Removal of Cadmium (II) from aqueous solutions onto Dodonaeae Viscose Leg powder using a green process: Isotherms, Kinetics and Thermodynamics

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A B S T R A C T

In the present study, Batch adsorption experiments of hazardous cadmium, Cd(II), ions onto low-cost Dodonaeae Viscose Legs (DVL) and processes were conducted with respect to contact time, solution pH, adsorbent dosage, initial Cd concentration and temperature. The DVLs were used without chemical or physical activation processes. Sorption isotherm, kinetic and thermodynamic models were used to describe the equilibrium stage and their constants were determined. The results showed that the adsorption capacity of DVLs for Cd(II) ions was found to be 25.29 mg/g at solution pH 5.26, 50 min and 30oC. The mean free energy was found to be 1.82E-02 using Dubinin-Radushkevich (DRK) isotherm, which indicates that the adsorption of Cd(II) ions onto DVL surface is physical adsorption. The activation energy (Ea) was 3.06 kJ/mole, which confirms that Cd(II)-DVL adsorption process is physical sorption. Pseudo-first-order, pseudo-second-order, Elovich, intra-particle and extra-particle diffusion models were used to describe the adsorption kinetics. The results showed strong correspondence to a pseudo-second-order kinetics. Thermodynamic parameters suggested that the adsorption of Cd(II) ions onto DVL surface is an exothermic process.

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INTRODUCTION

Over the past few decades, one of the most important problem facing bio systems is environmental pollution with non-degradable, non-destroyable and toxic heavy metals due to their bioaccumulation. Massive amount of industrial waste materials containing lead, copper, cadmium and chromium, etc has reached ground waters causing a serious problem to humanity at high concentrations. Cadmium (Cd) is reported to be extremely toxic heavy metal and can accumulate in human body especially in kidneys leading to disorder of the kidneys and osteomalacia. However, Cd has been included in the red and black list of priority of pollutants by Department of Environment, UK and Dangerous Substance Directive in European Economic Community, while it is classified as group B1 carcinogen by Environment Protection Agency, (EPA). Cadmium is reported to affect calcium metabolism, develop and skeletal calcification. Also, the permissible limit for Cd in drinking water by World Health Organization, WHO, is 0.005 mg/L [1].

Over the years, many technologies have been used and developed to remove heavy metals from industrial wastewaters including coagulation/flocculation process, member filtration, oxidation process, activated carbon adsorption, reverse osmosis ion exchange, solvent extraction, etc [2, 3]. However, these technologies need further costly processes and require skilled personal, which led to ineffective or expensive process due to heavy metal concentration in contaminated waters ranged between 1 to 100 mg/L. One of the most economically favorable and technically easy for water treatment processes is adsorption using non-conventional and low cost agricultural by-products. Numerous studies have been reported on effective to use by-products plants in order to remove heavy metals from aqueous solution with chemical or physical surface activation. In this research, the adsorption processes of Cd(II) ions onto inactivated or unmodified Dodonaeae Viscose leg (DVL) surface from aqueous solutions. Isotherm, kinetic and thermodynamic models were investigated.

MATERIAL AND METHOD
Dodonaeae Viscose leg charcoal
Dodonaeae Viscose, *Sapindacese* legs (DVLs) were collected from Faculty of Science garden at University of Sebha, Sebha, Libya and used without any further treatment such as physical or chemical processes. They were cut into small pieces, washed for 1 h to remove impurities, air dried at 105ºC for 24 h, then grounded, sieved through a 75µm mesh and stored in desiccators for further use.

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Preparation of solutions

All reagents used in this study were analytical grades purchased and used without further purification. Stock solution of Cd(II) ions with concentration of 1000 mg/L was prepared by dissolving cadmium acetate (Cd(CH$_3$COO)$_2$.2H$_2$O) in deionized water. Several dilutions were made in order to get the desired Cd(II) concentrations for each sorption experiment.

Batch adsorption procedure

The adsorption experiments were performed on a mechanical shaker equipped with thermostatic equipment to set the temperature. In order to investigate the effect of adsorbent dose, 10, 30, 50, 70, 90 mg of DVL was added to 100 ml of 200 mg/L Cd(II) ions and kept for 120 min at 30°C. In order to investigate the effect of pH values, 10 mg of DVL powder was added to 100 ml of 200 mg/L Cd(II) ions and pH values were adjusted to 2.0, 3.0, 4.0, 5.0, 6.0, and 7.0, and kept for 120 min at 30°C. In order to investigate the effect of time contact, 100 mg of DVL powder was added to 100 ml of 200 mg/L Cd(II) ions and then agitated for 120 min at 30, 40 and 50°C. In order to investigate the effect of Cd(II) initial concentrations, 100 mg of DVL powder was added to 100 ml of 100, 200, 300, 400, 500 mg/L Cd(II) ions and attired for 120 min at 30, 40 and 50°C. All solutions were stirred at 300 rpm, filtered through wathman filter paper 112v. Cd(II) concentration before and after adsorption process was determined by titration method using 0.0005M EDTA, zenol orange and buffer solution. All the experiments were repeated for triplicate values.

Calculations

The percent removal, and adsorption capacity, mg Cd(II)/g DVL**Error! Reference source not found.**, (at time t (q$_t$) and at equilibrium (q$_e$) of Cd(II) onto DVL surface were determined using the following equations:

$$Removal\% = \frac{C_o - C_e}{C_o} \times 100 \qquad (1)$$

$$q_e = (\frac{C_o - C_e}{w})v \qquad (2)$$

$$q_t = (\frac{C_o - C_t}{w})v \qquad (3)$$

Where: C$_o$ andC$_t$, C$_e$=Cd(II) initial, at time t (min) and equilibrium concentrations; v=total volume; w=weight of DVLs.

The best-fit for kinetic models used in this study was analyzed by the square sum of errors (SSE) values using the following equation:

$$SSE = \sum \frac{(q_{e(exp)} - q_{e(cal)})^2}{q_{e(exp)}} \qquad (4)$$

The lowest value of SSE is the best model for the particular system.

RESULTS AND DISCUSSION
Characterization of DVL surface

In order to identify the characteristic functional groups on DVL surface, FT-IR technique was used in the range 400-4000 cm^{-1}. The FT-IR spectrum of DVL before and after adsorption of Cd(II) ions is shown in Figure 1.
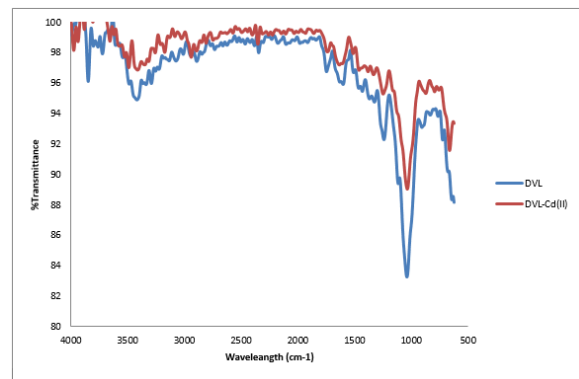

Figure 1. FTIR spectra of DVL before and after adsorption of Cd(II) ions

The broad band exhibited at 3386 cm^{-1} was responded to the presence of both free and hydrogen bonded O-H groups by stretching vibrations of aromatic and aliphatic O-H groups and for N-H stretching. The peaks at 2958 and 2884 cm^{-1} were dominated for C-H stretching in asymmetric methyl and methylene groups. The absorption at 1716 cm^{-1} reflects the stretched C=O. The absorption band at 1014 cm^{-1} corresponded to C-O stretching of alcoholic and carboxylic acids. Generally, the absorption intestines were decreased with the presence of Cd(II) ions which could be due to the adsorption of Cd(II) ions onto the surface of DVL. This is suggested that the functional groups present at the surface of DVL such as –OH or –NH at 3386 cm^{-1}, -COOH and C=O at 1714 and 1589 cm^{-1} and C-O at 1047 cm^{-1} might be responsible for adsorption mechanisms of Cd(II) ions onto the DVL surface.

Effect of contact time

Figure 2 shows the influence of contact time on the adsorption of Cd(II)-DVL in the range of 1-120 min for initial Cd concentration of 202.3 mg/L, 100 mg of DVL and stirring speed of 300 rpm at 303, 313 and 323K. The adsorption of Cd(II) onto DVL surface was studied as a function of time at fixed conditions of adsorbent dose (100 mg), pH 5.4, agitation speed 300 rpm, Cd concentration (202 mg/L) and at different temperature of 303, 313 and 323K. On the three different systems, the results are presented in Figure 2 which shows as increase of the percentage of removal as the contact time increased to certain time where the saturation stage takes place, no more Cd(II) ions removed by DVL surface. The adsorption of Cd(II) ions onto DVL surface was very rapid in the first 20 min and then increased gradually during the following 50 min until reach the equilibrium at 50 min. These results showed that the uptake of Cd(II) ions by DVL depends on the contact time and temperature. Therefore, the adsorption samples were taken after 60 min in order to ensure reach the equilibrium stage and used as optimum time for Cd(II)-DVL adsorption.

Effect of pH

Figure 3 shows the effect of pH on the adsorption of Cd(II)-DVL in the range of 2.21-6.28 for average initial Cd(II) concentration of 255.6 mg/L, 100 mg of DVL, and stirring speed of 300 rpm at 303K. The results indicate that Cd(II) ions
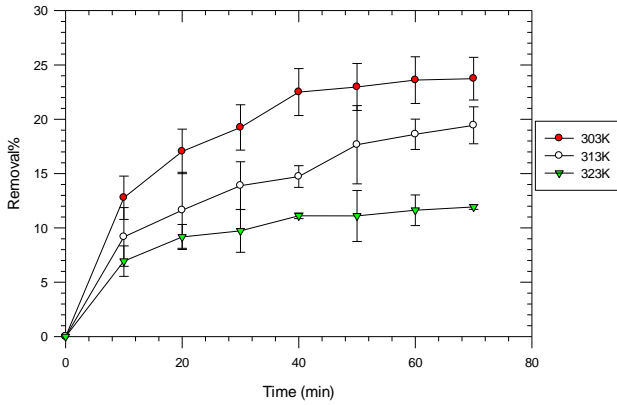
Figure 2. Effect of contact time on the adsorption of Cd(II) ions onto DVL surface at different temperatures

adsorption onto the surface of DVL was strongly pH-dependent and increased with an increase of pH until the pH reached 5.4, which called the sorption edge [4]. The highest removal efficiency in the Cd(II) adsorption onto the surface of DVL was obtained at pH 5.4, which recorded as the optimum pH value [4]. Therefore, the further adsorption experiments were set at pH 5.4 in order to ensure reach the optimum Cd(II)-DVL adsorption.

Effect of adsorbent dose
Figure 4 shows the effect of adsorbent dose on adsorption Cd(II) ions onto the surface of DVL surface with no change in other parameters such as pH of 5.4, Cd concentration of 200 mg/L, time of 60 min and temperature of 303K. It was noted that the percentage of removal was increased with an increase of DVL dosage, which could be due to either the more adsorption sites or an increase in the total surface area of DVL [1, 5]. Therefore, 100 mg of DVL were used for the further adsorption experiments in order to ensure reach the optimum Cd(II) removal.

Initial concentration effect
In order to investigate the optimum concentration of Cd(II), the adsorption batch of Cd(II) ions onto DVL surface was studied under varied Cd(II) concentrations ranging between 100 to 500 mg/L at pH 5.4, time of 60 min, temperature of
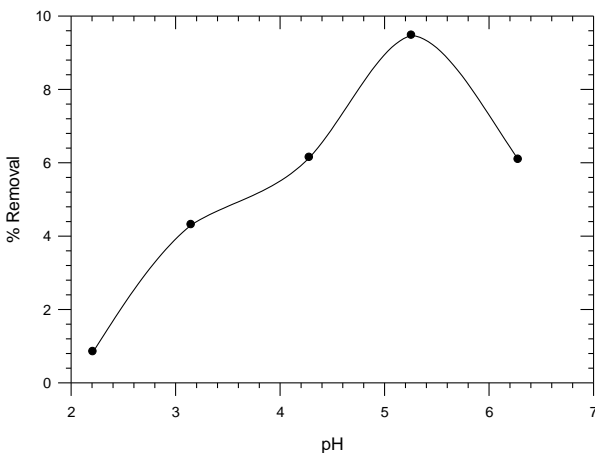

Figure 3. Effect of pH on the adsorption of Cd(II) ions onto DVL

303, 313 and 323K. From Figure 5, the adsorption capacities were increased with increasing the Cd(II) concentration and no saturation stage was observed. This indicates that more active sites on the surface of DVL was available to remove Cd(II) ions from solution. Also, the adsorption capacities were increased with increasing the solution temperature probably due to increase the number of active sites for Cd(II) ions on the surface of DVL with increasing temperature [6].
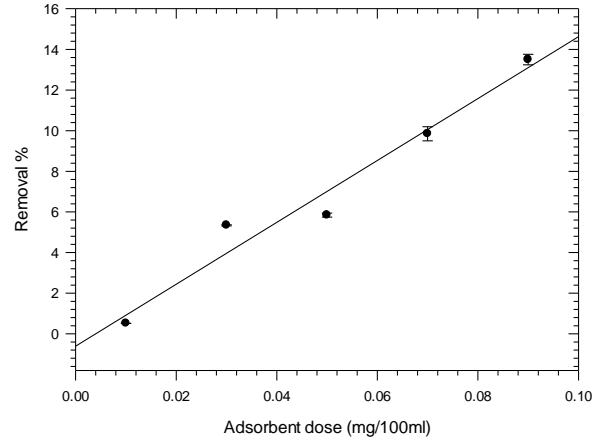

Figure 4. Effect of adsorbent dose on the adsorption of Cd(II) ions onto DVL surface
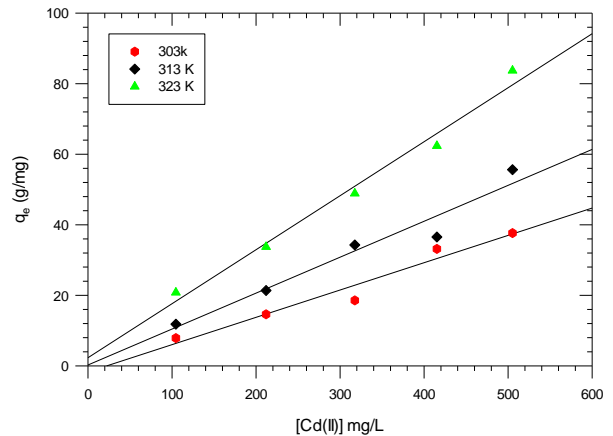

Figure 5. Effect of Cd concentration on the adsorption of Cd(II)-DVL

Adsorption isotherm models
Different adsorption isothermal models were used to analyze the sorption equilibrium of Cd(II)-DVL in terms of Freundlich, Langmuir, Temkin, DR isotherms.

Freundlich isotherm
The Freundlich isotherm model is given by in nonlinear and linear Equations (4) and (5), respectively:

$$q_e = k_F C_e^{1/n} \tag{5}$$

$$\log q_e = \log k_F + \frac{1}{n} \log C_e \tag{6}$$

Where: K_F =adsorption capacity, (mg/g)(L/g)$^{1/n}$, and n= bio-sorption intensity are Freundlich constants, which can be determined by plotting the q_e versus C_e. The Freundlich constants are also listed in TABLE 1. However, the 1/n values

TABLE 1. Isotherm constants

T		Freundlich Constants			Langmuir Constants	
K	K_F	1/n	R^2	q_m	K_L	R2
	L.g-1			mg/g	L.g-1	
303	0.173	0.998	0.9475	212.8	3.91E-04	0.9783
313	3.88	0.898	0.9566	175.4	8.86E-04	0.9872
323	83.5	0.826	0.991	172.4	1.62E-03	0.9817
T		**Temkin constants**				**DKR**		
K	K_T	q_m	B	R^2	D	q_m	E	R^2
	J/mol	mg/g			J/mol	mg/g		
303	1.32E-02	18.6	14.2E-02	0.8521	2057.6	28.8	1.56E-02	0.7702
313	1.74 E-02	47.9	5.53E-02	0.8786	1349.2	40.8	1.93E-02	0.8103
323	1.82E-02	71.5	3.69E-02	0.9037	1286.7	1.97E-02	1.97E-02	0.7832

were below one at three temperature systems, which indicates a normal adsorption of Cd(II) onto DVL surface and favorable adsorption process with expected high heterogeneity with increasing the temperature. Also, 1/n values decrease with increasing the temperature which indicates the better adsorption and stronger bonds between adsorbate and adsorbent at high temperature. The linear Freundlich equation represents the poor fit experimental data with $R^2 = 0.9475$, 0.9566 and 0.9910 for 303, 313 and 323K, respectively.

Langmuir isotherm
The Langmuir isotherm is commonly used to describe quantitatively the formation of a monolayer adsorption at specific homogenous sites on outer surface of DVLs with no further adsorption takes place. The Langmuir equations in linear are expressed as follows:

$$\frac{1}{q_e} = \frac{1}{K_L q_m C_e} + \frac{1}{q_m} \tag{7}$$

Where: q_m= monolayer sorption capacity (mg/g) and K_L=Langmuir equilibrium constant (L/mg). A straight line can be obtained by plotting $1/q_e$ versus $1/C_e$ with its intercept/slop of K_L and 1/intercept of q_m, figures are not shown here and the Longmuir constants are listed in TABLE 1. The q_m values are decreased with increasing temperature solution form 303 to 313 K indicating that the Cd(II) ions is not favorable adsorbed by DVL surface at low temperature and this is confirmed that the adsorption process is exothermic system. Also, K_L values are decreased with increasing temperature from 303 to 313 K, which indicating less adsorption of Cd(II) onto DVL surface with increasing temperature and the bond strength between Cd(II) and DVL decreased with increasing temperature. Also, this indicates that the adsorption process is exothermic.
On the other hand, the constant separation factor, R_L, is used to indicate the shape of isotherm by the Langmuir model:

$$R_L = \frac{1}{1 + bC_o} \tag{8}$$

The value of R_L can to be unfavorable ($R_L > 1$), favorable ($0 < R_L < 1$) and irreversible ($R_L = 1$). It was found that the R_L values are in the range of 0-1, which confirmed that the Cd(II)-DVL adsorption is more favorable under these conditions using Langmuir isotherm and at higher temperature.
Also, R_L values are greater than 0 but less than 1, confirming that Langmuir isotherm is favorable which proving by R^2 values. Moreover, the Cd(II)-DVL adsorption data was fitted well with Langmuir than Freundlich isotherm due to Langmuir data has higher R^2 values. The results from Freundlich and
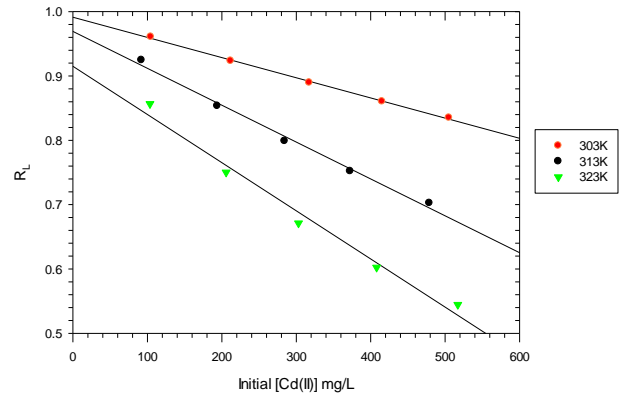

Figure 6. Plot of separation factor versus initial Cd(II) concentration

Longmuir data imply that the desorption of Cd(II) onto DVL surface shows a complex mechanism involving a multilayer surface condition (Figure 6).

Surface Coverage
The behavior of adsorption can be also understood by using surface coverage related with Langmuir equation type:

$$K_L C_o = \frac{\theta}{(1-\theta)} \tag{9}$$

where: K_L is Langmuir constant, C_i is the initial Cd concentrations and θ is the surface coverage. Figure 7 shows the relationship between θ versus initial Cd concentrations

Temkin isotherm
Temkin isotherm is usually used for adsorbent-adsorbate interactions and to study the heterogeneous surface energy systems (non-uniform distribution of sorption heat assuming the heat of the adsorption in layer decreases linearly with coverage. Temkin constants can be obtained from the liner plot (q_e versus ln C_e) [2, 5, 7].

$$q_e = \frac{RT}{b} \ln A + \frac{RT}{b} \ln C_e \tag{10}$$

Where: $\frac{RT}{b} = B$ constant related to heat of sorption (ΔH_{ads}, J/mol); A, slope = Temkin isotherm equilibrium binding constant (L/g); b, intercept = Temkin isotherm constant related to heat sorption as adsorption intensity (J/mol); R= universal gas constant (8.314 J/mol/K); T= Temperature at 303, 313 and 323 K. Temkin constants are listed in TABLE 1 and figures are not shown in here. However, the heat of Cd(II) adsorption, b, is

directly related to Cd(II) coverage onto the surface of DVL. It was found that the adsorption heat was decreased with increasing the system temperature from 14.2E-02, 5.53E-02 and 3.69E-02 J/mole for 303, 313 and 323K, respectively, as listed in TABLE 1 which indicates that the heat of adsorption is exothermic. However, the values of b are lower than 8 J/mol which indicating the adsorption process is a physical adsorption process. R^2 is found to be the poor fit of all experimental data and the fitting is increased with increasing the solution temperature.

Dubinin-Radushkevich (D-R) isotherm

The apparent energy of Cd(II) adsorption onto DVL surface can be determined using D-R isotherm from the following the linear equation:

$$\ln q_e = \ln q_m - \beta \varepsilon^2 \tag{11}$$

Where: β is the activity coefficient constant related to sorption energy; ε is Polanyi potential. The D-R constants are determined from the slop and intercept of the plot (ln q_e versus ε^2) to give β (mol^2/J^2) and q_m (mg/g) as listed in TABLE 1. The mean free energy (E) of sorption per molecule of the sorbate when it is transferred to the surface of the solid from infinity in the solution can be calculated by the following equation:

$$E = \frac{1}{\sqrt{2\beta}} \tag{12}$$

The E values were <8 at all temperature studied that reveals the sorption process follows physical adsorption as shown in TABLE 1.

Adsorption dynamic study

To study the speed and reasonable length of adsorption time, various kinetic models were used in this work for the experimental adsorption data of Cd(II) ions onto DVL surface. Lagergren pseudo-first order and pseudo-second-order were conducted to describe experimental data using the following equations:

$$\ln(q_e - q_t) = \ln q_e - K_1 t \tag{13}$$

$$\frac{t}{q_t} = \frac{1}{k_2 q_2^2} + \frac{t}{q_2} t \tag{14}$$

Where: q_e is the adsorption equilibrium capacity (mg/g), q_t is the amount of Cd(II) adsorbed (mg/g) at time t, k_1 is the rate constant of pseudo-first-order (1/min), q_2 is the maximum adsorption capacity (mg/g), k_2 is the rate constant of pseudo-second-order (g/mg/min), which were obtained from slope and intercept of pseudo-first-order and pseudo-second-order plots between log(q_e-q_t) versus t and (t/q_t) versus t, respectively [8]. All kinetic parameters for two models are shown in Figure 8 and presented in Error! Reference source not found.. As can be seen, the calculated q_m values were decreased with increasing the solution temperature, therefore, the adsorption process is confirmed to be exothermic system. From the values of R^2, the experimental data were followed pseudo-second-order kinetics comparatively better than pseudo-first-order. Also, the pseudo-second-order kinetic has lower SSE value (5.46) than pseudo-first-order kinetic (102.2). Therefore, pseudo-second-order is the best model to describe the Cd(II)-DVL adsorption process.
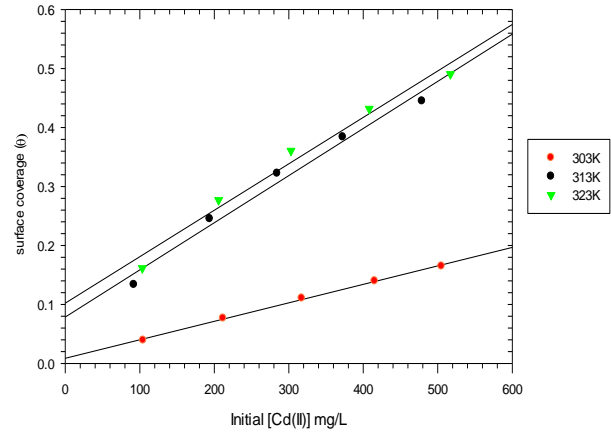

Figure 7. Surface coverage (θ) for the Cd(II) adsorption onto DVL surface at different initial Cd concentrations and temperature (pH=5.4, V=0.01 L, DVL dosage =100 mg)

The kinetic data were studied using Elovich, intra-particle and extra-particle diffusion models. However, Elovich equation is generally expressed as follows:

$$q_t = \frac{1}{\beta} \ln(\alpha\beta) + \frac{1}{\beta} \ln(t) \tag{13}$$

Where: a plot of q_t versus ln(t) gives linear relationship with a slop of (1/β) and intercept of (1/β)ln(αβ). The low values of R^2 were noted, which ascertained the unsuitability of Elovich adsorption model for the adsorption process of Cd(II)-DVL (Figure 8).

For porous adsorption process, the pore (intra-particle) diffusion model can be obtained by Morris-Weber equation:

$$q_t = k_{dif} t^{0.5} + C \tag{14}$$

$$\log q_t = \log k_{idf} + a \log t \tag{15}$$

Where: k_{idf} is the rate of intra-particle diffusion (mg/g.min^{-1}), which gives the idea about the thickness of boundary layer by plotting q_t versus $t^{0.5}$ (see Figure 9). The plot was linear over the range of adsorption but not pass the origin. Also, the data exhibited multi-linear plots, which indicated that two steps influence the Cd(II) adsorption process onto surface of DVL. From **Error! Reference source not found.**, the K_{id} was increased at high temperature, which indicated that the greater boundary layer effect. Therefore, the small value of intraparticle diffusion rate constant has less significant effect about the diffusion mechanism of Cd(II) ions uptake on the surface of DVL. Therefore, intraparticle diffusion process was not only the rate-controlling step.

The Boyd kinetics model was used to study film particle diffusion and expressed as follows:

$$Bt = -0.4977 - \ln(1 - \frac{q_t}{q_e}) \tag{16}$$

Where: qt/qe is the fraction of solute adsorbed at any time t. The plot of B_t versus t (min) was used to distinguish the kinetic data between particle and film diffusion. However, none of the intraparticle and film diffusion linear plots pass through zero suggested that these two diffusion models are not rate determining steps.

TABLE 2. Efluent quality and removal percentage of jar test experiment

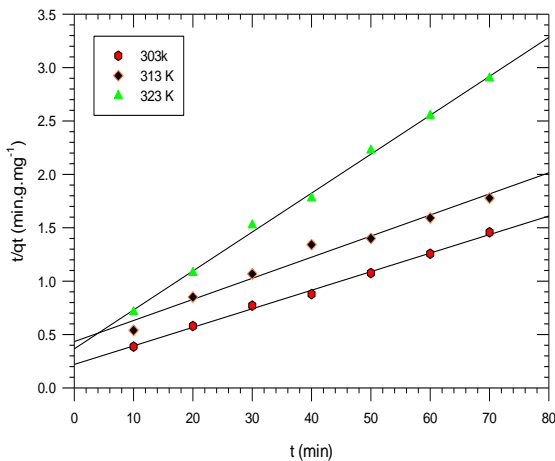| T	LPFO				PSO		
k	K1	q_{max}	R^2		q_m	K_L	R^2
	1/min	mg/g			mg/g	mg/g.min	
303	-8.59E-02	1.88	0.943		57.5	1.38E-03	0.9964
313	-4.92E-02	1.64	0.919		50.6	0.902 E-03	0.9758
323	-5.36E-02	1.25	0.954		27.4	3.64E-03	0.9977
T	intra-particle diffusion			Elovich			
k	K_T	A	R^2	α	β	R2	
	mg/g.min	mg/g		mg/g.min	mg/g		
303	16.9E-02	13.8	0.975	7.27E-02	8.27E-02	0.9750	
313	7.14E-05	12.5	0.975	4.24E-02	9.62E-01	0.9622	
323	12.8	5.99	0.976	3.22E-01	1.95E-01	0.9783	

Figure 8. Pseudo-second-order sorption kinetics of Cd(II) ions onto DVL surface
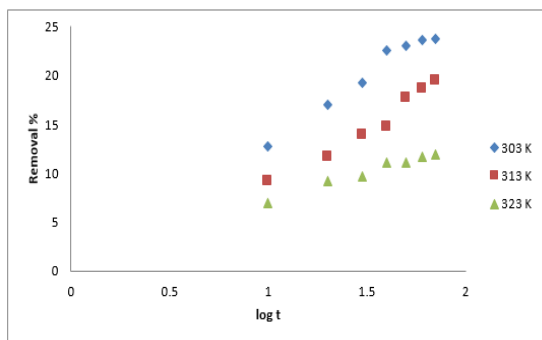

Figure 9. Plot of the intraparticle diffusion model for Cd(II) ions adsorbed onto DVL surface

Adsorption thermodynamics

The change in standard free energy (ΔGº), enthalpy (ΔHº) and entropy (ΔSº) of Cd(II)-DVL adsorption were calculated using the thermodynamic equilibrium constant (K_c) value from the following equation:

$$K_c = C_{Ae} / C_{Se} \qquad (17)$$

Where: C_{Ae} (mg/L) is the equilibrium Cd(II) concentration adsorbed on the surface of DVL and C_{Se} (mg/L) is the equilibrium Cd(II) concentration in solution after 60 min stirring [2, 9]. Then, the following thermodynamic equation is used to calculate the change in standard free energy (ΔGº), enthalpy (ΔHº) and entropy (ΔSº):

$$\Delta G^o = -RT \ln K_c \qquad (18)$$

Where: R= universal gas constant (8.314 J/mol/K and T=absolute temperature (K). Van't Hoff plot was estimated thermodynamic parameters from slope and intercept of ln K_c versus 1/T plot by following equation:

$$\ln K_c = \frac{-\Delta H^o}{RT} + \frac{\Delta S^o}{R} \qquad (19)$$

All calculated thermodynamic parameters are listed in TABLE 2**.** The values of ΔGº were negative at three temperature studied, which indicate the spontaneous.

The activation energy of Cd(II) ions onto DVL surface was also studied and calculated from Arrhenius equation:

$$\ln k_2 = \ln k_0 - \frac{E_a}{RT} \qquad (20)$$

Where k_2 is the rate constant of pseudo second order type II, K_0 is the factor of temperature and Ea is the activation energy. However, the magnitude of Ea was found to be 41.3 kJ/mol, which confirmed that the adsorption process was physical adsorption.

CONCLUSIONS

The findings in this research revealed that DVL powder, without surface modifications by physical or chemical activator, can be used as green adsorbent for Cd(II) ions from aqueous solutions at low temperature. The equilibrium data was described by Langmuir isotherm. The kinetic of the adsorption process was followed pseudo-second-order model. The biosorption mechanism of Cd(II)-DVL is physico-sorption process. The negative values of ΔHº and ΔSº showed that the Cd(II) adsorption process onto ACROL is exothermic in nature.

TABLE 2. Thermodynamic parameters for sorption of Cd(II) on DVL

Initial [Cd(II)]	ΔG^o (kJ/mol)	ΔG^o (kJ/mol)	ΔG^o (kJ/mol)	ΔH^o (kJ/mol)	ΔS^o (kJ/mol)	Ea (kJ/mol)
mg/L	303K	313K	323K			
100	-6.32	-4.99	-3.71	-9.65	-8.49E-02	41.3
200	-6.56	-5.44	-6.99			
300	-7.00	-5.17	-7.46			
400	-6.16	-5.78	-6.57			
500	-6.35	-5.28	-6.77			

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Persian Abstract

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چکیده

در مطالعه حاضر، آزمایش های جذب دسته ای از کادمیوم خطرناک، کادمیوم (II) بر روی کم هزینه Dodonaeae Legs ویسکوز (DVL) و فرایندها با توجه به زمان تماس، pH محلول، مقدار جاذب، مقدار اولیه Cd و دما انجام شد. DVL ها بدون فرآیند فعال سازی شیمیایی یا فیزیکی استفاده می شوند. مدل های ایزوترم، جنبشی و ترمودینامیکی Sorption برای توصیف مرحله تعادل و ثابت بودن آنها تعیین شد. نتایج نشان داد که ظرفیت جذب DVL ها برای یون های Cd (II) 25.29 میلی گرم بر گرم در محلول pH 5.26، 50 دقیقه و ۳۰ درجه سانتیگراد یافت شد. متوسط انرژی آزاد با استفاده از ایزوترم Dubinin-Radushkevich (DRK) به ترتیب E-021،۸۲ به دست آمد که نشان می دهد جذب یون های Cd (II) بر سطح DVL جذب فیزیکی دارد. انرژی فعال سازی (Ea) 3.06 kJ / mol بود که نشان می دهد فرآیند جذب فسفر DVL -(II) Cd جذب فیزیکی است. برای توصیف سینتیک جذب مورد استفاده قرار گرفته است. در این روش، شبیه به درجه اول، شبه مرتبه دوم، الوویچ، مدل های ذرات درون ذرات و انتشار اضافی ذرات استفاده شده است. نتایج نشان داد که مکاتبات شدید با سینتیک شبه دوم مرتب شده است. پارامترهای ترمودینامیکی نشان می دهد که جذب یون های Cd (II) بر روی سطح DVL یک فرآیند اکستریمیک است.