



As an Application of Sustainability: Utilizing Processed Rice Husk to Remove Cadmium Ions Cd (II) From Aqueous Phase by Adsorption

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Abstract

This study goals to reduce the importance of expensive commercial activated carbon while removing heavy metals from wastewater using cheap, locally available materials (rice husk). To accomplish this goal, a variety of pH values were tested, and it was found that batch studies at pH 5 had the best Cadmium ion removal effectiveness. 180 minutes was determined to be the ideal contact time for the process, and it was discovered that as contact time increased, adsorption effectiveness increased. 180 rpm is the recommended shaking speed, given studies on how agitation speed influences batch adsorption. The effectiveness of the rice husks capacity to eradicate Cadmium Cd (II) from aqueous solutions and absorb it, has assessed. The study revealed that Cd had a 98% effectiveness of removal. The recommended adsorbent's maximum Cd adsorption capability in a batch system was found to be 7.38 mg/g. Three models— Freundlich, Temkin, and Langmuir—were fitted to various equilibrium isothermal experiments. For this system, the experimental best fit was provided by the Freundlich isotherm model, with an R^2 value of 0.97. The equilibrium isotherms were discovered to be of a favourable type. When the correlation coefficient (R^2) values of each curve for the four models are compared, it appears that the Elovich model best captures the kinetics of the Cadmium ions adsorption onto rice husk. Were the values (Elovich> pseudo-second order> intra-particle diffusion> Pseudo-First Order). According to the research, rice husk may be useful for filtering out wastewater from contaminants and impurities. So, it is a good alternative for expensive activated carbon.

Keywords: Rice Husk, Cadmium Ions, Isotherm, Adsorption, Kinetics

الخلاصة: تهدف هذه الدراسة إلى تقليل أهمية الكربون المنشط التجاري الباهظ الثمن في إزالة المعادن الثقيلة من مياه الصرف باستخدام مواد رخيصة ومتوفرة محلياً (قشر الأرز). لتحقيق هذا الهدف، تم اختبار مجموعة متنوعة من قيم الأس الهيدروجيني، ووجد أن الدراسات على دفعات عند الرقم الهيدروجيني 5 كان لها أفضل فعالية في إزالة أيون الكاديوم. تم تحديد 180 دقيقة على أنها وقت الاتصال المثالي للعملية، وتم اكتشاف أنه مع زيادة وقت الاتصال، تزداد فعالية الامتزاز. 180 دورة في الدقيقة هي سرعة الاهتزاز الموصى بها، بالنظر إلى الدراسات حول كيفية تأثير سرعة التحريك على امتصاص الدفعات. تم تقييم فعالية قدرة قشور الأرز على إزالة الكاديوم (II) من المحاليل المائية وامتصاصه. كشفت الدراسة أن الكاديوم له فعالية إزالة بنسبة 98%. تم العثور على أقصى قدرة لامتصاص الكاديوم الموصى بها للممتصات في نظام الدفعات لتكون 7.38 مجم / جم. تم تركيب ثلاثة نماذج - Freundlich و Temkin و Langmuir - لتجارب توازن متساوي الحرارة. بالنسبة لهذا النظام، تم توفير أفضل ملائمة تجريبية بواسطة نموذج متساوي الحرارة Freundlich، بقيمة R^2 تبلغ 0.97. تم اكتشاف أن درجات حرارة التوازن من النوع المناسب. عند مقارنة قيم معامل التحديد (R^2) لكل منحنى للنماذج الأربعة، يبدو أن نموذج Elovich يلتقط بشكل أفضل حركية امتصاص أيونات الكاديوم على قشر الأرز. كانت القيم R^2 (Elovich> pseudo-second order> intra-particle diffusion> Pseudo-First Order) (إيلوفج> بسيدو الرتبة الثانية > الانتشار داخل الجسيم> بسيدو الرتبة الأول). وفقاً للبحث، كان قشر الأرز مفيداً في تصفية المياه العادمة من الملوثات والشوائب، لذا فهو بديل جيد للكربون المنشط الباهظ الثمن.

1. INTRODUCTION

"Drinking water" is defined by the World Health Organization (WHO) as water that is adequate for domestic use and human intake (World-Health-Organization, 2002). Environmental contamination that effects human health and potable water is becoming more of a worry with the production of heavy metals. Due to this production, enormous metal quantities end up in the environment every day [1]. There are several environmental concerns as a result of the large-scale release of heavy metals into the environment. Since they can collect in nature and are not biodegradable, toxic metals can be separated from other types of contaminants. When they reach certain limitations, they also contribute to a number of diseases and ailments [2]. The water streams is exposed to heavy metals as a result of activities of industries like ore refining, mining, tanneries, fertilizer industries, battery industries, pesticides, and paper industries. Water pollution has an effect on ecosystems, human health, and aquatic animals and plants. Heavy metals like arsenic (As), copper (Cu), cadmium (Cd), zinc (Zn), lead (Pb), chromium (Cr), iron (Fe), vanadium (V), selenium (Se), cobalt (Co), mercury (Hg), and nickel (Ni) are the primary hazardous dangerous substances for people and other forms of life. Coprecipitation/adsorption, membrane filtration, carbon adsorption, Chemical precipitation, and ion exchange are a few of the procedures used to treat waste streams that contain metal contamination [3].

It is necessary to use cost-effective alternative technologies or sorbents to treat water. Large-scale natural resources or specific agricultural or industrial waste materials may have the ability to function as low-cost sorbents. These materials are inexpensive, which allows for easy disposal after use without the need for pricey regeneration [4]. If a sorbent demands small processing, is waste product from another industry or a by-product or is plentiful in nature, it is frequently regarded as "low cost". Of fact, increased sorption capacity may offset the expense of further processing [5]. Activated carbon adsorbent has been investigated the most, but alternative adsorbent materials for metal ion removal are increasingly garnering a lot of interest. The ability of waste rice husk, which was chosen as the source material in this study instead of granular activated carbon, to adsorb Cd (II) ions from aqueous solutions was evaluated. Under kinetic and equilibrium conditions, the contact duration effects, pH, initial metal ion concentration, and dosage of adsorbent on rice husk were explored.

2. MATERIALS AND METHOD

2.1. Adsorbate Material

This issue is a significant one on a worldwide scale due to the poor biodegradability, high toxicity, and accumulation of heavy metals in water brought on by industrial and urban activities. Batteries, phosphate fertilizers, metal paints, pigments, and pigment stabilizers are a few of the major causes of cadmium pollution in the environment. And for this reason, cadmium was the heavy metal investigated in this research (Cd).

2.2. Adsorbent Material

In this study, the rice husk used was supplied by the mill in the Iraqi city of Ghammas, which is located in the Diwaniyah Governorate. Tap water was used to wash this husk several times to eliminate soil and contaminants. Then, after it was rinsed in distilled water, an oven was used to dry it for two hours at 105 °C. To improve surface area and the capacity of adsorption, the rice husk (Adsorbent Material) was crushed by a high-speed multi-functional crusher and sieved to different particulate sizes. Then, it was modified with an acidic solution (phosphoric acid H_3PO_4 was used) at a concentration of 1 percent by volume to handle fractured rice husks so they could move through different sieve volumes and become an adsorbent with a consistent dimension (1.18–2 mm) and (2–3.35 mm). After that, after being rinsed multiple times with non-ionized water until the pH hit 6, it was dried for three hours at 80 °C to eliminate moisture. After drying, rice husk was activated and given a boost in adsorption effectiveness by spending two hours in an electric muffle furnace that had been warmed to 300 °C.

2.3. The Aqueous Solution's Preparation

Due to the fact that heavy metals have long been known as ecotoxicologically dangerous substances. They were also selected for this investigation because of their tendency to accumulate in living things and chronic toxicity. The heavy metal utilized in this operation is cadmium. To reach the desired level of cadmium in the synthetic water, metal salts (Cadmium nitrate) $Cd(NO_3)_2 \cdot 4H_2O$ were dissolved in deionized water. During the trial using synthetic solutions with a temperature of 25–5 °C and a pH of 6, adsorption experiments were carried out. To obtain a heavy metal content of 100 mg/L in distilled water, the following equation was used [2]:

$$W = V \times C_i \times \frac{M.Wt}{At.Wt}$$

Where: W donates the weight of heavy metal salt (mg). C_i donates initial concentration of metal ion in solution (mg/L). V refers to solution volume (L). $M.Wt$ is the metal salt molecular weight (g/mole). $At.Wt$ is the atomic metal ion weight (g/mole).

2.4. Process for conducting batch experiments

To make all of the working solutions, distilled water was used to reduce the stock solutions to the proper concentration. PH level, contact duration, agitation speed, and the mass of the adsorbent were used in various value to apply the batch tests. The test was carried out using synthetic water with a pH of 6. All of the experiments were conducted using a total of 23 beakers, each containing a 500 mL volume of synthetic solutions with a starting concentration of 87.4 mg/l of cadmium ions. Seven of them are used for the PH test, five for the contact time test, five for the agitation speed test, and the final six are used for the dosage adsorbent test. The amounts of adsorbent ranged from (0.5,1,1.5,2,2.5 and 3 g). A tabletop digital pH meter (model PHS-3C, China) was employed to measure the pH of the mixture after adding 0.5 g of modified rice husk to every 100 millilitre of solution. With the addition of HCL or NaOH, the solution pH was kept at a specified level. The beakers were placed on Heated Plate Magnetic Stirrers (Labinco L-82, Netherlands) and magnetic stirring was used to continuously agitate the beakers for three hours at 25°C. The content has reached equilibrium at this time. After a time, limit was reached, the two phases were separated by a filtration apparatus using Whatman No. 42 type filtering papers, and the filtered solution was then gathered to determine the concentration of metal ions. An atomic absorption spectrometer (model ASC-7000) was used to measure the initial and final concentrations for Cadmium and it operates at a wavelength of 228.3 nm. The following equation [6] was used to determine the adsorbent's percentage removal of heavy metals:

$$\% \text{ Adsorption} = \frac{C_0 - C_e}{C_0} \times 100$$

The formula below was utilized to determine the adsorbed amount, q_e : $q_e = \frac{V_L(C_0 - C_e)}{W_0}$

Where: the equilibrium adsorption (q_e) is expressed in mg/g. V is the solution volume (l). The starting concentration C_0 is in mg/l. Equilibrium concentration (C_e) is measured in mg/l. The mass of the adsorbent is W_0 (g).

3. RESULTS AND DISCUSSION

3.1. Factors affecting adsorption

3.1.1. The pH effect

It is believed that the concentration of hydrogen ions is one of the major factors influencing how adsorbate ions in effluent respond during adsorption. Batch experiments were carried out using synthetic effluent that had been produced in a lab and contained 87.4 mg/L of cadmium to see if pH had an impact on the heavy metal adsorption. A beaker of 500 ml was filled with 100 ml of synthetic effluent and 1.5 g of modified rice husk. Prior to adding the adsorbent, the pH value was changed between the limits of 3 and 9 by introducing solutions of NaOH [0.1 N] or HCl [0.1 N]. Following that, the beakers were put on a hot plate magnetic stirrer and vigorously agitated for 150 minutes at 200 rpm, 25 ± 5 °C. Figure 1 illustrates how elimination changes as a function of pH.

The figure1 showed that as solution pH rose above pH 3, the quantity of adsorbed Cd (II) ion increased until it reached a peak at pH 5.0. As a result, the research on the variance in solution pH was stopped at pH < pH 6.0. The deprotonation of the husks surface at pH > pH_{pzc} is what is responsible for the significant rise in the quantity of adsorbed adsorbate with pH rise (from pH 3-pH 5.0). [7] Defined pH_{pzc} as the pH level at which an adsorbent's surface has a net neutral charge.

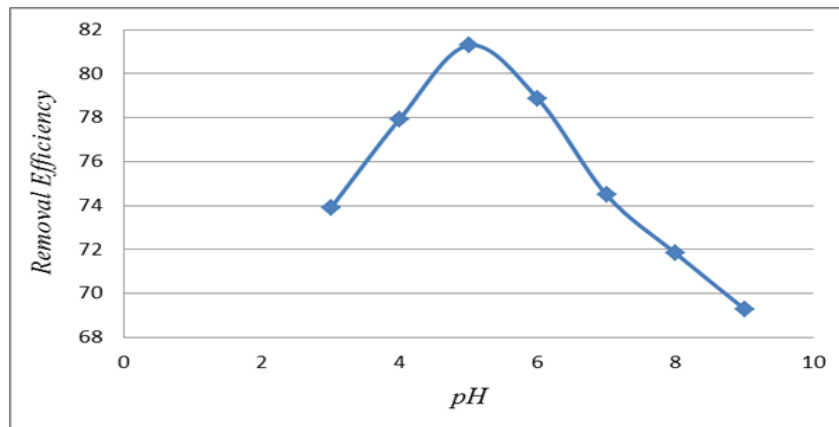


Figure 1 Cadmium (Cd) adsorption percentage on modified rice husks at various pH levels.

In order to establish the best pollutant chelation, the deprotonated rice husk surface consequently engaged in an electrical contact with the cadmium cations. Notably, at pH 2.0, the quantity of Cd (II) ions adsorbed is almost negligibly tiny. Because of the elevated husk surface protonation in the acidic medium, which increased the likelihood of adsorbate-adsorbent electrostatic repulsion and favoured the reverse reaction, this phenomenon occurred (cadmium ion desorption) [8]. The findings are similar to the outcomes of [9]

3.1.2. The effect of agitation speed

As shown in Figure 2 for different agitation rates, the modified rice husk successfully removes cadmium ions. The removal effectiveness was seen to increase as the agitation speed was increased. The film's resistance and thickness both decline at greater velocities, and there is also better contact between the adsorbent and adsorbate. The findings were in strong agreement with [10].

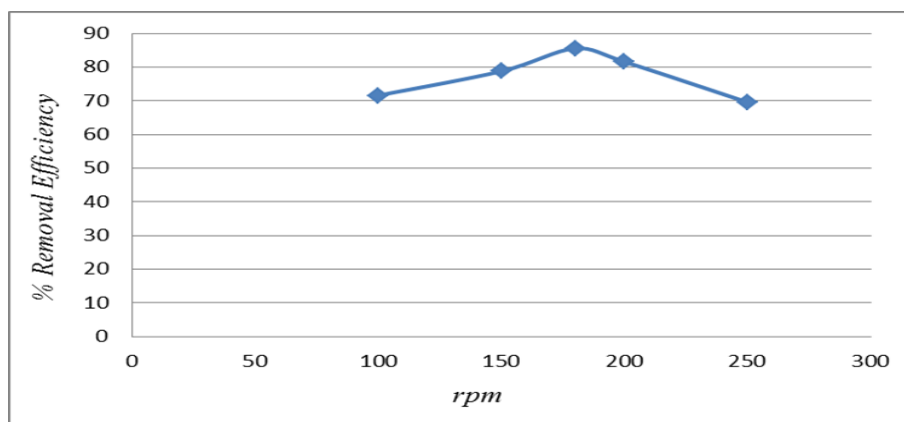


Figure 2 Cadmium (Cd) adsorption percentage onto Modified Rice Husks for different agitation speeds.

3.1.3. The contact time effect

This set of trials involved stirring for a total of 90 to 210 minutes. The tests were performed utilizing the concentration of cadmium ions at 87.4 mg/L, and all other operation parameters (dose, pH, and speed of the rotating shaker) were constant and the same as in the prior investigations. The results are shown in Figure 3 for different contact periods. According to Figure 3, under optimal conditions for the other factors, the removal of cadmium ions content improves with longer contact times and reaches balance after 180 minutes. As interaction time has been prolonged even further, the effect on the elimination of ions content has been disregarded. Because there were so many active sites available for binding at first, the removal of ions grew. After gradually filling up, the locations reached balance after about 180 minutes. Since the surface of the adsorbent was coated with metal molecules at equilibrium, an extended mixing time does not encourage the removal of residual ions from wastewater. This equilibrium time finding is in line with what [11] was able to achieve.

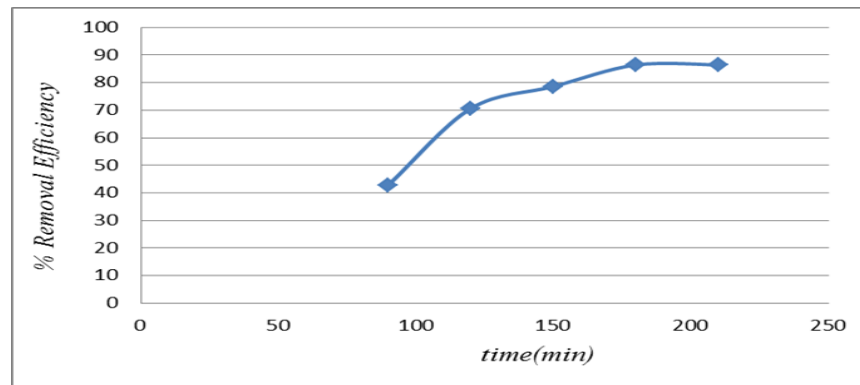


Figure 3 Contact time effect on the Cadmium ions Cd (II) percentage adsorbed onto Modified Rice Husk

3.1.4. The adsorbent dose effect

The dose of adsorbent is a vital amount because it has a substantial effect on the adsorbent capacity at a specific initially concentration of adsorbate. Because of this, the batch procedure was carried out in six beakers filled with synthetic water with a cadmium concentration of 87.4 mg/L with exact quantities of rice husk varying from (0.5g, 1g, 1.5g, 2g, 2.5g and 3 g) per 100 millilitre. Following that, the Beakers were placed on a magnetic stirrer and continuously agitated for 180 minutes at 180 rpm.

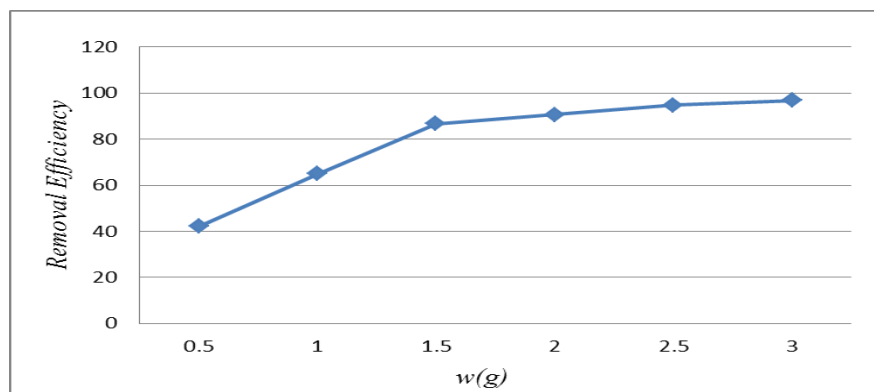


Figure 4 Modified rice husk dosage effect on the elimination of cadmium ions Cd (II)

Figure 4 shows that the amount of cadmium adsorption risen quickly as the rice husk mass grew up to a point when it reached 3 g, which corresponds to an efficiency of removal of 96.83%. Increasing the dosage of adsorbent may rise the adsorbent surface area and provide more adsorption sites, which may explain this effect. The findings of [12] for the rice husk adsorbents that are employed to treat water contaminated with heavy metals are consistent with those of this study.

3.2. Equilibrium Isotherm of Rice Husk

The results in Table 1 clearly demonstrate the value of the inexpensive adsorbent rice husk is incredibly successful at extracting Cd (II) from its solution. 7.38 mg/g of Cd ions is the maximum quantity that rice husks can adsorb. A low mass of adsorbent led to the highest Cd (II) absorption, whereas a large adsorbent mass led to the highest Cd (II) elimination rate. Table 1 shows that the amount of cadmium that was adsorbed onto rice husk reduced as the adsorbent dosage was raised. The Cd adsorption capacity quickly declined between doses of 0.5 g and 3 g of adsorbent, where it was 7.38 mg/g and 2.821 mg/g, respectively. There may have been overlapping adsorption sites due to the overcrowding of the adsorbent particles, which would explain these results.

Table 1 Equilibrium Isotherm of Rice Husk with Cd (II) at (pH = 5, Cadmium concentration C0 = 87.4 mg/L, agitation speed = 180 rpm, and contact duration = 180 min.)

w(g)	c_e (mg/l)	q_e (mg/g)	Removal %
0.5	50.5	7.38	42.2
1	30.67	5.67	64.9
1.5	11.74	5.04	86.65
2	8.12	3.96	90.7
2.5	4.56	3.31	94.78
3	2.77	2.821	96.83

3.3. Adsorption Isotherm Models

Langmuir Isotherm Model: It assumes that each sorption site has the same energy and that sorption occurs in a structurally homogeneous adsorbent [13]. Surface coverage is a monolayer. This isotherm was expressed by the following equation [14]:

$$q_e = \frac{X}{M} = \frac{q_m k_l c_e}{1 + k_l c_e}$$

The adsorption capacity of an adsorbent per mass of adsorbed adsorbate at equilibrium (mg/g) refers to known as q_e . The adsorbent's mass is M (mg). X : The adsorbate's mass (mg). C_e . denotes the solution's equilibrium concentration in mg/l. K refers to the equilibrium adsorption constant, and q_{max} refers to the maximum adsorption capacity. The intercept and slope of the Langmuir plot's Figure 5 were used to get the values of, q_m and k_1 .

The Freundlich isotherm model predicts an unlimited number of multilayers formation of a heterogeneous surface with infinite surface coverage and adsorbed species. The higher energy sites those with a greater attraction for the adsorbate are filled first, followed by the lower energy sites, according to a logarithmic distribution of the enthalpies of the adsorbent surface sites. The sorption method is averaged around all locations, and the following expression represents this isotherm [15]:

$$q_e = \frac{x}{m} = k_F C_e^{1/n}$$

The two Freundlich factors, k_F and n , are corresponding to C_e and q_e , the favorability of adsorption and the capacity of adsorption, respectively. Particularly, the number of n demonstrates how advantageous the adsorption procedure is. When "n-value" is between 2 and 10, it indicates favourable adsorption, while "n-value" less than unity indicates poor sorption characteristics [16]. The Temkin isotherm model, like the Freundlich isotherm model, assumes the variability of an adsorbent surface with a linear adsorption energy distribution. The linear version of the Temkin isotherm model is given by the following equation:

$$q_e = q_T \ln k_T + q_T \ln C_e$$

Where: $q_T = \frac{RT}{b_t}$ is the Temkin isotherm parameter (mg/g). R : denotes constant of the universal gas equal to 8.3145 (J.mol⁻¹.k⁻¹). T : is the absolute temperature (Ko). b_t : is related to the heat adsorption (J/mol). k_T : is the equilibrium binding constant (L/mg) [17].

3.4. Calculation of Rice Husk Adsorption Isotherm Constants

Figures 5 through 8 illustrate the rice husk equilibrium adsorption isotherms for cadmium at 25 ± 5 °C. Additionally, to the Equilibrium Adsorption Isotherm, Freundlich, Langmuir, Timken, and others. The determination coefficient (R^2) was applied to assess each isotherm's fit to the experimentation data in order to gauge its dependability and ability to correspond with the results of the experiment. Table 2 shows that Freundlich outperforms Langmuir and Temkin in terms of coefficients of determination. The Freundlich isotherm clearly best matches the experiments with a strong association coefficient of $R^2 = 0.971$. a form $1/n < 1$ There was a Cd (II) removal equilibrium isotherm.

Table 2 Modelling parameters for the adsorption of Cd (II) on modified rice husk using the Langmuir, Freundlich, and Temkin models.

Isotherm Model	Parameters	Values
Langmuir Isotherm	q_{max} (mg/g)	2.369
	K_L (L/mg)	0.391
	R_L	0.0284
	R^2	0.9209
Freundlich Isotherm	$1/n$	0.3184
	K_f (mg/g)	2.072
	R^2	0.971
Temkin Isotherm	B_T (J/mol)	1.4873
	K_T (L/mg)	2.12
	R^2	0.954

An R_L value of 0.028 ($0 < R_L < 1$) was generated by the fitness of the Langmuir model, indicating favourable Cd (II) adsorption onto the rice husk surface.

Figure 6 shows the relationship between, $\log q_e$. and $\log C_e$ for the Freundlich adsorption isotherm with, $R^2 = 0.97$, Figure 5 show the relationship between C_e/q_e (g/l) and, C_e (mg/l) for the Langmuir adsorption isotherm with a correlation coefficient of, $R^2=0.92$, and Figure 7 illustrates the relationship among, q_e (mg/g) versus, $\ln C_e$ for the Temkin adsorption isotherm with, $R^2=0.95$.

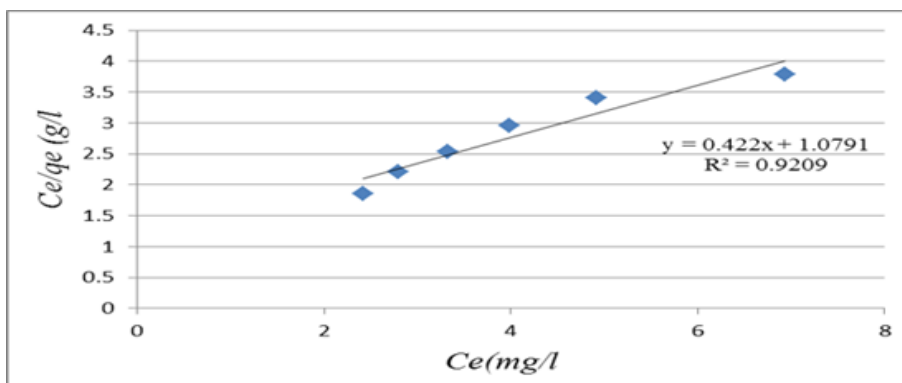


Figure 5 Langmuir Adsorption Isotherm for Cd (II) onto Rice Husk

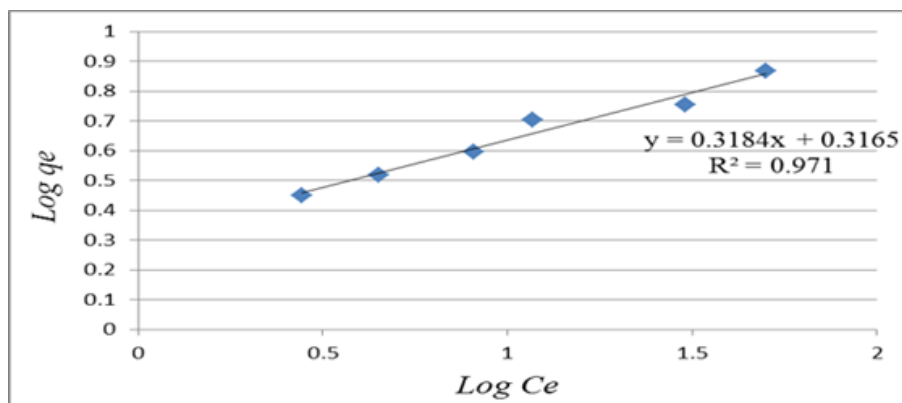


Figure 6 Freundlich Adsorption Isotherm for Cd (II) onto Rice Husk.

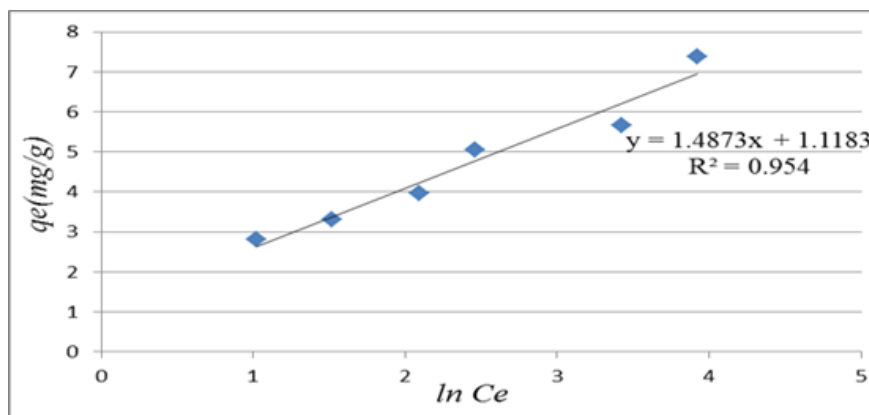


Figure 7 Temkin Adsorption Isotherm for Cd (II) onto Rice Husk

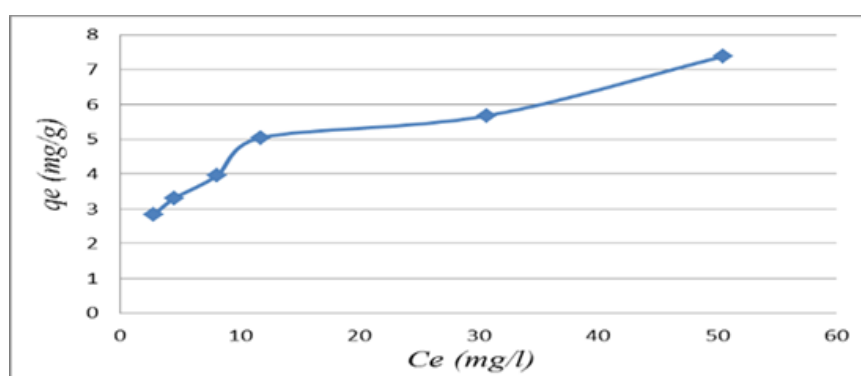


Figure 8 Equilibrium Adsorption Isotherm for Cd (II) onto Rice Husk at pH=5

3.5. Adsorption kinetics for adsorption of cadmium ions

The importance of kinetic analysis in an adsorption process can be seen in how rapidly the adsorbate is absorbed and how it controls how long the process will last in total [18]. The rates of Cd (II) ion binding onto the modified rice husk were predicted using kinetic models. To comprehend the type/nature of the adsorption processes, this research is necessary. Also to assess the efficacy of an adsorption procedure [19]. The rates of adsorption can be demonstrated using a kinetic isotherm, which is a depiction of uptake vs. time. Since the shape of this plot denotes the fundamental kinetics of the process, it acts as the basis for all kinetics study. The rates depend on material factors like the sort of adsorbent and adsorbate as well as laboratory variables like temperature and pH [20]. In the current study, four kinetic models were utilized to analyze the kinetics of Cadmium ions adsorption on the rice husk, namely, Intraparticle diffusion and Elovich, Pseudo-first-order (PFO), Pseudo-second-order (PSO) models. The degree of alignment between model and experiments predictions was stated using correlation coefficients (R^2 , values close to or equal to 1). A reasonably high R^2 number implies that the model accurately depicts the cadmium ion adsorption kinetics.

3.5.1. Pseudo-First-Order PFO Model

According to the Pseudo- first-order, the ratio of the empty sites number to the rate of adsorption site filling is constant [21]. The pseudo first-order equation is typically represented as follows [22]:

$$\frac{dq_t}{dt} = k_1(q_e - q_t)$$

where: k_1 denotes the rate constant of pseudo first-order adsorption ($l \cdot min^{-1}$). q_e and q_t are the capacity of adsorption at equilibrium and at time t , respectively ($mg \cdot g^{-1}$). Following integration and applying boundary circumstances $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$, the integrated form of previous equation yields [23]:

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

The numbers of $\log(q_e - q_t)$ and t had a linear relationship. The slope and intercept of the $\log(q_e - q_t)$ vs. t plot should demonstrate a linear relationship from which k_1 and q_e can be determined, correspondingly.

3.5.2. Pseudo-Second-Order PSO Model

The adsorption kinetics can be explained by a pseudo-second order model. This paradigm is based on the idea that second-order chemisorption is followed by adsorption. Second-order adsorption is defined as an adsorption whose rate is governed by the quantity of one reactant raised to the second degree. The pseudo second-order adsorption kinetic rate equation is presented as [6; 24]:

$$\frac{dq_t}{dt} = k_2(q_e - q_t)^2$$

According to the same border conditions, the preceding equation's integrated form is:

$$\frac{1}{(q_e - q_t)} = \frac{1}{q_e} + k_2 t$$

can be written as:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e}$$

Where: q_t and q_e are the capacity of adsorption at time t and at equilibrium, respectively (mg. g-1). k_2 is the rate constant of pseudo second order adsorption (g/mg. min). A plot between t/q_t versus t gives the value of this constant. q_e and k_2 based on the slope and intercept of the plot, these values can be determined.

3.5.3. Intra-particle Diffusion IPD Model

Widely used in the study of adsorption kinetics is the intraparticle diffusion model (IPD) proposed by Weber and Morris [25]. is expressed as:

$$q = K_{id}\sqrt{t} + B$$

where: K_{id} is the IPD rate constant [mg/ (g. min^{0.5})]. B denotes the initial adsorption (mg/g) and. A plot of q vs \sqrt{t} should be linear. IPD model is a common name for this model. In relation to the slope and intercept, respectively, are the K_{id} and B . K_{id} often rises as initial adsorptive concentration rises. In environmental remediation, this model ranks third in terms of potential models for liquid adsorption kinetics, after the PFO and PSO models. When dynamics is completely controlled by IPD, the line must go all through the center ($B=0$) [20].

3.5.4. Elovich equation

First proposed by Roginsky & Zeldovich in 1934 to describe CO adsorption on manganese dioxide, is written as [26]:

$$\frac{dq}{dt} = \alpha \exp(-\beta q)$$

It is the integrated form:

$$q = \frac{1}{\beta} \ln(1 + \alpha\beta t)$$

It is the linearized form:

$$q = \frac{1}{\beta} \ln \alpha\beta + \frac{1}{\beta} \ln t$$

Kinetics based on the Elovich equation should make a straight line on the q vs. $\ln t$ diagram. The slope is $\frac{1}{\beta}$, and the intercept is $[\ln \alpha\beta]/\beta$. α is the initial rate of adsorption (mg/g. min), and β is links the quantity of surface covering and chemisorption activation energy as a desorption constant.

The results of using trial data with the four models mentioned above are displayed in Table 3 and Figures 9 to 12. Figures 9 to 12 display the coefficients of determination R^2 values for the pseudo-first order, pseudo-second order, and intra-particle diffusion models, which are, respectively, (0.714), (0.976), and (0.9648). while the Elovich Model has a higher coefficient of determination R^2 value (0.9842) for fitting the experimental data. The higher R^2 values in Figure12 show that the Elovich Model mimics adsorption properly. The resulting kinetic values are shown in Table 3. According to the values of R^2 and the values of α derived from the slope of a plot of q_t vs. $\ln t$ Figure 12, The values of calculated from the intercept reveal an increase in adsorption rate and demonstrate a superior adsorption mechanism, which is linked to a better bonding between Cd ions and the adsorbent particles. The Elovich process is the rate-limiting phase. The values of q_e derived from the pseudo-second-order model are higher than those generated from the pseudo-first-order model, as shown by Figure 10 and Table 3. The best-fitting kinetic model's tendency is shown to be Elovich > pseudo-second-order > intra-particle diffusion > pseudo-first-order in the final analysis.

Table 3 Adsorption kinetics parameters onto modified rice husk particles

Kinetic Model	Parameter	Value
Pseudo-First Order	q_e mg/g	3.96
	k_1	0.023
	R^2	0.714
Pseudo-Second Order	q_e mg/g	5.44
	k_2	0.00849
	R^2	0.976
Intra-particle diffusion	K_{id}	0.3637
	B	0.5278
	R^2	0.9648
Elovich	α	1.02
	β	1.236
	R^2	0.9842

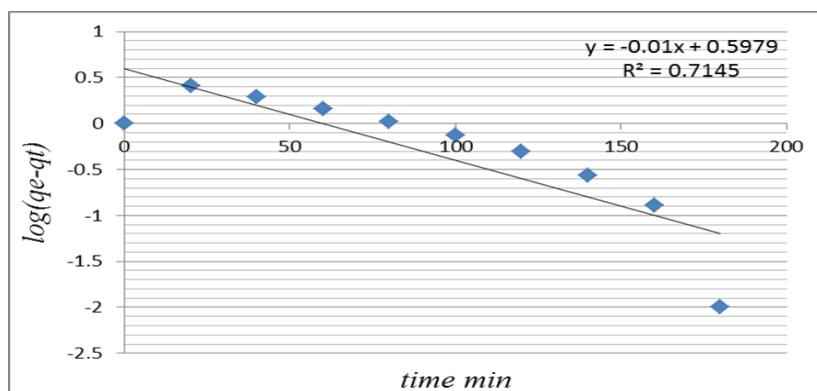


Figure 9 Pseudo-first-order kinetic model for adsorption of Cd (II) onto Modified Rice Husk at pH=5.

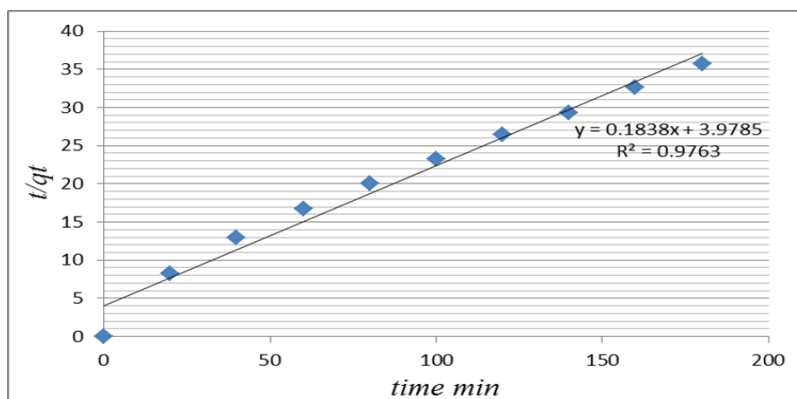


Figure 9 Pseudo-second-order kinetic model for Cd (II) adsorption ions onto Modified Rice Husk at pH=5.

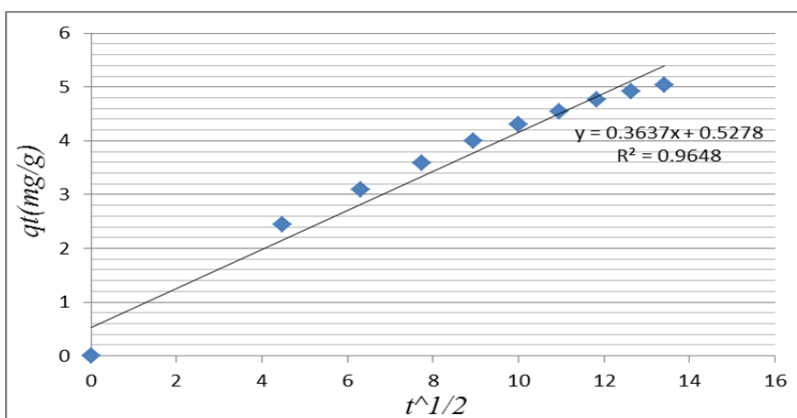


Figure 9 Pseudo-second-order kinetic model for Cd (II) adsorption ions onto Modified Rice Husk at pH=5.

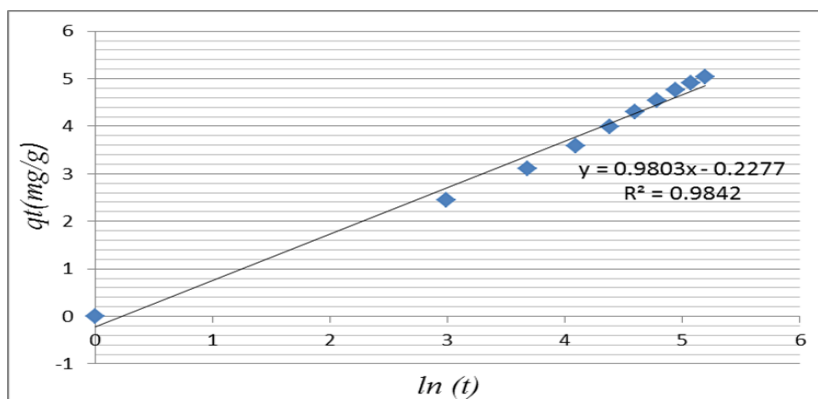


Figure 12 Elovich kinetic model for Cd(II) ions adsorption onto Modified Rice Husk at pH=5.

4. Conclusions

Modified rice husk (MRH) was used as an adsorbent substance in the present study. The findings show that MRH can be utilized as a relatively cheap adsorbent to extract cadmium from water solution. According to the results, the weight of the adsorbent dose and the length of connection have an impact on how much cadmium is removed. The highest q_e is achieved at a dose of 0.5g of adsorbent, or 7.38mg/g. The adsorption process becomes greater as the pH increases until it hits 6 and then it becomes weaker. The Temkin, Freundlich, and Langmuir isotherms can be utilized to explain the adsorption equilibrium of cadmium onto MRH. The data of equilibrium adsorption discovered to be more accurately with the Freundlich isotherm than with the Temkin and Langmuir models. The rates of adsorption matched the Elovich model. The results show that rice straw is an excellent option for treating effluent.

Future research is advised to (1) examine the economics of using rice husk as an adsorbent as a substitute of activated charcoal in the adsorption process, as well as the drawbacks and advantages of doing so.(2) Because physicochemical factors including pore volume, active sites, and specific surface area significantly affect adsorbent effectiveness, rice husk particles can be further processed to enhance these characteristics.(3) Researching heavy metal-contaminated rice husks as potential study subjects in order to come up with ways to get rid of them.

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