

Research Article

Activated and Nonactivated Date Pits Adsorbents for the Removal of Copper(II) and Cadmium(II) from Aqueous Solutions

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The present study aims to investigate the adsorption behavior of Cu(II) and Cd(II) ions from wastewater onto low-cost adsorbents either raw date pits (RDP), cheap agricultural and nontoxic materials, or chemically activated carbon (ADP) prepared by modified date pits using phosphoric acid. A series of experiments were conducted in a batch system to evaluate the effect of system variables. The adsorption process is affected by various parameters such as solution pH, contact time, initial concentrations of metals, and adsorbent dose. The optimum pH required for maximum adsorption was found to be 5.8 ± 0.5 . The experimental data were tested using Langmuir, Freundlich, Dubinin-Radushkevich (D-R) isotherm equations. It was observed that the adsorption capacity of date pits increased after treatment with phosphoric acid. The maximum uptake capacities (Q_m) were 7.40 and 33.44 mg copper(II) per gram of RDP and ADP, respectively, while 6.02 and 17.24 mg cadmium(II) per gram of RDP and ADP, respectively. The results showed that although the equilibrium data could be described by the three models used, Langmuir model gave slightly better results while Freundlich model gave better results when using raw and activated date pits.

1. Introduction

Contamination of aqueous environments by toxic heavy metals through the discharge of industrial wastewater is a particularly intractable problem threatening the ecosystem. Rapid industrialization has seriously contributed to the release of toxic heavy metals to water streams [1]. Toxic metal compounds not only contaminate surface water sources (seas, lakes, ponds, and reservoirs), but also contaminate underground water in trace amounts by leaching from the soil after rain and snow [2]. Cd is a nonessential, nonbeneficial, and highly toxic element to plants and animals [3]. Cd is introduced into the water from smelting, metal plating, cadmium-nickel batteries phosphate fertilizers, mining, pigments, stabilizers, alloy industries, and sewage sludge. Cadmium(II) is listed as the sixth most poisonous substance jeopardizing human health. Exposure to lower amounts of cadmium may cause gastrointestinal irritation, vomiting, abdominal pain, and diarrhea. Acute exposure may affect kidneys, resulting in tubular proteinosis and sometimes fatality [4].

Copper is an essential nutrient, required by the body in very small amounts. Short periods of exposure can cause gastrointestinal disturbances, including nausea and vomiting. Use of water that exceeds the permissible level over many years could cause liver or kidney damage. Copper is rarely found in source water, but copper mining and smelting operations and municipal incineration may be sources of contamination [5].

There are several methods to treat the metal contaminated effluent, but the selection of the wastewater treatment methods is based on the concentration of waste and the cost of treatment [6–15]. However, these methods are either inefficient or expensive especially when the concentration of the heavy metal ion is low, in the range of 1–100 mg/L [16]. This has, therefore, led to the use of agricultural wastes in removal of heavy metals.

Agricultural wastes are characterized by ready availability, affordability, ecofriendliness, and high uptake capacity for heavy metals due to the presence of functional groups which can bind metals to affect the removal of heavy metal from effluents [17]. Adsorption is one of the more popular

methods for the removal of metals ions from the aqueous solutions. Adsorption is a surface phenomenon, in which molecules of adsorbate are attracted and held to the surface of an adsorbent until an equilibrium is reached between adsorbed molecules and those still freely distributed in the carrying gas or liquid. The adsorption phenomenon depends on the interaction between the surface of the adsorbent and the adsorbed species. The interaction may be due to: (1) chemical bonding; (2) hydrogen bonding; (3) hydrophobic and (4) van der Waals forces [18]. The adsorption isotherms represent the relationship between the amount adsorbed by a unit weight of solid adsorbent and the amount of solute remaining in the solution at equilibrium. Langmuir and Freundlich isotherms models are frequently used isotherm models for describing adsorption of metal ions by different materials.

In the present investigation, raw date pits (RDP) and an activated carbon (ADP) prepared from it have been used as adsorbents for the removal of cadmium(II) and copper(II). The aim of the present work is to explore the possibility of utilizing RDP and ADP for the adsorptive removal of copper(II) and cadmium(II) from wastewater. The effect of such factors as initial pH, adsorbent dose, contact time, and initial concentration was investigated. The kinetics of cadmium(II) and copper(II) adsorption on both adsorbents was analyzed by various kinetic models. Experimental equilibrium data were fitted to the Langmuir, Freundlich, and Dubinin-Radushkevich (D-R) isotherm equations to determine the best-fit isotherm equation. Different error analysis methods were used to determine the isotherm parameters for accurate elucidation of the experimental data.

2. Material and Methods

2.1. Adsorbent Preparation. Date pits were collected and washed with hot tap water then by distilled water and allowed to dry in an oven at 80°C for 2 hours. The dried samples were crushed and ground by using an electric agitated mortar. The powdered sample was sieved in a sieve series 60-mesh size ($D < 125$ nm). The sieved date pits were used for batch experiments as raw material (RDP) and as activated carbon (ADP). Date pits powder was mixed with 85% phosphoric acid in weight ratio 1 : 3, then diluted 5 times with deionized water in a 1000 mL beaker. The mixture was gently boiled with stirring for few hours until the mixture turned to a black paste. The temperature of the paste at this stage was kept at 160°C. Primary air activation was carried out during continuous heating while the material stirred for 15 min. During this period of carbonization and activation, the temperature was increased from 160 to 215°C. This is followed by secondary air activation in which the black paste was heated electrically for 30 min at a temperature of about 600°C. After activation, the synthesized carbon was cooled for 10 min with the tap water, then washed with boiling deionized water the slurry was filtered; the activated carbon date pits (ADP) were dried in an oven at 100°C for 12 h, then cooled in desiccators, weighed, grounded, transferred to a container, and stored in the desiccators.

2.2. Adsorbate Preparation. Stock solutions of 1000 mg/L of Cd and Cu ions were prepared by diluting with deionised water. The adsorbate stock solutions containing Cd(II) and Cu(II) were prepared from cadmium chloride ($\text{CdCl}_2 \cdot 2\text{H}_2\text{O}$) and copper chloride ($\text{CuCl}_2 \cdot 6\text{H}_2\text{O}$). All adsorption experiments were carried out using reagent bottles of 250 mL capacity containing different amounts of each adsorbent in 200 mL solutions of different concentrations. The pH of each experimental solution was adjusted to the required initial pH value using 0.1 N HCl or 1 N NaOH before mixing the adsorbent.

2.3. Batch Adsorption Studies. Batch experiments were performed at $25 \pm 1^\circ\text{C}$ and carried out at various pH (2.1–9.05), initial concentration of Cd(II) or Cu(II) (10–110 mg/L), adsorbent dose (0.01–2 g/L), and stirring speed (180 rpm) for a contact time from 0 to 200 min. For each batch experiment, 200 mL of 50 mg/L of two metal ions solution was used. After setting pH and adding desired amount of adsorbent, the mixture was agitated on mechanical shaker for 45 min. After that the mixture was filtered to separate the adsorbent from supernatant. The residual concentration of both ions was determined by flame atomic spectrometer. All experiments were replicated thrice for all the adsorbents, and results were averaged.

2.4. Analytical Techniques. Atomic absorption spectrophotometer with an air acetylene flame and hollow cathode lamps for Cu and Cd was used for metal ions analysis. The pore structure in raw and activated date pits was observed by using scanning electron microscope (SEM).

The removal efficiency percentage (RE%) of copper and cadmium ions was calculated for each run by the following expression:

$$\text{RE}\% = \left[\frac{(C_o - C_e)}{C_o} \right] 100, \quad (1)$$

where C_o and C_e are the initial and equilibrium concentrations of both metal ions in the solution. The adsorption capacity of an adsorbent which is obtained from the mass balance on the sorbate in a system with solution volume V is often used to acquire the experimental adsorption isotherms. Under the experimental conditions, the adsorption capacities of all the adsorbents for each concentration of Cu(II) and Cd(II) ions at equilibrium were calculated as follows:

$$q_e \text{ (mg/g)} = (C_o - C_e) \frac{V}{M}, \quad (2)$$

where C_o and C_e are the initial and equilibrium concentrations of both ions in the solution, respectively. V is the volume of solution (L), and M is the mass of adsorbent (in g) used.

3. Results and Discussion

3.1. Characteristics of Adsorbent. A scanning electron microscope (SEM) was used to examine the surface of the raw

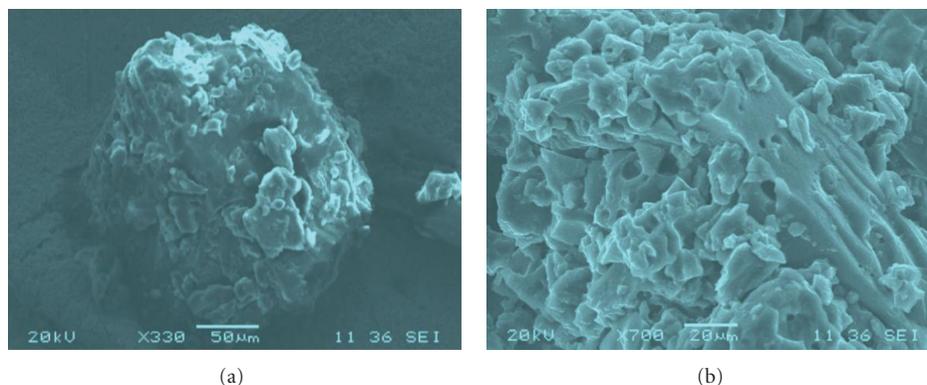


FIGURE 1: Scanning electron micrographs of (a) raw date pits, RDP and (b) activated carbon of date pits, ADP.

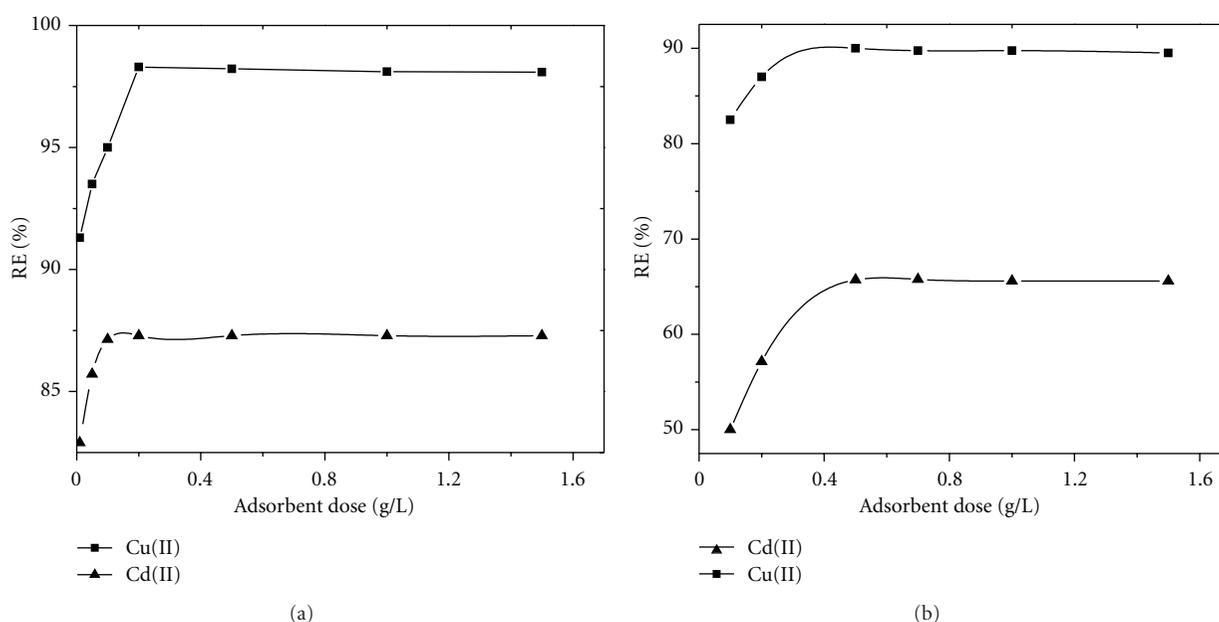


FIGURE 2: Effect of adsorbent dosage of (a) ADP and (b) RDP on adsorption of Cd(II) and Cu(II).

and activated date pits (RDP and ADP). The SEM image (Figures 1(a) and 1(b)) revealed changes in surface morphology of raw material as it underwent both physical and chemical carbonization. The activated carbon (ADP) showed high porosity compared to raw material (RDP). This was because during carbonization process of raw material with phosphoric acid at high temperature (600°C), most volatile matter was lost and thus created a system with advanced pore structure. Impregnation with phosphoric acid followed by the second carbonization dehydrated the cellulose material, resulting in weakening of the precursor structure and creation of pores. During chemical activation process, phosphoric acid was responsible for decomposition of organic material to release volatile matter and development of microporous structure which could increase the adsorption capacity [19]. Besides, phosphoric acid was also important in minimizing the formation of tars and other liquids which could clog up the pores and inhibit the development of pores [20]. The porosity created in the

carbon structure was also resulted from phosphoric acid removal from carbon structure by intense washing. Pores development in an activated carbon is important since pores act as active sites, playing the main role in adsorption. Pores formed on surface of adsorbent are sites for metals to be adsorbed onto the adsorbent.

3.2. Effect of Adsorbent Dosage. The dosage of adsorbent was a key parameter to control both availability and accessibility of adsorption sites [21]. The effect of adsorbent dosage (0.1–1.5 g of RDP and 0.01–1.5 g of ADP) on the removal of Cu(II) and Cd(II) ions was presented in Figures 2(a) and 2(b). The effect of varying doses of RDP and ADP was investigated using 50 mg/L initial concentration of two metals, at initial $\text{pH } 5.8 \pm 0.5$ and contact time 60 min.

The results show an increase in removal efficiency percentage of cadmium and copper with the increase in dose of adsorbent up to a certain limit and then it remains almost

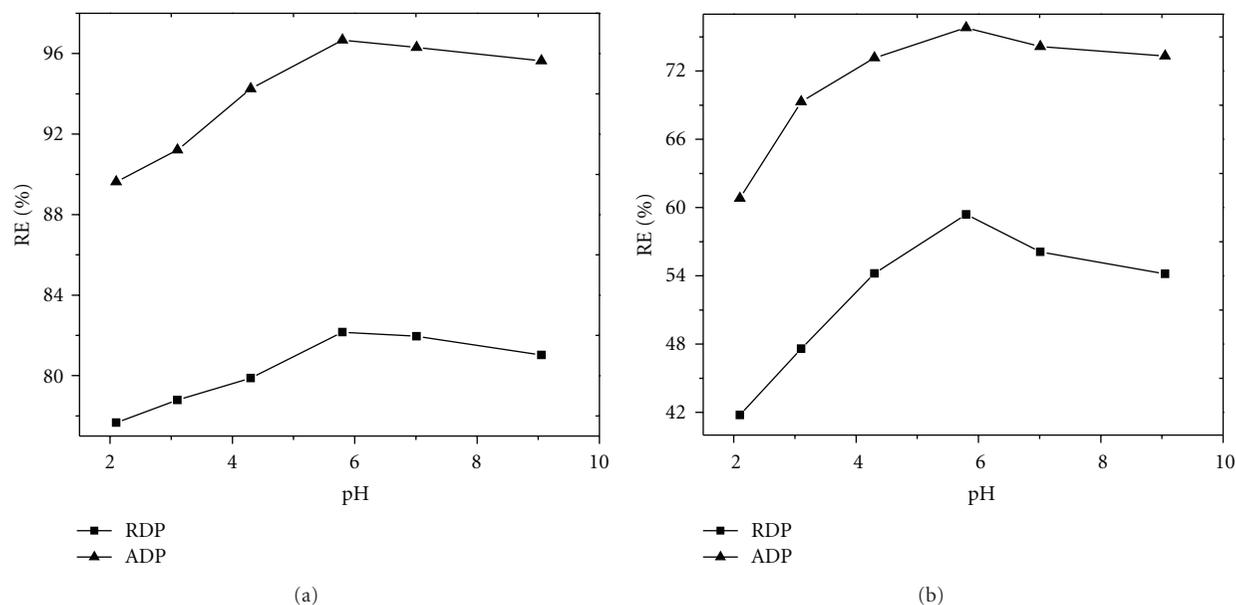


FIGURE 3: Effect of pH on adsorption of (a) Cu(II) and (b) Cd(II) onto selected adsorbent at adsorbent dosage (0.5 g RDP and 0.2 g ADP), initial concentration 50 mg/L.

constant. Increase in the adsorption with increasing dose of adsorbent is expected due to the increase in adsorbent surface area and the availability of more adsorption sites [22]. The relative increase in the percentage removal of Cu(II) and Cd(II) ions is found to be insignificant 0.2 g of ADP and 0.5 g of RDP, which is fixed as the optimum dose.

The data clearly shows that the ADP is more effective than RDP for removal of Cu(II) and Cd(II) ions from aqueous solution. The removal of metal from Cd(II) and Cu(II) solutions reached to 98.3% and 87.3% at 0.2 g dosage of ADP adsorbent, whereas 90% and 65.7% at 0.5 g dosage of RDP adsorbent for Cu(II) and Cd(II), respectively. Lower Cd(II) removal may be due to the fact that the adsorption of Cu(II) was limited to only monolayer adsorption. This is proved by the calculation of correlation coefficient, R^2 value from Langmuir isotherm.

3.3. Effect of Initial PH. The pH of the solution affects the surface charge of the adsorbents as well as the degree of ionization and speciation of different pollutants [23]. It is known that metal species $[M(II) = Cd(II), Cu(II)]$ are present in deionized water in the form of M^{+2} , $M(OH)_2$, $M(OH)(S)$, and so forth [24]. It is obvious that the adsorption of $M(II)$ must be higher in alkaline solution. But at higher pH, the precipitation as $M(OH)_2(S)$ plays the main role in removing the $M(II)$ ions. Therefore, all the experiments were conducted at $pH \leq 8$. Figures 3(a) and 3(b) represent the effect of initial pH of the solution on the adsorption of Cu(II) and Cd(II) onto 0.5 g RDP and 0.2 gm ADP using 50 mg/L initial metal ion concentration. The optimum pH was found to be $pH 5.8 \pm 0.5$ for both studied adsorbents. The maximum removal of Cu(II) efficiency was 82.16% and 96.67% for RDP and ADP, respectively, and the maximum removal of Cd(II) efficiency was 41.75%

and 60.00% for RDP and ADP, respectively. This may be attributed to the competition between the hydrogen and metal ions on the sorption sites, at low pH values. At pH values higher than 6.0 insoluble, metal hydroxide (Cd or Cu) starts precipitating from the solutions making true sorption studies impossible [24]. Consequently, the working pH value for copper removal onto RDP and ADP was chosen as 5.8 ± 0.5 , and the other adsorption experiments were performed at this pH value.

3.4. Effect of Contact Time. Effect of contact time for the removal of Cd(II) and Cu(II) by 0.5 g RDP and 0.2 g ADP from aqueous solution is shown in Figures 4(a) and 4(b). There was a rapid adsorption of Cd(II) and Cu(II) in the first 20 min, and, thereafter, the rate of adsorption become slower; this is due to decreased or lesser number of active sites [25]. The maximum removal efficiency of Cd(II) was (86% and 97.5%), and it was attained in about 65 and 50 min for RDP and ADP, respectively, and the maximum removal efficiency of Cu(II) was 59% and 82% for RDP and ADP, respectively.

3.5. Effect of Initial Metal Ion Concentration. The adsorption experiments were carried out with metal ions concentrations of 10, 25, 50, 75, 100, and 110 mg/L with a constant raw and activated date pits amounts of 0.5 and 0.2 g, respectively, contact time 60 min and $pH 5.8 \pm 0.5$. The amount adsorbed per unit mass of cadmium and copper ions at different concentrations is shown in Figures 5(a) and 5(b). As in Figures 5(a) and 5(b) is shown the amount adsorbed per unit, mass q_e increased with an increase in metal ions concentration.

There are various possible interaction effects between different species in solution and, in particular, potential interactions on the surface depending on the adsorption

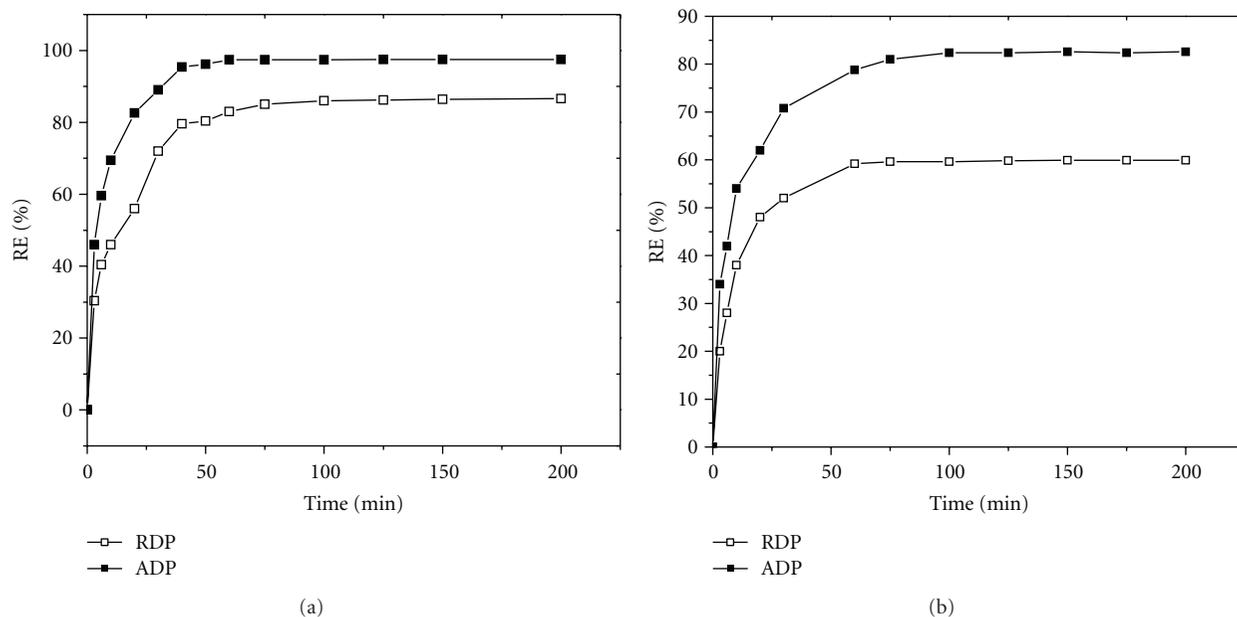


FIGURE 4: (a) Effect of the contact time on adsorption of Cu(II) by selected adsorbent at pH = 5.8 ± 0.5, adsorbent dosage (0.5 g RDP and 0.2 g ADP), initial concentration 50 mg/L. (b) Effect of the contact time on adsorption of Cd(II) by selected adsorbent at pH = 5.8 ± 0.5, adsorbent dosage (0.5 g RDP and 0.2 g ADP), initial concentration 50 mg/L.

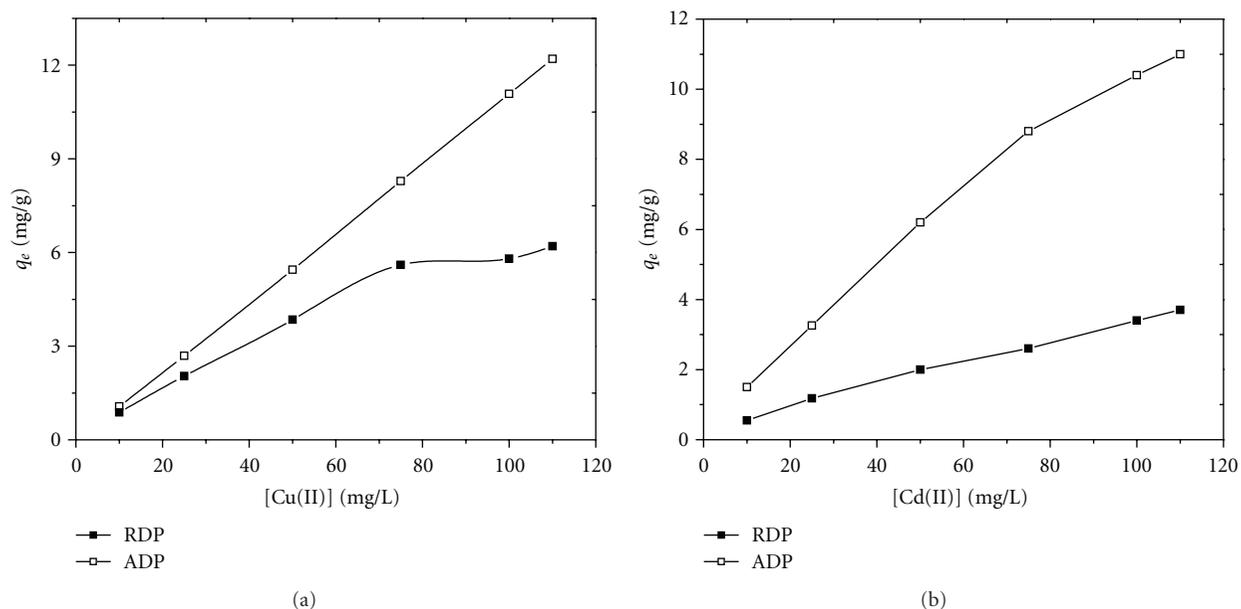


FIGURE 5: Effect of initial concentration on the adsorption of metal ions by selected adsorbent at pH = 5.8 ± 0.5, adsorbent dosage (0.5 g RDP and 0.2 g ADP), 60 min contact time.

mechanism. Factors that affect the binding sites (e.g., functional groups, structures, and surface properties), the properties of the adsorbates (e.g., concentration, ionic nature, or standard redox potential), and the solution chemistry (e.g., pH and ionic strength). In the context of adsorption, a number of properties have been suggested for use in the ordering of affinity rank, including ionic radius and solubility product constant as hydroxides [26], pulling

electronegativity and standard reduction potential [27], first hydrolysis constant [28].

The properties may play an important role in metal ion adsorbent interaction, but can only partly explain high- or low-adsorption capacities. The atomic weight of Cd(II) is highest as compared to Cu(II), and the ionic radius of Cd(II) is highest as compared to Cu(II). Both of the tested adsorbents showed higher adsorption capacity for

TABLE 1: Isotherm parameters for adsorption of Cu(II) onto selected adsorbents, RDP and ADP.

Adsorbent	Langmuir model				n	Freundlich model		Dubinin-Radushkevich (D-R) model		
	Q_m	K_L	R_L	R^2		K_f	R^2	X_m	$\lambda(10)^7$	R^2
RDP	7.40	0.103	0.08–0.49	0.990	1.19	0.90	0.991	1.10	0.19	0.877
ADP	33.44	0.045	0.17–0.69	0.970	1.86	1.50	0.999	1.98	0.20	0.900

TABLE 2: Isotherm parameters for adsorption of Cd(II) onto selected adsorbents, RDP and ADP.

Adsorbent	Langmuir model				n	Freundlich model		Dubinin-Radushkevich (D-R) model		
	Q_m	K_L	R_L	R^2		K_f	R^2	X_m	$\lambda(10)^7$	R^2
RDP	6.02	0.019	0.32–0.84	0.963	1.49	0.203	0.999	0.75	0.14	0.955
ADP	17.24	0.032	0.22–0.76	0.985	1.51	0.82	0.997	1.04	0.14	0.900

Cu(II) ions as compared to Cd(II). However, the adsorption order is found to be in the order of increasing molecular weight and ionic radius, for example, Cu(II) > Cd(II). The increase in initial metal ion concentrations also enhances the interaction between the metal ions in the aqueous phase and the adsorbents. Therefore, an increase in the initial metal ion concentrations enhances the adsorption uptake of Cu(II) and Cd(II) onto RDP and ADP as shown in Figures 5(a) and 5(b).

3.6. Adsorption Equilibrium Study. The purpose of the adsorption isotherm is to relate the adsorbate concentration in the bulk solution and the adsorbed amount at the interface. The analysis of the isotherm data is important to develop an equation which accurately represents the results and which could be used for the design purpose.

Langmuir and Freundlich; Temkin and Dubinin-Radushkevich (D-R) isotherm models were used to describe the adsorption equilibrium. Experimental isotherm data were conducted at an equilibrium time of 200 min for different dosages of adsorbate.

3.6.1. Langmuir Isotherm. The Langmuir adsorption isotherm is based on the assumption that all sites possess equal affinity for the adsorbate. It may be represented in the linear form as follows [29]:

$$\frac{C_e}{q_e} = \frac{1}{K_L Q_m} + \frac{C_e}{Q_m}, \quad (3)$$

where C_e is the equilibrium concentration (mg/L¹), q_e is the amount adsorbed at equilibrium (mg/gm), and Q_m and K_L are Langmuir constants related to adsorption capacity (mg/gm and energy of adsorption capacity (L/mgm), respectively. The linear plots of C_e/q_e versus C_e suggest the applicability of the Langmuir isotherms. The values of Q_m and K_L were determined from slope and intercepts of the plots for two heavy metal ions [Cu(II) and Cd(II)] and are presented in Tables 1 and 2 and Figures 6 and 7. The shape of the Langmuir isotherm was investigated by the dimensionless constant separation term (R_L) to determine high-affinity adsorption [30]. R_L was calculated as follows:

$$R_L = \frac{1}{(1 + K_L C_o)}, \quad (4)$$

where C_o is the initial metal ion concentration (mg/L). R_L indicates the type of isotherm to be irreversible ($R_L = 0$), favorable ($0 < R_L < 1$), linear ($R_L = 1$), (or) unfavorable ($R_L > 1$). In the present investigation, the R_L values for RDP and ADP were less than one for two metals, showing favorable adsorption.

3.6.2. Freundlich Isotherm. Freundlich isotherm is an empirical equation. This equation is one among the most widely used isotherms for the description of adsorption equilibrium. Freundlich isotherm is capable of describing the adsorption of organic and inorganic compounds on a wide variety of adsorbents. The Freundlich equation form could be written as follows [31]:

$$\log q_e = \log k_f + \frac{1}{n} \log C_e. \quad (5)$$

The constants K_f and $1/n$ were calculated from the intercept and slope of the plot of $\log q_e$ versus $\log C_e$ as in Figures 8 and 9, and the results were tabulated in Tables 1 and 2. Where K_f and n are the Freundlich constants related to the adsorption capacity and adsorption intensity. The values of n were greater than one indicating the favorable adsorption.

3.6.3. Dubinin-Radushkevich (D-R) Isotherm. The Dubinin-Radushkevich (D-R) isotherm approach assumes that there is a surface area where the adsorption energy, is homogeneous [32]. The D-R isotherm has the form:

$$\ln q_e = \ln X_m - \lambda \epsilon^2, \quad (6)$$

where X_m represents the maximum sorption capacity of the sorbent, λ is a constant related to sorption energy, and ϵ Polanyi sorption potential can be expressed as

$$\epsilon = RT \ln \left(1 + \frac{1}{C_e} \right). \quad (7)$$

The Polanyi adsorption theory postulates [33] fixed volume of sorption site close to sorbent surface and existence of sorption potential over these site. The sorption potential is related to an excess of sorption energy over the condensation energy and is independent of temperature. A plot of $\ln q_e$ versus ϵ^2 gave a straight line, from which values of X_m and λ

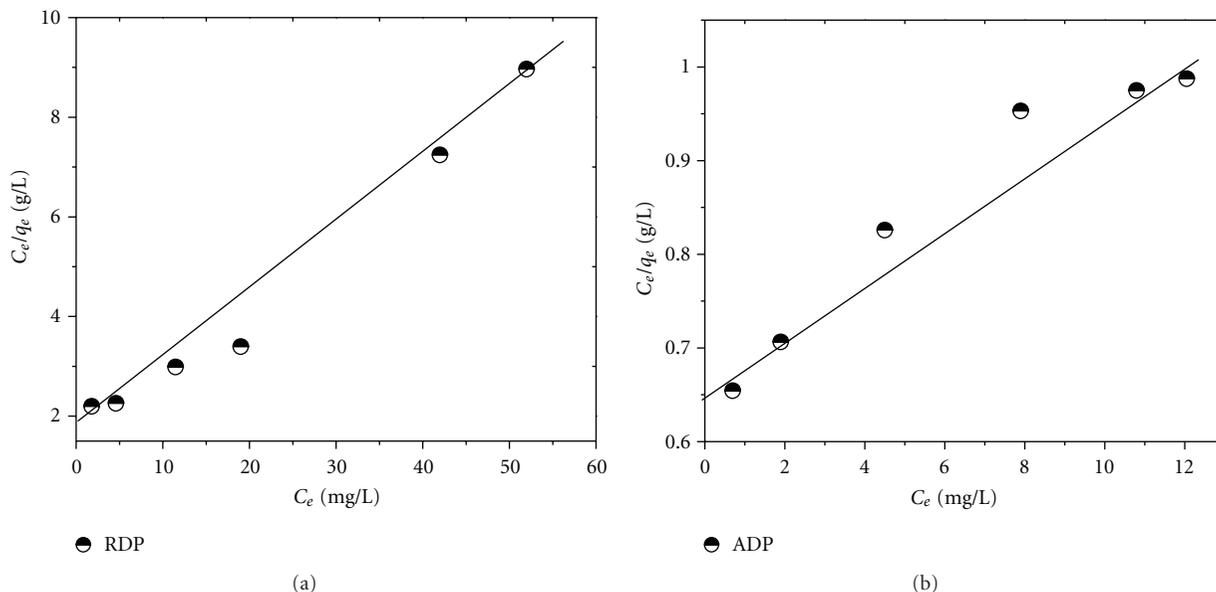


FIGURE 6: Langmuir isotherm plot for adsorption of Cu(II) onto selected adsorbent.

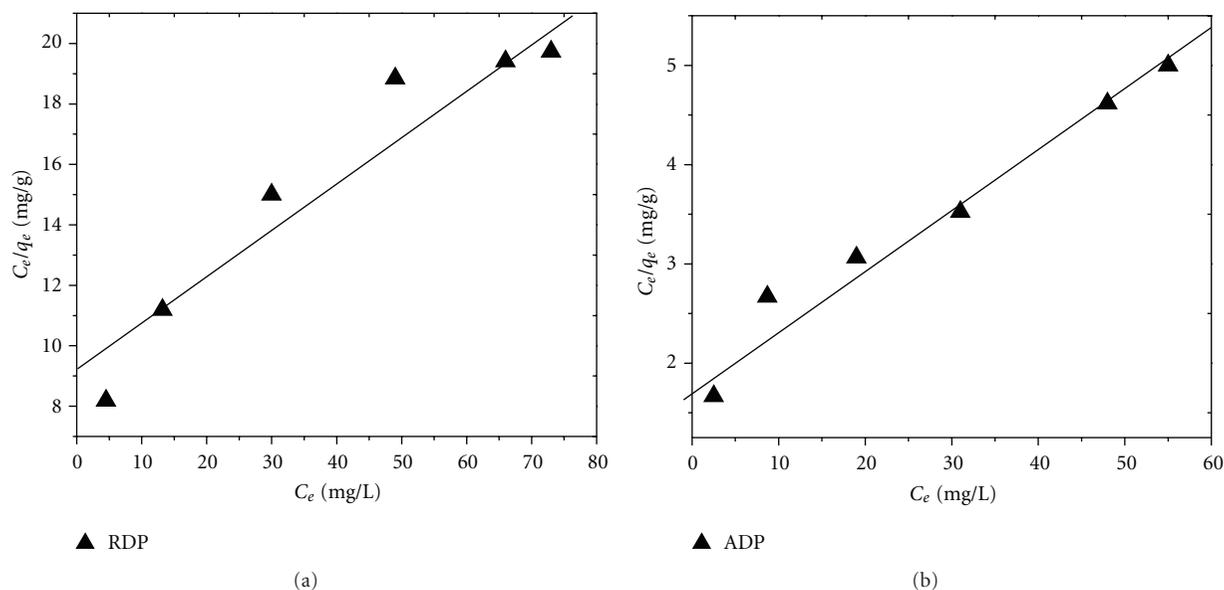


FIGURE 7: Langmuir isotherm plot for adsorption of Cd(II) onto selected adsorbent.

for Cu(II) and Cd(II) onto RDP and ADP were evaluated in Tables 1 and 2.

The isotherm constants were determined from linear isotherm graphs for each of the isotherm equations tested. The values of the isotherm constants with the correlation coefficients are given in Tables 1 and 2. The Freundlich equation represents the better fit of experimental data than other isotherm equations.

3.7. Adsorption Kinetic Study. In order to investigate the controlling mechanism of adsorption processes such as mass transfer and chemical reaction, the pseudo-first-order and

pseudo-second-order equations are applied to model the kinetics of metal ions adsorption onto RDP and ADP.

3.7.1. Pseudo-First-Order Kinetic Model. Natarajan and Khalaf—as cited by Kannan and Veemaraj proposed a pseudo-first-order kinetic model [34]. The integral form of the model is

$$\log\left(\frac{C_o}{C_e}\right) = \left(\frac{k_1}{2.303}\right)t. \tag{8}$$

A plot of $\log(C_o/C_e)$ versus t gives a linear correlation, from which the values of first-order rate constants k_1 of

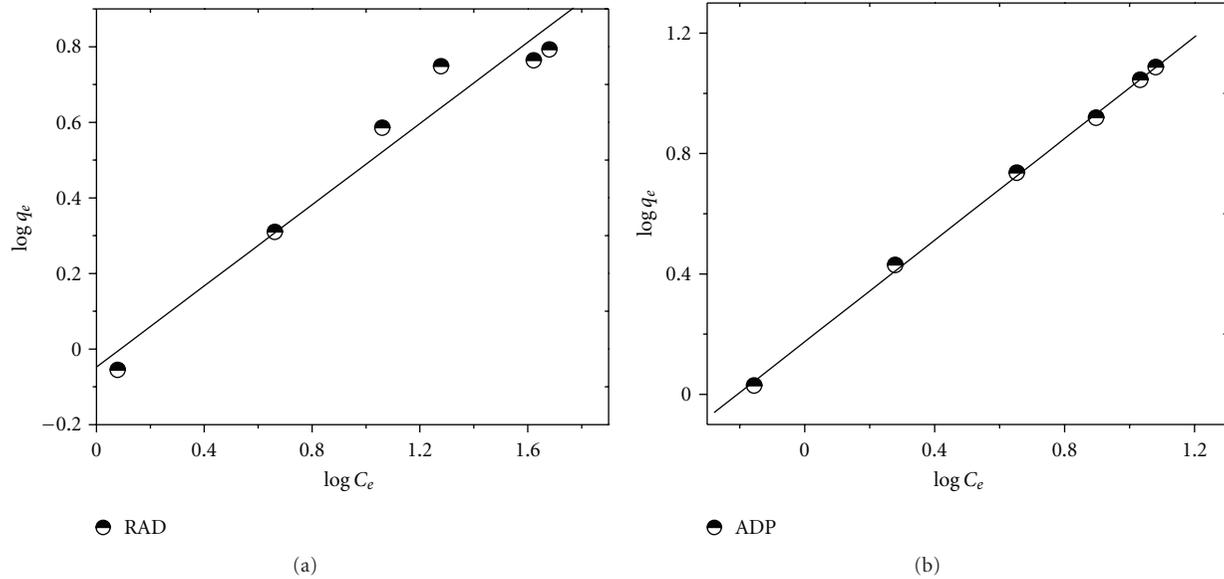


FIGURE 8: Freundlich isotherm plot for adsorption of Cu(II) onto selected adsorbent.

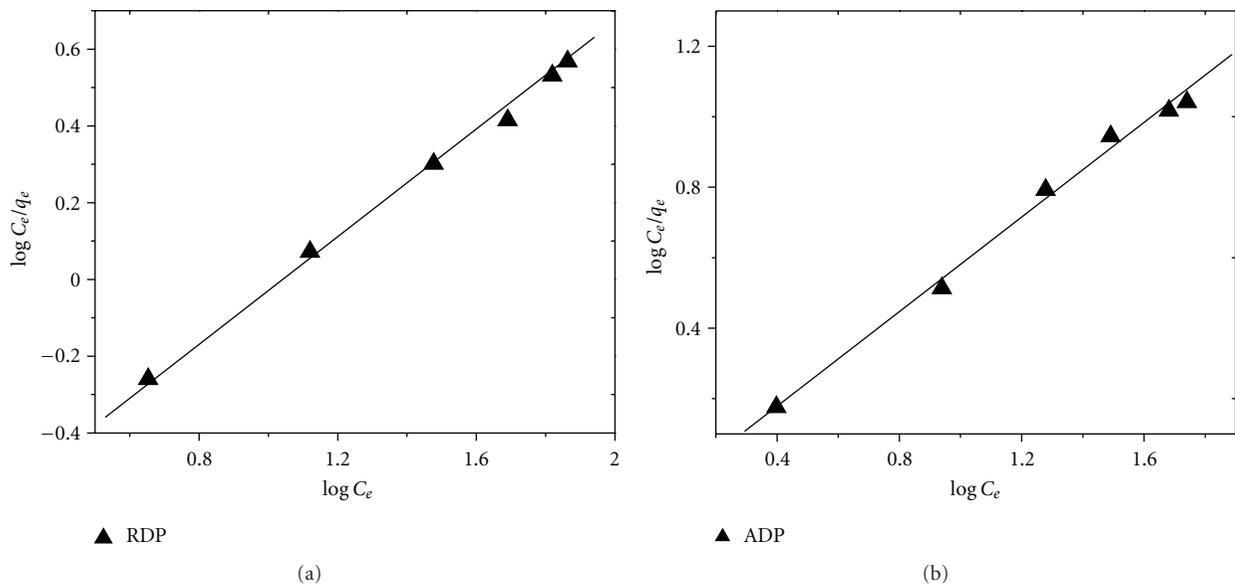


FIGURE 9: Freundlich isotherm plot for adsorption of Cd(II) onto selected adsorbent.

Cu(II) and Cd(II) are calculated and presented in Tables 3 and 4. This model was successfully applied to describe the kinetics of many adsorption systems.

3.7.2. Pseudo-Second-Order Kinetic Model. The adsorption kinetics may also be described by a pseudo-second-order reaction, which represent in Figures 10(a) and 10(b). The linearized integral form of the model is

$$\frac{t}{q_e} = \frac{1}{K_2 q_e^2} + \frac{t}{q_e}. \quad (9)$$

A plot of t/Q_t versus t gives a linear relationship (Figures 9(a) and 9(b)), from which Q_e and k_2 were determined

from the slope and intercept of the plot, respectively; these values are presented in Tables 3 and 4. For all the systems studied, good correlation coefficients were obtained ($R^2 \approx 1$) by fitting the experimental data to pseudo-second-order kinetics than that for the pseudo-first-order kinetic model. Therefore, the sorption was more favorably by pseudo-second-order kinetic model, which was based on the assumption that the rate limiting step may be chemisorptions involving valences forces through sharing or exchange of electrons between sorbent and sorbate [35].

3.8. Comparison of Metal Ions Removal with Different Adsorbents Reported in the Literature. The adsorption capacities

TABLE 3: The kinetics constants for the adsorption of Cu(II) onto RDP and ADP, (initial concentration of Cu(II) = 50 mg/L).

Adsorbents	Pseudo-first-order kinetics		Pseudo-second-order kinetics	
	k_1, min^{-1}	R^2	$k_2, \text{gm} (\text{mg min})^{-1}$	R^2
RDP	4.86×10^{-3}	0.923	0.097	0.998
ADP	0.017	0.778	0.131	0.999

TABLE 4: The kinetics constants for the adsorption of Cd(II) onto RDP and ADP, (initial concentration of Cd(II) = 50 mg /L).

Adsorbents	Pseudo-first-order kinetics		Pseudo-second-order kinetics	
	k_1, min^{-1}	R^2	$k_2, \text{g} (\text{mg min})^{-1}$	R^2
RDP	3.45×10^{-3}	0.763	0.018	0.999
ADP	7.23×10^{-3}	0.829	0.028	0.999

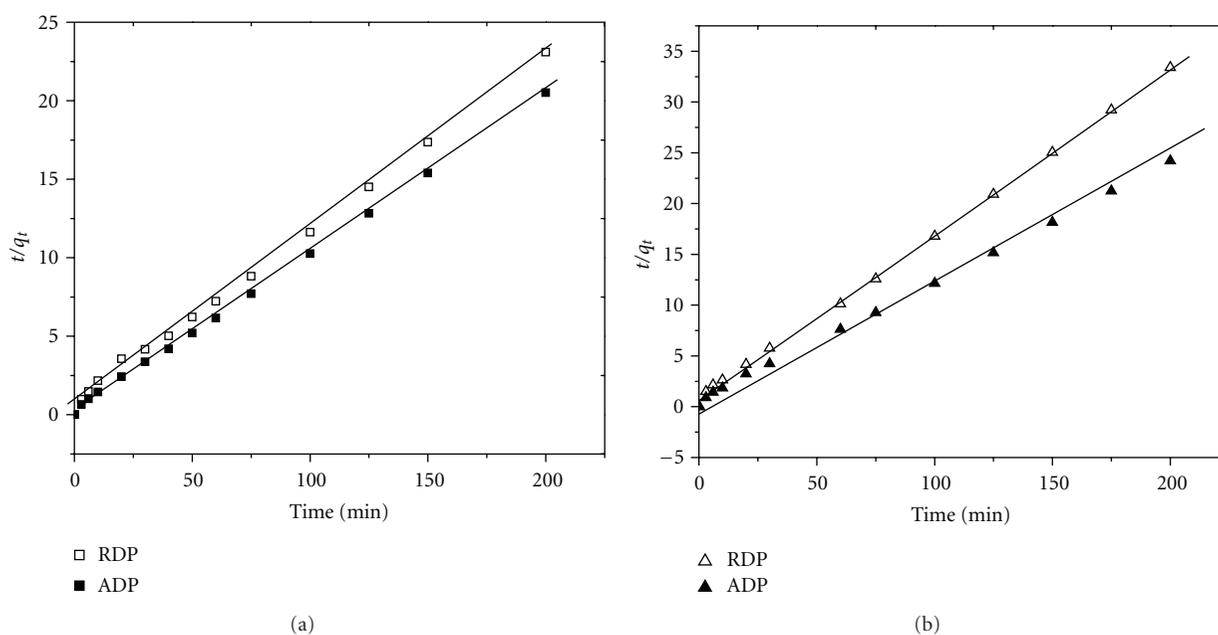


FIGURE 10: Pseudo-second-order plot for adsorption of (a) Cu(II) and (b) Cd(II) onto RDP and ADP.

of the adsorbents for the removal of both ions have been compared with those of other adsorbents reported in the literature, and the values of adsorption capacities have been presented in Table 5. The values are reported in the form of monolayer adsorption capacity. The experimental data of the present investigations are higher than other reported values in some cases. The adsorption capacity varies, and it depends on the characteristics of the individual adsorbent and the initial concentration of the adsorbate. However, the present experiments are conducted to find the technical applicability of the low-cost adsorbents to treat Cu(II) and Cd(II).

4. Conclusion

Raw date pits (RDP) and an activated carbon prepared from date pits (ADP) have been used as adsorbents for the removal of copper(II) and Cd(II) from wastewater. Adsorption was influenced by various parameters such as initial pH, initial

TABLE 5: Comparison of adsorption capacity of various adsorbents for Cu(II) and Cd(II).

Adsorbent	Adsorbent capacity (mg/g)		
	Cu(II)	Cd(II)	Reference
Lentinus edodes pellets	—	78.6	[36]
Activated pine bark	—	30.21	[37]
Black gram husk	—	39.99	[26]
Orange peel	3.19	—	[38]
Sawdust	3.12	—	[38]
Bagasse	2.89	—	[38]
Papaya seed	3.9	—	[39]
Raw date pits	7.40	6.02	This study
Activated date pits	33.44	17.24	This study

metal ions concentrations, and dose of adsorbents. The maximum uptake of two metals ions occurred at an initial

pH of 5.8 ± 0.5 . Adsorption was increased with increasing dose of adsorbent and decreased with increasing initial metal ions concentrations. The equilibrium time for adsorption of metal ions from aqueous solutions was achieved within 60 min of contact time. The Freundlich adsorption isotherm model was better used to represent the experimental data. The adsorption kinetics fits to pseudo-second-order model. It is important to remark that date pits are very cheap and highly available material; further, they are more effective compared to other some adsorbents. The results obtained in this study show that date pits are a good and effective adsorbent for the removal of heavy metals and could be used in water and wastewater treatment.

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