424	-1.0315
	15	0.64	0.9573	-1.1950	-1.3699
CTR	2	1.77	0.115	-1.2403	-0.0531
	4	2.23	0.4425	-0.9561	-0.2538
	8	2.65	0.687	-1.0778	-0.4798
	10	3.38	0.662	-1.1791	-0.4711
	15	4.42	0.705	-1.3299	-0.5302
STR	2	1.77	0.115	-1.2403	-0.0531
	4	3.32	0.17	-1.3716	-0.0809
	8	2.26	0.717	-1.0473	-0.5489
	10	3.48	0.652	-1.858	-0.4584
	15	4.42	0.705	-1.3279	-0.5302

The low correlation $R^2 = 0.455$ for CD indicates non-compliance of the data to the model whereas the high correlation value of 0.948 and 0.761 for CTR and STR respectively indicates that the data can be described using this model [23].

Dubinin-Kaganger-Radushkevich (DKR) isotherm is used to estimate the characteristic porosity and apparent free energy of adsorption. The model is of the form

$$\ln q_e = \ln q_p - \beta_p RT (1 + 1/C_e)^2 \quad (6)$$

A plot of $\ln q_e$ against $RT \ln (1 + 1/C_e)^2$ yields a straight line.

Where q_e is the maximum number of metal ion absorbed per unit mass of the adsorbent (mgg^{-1}), q_p is the maximum sorption capacity, β_p is the porosity factor which is related to the sorption energy and

$$RT \ln(1 + 1/C_e)^2 = E^2.$$

R = Universal gas constant = $8.314 \text{ JK}^{-1} \text{ mol}^{-1}$, T = absolute temperature (K). The calculation gives the results as presented in Table 4.5.

Table 4.5: The DRK Isotherm Data for Ion Exchange Reaction of CD, CTR, STR

	$C_o \text{ mgL}^{-1}$	$X_e \text{ mgL}^{-1}$	$Q_e \text{ mgg}^{-1}$	$\ln q_e$	$RT \ln(1 + 1/C_e)^2$
CD	2	1.95	0.2925	-1.2208	16858.855
	4	3.53	0.5295	-0.6358	6314.258
	8	7.83	1.1745	0.1613	10681.500
	10	9.07	1.3605	0.3079	4042.832
	15	14.36	2.154	0.7673	606.452
CTR	2	0.23	0.0345	-3.3668	2480.040
	4	1.77	0.2655	-1.3261	2051.513
	8	5.35	0.8025	-0.2200	1772.908
	10	6.62	0.993	-0.0070	1435.155
	15	10.58	1.587	0.4618	1129.394
STR	2	0.23	0.0345	-3.3668	2480.040
	4	0.68	0.102	-2.2821	1454.955
	8	5.74	0.861	-0.1497	2028.709
	10	6.52	0.978	0.022	1398.706
	15	10.58	1.587	-0.4618	1729.394

Effect of Contact Time on Adsorption of Cd (II) by Resins

The adsorption data for the uptake of Cd (II) ions at varying contact time for a fixed adsorbent dose of 0.2g and with metal concentration of 10 mgL^{-1} , particle size of $100 - 106 \mu\text{m}$ at pH 7.0 is shown in Table 4.6. It shows increasing adsorption with time and attains equilibrium after 90mins for CD and STR but a decrease in adsorption and attaining equilibrium at 120mins for CTR. The integrated form of pseudo-first order kinetic is $\log (q_e - q_t) = \ln q_e - K_1 t/2.30$ where K_1 is the pseudo first order rate constant for the adsorption process. Table 4.6 presents the values of the constant of kinetic models for the sorption of Cd(II) on CD and STR. The rate of constant K_1 are -0.023 and -0.0368 for CD and STR respectively which are low indicates that the adsorption process does not obey pseudo first order kinetic. This is given in the following linear form $t/q_t = 1/k_2 q_e^2 + t/q_e$. The sorption rate constant K_2 and the sorption capacity q_e of the pseudo second order kinetic are shown in Table 4.6 for CD, CTR and STR. The correlation coefficient relatively higher, $R^2 = 1, 0.979$ and 0.996 for CD, CTR and STR respectively

showing that the sorption process follows the pseudo second order reaction mechanism. The distribution of the ions on the resins surface is illustrated above. According to the plot, the distribution decreases with time an attained equilibrium at 90 – 120mins for CTR and increased with time for CD and STR and attained equilibrium at 60 – 90mins. The fractional attainment of equilibrium for the sorption process of Cd (II) on CD and STR is represented in Table 4.6. It indicates that both CD and STR attain equilibrium at 60 – 90mins for the adsorption of Cd (II) ions from aqueous solution.

Table 4.6: Effect of Time in the Adsorption of Cd (II) on CD, CTR, STR

	Time (min)	MgL ⁻¹ Ct	MgL ⁻¹ \bar{x}	Mgg ⁻¹ q_t	Mgg ⁻¹ (q _e -q _e)	Log (q _e -q _e)	gmg ⁻¹ α	In(1- α)	D	% ion Exchange
CD	0.5	1.88	8.12	1.2180	0.2220	-0.6536	0.8458	-1.8695	4.3191	81.2
	5	0.57	9.43	1.4145	0.0255	-1.5935	0.9823	-4.0342	16.5439	94.3
	10	0.55	9.45	1.4175	0.0225	-1.6478	0.9844	-4.1605	17.1818	94.5
	30	0.48	9.52	1.4280	0.0120	-1.9208	0.9917	-4.7915	19.8333	95.2
	60	0.40	9.60	1.4400	0.0000	-	1.0000	-	24.0000	96.0
	90	0.40	9.60	1.4400	0.0000	-	1.0000	-	24.0000	96.0
CTR	0.5	5.84	4.16	0.6240	-0.5325	-	6.8197	-	0.7123	41.6
	5	7.76	2.24	0.3360	-0.2445	-	3.6721	-	0.2887	22.4
	10	8.62	1.38	0.2070	-0.1155	-	2.2623	-	0.1601	13.8
	30	9.08	0.92	0.1455	-0.0540	-	1.5082	-	0.1032	9.2
	60	9.29	0.71	0.1065	-0.0150	-	1.1639	-	0.0764	7.1
	90	9.39	0.61	0.0915	0.0000	-	1.0000	-	0.0650	6.1
	110	9.39	0.61	0.0915	0.0000	-	1.0000	-	0.0650	6.1
STR	0.5	0.51	0.51	0.0765	0.3450	-0.4622	0.1815	-0.2003	0.0537	5.1
	5	1.13	1.13	0.1695	0.2520	-0.5986	0.4733	-0.6411	0.1274	11.3
	10	2.45	2.45	0.3675	0.0540	-1.2671	0.8719	-2.0594	0.3245	24.5
	30	2.60	2.60	0.3900	0.0315	-1.5017	0.9253	-2.5943	0.3514	26.0
	60	2.81	2.81	0.4215	0.0000	-	1.0000	-	0.3908	28.1
	90	2.81	2.81	0.4215	0.0000	-	1.0000	-	0.3908	28.1

CONCLUSION

The study of Coir Dust (CD), Carboxylated Toluene Resin (CTR) and Sulphonated Toluene Resin (STR) indicate that equilibrium amount of metal ions sorbed from solution was attained at 90 minutes for Coir Dust and Sulphonated Toluene Resin and at 120 minutes for Carboxylated Toluene Resin. Amount of metal ions sorbed from solution increased with increase in initial concentration for CD and STR but decreased for CTR. The three resins used, Coir Dust showed high level of metal uptake. It can be employed in the adsorption of metal from solution and in treatment of contaminated water and can be used in the recovery and removal of Cd (II) from aqueous solution.

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