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Utilization of Dolochar for Lead Removal from Industrial Waste Water

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Abstract*: This study investigates the efficacy of utilizing dolochar, a waste byproduct from iron factories, for the removal of lead from polluted water. Through a comprehensive analysis, the composition of dolochar was examined using diverse analytical techniques. Various kinetic models were compared to elucidate the rate at which dolochar captures lead. The findings highlight that lead adsorption adheres to a specific kinetic pattern, particularly the pseudo-second-order model, demonstrating exceptional precision (R^2 = 0.999). The research delves into how three key variables—dolochar quantity, initial lead concentration, and water pH—affect lead removal efficiency. A series of experiments, totaling 15, were conducted to identify the optimal conditions for lead removal employing dolochar. A predictive model was developed to estimate lead removal based on these parameters, yielding highly accurate results (R^2 = 0.999). The study reveals that under optimal conditions, characterized by a specific dolochar quantity and near-neutral pH, dolochar can effectively eliminate a substantial portion (92.8%) of lead from water, even in scenarios mimicking highly contaminated water sources such as mining sites. These findings underscore the promising potential of dolochar as a cost-effective and efficient solution for mitigating lead contamination in water sources.*

Keywords: Adsorption, Box-Behnken experimental design, Dolochar, Lead removal, Response surface methodology

I. INTRODUCTION

Rapid industrialization and urban expansion are contributing to an increase in heavy metal pollution, with substances such as lead, chromium, and mercury becoming more prevalent in the environment. These toxic metals persist for extended periods, posing grave risks to human health, wildlife, and ecosystems. Lead, for instance, is associated with severe organ damage, particularly when present in elevated concentrations. Various industrial activities, spanning mining to electronics manufacturing, discharge wastewater laden with hazardous heavy metals like lead, which can infiltrate drinking water sources, leading to detrimental effects on brain function and the nervous system, particularly in young individuals.

Numerous techniques are available for lead removal from water, including solvent-based methods and specialized filtration systems. However, adsorption stands out due to its cost-effectiveness, environmental friendliness, efficiency, ease of implementation, and the wide array of available materials (adsorbents). Researchers have investigated the use of various waste materials, such as steel production slag or sawdust, for lead capture. Nonetheless, some of these methods may be cumbersome or intricate to establish. Consequently, the quest continues for novel and economical approaches to eliminate lead from water, leading to the exploration of dolochar, a byproduct of iron factories.

Dolochar, a residual material generated by iron factories, shows promise as a water pollutant remover. Its widespread availability in various regions makes it an appealing subject for researchers. Although some investigations have delved into dolochar's applications, its specific efficacy in lead (Pb) removal from water remains relatively unexplored.

Conventional approaches to studying adsorption are typically time-consuming and constrained. They tend to maintain specific parameters constant while altering only one variable at a time. However, this simplistic approach fails to capture the complexity of real-world conditions, where multiple factors can interact simultaneously.

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To tackle this issue, a more sophisticated technique known as response surface methodology (RSM) was employed. This method enables the researchers to explore the combined effects of factors such as lead concentration, dolochar dosage, and water pH on the process of lead removal from water.

II. MATERIALS

Adsorbent

The dolochar, sourced from iron factories in Odisha, India, underwent several preparation steps before being used in the study. Initially, it was crushed and sieved to ensure uniform particle size. Subsequently, the dolochar underwent thorough washing with purified water to eliminate any impurities, loose materials, or soluble components adhering to its surface. Following washing, the dolochar was dried in a hot air oven at 105°C overnight. Stored in airtight containers to prevent contamination, the prepared dolochar was then ready for use in lead removal experiments. The entire preparation process is illustrated in Figure 1.

How Dolochar Removes Lead from Water (Experiments)

A series of tests were conducted to find the best settings (process parameters) for removing lead from water using dolochar. We used a specific method (Box-Behnken design) to optimize these factors. Here's a breakdown of what we did: (i) The lead solutions were preparedat different concentrations (0 to 50 milligrams per liter) and adjusted the water acidity (pH) between 3 and 9. (ii) Those measured out 100 milliliters of each lead solution and added it to flasks. (iii) Then those added different amounts of dolochar (10 to 30 grams per liter) to each flask. (iv) Each flask was shaken for different lengths of time (0 to 120 minutes) at a constant speed (150 rpm) at room temperature.(v) After shaking, separated the dolochar from the water using filter paperand measured the remaining lead concentration in the clean water using a special instrument (Atomic Absorption Spectrophotometer).(vi) It was also measured the water acidity (pH) in each flask. (vii) To ensure accuracy, we repeated each test three times, and the measurements varied by less than 5%.

Based on these measurements, we calculated how much lead the dolochar removed from the water using a specific formula (Equation 1, not shown here).

$$\eta = \frac{C_0 - C_t}{C_0}.100 \qquad (1)$$

Where,(i) The percentage of lead removed (removal efficiency) is represented by the symbol η (eta), (ii) Co represents the starting concentration of lead in the water (milligrams per liter, mg/L). (iii) Ct represents the amount of lead remaining in the water at any specific time (t) during the experiment (also in milligrams per liter, mg/L).

Utilizing Response Surface Methodology (RSM) for Experimental Design, Modeling, and Statistical Analysis.

The Running experiments one factor at a time can be slow and expensive. It requires a lot of materials and time.The use of a special method called Response Surface Methodology (RSM) to optimize experiments.RSM helps them find the best settings (process variables) for a process by analyzing data from multiple experiments.This method allows them to quickly gather the information they need compared to traditional methods that test one factor at a time.

What design was used in this study?

The use of a specific design called Box-Behnken Design (BBD) for their experiments.This design is popular because it allows them to optimize the process with a relatively small number of experiments.It also helps them analyze how different factors interact with each other.

How many experiments were conducted?

In this study, the scientists conducted a total of 15 experiments using the BBD design.The number of experiments is based on the number of factors being studied and the need for repeat measurements for accuracy.

For more details:

Table 1 provides the specific range of values used for each factor in the lead removal experiments.

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Table 1.

Experimental ranges of parameters

Variables	Ranges of Variables
Adsorbent dose (g/l) (X_1)	10-30 g/L
pH (X_2)	3-9
Initial concentration (mg/l) (X_3)	10-50 mg/L

Making the Experiments Accurate

To account for any errors or unexpected variations in the results, we included three experiments with the same settings (center points) in their design. Table 2 shows the overall plan for the 15 experiments created using the Box-Behnken Design (BBD). We used special software (Design Expert) to analyze the results, which involved both calculations and visual representations (graphs).

The Math Behind the Model

The mathematical formula (quadratic response model) to predict how well lead would be removed based on the different factors were studied (independent variables) and how those factors might influence each other (interactive effects).

$$Y=b_0+\sum_{i=1}^{n}b_iX_i+\sum_{i=1}^{n}b_{ii}X_{ii}^2+\sum_{i=1}^{n}\sum_{j=i+1}^{n}b_{ij}X_iX_j \quad (2)$$

Equation (2) is a general example of this type of formula, where Y represents the predicted removal efficiency, Xi are the individual factors, and various b terms represent different effects (offset, linear, square, interaction).

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X^2_1 + b_{22}X^2_2 + b_{33}X^2_3 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 \quad (3)$$

Based on the experiments, the specific formula for this study looks like Equation (3). This equation considers the individual factors (X1, X2, X3), their own squares (X1^2, X2^2, X3^2), and how they interact with each other (X1X2, X1X3, X2X3).

In simpler terms:

The formula to predict lead removal efficiency based on the factors they studied and how those factors might influence each other.

The coefficients of the model were assessed through multiple regression analysis, while the adsorption performance of Pb(II) was examined via analysis of variance (ANOVA).

Table 2: BBD based experimental plans and results

Runs	Adsorbent dose (g/L)	pH	Concentration (mg/L)	Removal Efficiency (%)	
				Experimental	Predicted
1	20	3	10	68	67.9
2	10	3	30	63.9	64.13
3	20	9	10	92	91.8
4	20	6	30	95	95
5	10	9	30	88.9	89.23
6	30	9	30	92	91.78
7	10	6	10	94.6	94.48
8	20	6	30	95	95
9	20	6	30	95	95
10	30	3	30	69.4	69.08
11	30	6	50	95.7	95.83
12	10	6	50	92.6	92.18
13	20	9	50	89.3	89.4
14	20	3	50	65.3	65.5
15	30	6	10	97.9	98.33

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Equilibrium Kinetics and Rate-Limiting Investigations

Understanding How Quickly Lead Sticks to Dolochar.The different mathematical models were used(like pseudo-first order, pseudo-second order, and Elovich) to see which one best described how fast lead particles attached to the dolochar over time. It was compared the experimental results to the predictions of these models to find the best fit.We also applied additional models (kinetic, Boyd, and Weber-Morris) to the data. These models helped us understand: (i) How lead molecules moved within the dolochar particles, (ii) The slowest step in the overall lead removal process (the rate-limiting step).

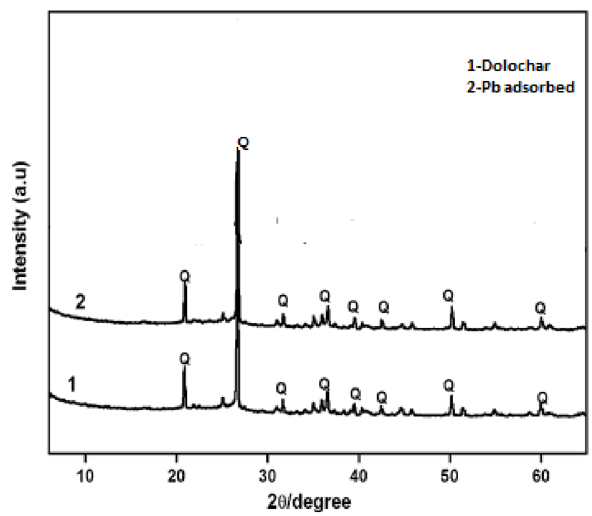
In simpler terms, it was investigated how quickly lead gets captured by the dolochar and what factors might be slowing down this process.

IV. FINDINGS AND DISCUSSION

Characterization of the Adsorbent

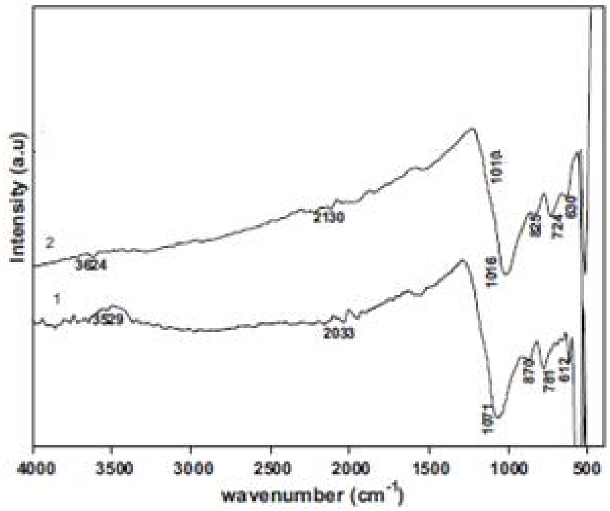
Dolochar Properties**:** The dolochar used in this study is black colored, likely due to the presence of carbon. The dolochar particles are fairly large, about half a millimeter in size. Dolochar is a relatively dense material, with a density of around 3.25 grams per cubic centimeter. Tests showed that dolochar has a good surface area for adsorption, which is important for capturing lead. The Langmuir surface area is 97.56 m^2/g and the BET surface area is 62.42 m^2/g (surface area is like having many nooks and crannies for lead to stick to).

Dolochar and Lead Analysis (XRD): (i) Figure 2 shows a comparison of two scans (XRD spectra) of the dolochar: one before and one after it captured lead particles. These scans reveal the material's composition like a fingerprint. (ii) Both scans show peaks that indicate the presence of quartz, a common mineral. (iii) While not entirely certain, there might be a slight increase in the intensity of some quartz peaks in the scan of the lead-adsorbed dolochar. This could suggest that lead ions are interacting with the dolochar.



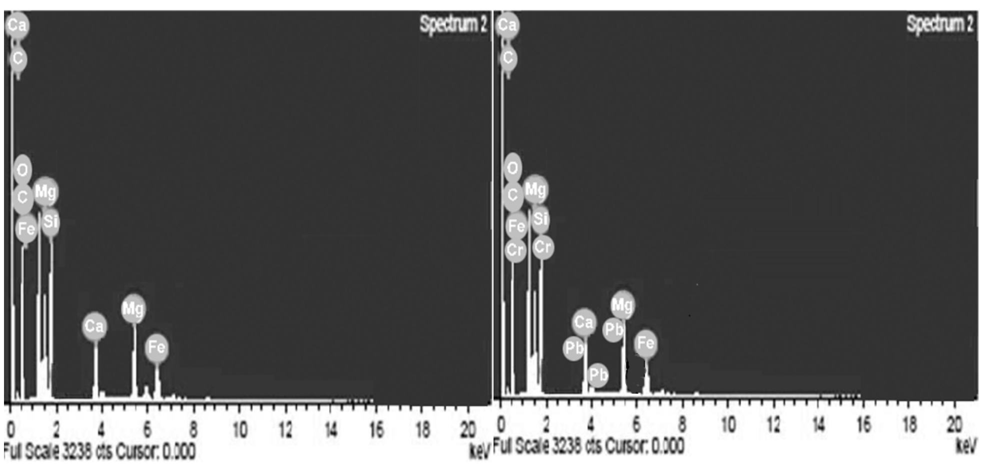
XRD spectra of both dolochar and samples after adsorption of Pb.

Dolochar Analysis After Lead Removal (FTIR) : (i) The scientists used a tool called FTIR to analyze the dolochar before and after it captured lead particles (like looking at its tiny building blocks). Figure 3 shows the results. (ii) Interestingly, the overall analysis of both dolochar samples looked quite similar. (iii) However, there were some minor shifts in the location and intensity of certain peaks in the scans. This suggests that lead attaching to the dolochar slightly altered the arrangement of these building blocks on the dolochar's surface.(iv) In simpler terms, the way lead interacted with the dolochar caused slight changes in the "fingerprint" of the dolochar material.



FTIR spectra of dolochar and dolochar after adsorption of Pb.

A powerful tool used called Energy Dispersive X-ray Spectrum (EDS) to get a super close look at the elements present on the surface of the dolochar (like a magnified fingerprint). Figure 4a shows the results before lead capture: The analysis revealed elements like carbon, silicon (which is the main component of glass and sand), oxygen, calcium, magnesium, and iron. This suggests that carbon and silica might be good at attracting and holding lead. Figure 4b shows the results after lead capture: The analysis confirmed the presence of metal ions, which most likely refers to the lead that was removed from the water.



(b)

EDX spectrum of dolochar (a) before adsorption (b) after adsorption

Finding the Best Settings for Lead Removal :- (i) A special method (Box-Behnken Design) used to run experiments and explore how different factors (adsorbent amount, water acidity (pH), and starting lead concentration) affect the percentage of lead removed from the water. (ii) We considered the range of values for each factor as described earlier (Section 2.5, not shown here). (iii) Based on this design, we conducted a total of 15 experiments. The results were shown in Table 2 . (iv) The lead removal percentage achieved in these experiments varied widely, ranging from 65.9% to 98.1%. This large variation suggests that the amount of lead removed is highly dependent on the factors they investigated. (v) The analysis using the Box-Behnken Design method suggested that a specific mathematical formula (quadratic model) would best describe the relationship between lead removal efficiency and the three factors they studied.

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A specific mathematical equation with regression coefficients.

$$Pb(II)\ removal\ (\%) = Y = 1.14 + 0.295X_1 + 26.383X_2 - 0.0775X_3 + 0.0005X^2_1 - 1.833X^2_2 + 0.0004X^2_3 - 0.02X_1X_2 - 0.0003X_1X_3 + 0.0X_2X_3 \quad (10)$$

This equation represents the relationship between lead removal efficiency and the three factors (adsorbent amount, water acidity, and starting lead concentration).

Equation (10) describes how well lead is removed from water using dolochar.According to the equation, the amount of lead removed increases proportionally with the amount of dolochar used (adsorbent dose), the water acidity (pH), and the starting lead concentration in the water (adsorbent concentration).However, the equation also suggests that these factors can influence lead removal in more complex ways. For instance, the amount of lead removed might not increase at the same rate as the amount of dolochar is increased. Similarly, the combined effects of two factors, like the amount of dolochar and the water acidity (or any other two factors), can also influence lead removal.

To see how reliable the formula (mathematical model) was for predicting lead removal, we used a statistical analysis method (ANOVA) presented in Table 3 .This analysis considers two factors: (i) F-values: A larger F-value indicates that the formula well explains the changes in lead removal observed in the experiments. (ii) p-values: A p-value less than 0.05 suggests a statistically significant factor. In simpler terms, this means the factor has a real impact on lead removal, not just a random effect.

What do these factors mean?

If a factor in the formula has a low p-value (less than 0.05), it has a significant impact on lead removal according to the model. On the other hand, a factor with a p-value greater than 0.05 likely has little to no influence on how much lead is removed, regardless of how much that factor changes.

Table 3: ANOVA for the percentage removal of Pb(II) is conducted to assess the significance of different factors in the experimental setup.

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Significance
Model	2201.76	9.00	244.64	1519.51	< 0.0001	significant
X_1	29.56	1.00	29.56	183.62	< 0.0001	
X_2	1963.36	1.00	1963.36	12194.78	< 0.0001	
X_3	10.91	1.00	10.91	67.79	0.0004	
X_1X_2	1.44	1.00	1.44	8.94	0.0304	
X_1X_3	0.01	1.00	0.01	0.06	0.8131	
X_2X_3	0.00	1.00	0.00	0.00	1.0000	
X_1^2	0.01	1.00	0.01	0.06	0.8203	
X_2^2	1005.23	1.00	1005.23	6243.67	< 0.0001	
X_3^2	0.08	1.00	0.08	0.52	0.5047	
Residual	0.80	5.00	0.16			
Lack of Fit	0.80	3.00	0.27			
Pure Error	0.00	2.00	0.00			
Cor Total	2202.57	14.00				

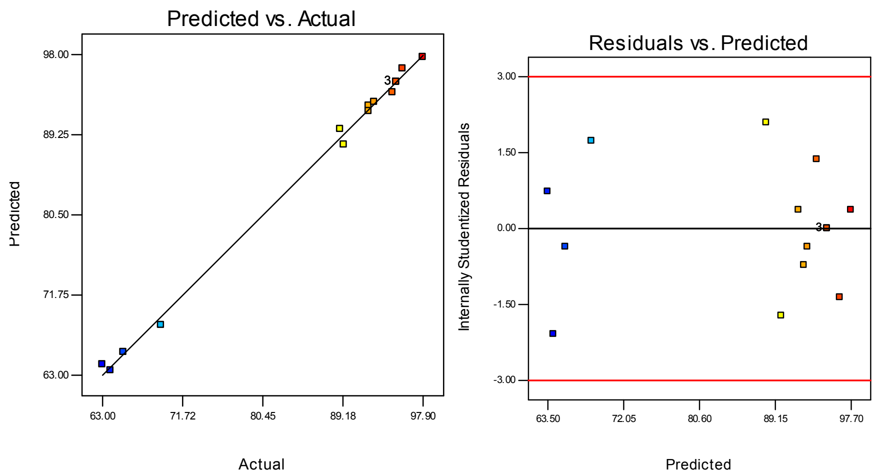
S= 0.40; R^2= 0.9996 ; $R^2_{(adj)}$= 0.999; $R^2_{(pred)}$= 0.9994 ; CV=0.46%; PRESS= 12.88

The Mathematical Model is Reliable as we performed several tests to see how well their formula (regression model) predicted lead removal based on the experiments. Here's a breakdown of what they found: (i) Overall significance:-The F-value (1519.91) and p-value (0.000) indicate that the model is statistically significant. This means it's highly unlikely that the good results were just due to chance.

How well the model explains the data(i) R-squared (R^2) values closer to 1 show a better fit.

In this case:R^2 (0.999) means the model explains 99.9% of the variation in lead removal observed in the experiments. Adjusted R^2 (0.999) and Predicted R^2 (0.9994) are very high, further indicating a good fit.The small difference between adjusted R^2 and predicted R^2 suggests they agree well.

(ii)Model precision: A low standard deviation (not shown here) indicates a precise and reliable model.The coefficient of variation (CV) of 0.46% is well below 10%, which is a good sign for reliability.(iii) Signal to noise ratio:A high value for "adequate precision" (104.39 in this case) indicates a good signal-to-noise ratio. This means the model captures the important effects and minimizes random noise.



(b)

Fig. 5. Plots between (a) Actual versus predicted (b) Predicted versus Residuals.

Response surface and contour plots were generated to visualize the relationship between the process variables and lead removal efficiency. These plots provide insights into how changes in the variables impact the response.

How Do Different Factors Work Together to Affect Lead Removal?

The use of 3D surface plots to examine how the factors (amount of dolochar, water acidity, and starting lead concentration) interact with each other to influence lead removal efficiency. This approach is based on previous work by Aktas (2005).To create these plots, we investigated the effect of changing two factors at a time while keeping the third factor constant.Here's a breakdown of what the plots reveal: (i) Surface plots: These plots show how the predicted lead removal efficiency changes as two factors are varied. (ii) Contour plots: These plots are like a "top-down" view of the surface plots, but on a flat surface. They are useful for analyzing how the two factors interact with each other.Circular contour lines indicate that the factors have little to no interaction on lead removal.Elliptical contour lines suggest that the factors interact significantly. In other words, the effect of one factor on lead removal depends on the level of the other factor.

Visualizing How Factors Affect Lead Removal.

We used 3D surface plots, like Figure 6, to understand how two factors interact and influence lead removal efficiency.

Impact of Adsorbent Dose and pH.

Figure 6 focuses on how the amount of dolochar used (adsorbent dose) and water acidity (pH) influence lead removal efficiency together. Here, the starting lead concentration was fixed at 30 mg/L.Key takeaways from this figure: (i) **pH is crucial:** Lead removal efficiency increases as the water becomes more neutral (pH rises from 3 to 7.1). This implies that pH significantly affects lead adsorption. (ii) **Optimal pH for removal:** The highest lead removal (almost 99.5%) occurs at a near-neutral pH (around 7.1). This pH likely creates a favorable surface charge on the dolochar, attracting lead ions. (iii) **Influence of pH on removal:** Lead removal increases from 61.5% to 94.5% as pH goes from 3 to 7.1, but then decreases slightly at even higher pH values. (iv) **More dolochar, better removal:** Increasing the amount of dolochar used (from 10 to 30 g/L) also improves lead removal from the water.

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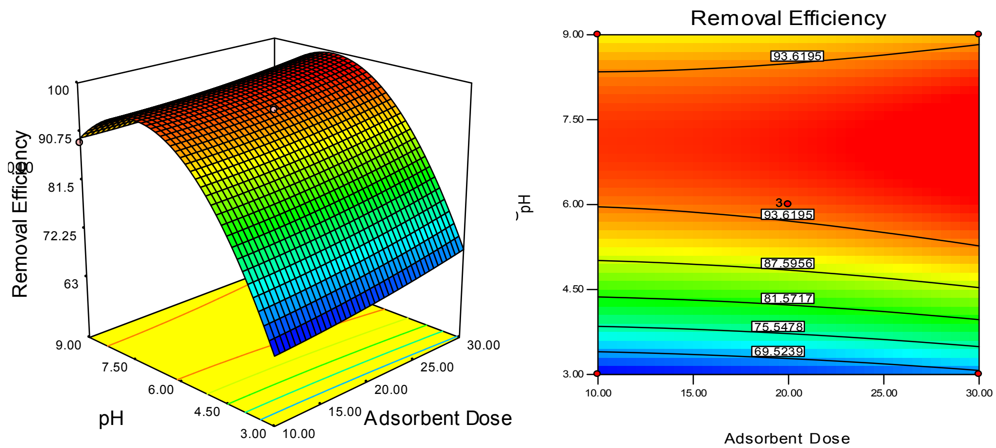

(a) (b)

Figure 6 illustrates the interactive effect of pH and adsorbent dose (g/L) on lead removal efficiency (%) at an initial lead concentration of 30 mg/L. Panel (a) shows the response surface plot, while panel (b) displays the contour plot. These plots provide visual insights into how changes in pH and adsorbent dose impact the efficiency of lead removal.

The impact of adsorbent dose and lead concentration on the removal process is analyzed in this section.

Understanding How Different Factors Affect Lead Removal ,Figure 7 examines how two factors interact to influence lead removal efficiency: (i) The amount of dolochar used (adsorbent dose) (ii) The starting lead concentration in the water

Effect of Lead Concentration on Removal

The Figure 7 shows how these two factors affect lead removal at a constant water acidity (pH) of 6.0.A key observation is that increasing the starting lead concentration reduces the percentage of lead removed.

Here's why this might happen: (i) At lower lead concentrations, there's plenty of surface area on the dolochar particles to capture lead ions. So, the amount of lead initially present in the water doesn't significantly affect how much lead is removed. (ii) At higher lead concentrations, there are more lead ions than available space on the dolochar particles. This reduces the efficiency of lead removal.

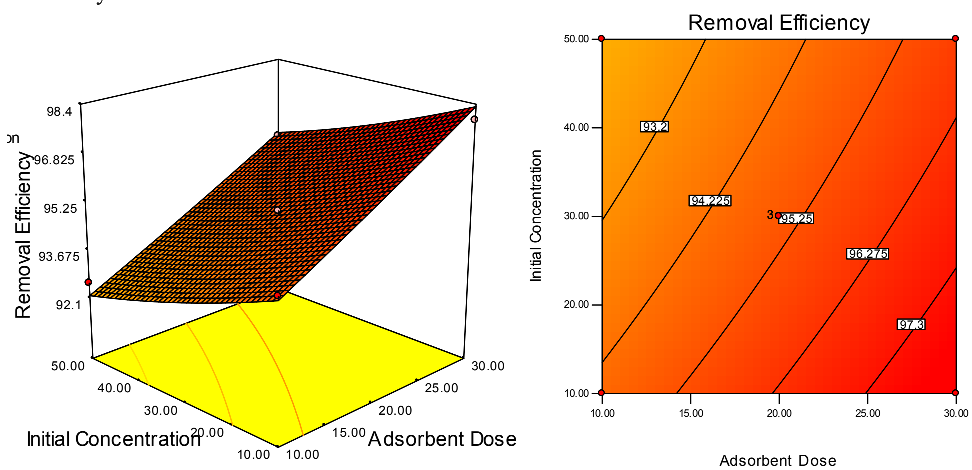

Figure 7 illustrates the interactive effect of adsorbent dose (g/L) and initial lead concentration (mg/L) on the removal efficiency (%) at a constant pH of 6.0. The response surface plot (a) and contour plot (b) provide insights into how changes in adsorbent dose and initial lead concentration affect the efficiency of lead removal.

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The impact of pH and adsorbate concentration on the system was investigated.

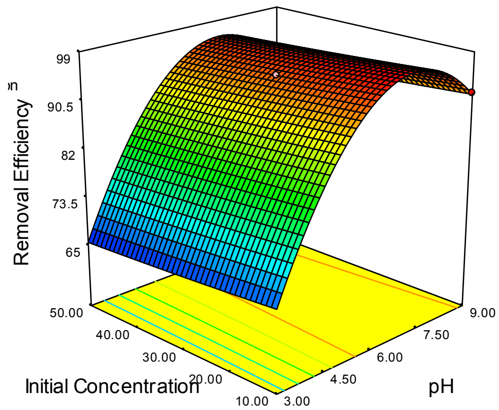
Understanding How Different Factors Affect Lead Removal,Figure 8 explores how two factors influence lead removal efficiency: (i) The water acidity (initial pH). (ii) The starting lead concentration in the water.

Effect of pH on Removal

This figure considers a constant amount of dolochar (20.0g/L). The text says that lead removal is very sensitive to changes in water acidity.

Key observations about pH: (i) Lead removal is highest at a neutral pH (around 7). (ii) Lead removal is significantly lower at very acidic or very basic pH levels. (iii) A neutral pH provides a favorable surface charge on the dolochar for attracting lead ions. (iv) At very acidic pH, the dolochar surface becomes positively charged, repelling lead ions (which are also positively charged). (v) At very basic pH, lead ions might precipitate out of the water as Pb(OH)2, reducing the amount available for adsorption.

Effect of Lead Concentration on Removal,The text also mentions that the starting lead concentration has a minor effect on lead removal within the range investigated (10 to 50 mg/L).



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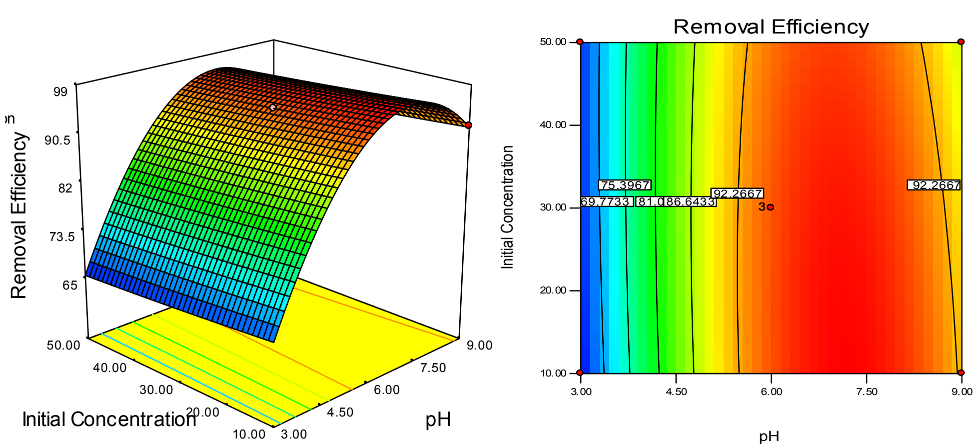

Figure 8 illustrates the interactive effect of pH and initial lead concentration (mg/L) on removal efficiency (%) at an adsorbent dose of 20.0 g/L. The response surface plot (a) and contour plot (b) provide visual representations of how changes in pH and initial lead concentration affect the removal efficiency.

Adsorption kinetics

This batch experiment designed to investigate the removal of lead from water using a specific adsorbent (doloch). Here's a breakdown of the key points:

Experiment Setup:

Type of operation: Batch (all the lead-bearing water and dolochar are added at once)

Synthetic water: Lead was artificially added to clean water to a starting concentration of 10 mg/L.

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Dolochar dosage: The optimal amount of dolochar used was 20 g/L.
Water acidity (pH): The pH of the solution was maintained at 6.0 (slightly acidic).
Temperature: Room temperature

Purpose of Kinetic Study:

Kinetic studies help understand the rate of a reaction over time. In this case, the reaction is the lead being adsorbed by the dolochar.

Kinetic information is essential for designing efficient lead removal processes. It helps determine factors like:
How much lead is removed over time (solute uptake)
The optimal amount of dolochar to use (adsorbent dose)
The rate constants that govern the adsorption process (reaction coefficients)

Data Analysis:

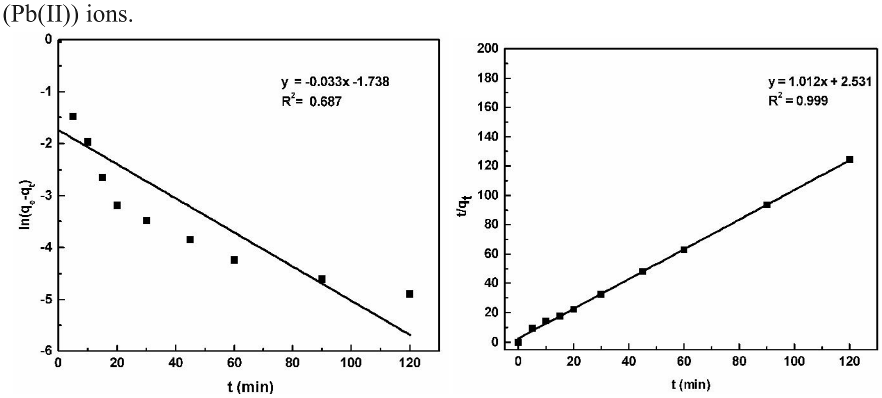
The study employed different kinetic models (mathematical equations describing the rate of lead removal).
The model with the best fit was selected based on its R-squared (R^2) value. R^2 indicates how well the model explains the experimental data (higher R^2 means a better fit).

Table 4: The Single-component kinetic models employed in the study

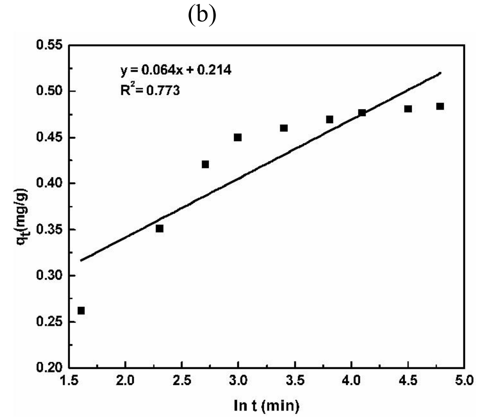
Type of kinetics	Linear form	Parameters
Pseudo 1st Order	$\ln\left(1-\frac{q}{q_e}\right)=-k_1t$	**q(t):** This represents the amount of lead adsorbed on the dolochar (in mg/g) at a specific time 't' (minutes). It's essentially the concentration of lead on the dolochar at that time.**qe:** This represents the amount of lead adsorbed on the dolochar at equilibrium (in mg/g). In other words, it's the maximum amount of lead the dolochar can hold under the specific conditions used in the experiment.**t:** This represents the contact time (in minutes). It refers to the time elapsed since the lead-bearing water and dolochar were first mixed.**k1:** This represents the rate constant of the pseudo-first-order kinetic model (units are typically min^-1). It characterizes the speed at which the adsorption reaction occurs. A higher k1 value indicates faster adsorption.
Pseudo 2nd Order	$\left(\frac{t}{q_t}\right)=\frac{1}{k_2q_e^2}+\frac{t}{q_e}$	**q(t):** This represents the amount of lead adsorbed on the dolochar (in mg/g) at a specific time 't' (minutes). It's essentially the concentration of lead on the dolochar at that time.**qe:** This represents the amount of lead adsorbed on the dolochar at equilibrium (in mg/g). In other words, it's the maximum amount of lead the dolochar can hold under the specific conditions used in the experiment.**t:** This represents the contact time (in minutes). It refers to the time elapsed since the lead-bearing water and dolochar were first mixed.**k2:** This represents the rate constant of the pseudo-second-order kinetic model (units are typically g/mg·min). It characterizes the interaction between the lead and the available adsorption sites on the dolochar. A higher k2 value indicates a stronger interaction or faster adsorption.

Elovich	$q_t = \frac{1}{b}\ln ab + \frac{1}{b}\ln t$	**q(t):** This represents the amount of lead adsorbed on the dolochar (in mg/g) at a specific time 't' (minutes). It's essentially the concentration of lead on the dolochar at that time.**t:** This represents the contact time (in minutes). It refers to the time elapsed since the lead-bearing water and dolochar were first mixed.**a:** This represents the initial sorption rate (in mg/g·min). It reflects how quickly lead is adsorbed onto the dolochar at the beginning of the process.**b:** This represents a parameter related to the activation energy for chemisorption and surface coverage (units are g/mg).

Kinetic Model Fitting: Figure 9 likely shows plots used to compare how well each kinetic model (pseudo-first-order, pseudo-second-order, and Elovich) fits the experimental data on lead adsorption.
R-squared Values: The text uses R-squared (R^2) to assess the fit of each model. A higher R^2 value indicates a better fit. Here's what the text reports:(i) Pseudo-second-order model: $R^2 = 0.999$ (very good fit).(ii) Pseudo-first-order model: $R^2 = 0.835$ (worse fit than pseudo-second-order). (iii) Elovich model: $R^2 = 0.847$ (slightly better fit than pseudo-first-order, but worse than pseudo-second-order).
Based on the R^2 values, the pseudo-second-order kinetic model best describes the lead adsorption process on dolochar in this study.**(i) Kinetic Model Parameters:** Table 5 (not shown here) likely summarizes the specific values of the parameters (like k1, k2, a, and b) obtained from each kinetic model.**(ii) Comparison with Other Adsorbents:** Table 6 (not shown here) likely compares the lead adsorption capacity of the dolochar used in this study with the capacities of other reported waste materials. The text suggests that the dolochar performs competitively for treating wastewater containing lead (Pb(II)) ions.



(b)



(c)

Fig. 9. (a) Linear fitting for (a) pseudo-first-order kinetics (b) pseudo-second-order kinetics (c) Elovich kinetics.

Table 5: Kinetic model parameters at different concentrations

Models	Pseudo 1st -order		Pseudo 2nd-order		Elovich		
Initial Conc. (mg/L.)	K_1 (1/min)	R^2	K_2 (g/mg.min)	R^2	1/b	(1/b) ln ab	R^2
10	0.033	0.687	0.405	0.999	0.064	0.214	0.773

Table 6: Comparison of adsorption capacities of various adsorbents for lead adsorption

Adsorbents	Adsorption capacity (mg/g)	Reference
Fly ash	18.8	[23]
Biomass slurry	28.0	[24]
Olive stone waste	9.26	[25]
Treated rice husk	12.61	[9]
Lignin	8.2-9.0	[26]
Blast furnace slag	40.0	[27]
Dolochar		Present study

V. CONCLUSION

In this study, we explored the potential of using dolochar, an industrial waste product, for removing lead from water. Our objective was to identify the optimal conditions (process variables) for maximizing lead removal efficiency, employing statistical methods such as Response Surface Methodology (RSM).

(i) We investigated three key factors: water acidity (pH), initial lead concentration, and dolochar dosage, while maintaining other parameters constant. (ii) Throughout the experiments, factors like mixing time, speed, and temperature remained unchanged to isolate the effects of the variables under study.

Our analysis revealed a significant relationship between lead removal efficiency and the investigated factors, indicating the accuracy of our mathematical model in representing real-world scenarios. Notably, water acidity demonstrated minimal influence on removal efficiency, except under extremely acidic or basic conditions.

In conclusion, dolochar emerged as a cost-effective and efficient solution for lead removal from water. The optimal conditions identified were: (i) Slightly acidic water with a pH of 5.5, (ii) Initial lead concentration of 50 milligrams per liter, and (iii) Dolochar dosage of 10 grams per liter.

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