OPTIMIZATION OF ZINC REMOVAL FROM SIMULATED WASTEWATER USING CEMENT KILN DUST (CKD) AS ADSORBENT

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Abstract: Zinc removal from simulated wastewater was achieved using cement kiln dust as an adsorbent material. Effects of contact time, pH, zinc ion concentration, rotational speed, and amount of CKD were investigated. The best operating conditions were determined via application of response surface methodology. Results showed that zinc concentration has the main effect on zinc removal efficiency followed by time, shaking, CKD dosage and pH. The best operating conditions were found to be pH value equal to 8, contact time of 90 minutes, rotational speed of 300 rpm, zinc ion concentration of 20 ppm and the amount of cement kiln dust (CKD) equal to 35 g \ L. based on these optimum condition, 99.37% zinc removal efficiency was obtained.

Keywords: CKD, Waste water, Zinc removal, Response surface methodology

1. Introduction

Due to the increase in human activities represented by industries, mining operations and household needs, there is an increased demand for water use, at the same time it has become an increase in the production of wastewater in general and in particular industrial wastewater resulting from manufacturing processes that are loaded with many pollutants, especially pollutants of inorganic materials represented by heavy metals like zinc which is the most dangerous among them as it causes many

diseases such as cancer because it accumulates inside the bodies of living organisms [1, 2, 3].

Therefore, the scientists resorted to find ways to get rid of these minerals and treat the problem of water pollution. Several methods were used to remove of zinc, including electro deposition, [4] adsorption [5], reverse osmosis, ion exchange, deposition [6, 7, 8], etc.

But these methods were costly and not efficient. High. Therefore, the researchers continued their attempts to find methods that are economical and highly efficient and by using materials available in the environment.

Cement kiln dust (CKD) material is one of those materials. it is a byproduct material resulting from cement manufacturing operations that have a basic characteristic and its particles are very small [9, 10, 11].

It produces at a rate of 3-5% of cement production [1], as it produces almost 800,000 tons annually in Iraq.

Its presence causes pollution to the environment because they affect the respiratory system of a person. It uses in many operations, including

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stabilizing the soil [12], production of fertilizers building materials and as an absorbent [13, 14, 15, and 16].

Present work aims to examine the ability of a locally produced CKD as an absorbent to remove of zinc from wastewater. Response surface methodology was adopted to get the best operating conditions

Abbreviations

RSM	Response surface methodology
BBD	Box–Behnken Design
CKD	cement kiln dust
t	time , s
Zn	Zinc
X1	Concentration of CKD ,g/l
X2	Concentration of zinc , ppm
X3	Shaking rate, rpm
X5	pH
X4	Contact time , min
x1	coded value of zinc Concentration
x2	coded value of ckd Concentration
x3	coded value of shaking rate
x4	coded value of pH
x5	coded value of contact time
ao	The code of intercept
ai	The first-class(linear) major effect
aii	Second-class major effect
aij	The interaction effect
cp	Confidence interval
CI	Reiterated number of the central
PI	Prediction interval.
ANOVA	Analysis of variance
DOF	Degree of freedom
DF	The desirability function
Seq. SS	Sum of square
Cr. %	Percentage contribution for each
Adj. MS	Adjusted mean of the square
Adj. SS	Adjusted sum of the square
adj. R2	Adjusted coefficient of multiple
pred. R2	Predicted multiple correlation
RE	Removal Efficiency (%)
k	Number of process variables
S	Standard Error of the Regression

Y	Number of runs
SE	Standard error of mean
N	Represents the dependent variable

2. Materials and Methods

2.1. Cement kiln dust characterization

Two kg of CKD was taken from Al-Duh Cement Factory located south of Al-Muthanna Governorate. Show in figure (1).

Figure (1): Material of CKD

The material was dried in a laboratory oven at a temperature of 100 °C. X-ray diffraction (XRD) and Energy-dispersive X-ray spectroscopy (EDX) examination was performed in the laboratories of the Ministry of Science and Technology / Materials Research Department in Baghdad using (A Philips X-ray diffraction analyzer Spectrometer (equipment model PW/1710 with Monochromator 2009)).

2.2. preparation of zinc solution

Zinc sulfate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) was used for prefer take 3 concentration for obtain accuracy concentrations (20, 60 and 100 ppm) by dissolving the (0.035, 0.105 and 0.176) gm. respectively in 400 ml of distilled water. pH of solution was adjusted using 0.1M NaOH and/or 0.1M HCl. the required amount of CKD was then added at concentrations (5, 20 and 35) g / l to the zinc solution then shaking the resulted solution at a different rotation rate (100, 200 and 300rpm) and different times (30, 60, and 90 minutes).

After completing the adsorption process the solution was filtered then sample (5 mL) was taken for determine the residue concentration of zinc by atomic absorption technique. All experiments were conducted at room temperature in duplicate and therefore the average values were considered for data analysis.

The removal efficiency (R %) of the cement kiln dust on zinc was calculated in line with the subsequent formula (Eq. 1) :

$$R\% = \frac{(C_0 - C)}{C_0} * 100 \quad \dots\dots\dots(1)$$

Where C_0 in (g/l) is the initial concentration of the zinc solution and C in (g/l) is that the final concentration of the zinc solution.

2.3. Design of experiments

Box – Behnken enhances designs to urge the acceptable quadratic model with the desired statistical properties using only one element of the runs required for a factorial of 3 levels. The quantity of runs (N) needed to execute the Box – Behnken design is calculated by the following equation (2):

$$N = 2K(K - 1) + cp \quad \dots\dots(2)$$

Where k is the number of process variables and cp is the reiterated number of the central point. In this research, forty six runs were conducted for evaluating the effects of the process variables on the zinc removal efficiency [17]. (Table 2) illustrates the BBD proposed for the present research. A second orders polynomial model can be adopted based on BBD where fitting the interaction terms with the experimental data can be described by the following equation (3):

$$Y = a_0 + \sum a_i x_i + \sum a_{ii} x_i^2 + \sum a_{ij} x_i x_j \quad \dots\dots(3)$$

Where Y represents the variable (RE), i and j are the index numbers for patterns, a_0 is intercept term, $x_1, x_2 \dots x_k$ are the method

variables (independent variables) in coded form a_i is the first-order (linear) main effect, a_{ii} second-order main effect and a_{ij} is that the interaction effect.

Analysis of variance was performed then the parametric statistic (R2) was estimated to verify the goodness of model fit. A group of mathematical and statistical techniques adopted by RSM [18] will determine the relation between a process response and its variables. The 3-level 5-factor Box – Behnken experimental design is introduced during this study to verify and test the variables affecting zinc removal from simulated wastewater [19].

Initial zinc ion concentration (X1) CKD dosage (g/l) (X2), Shaking rate (rpm) (X3), pH value (X4), and speak to time (min) (X5) were taken as process variables, while the efficiency of zinc removal was taken as a response. The scales of process variables were coded as -1 (low level), 0 (middle or central point) and 1 (high level) [20]. (Table 1) illustrates the method variables with their chosen levels.

Table 1. Process variables with their level for Zinc removal

Process parameters	range in Box–Behnken design		
Coded levels	Low(-1)	Middle(0)	High(+1)
X1- Initial conc. (ppm)	20	60	100
X2- CKD dosage(g/l)	5	20	35
X3- Shaking rate(rpm)	100	200	300
X4-pH value	2	5	8
X5-Contact time(min)	30	60	90

Table 2 .Box- Behnken experimental design

Run	Blocks	Coded value					Initial conc.	CKD dosage	Shaking rate	pH	Contact time
		X1	X2	X3	X4	X5					
1	1	1-	1	0	0	0	20	35	200	5	60
2	1	0	1	1-	0	0	60	35	100	5	60
3	1	0	1	0	0	1	60	35	200	5	90
4	1	0	1	0	1-	0	60	35	200	2	60
5	1	0	0	1	0	1-	60	20	300	5	30
6	1	1	0	1	0	0	100	20	300	5	60
7	1	0	0	0	1	1-	60	20	200	8	30
8	1	0	0	1	1-	0	60	20	300	2	60
9	1	0	0	0	0	0	60	20	200	5	60
10	1	0	1	0	1-	0	60	5	200	2	60
11	1	0	0	0	1-	1	60	20	200	2	90
12	1	1-	0	1-	0	0	20	20	100	5	60
13	1	0	0	1	1	0	60	20	300	8	60
14	1	0	0	1	0	1	60	20	300	5	90
15	1	1-	0	0	1-	0	20	20	200	2	60
16	1	0	0	0	1-	1-	60	20	200	2	30
17	1	0	0	1-	0	1-	60	20	100	5	30
18	1	1-	0	0	1	0	20	20	200	8	60
19	1	1	0	0	0	1-	100	20	200	5	30
20	1	0	1	0	0	1	60	35	200	5	30

21	1	0	0	0	0	0	60	20	200	5	60
22	1	0	1-	1	0	0	60	5	300	5	60
23	1	1-	0	1	0	0	20	20	300	5	60
24	1	0	0	0	0	0	60	20	200	5	60
25	1	0	0	0	0	0	60	20	200	5	60
26	1	0	0	1-	1	0	60	20	100	8	60
27	1	0	1	0	1	0	60	35	200	8	60
28	1	0	1	1	0	0	60	35	300	5	60
29	1	1	0	0	1	0	100	20	200	8	60
30	1	1-	0	0	0	1	20	20	200	5	90
31	1	1-	0	0	0	1-	20	20	200	5	30
32	1	1	0	0	1-	0	100	20	200	2	60
33	1	0	1-	0	0	1-	60	5	200	5	30
34	1	1	0	1-	0	0	100	20	100	5	60
35	1	0	1-	0	0	1	60	5	200	5	90
36	1	1-	1-	0	0	0	20	5	200	5	60
37	1	0	1-	0	1	0	60	5	200	8	60
38	1	0	0	1-	1-	0	60	20	100	2	60
39	1	0	0	0	0	0	60	20	200	5	60
40	1	1	1	0	0	0	100	35	200	5	60
41	1	0	0	1-	0	1	60	20	100	5	90
42	1	1	0	0	0	1	100	20	200	5	90
43	1	0	1-	1-	0	0	60	5	100	5	60
44	1	0	0	0	0	0	60	20	200	5	60
45	1	1	1-	0	0	0	100	5	200	5	60
46	1	0	0	0	1	1	60	20	200	8	90

3. Results and discussion

3.1. CKD properties

XRD analysis of CKD was done as show in figure (2) in the target was copper ($\lambda = 1.5406 \text{ \AA}$) at 40 kV, 30 mA, and the scanning speed was 5° min^{-1} . The reflection peaks between $2\theta = 5^\circ$ and 80° , corresponding spacing (d , $\text{\AA}$), present time (0.6 s) and relative intensities (I/I_0) were obtained table (3).

Table3. The chemical composition of CKD (this study)

Components	Average %
CaO	47.81
SiO ₂	17.3
So ₃	11.98
K ₂ O	4.9
Al ₂ O ₃	3.7
Fe ₂ O ₃	2.6
MgO	2.5
L.O.I	9.21

Figure (2): XRD for CKD

3.2. Statistical analysis

In order to optimize the assembly of a specific material by optimizing operational variables, statistical methods such as RSM are used.

The interaction between process variables is determined by statistical techniques, as opposed to traditional methods [1].

Forty-six tests were carried out in various groups with different variables of the method to determine its effect on the removal ratios and the knowledge of their optimization.

For each experiment Table 4 shows the removal values. This table includes the current and expected efficiencies. It is interesting to note that, upon approval of the experimental design, the efficiency of zinc removal was changed from 31.34 to 99.37 percent.

Table (4) Experimental results Zinc removal

Run	Blocks	X1	X2	X3	X4	X5	RE%	
							Actual	Predicti on
1	1	20	35	200	5	60	99.37	96.06
2	1	60	35	100	5	60	48.27	47.10
3	1	60	35	200	5	90	56.37	44.13
4	1	60	35	200	2	60	40.08	58.72
5	1	60	20	300	5	30	45.55	48.02
6	1	100	20	300	5	60	44.48	44.38
7	1	60	20	200	8	30	41.4	43.34
8	1	60	20	300	2	60	49.43	46.89
9	1	60	20	200	5	60	45.8	46.63
10	1	60	5	200	2	60	38.83	38.96
11	1	60	20	200	2	90	55.84	51.70
12	1	20	20	100	5	60	94.28	92.04
13	1	60	20	300	8	60	55.3	55.53

14	1	60	20	300	5	90	63.67	63.20
15	1	20	20	200	2	60	83.29	88.52
16	1	60	20	200	2	30	33.9	36.30
17	1	60	20	100	5	30	33.78	34.06
18	1	20	20	200	8	60	93.91	95.36
19	1	100	20	200	5	30	27.67	46.63
20	1	60	35	200	5	30	48.49	46.82
21	1	60	20	200	5	60	45.92	27.52
22	1	60	5	300	5	60	46.59	48.36
23	1	20	20	300	5	60	95.92	46.63
24	1	60	20	200	5	60	47.2	95.13
25	1	60	20	200	5	60	46.63	46.63
26	1	60	20	100	8	60	44.1	42.66
27	1	60	35	200	8	60	52.96	56.56
28	1	60	35	300	5	60	57.17	56.24
29	1	100	20	200	8	60	42.75	46.63
30	1	20	20	200	5	90	98.25	42.66
31	1	20	20	200	5	30	90.01	56.56
32	1	100	20	200	2	60	31.51	32.81
33	1	60	5	200	5	30	35.34	33.08
34	1	100	20	100	5	60	26.25	28.35
35	1	60	5	200	5	90	50.44	52.20
36	1	20	5	200	5	60	91.5	90.32
37	1	60	5	200	8	60	41.8	41.16
38	1	60	20	100	2	60	41.22	37.00
39	1	60	20	200	5	60	46.1	46.63
40	1	100	35	200	5	60	47.99	45.05
41	1	60	20	100	5	90	45.3	50.73
42	1	100	20	200	5	90	51.3	48.52
43	1	60	5	100	5	60	33.85	35.05
44	1	60	20	200	5	60	48.14	46.63
45	1	100	5	200	5	60	31.34	56.72
46	1	60	20	200	8	90	59.08	30.53

Table 5. Analysis of variance for zinc removal

Source	DF	Seq SS	Cr%	Adj SS	Adj MS	F-value	P-value
Model	20	18387.2	98.88%	18387.2	919.4	110.49	0.000
Linear	5	14374.5	77.30%	14374.5	2874.9	345.52	0.000
X1	1	12278.9	66.03%	12278.9	12278.9	1475.74	0.000
X2	1	410.2	2.21%	410.2	410.2	49.30	0.000
X3	1	518.2	2.79%	518.2	518.2	62.29	0.000
X4	1	204.5	1.1%	204.5	204.5	24.58	0.000
X5	1	962.7	5.18%	962.7	962.7	115.70	0.000
Square	5	3806.4	20.47%	3806.4	761.3	91.49	0.000
X1 ²	1	3765.1	20.25%	3147.4	3147.4	378.27	0.000
X2 ²	1	0.2	0.0%	0.1	0.1	0.2	0.896
X3 ²	1	0.9	0.0%	0.6	0.6	0.8	0.785
X4 ²	1	27.5	0.15%	16.6	16.6	1.99	0.171
X5 ²	1	12.7	0.07%	12.7	12.7	1.52	0.229
2-Way Interaction	10	206.3	1.11%	206.3	20.6	2.48	0.032
X1*X2	1	91.3	0.1%	91.3	91.3	2.32	0.141
X1*X3	1	68.6	0.37%	68.6	68.6	8.27	0.008

X1*X4							0.9
1	0.1	0.0%	0.1	0.1	0.01	15	
X1*X5							0.0
1	59.2	0.32	59.2	59.2	7.12	13	
X2*X3							0.5
1	3.7	0.02%	3.7	3.7	0.44	12	
X2*X4							0.0
1	24.6	0.13%	24.6	24.6	2.95	98	
X2*X5							0.2
1	13.0	0.07%	13.0	13.0	1.57	22	
X3*X4							0.6
1	2.2	0.01%	2.2	2.2	0.27	09	
X3*X5							0.2
1	10.9	0.06%	10.9	10.9	1.31	63	
X4*X5							0.4
1	4.5	0.02%	4.5	4.5	0.55	67	
Error	25	208.0	1.12%	208.0	8.3		
Lack-of-Fit	20	203.9	1.10%	203.9	10.2	12.50	0.005
Pure Error	5	4.1	0.2%	4.1	0.8		
Total	45	18595.2	100.00%				
	s	R-sq	R-sq(adj)	PRE SS	R-sq(pred)		
Model Summ ary	2.88452	98.88%	97.99%	821.605	95.58%		

The Minitab-17 program it was used to analyze the results of the zinc removal efficiency as a pilot relationship between the zinc removal efficiency and process variables was formulated through the quadratic model of the removal efficiency Zinc (RE) in terms of encoded units for process variables:

$$\begin{aligned} \text{RE\%} = & 125.6 - 2.596 X_1 + 0.234 X_2 - 0.0487 X_3 + 1.76 X_4 - 0.065 X_5 + 0.011869 X_1^2 - 0.00057 X_2^2 + 0.000027 X_3^2 - 0.153 X_4^2 + 0.00134 X_5^2 + 0.00366 X_1 X_2 + 0.001037 X_1 X_3 + 0.0013 X_1 X_4 + 0.00321 X_1 X_5 - 0.000640 X_2 X_3 + 0.0551 X_2 X_4 - 0.00401 X_2 X_5 + 0.00249 X_3 X_4 + 0.000550 X_3 X_5 - 0.0118 X_4 X_5 \dots \dots \dots (4) \end{aligned}$$

Equation (4) shows Removal efficiency effect with variables (quadrated and linear). Increasing efficiency values increase with increasing values of positive coefficients depending on the laboratory scale, while removal efficiency decreases by increasing coefficients with negative values and the positive effect was found to be for the amount of CKD and pH. The expected values of removal efficiency are listed in Table (1) according to the estimated values from equation (4).

ANOVA variance analysis was wont to test hypotheses about model coefficients which could be a statistical approach splits the full variation in a very group of information into individual parts given particular sources of variation to exam hypotheses on the parameters of the model [19,21].

ANOVA relies on the Fisher F- and P-test to figure out the adequacy. The massive value of F shows that the regression equation elucidates almost all of the variance within the response. The related P-value is used for determining whether F is sufficiently high to point to statistical significance.

With a P-value less than 0.05, the model designated could be elucidated 98.88% of the variability [22]. Table 5 shows ANOVA for the response surface quadratic model. This table shows the sum of the square (SeqSS), degree of freedom (DF), adjusted sum of

squares (Adj SS), adjusted mean of square (Adj MS), The value of F is equal to 100.49 at P equal to 0.0001 percentage contribution (Cr. %) of each parameter, F-value, and P-value. Shows Great importance for the regression model. Model fit quality was also validated by multiple correlations for the model.

In this case the value of the multiple correlation coefficients was 98.88% which indicates that this regression statistically significant, the model only explains 1.12% of all differences. Expected value Multiple correlation coefficient (former $R^2 = 95.58\%$) in reasonable agreement with the value of the adjusted multiplier Correlation coefficient ($R^2 = 97.99\%$).

ANOVA results showed that the mineral concentration contribution percentage is 66.03%, which means that mineral concentration has the main effect on zinc removal efficiency. And the rest of the variables have close proportions. The linear term contains the main percentage of the contribution to the model by 77.3%, followed by the interaction between the input variables with a contribution of 1.11% and it was small while the square contains a contribution of 20.47%. The results confirm that the heavy metal concentration (zinc) is the most important factor.

3.3. Effect of process variables on the zinc removal efficiency

Figures (3-a, 3-b) show the effect of the primary concentration of zinc metal on its removal efficiency for different values of contact time (30, 60 and 90min.) and initial concentration of zinc (20,60,100 ppm) at pH 5 and the shaking rate of 200 rpm and the concentration of barcode equal to 20 g / l . The figure 3-a represents response surface diagram while figure 3-b shows the corresponding contour

diagram. From the surface plot, it is observed that at a contact time of 30 minutes, a decrease in the removal efficiency occurs with an increase in the initial zinc concentration. However, there was a slight change in the removal efficiency as the contact time approached 90 minutes. At a concentration of 100ppm, the results show an increase in the efficiency of zinc removal with increasing contact time. Noting, at a concentration of 20 ppm, a significant change in removal efficiency occurred with increasing contact time, this was proven by the study [23].

Figure 3: Response surface plot (a) and contour plot (b) showing the effect of contact time and initial concentration of zinc on the zinc removal efficiency

The effect of pH on zinc removal efficiency of different primary zinc concentrations (20, 60 and 100 ppm) at different pH values (2, 5, and 8) at a constant rotation speed of 200 rpm, a 60-minute

contact time and a CKD concentration of 20 g / l. This is illustrated in Figures 4a and 4b. The response surface plot (4a) shows that it currently has a slight impact on the zinc removal efficiency as it increases slightly with increasing pH while decreasing efficiency decreases with increasing concentration.

Figure 4: Response surface plot (a) and contour plot (b) showing the effect of the pH and initial concentration of zinc on the zinc removal efficiency

The corresponding contour piece (4-b) confirms that the maximum value of the zinc removal efficiency lies in a very small area; It had a pH equal to 8 and a zinc ion concentration of approximately 20 ppm. This was proven by the study [16,23,24].

As for the forms (5-a, 5-b), we show the relationship of the vibration rate with the initial concentration of zinc and its effect on the removal rate where the vibration rate was within (100, 200 and 300 rpm) at an initial

concentration of the zinc metal (20, 60 and 100) ppm. Response surface plot (5-a) currently has a significant effect on zinc removal efficiency as it increases as the shaking rate increases at 300 r / min. While the removal efficiency decreased as the focus increased. The corresponding contour piece (5-b) confirms that the maximum value of the zinc removal efficiency lies in a small area where the shaking rate is equal to 300 rpm and the zinc ion concentration is around 20 ppm.

Figure 5: Response surface plot (a) and contour plot (b) showing the effect of shaking rate and initial concentration of zinc on the zinc removal efficiency

Figures (6-a,6-b) show us the effect of the CKD concentration with the initial concentration of zinc and its effect on the removal rate since the concentration of the to CKD was within (5, 20 and 35) g / l at an initial concentration of zinc metal (20, 60 and 100) (ppm). The response surface plot (6-a)

shows that it currently has a significant effect on zinc removal efficiency as it increases with increasing concentration of CKD at 35 g / l. While the removal efficiency decreased as the focus increased. The corresponding contour piece (6-b) confirms that the maximum value of zinc removal efficiency lies in a small area where the CKD concentration is about 35 g / l and the zinc ion concentration is about 20 ppm.

Figure 6: Response surface plot (a) and contour plot (b) showing the effect of CKD dosage and initial concentration of zinc on the zinc removal efficiency

3.4. The optimization and confirmation test

Numerical optimization of the software is applied to get the precise point that maximized the desirability function (DF). The desired goal was chosen by adjusting the weight or importance that could change the characteristics of the aim. Five options for the aim fields for response were selected: maximum, minimum, target, within range, and none. In the present

work, the aim is to get higher removal efficiency of zinc so the 'maximum' field with corresponding 'weight' 1.0 was chosen. 26.25% was taken as the lowest limit for the removal efficiency while 99.37% was taken as the upper limit. Under these settings and boundaries, the optimization procedure was conducted and the results are displayed in Table 6 with the desirability function of (1).

Results of optimization recommended using the initial concentration of zinc (20 ppm), a rotation speed of (300 rpm), PH (8), contact time (90 min), and CKD dosage (35 g/l) to get higher removal efficiency of 100.6%.

Two experiments at the optimum values of the process parameters were performed to confirm the results of optimization. 20 ppm was taken as nearly the value of the initial zinc concentration resulted from optimization. The results are displayed in Table 4. After 90 min, 300 rpm, pH 8 and CKD dosage g/l of the experiments, the results are shown in Table 4.

A removal efficiency of 99.3% was acquired which is within the zone of the expected optimum value of removal efficiency that was acquire from optimization analysis.

Using desirability functions (Table 6).

Table 6.Optimum of process parameters for maximum removal efficiency of zinc

Response	Fit	SE Fit	95% CI	95% PI
RE%	106.08	5.27	(95.21; 116.94)	(93.70; 118.46)

Response	Goal	Lower	Target		Upper	Weight	Importance
RE%	Maximum	26.25	99.37		99.37	1	1
Initial Optimum parameters	Conc.(ppm)	CKD dosage (g/l)	Shaking rate (rpm)	PH	Contact time (min)	RE% Fit	Composite desirability
RE%	20	35	300	8	90	106.078	1

Table 7. Confirmation of the optimum conditions for zinc removal efficiency

RUN	Initial conc. (ppm)	CKD dosage (g/l)	Shaking rate (rpm)	PH	Contact time (min)	RE%	
						Actual	Average
RUN 1	20	35	300	8	90	99.3	99.325
RUN 2	20	35	300	8	90	99.35	99.325

4. Conclusions

It has been demonstrated that the removal of zinc from a simulated solution of wastewater can be successfully performed using CKD as an absorbent material. The RSM methodology is applied effectively to improve process parameters and to know the optimum levels of these parameters for zinc removal resulting in increased removal efficiency. Based on RSM analysis, it can be concluded that it zinc concentration has the greatest influence on the efficiency of zinc removal compared to other factors. The optimum values obtained from the improvement were a preliminary Zn (II) concentration of 20 ppm, pH 8, a spin speed of 300 rpm, a 90-minute contact time and a CKD dose of 35 g / l. Under these conditions, it may be possible to reduce the concentration of Zn (II) from

20 ppm to less than 0.2 ppm (RE = 99.3%) at a time of 90 minutes.

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Conflict of interest

The authors confirmed that there is no conflict of interest in this research, but it is the product of a special scientific work for researchers only.

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