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Use of cement kiln dust to remove copper from simulated wastewater using the Response surface methodology

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ABSTRACT

Copper removal from simulated wastewater was achieved using Cement Kiln Dust (CKD) as adsorbent. The effects of contact time, pH, initial copper ion concentration, rotational speed, and Cement Kiln Dust (CKD) amount were studied. The best operating conditions were determined by applying a Response Surface Methodology (RSM). The results showed that the copper concentration has the main effect on the efficiency of copper removal followed by time, shaking rate, dosage of cement kiln dust, and pH. The best operating conditions were found to have a pH value of 8, contact time 90 minutes, shaking rate of 300 rpm, copper ion concentration 20 ppm, and a quantity of CKD equivalent to 35 g / l. Based on this optimum condition, 99 % of the efficiency of copper removal was achieved.

1. Introduction

Due to the increase in human activities represented by factories, mining operations, and household needs, there is a growing demand for water usage and, at the same time, there has been an increase in the output of wastewater in general, especially industrial wastewater resulting from the production processes. This water is charged with many pollutants, in particular pollutants represented by inorganic materials with heavy metals such as copper. Copper is considered as the most dangerous pollutant in the water among other inorganic pollutants because it may cause many diseases such as cancer as can be accumulated inside the bodies of living organisms [1, 2]. Although copper is important to the body of the living organism, but the increase of its concentration in water above 3.0 mg / l causes liver cirrhosis, brain necrosis, and kidney damage [3, 4]; therefore, scientists resorted to finding ways to get rid of these minerals and address the problem of water pollution Bailey et al. [5]. Several methods have been used to remove copper, including electrodeposition, adsorption, reverse osmosis, etc. [5-9], but these methods were expensive, not highly efficient; therefore, the researchers continued their attempts to find economical and highly efficient methods by using the materials available in the environment.

Recently, adsorption was used by many authors, and an inexpensive material such as Cement Kiln Dust (CKD) as a sorbent. CKD is a by-product of cement manufacturing operations which has a basic property and its particles size very small Mustafa et al. [10]. Its presence causes environmental pollution because it affects a person's respiratory system. It is used in many processes, including soil stabilization Rahman et al. [11], the production of fertilizers and building materials, and as an absorbent [12-15].

The present research aims to investigate the capacity of the CKD generated locally as a pipette to extract copper from wastewater. To obtain optimum operating conditions, for the response surface methodology, has been adopted.

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Nomenclature

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

2. MATERIALS AND METHODS

2.1 CKD characterization

A quantity of 2kg of CKD was taken from Al-Duh Cement Factory located south of Al-Muthanna Governorate. The material was dried in a laboratory oven at a temperature of 100 ºC. XRD and EDX examination were performed in the laboratories of the Ministry of Science and Technology / Materials Research Department in Baghdad using an analyzer Spectrometer (A Philips X-ray diffraction (equipment model PW/1710 with Monochromatic 2009)).

2.2. Preparation of copper solution

Copper sulfate ($CuSO_4.5H_2O$) was used to prepare the copper ions solution at concentrations (20, 60, and 100 ppm) by dissolving the appropriate amount in 400 mL of distilled water. Then adjust the pH of the prepared solution using 0.1M NaOH and/or 0.1M HCl to (2, 5, and 8) pH. After that, the required amount of CKD was added at concentrations of (5, 20, and 35) g / L to the copper solution and then shake the solution at a rate of Different rotations (100, 200, and 300 rpm) and different times (30, 60 and 90 minutes). After the adsorption process was completed, the solution was filtered and a sample (5 ml) was taken to determine the concentration of copper residue with the atomic absorption spectrometer (japan, 2002).

All experiments were conducted at room temperature, hence average values were considered for data analysis.

The copper removal efficiency (R %) by using CKD was calculated according to the following formula (Eq. 1)

$$R\% = (C_0 - C)/C_0 * 100 \quad (1)$$

Where C_0 is the initial concentration of the copper solution and C is that the final concentration of the copper solution.

2.3 Design of experiments

The relationship between a process response and its variables will be determined by applying a group of mathematical and statistical techniques adopted by RSM Bezerra et al. [16]. During this study, the 3-level 5-factor Box–Behnken experimental designs are implemented to verification and check the variables that influenced the removal of copper from simulated wastewater. Initial copper ion concentration (X1) CKD dosage (g/l) (X2), shaking rate (rpm) (X3), pH value(X4), and contact time (min) (X5) were taken as process variables, while the efficiency of copper 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) Evans et al. [17]. **Table 1** illustrates the method variables with their chosen levels. Box–Behnken improves designs to urge the acceptable quadratic model with the desired statistical properties by using only an element of the runs needed for a 3-level factorial Huiping et al. [18]. The number of runs (N) needed for performing of Box–Behnken design will be determined by the subsequent equation [2]:

$$N = 2k\,(k-1) + cp \quad (2)$$

Where k is the number of process variables and cp is the reiterated number of the central point.

In this work, forty six runs were conducted to evaluating the effects of the process variables on the copper removal efficiency. **Table 2** illustrates the Box–Behnken Design (BBD) proposed for the present research.

A second order polynomial model can be adopted based on BBD were fitting the interaction terms with the experimental data can be described by the following equation [3]:

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

Where Y represents the variable (RE), i and j are the index numbers for patterns, a_0 is intercept term, x_1, x_2 … x_k are the method variables (independent variables) in coded form. a_{iis} 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 (R^2) was estimated to verify the goodness of model fit.

Table 1. Process variables with their level for Copper 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** X1	X2	X3	X4	X5	**Initial conc. (ppm)**	**CKD dosage (g/l)**	**Shaking rate (rpm)**	**pH**	**Contact time (min)**
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 carried out in the target was copper (λ = 1.5406 A°) at 40 kV, 30 mA, and the scanning speed was 5° min−1. The reflection peaks between 2θ =5°and 80°, corresponding spacing (d, A°), present time (0.6 s) and relative intensities (I/Io) were obtained **Table 3**.

Table 3. The chemical composition of CKD

Components	CaO	Sio2	So3	K2O	Al2O3	Fe2O3	MgO	L.O.I
Average %	47.81	17.3	11.98	4.9	3.7	2.6	2.5	9.21

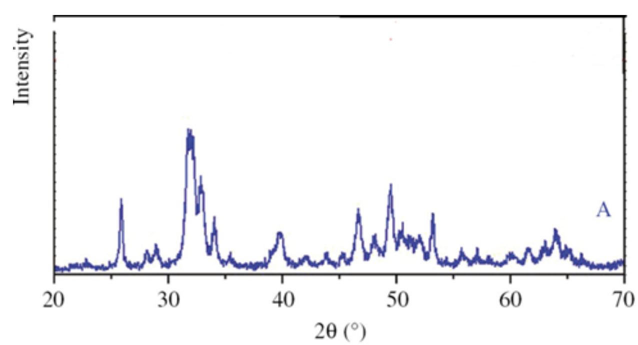


Figure 1. XRD for CKD

3.2 Statistical analysis

Statistical approaches like RSM are employed to maximize the assembly of a special substance by optimization of operational factors. In contrast to traditional methods, the interaction among process variables is determined by statistical techniques.46 experiments were performed with different variables of the process in different groups to determine their effect on the removal ratios and the knowledge of the optimization between them.

Table 4 shows the removal values for each experiment. The current and expected efficiencies are included in this table. It is interesting to note that the copper removal efficiency was changed from 35.59 to 100%, upon approval of the experimental design.

The Minitab-17 program is used to analyze the results of the copper removal efficiency as a pilot relationship between the copper removal efficiency and process variables were formulated through the quadratic model of the Removal Efficiency copper (RE) in terms of encoded units for process variables:

RE% = 148.0 - 1.599 X1 - 0.515 X2 - 0.091 X3 +2.17 X4- 1.173X5+ 0.00623 X12+ 0.00434 X22+ 0.000259 X32 - 0.080 X42 +0.00986 X52+0.00798 X1 X2+ 0.000096 X1 X3 +0.0041 X1 X4 + 0.00123 X1 X5 - 0.00060 X2 X3+ 0.0816 X2 X4 + 0.00343 X2 X5+ 0.00162 X3 X4+ 0.000765 X3 X5-0.0162X4X5 (4)

Equation (4) shows the effect of removal efficiency with the variables (squared and linear). Increasing efficiency values increase with increasing values of positive coefficients depending on the laboratory scale, whereas.

Table 4. The experimental results of "Box–Behnken design" for the copper removal

Run	Blocks	Initial conc.	CKD dosage	Shaking rate	pH	Contact time	RE% Actual	RE% Prediction
1	1	20	35	200	5	60	97.03	91.90
2	1	60	35	100	5	60	58.76	61.07
3	1	60	35	200	5	90	79.73	80.74
4	1	60	35	200	2	60	53.46	58.03
5	1	60	20	300	5	30	68.21	66.30
6	1	100	20	300	5	60	54.64	53.67
7	1	60	20	200	8	30	69.49	64.74
8	1	60	20	300	2	60	57.29	61.26
9	1	60	20	200	5	60	57.83	57.88
10	1	60	5	200	2	60	52.37	50.24
11	1	60	20	200	2	90	74.31	70.23
12	1	20	20	100	5	60	91.2	87.96
13	1	60	20	300	8	60	65.83	70.22
14	1	60	20	300	5	90	87.76	84.37
15	1	20	20	200	2	60	89.99	86.76
16	1	60	20	200	2	30	55.69	53.83
17	1	60	20	100	5	30	60.26	58.89
18	1	20	20	200	8	60	95.15	93.77
19	1	100	20	200	5	30	39.31	45.36
20	1	60	35	200	5	30	63.5	64.17
21	1	60	20	200	5	60	57.98	57.87
22	1	60	5	300	5	60	65.98	63.61
23	1	20	20	300	5	60	100	99.19
24	1	60	20	200	5	60	57.86	57.87
25	1	60	20	200	5	60	57.88	57.87
26	1	60	20	100	8	60	52.19	57.24
27	1	60	35	200	8	60	62.49	67.69
28	1	60	35	300	5	60	70.18	71.26
29	1	100	20	200	8	60	48.51	48.46
30	1	20	20	200	5	90	99.13	105.13
31	1	20	20	200	5	30	91.97	94.60
32	1	100	20	200	2	60	41.38	39.49
33	1	60	5	200	5	30	57.27	57.80
34	1	100	20	100	5	60	44.3	40.98
35	1	60	5	200	5	90	67.33	68.19
36	1	20	5	200	5	60	86.86	92.02
37	1	60	5	200	8	60	58.05	56.55
38	1	60	20	100	2	60	45.59	50.23
39	1	60	20	200	5	60	57.85	57.87
40	1	100	35	200	5	60	64.92	55.20
41	1	60	20	100	5	90	70.63	67.78
42	1	100	20	200	5	90	52.37	61.79
43	1	60	5	100	5	60	50.94	49.80
44	1	60	20	200	5	60	57.85	57.87
45	1	100	5	200	5	60	35.59	36.16
46	1	60	20	200	8	90	82.27	75.30

Removal efficiency decreases by increasing coefficients with negative values and it was found that the positive effect is for the amount of CKD and pH. The expected values of removal efficiency are listed in **Table 5** according to the estimated values from equation (4).

Table 5 Analysis of variance for copper removal

Source	DF	SeqSS	Cr%	Adj SS	Adj MS	F-value	P-value
Model	20	12134.4	95.10%	12134.4	606.72	24.29	0.000
Linear	5	10486.7	82.19%	10486.7	2097.34	83.95	0.000
X1	1	8570.6	67.17%	8570.6	8570.59	343.06	0.000
X2	1	358.0	2.81%	358.0	357.97	14.33	0.001
X3	1	576.2	4.52%	576.2	576.24	23.07	0.000
X4	1	255.2	2.00%	255.2	255.20	10.21	0.004
X5	1	726.7	5.70%	726.7	726.71	29.09	0.000
Square	5	1499.6	11.75%	1499.6	299.91	12.00	0.000
$X1^2$	1	703.5	5.51%	867.2	867.17	34.71	0.000
$X2^2$	1	8.6	0.07%	8.3	8.34	0.33	0.569
$X3^2$	1	7.0	0.05%	58.3	58.35	2.34	0.139
$X4^2$	1	93.1	0.73%	687.4	4.56	0.18	0.673
$X5^2$	1	687.4	5.39%	4.6	687.38	27.51	0.000
2-Way Interaction	10	148.2	1.16%	148.2	14.82	0.59	0.804
X1*X2	1	91.8	0.72%	91.8	91.78	3.67	0.067
X1*X3	1	0.6	0.00%	0.6	0.59	0.02	0.879
X1*X4	1	1.0	0.01%	1.0	0.97	0.04	0.845
X1*X5	1	8.7	0.07%	8.7	8.70	0.35	0.560
X2*X3	1	3.3	0.03%	3.3	3.28	0.13	0.720
X2*X4	1	2.8	0.02%	2.8	2.81	0.11	0.740
X2*X5	1	9.5	0.07%	9.5	9.52	0.38	0.543
X3*X4	1	0.9	0.01%	0.9	0.94	0.04	0.848
X3*X5	1	21.1	0.17%	21.1	21.07	0.84	0.367
X4*X5	1	8.5	0.07%	8.5	8.53	0.34	0.564
Error	25	624.6	4.90%	624.6	24.98		
Lack-of-Fit	20	624.6	4.90%	624.6	31.23	10731.3	0.000
Pure Error	5	0.0	0.00%	0.0	0.00		
Total	45	12759.0	100 %				
	s	R-sq	R-sq(adj)	PRESS	R-sq(pred)		
Model Summary	4.998 31	95.10%	91.19%	2498.27	80. 42%		

ANOVA variance analysis was used to test hypotheses about the 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, 20]

ANOVA depends on the Fisher F-test and P-test to work out the adequacy. The massive value of F reveals that almost all of the variation within the response is elucidated by the regression equation. The associated P-value is employed to judge whether F is large enough to point statistical significance. With a P-value of 0.00, the model designated could be elucidated 95.10% of the variability Segurola et al. [21].

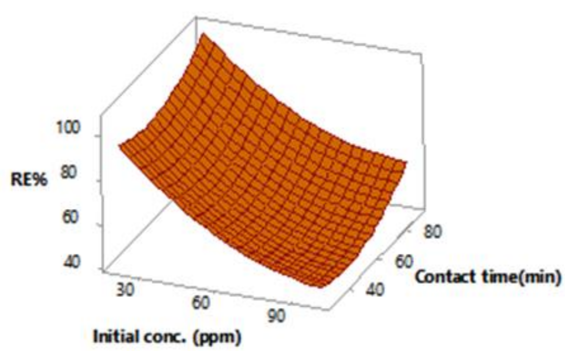
Table 5 shows ANOVA for the response surface quadratic model. This table presents the sum of the square (SeqSS), Degree of Freedom (DF), adjusted sum of squares (Adj SS), adjusted mean of square (Adj MS., The value of F is equal to 24.29 at P equal to 0.00 percentage contribution (Cr. %) of each parameter, F-value, and P-value. It 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 95.10% which indicates that this regression statistically significant, the model only explains 4.90% of all differences. Expected value Multiple correlation coefficient (former R2 = 80. 42%) which is in a reasonable agreement with the value of the adjusted multiplier Correlation coefficient (R2 = 91.19%).

ANOVA results showed that the mineral concentration contribution percentage is 67.17%, which means that mineral concentration has the main effect on copper 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 82.19%, followed by the interaction between the input variables with a contribution of 1.16% and it was small while the square contains a contribution of 11.75%. The results confirm that the heavy metal concentration (copper) is the most important factor.

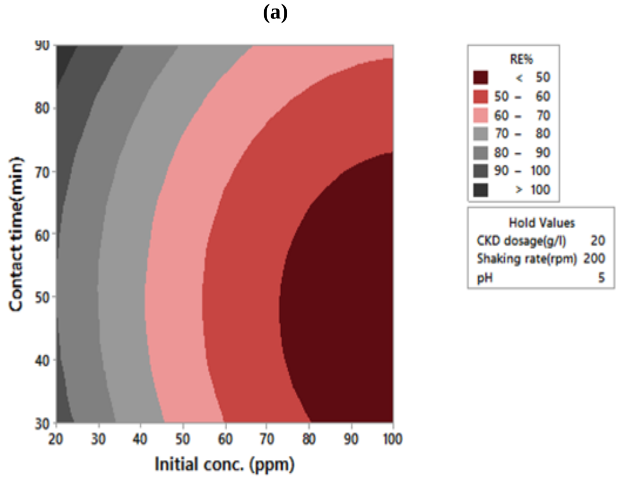
3.2. Effect of process variables on the copper removal efficiency

Fig. (2-a, 2-b) illustrates the effect of the initial concentration of copper metal on its removal efficiency for different values of contact time (30, 60 and 90 min.) and initial concentration of Cu is(20,60,100 ppm) at pH 5 and the shaking rate of 200 rpm and the CKD dosage equal to 20 g / l.

Fig. 2- a represents response surface diagram while **Fig. 2-b** shows the corresponding contour diagram. It can be seen clearly from the surface plot that at a contact time of 30 minutes, a decrease in the removal efficiency occurs with an increase in the initial copper concentration. However, there was a slight change in the removal efficiency as the contact time approached 90 minutes. In addition, at a concentration of 100 ppm, the results show an increase in the efficiency of copper removal with increasing contact time. Noting that, at a concentration of 20 ppm, a significant change in the removal efficiency occurred with increasing contact time, this was proven by the study El-Awady et al. [22].



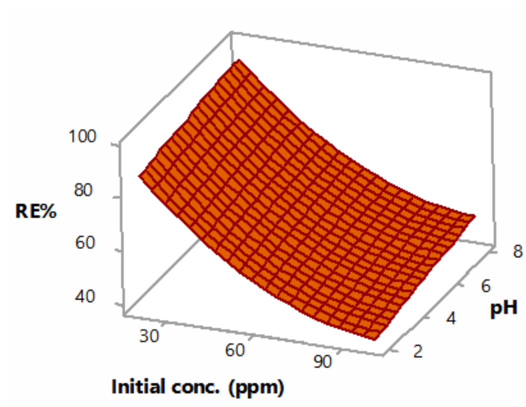
(a)



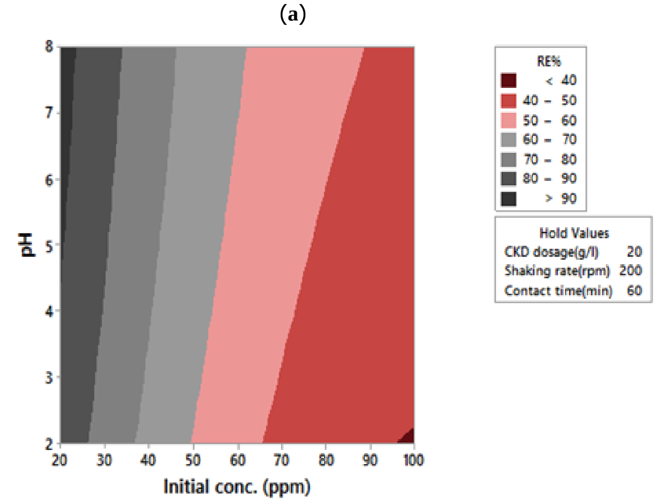
(b)

Figure 2: Response surface plot (a) and contour plot (b) showing the effect of contact time and initial concentration of copper on the copper removal efficiency

Fig.3 a and **3b** illustrate the effect of pH on copper removal efficiency of different primary copper concentrations (20, 60, and 100 ppm) at different pH values (2, 5, and 8) at a shaking rate of 200 rpm, a 60-minute contact time and a CKD dosage of 20 g / l. The response surface plot (3a) shows that it currently has a slight impact on the copper removal efficiency as it increases slightly with increasing pH while decreasing efficiency decreases with increasing concentration. The corresponding contour piece (3-b) confirms that the maximum value of the copper removal efficiency lies in a very small area; It had a pH equal to 8 and a copper ion concentration of approximately 20 ppm. This was proven by the study Coruh et al.[14], [20, 21]



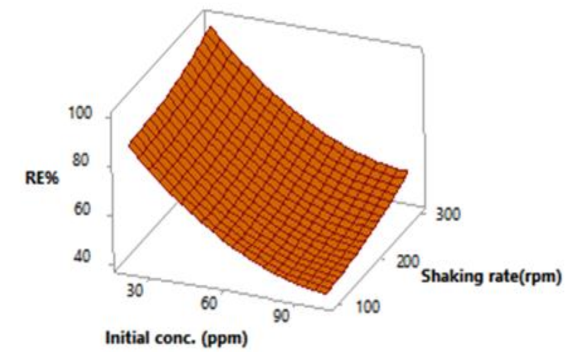
(a)



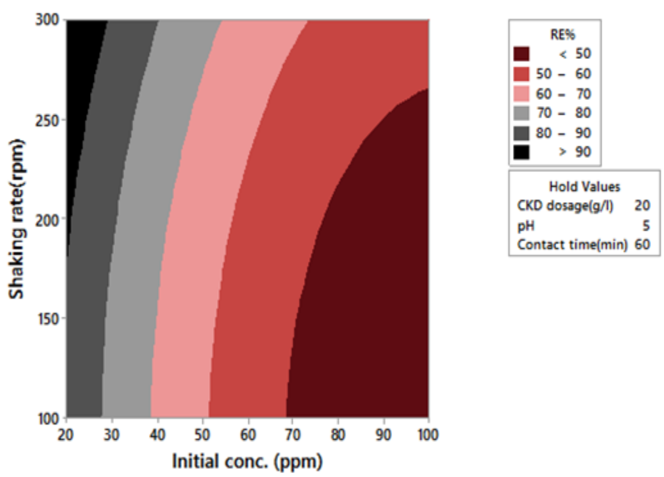
(b)

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

As for the forms (4-a, 4-b), presents the relationship of the shacking rate with the initial concentration of copper and its effect on the removal rate where the shaking rate was within (100, 200, and 300 rpm) at an initial concentration of the copper metal (20, 60 and 100) ppm. It is clear from the response surface plot (4-a) it has a significant effect on copper removal efficiency as it increases as the shaking rate increases at 300 rpm, while the removal efficiency decreased as the focus increased. The corresponding contour piece (4-b) confirms that the maximum value of the copper removal efficiency lies in a small area where the shaking rate is equal to 300 rpm and the copper ion concentration is around 20ppm.

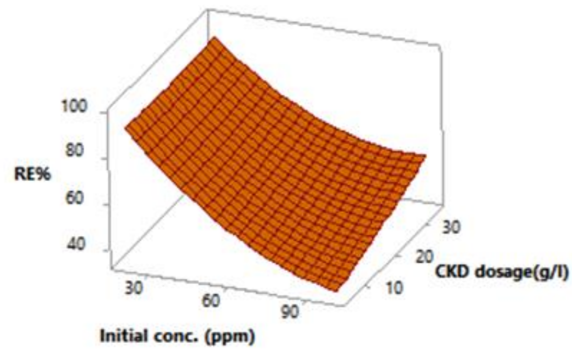


(a)

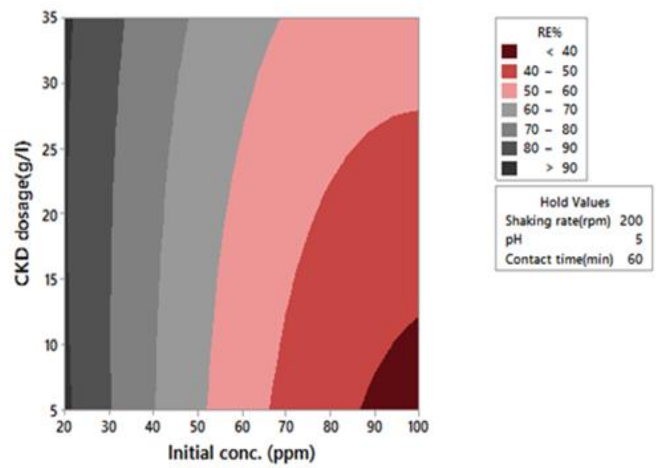


(b)

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



(a)



(b)

Figure 5: Response surface plot (a) and contour plot (b) showing the effect of CKD dosage and initial concentration of copper on the copper removal efficiency

Fig. (5-a, 5-b) shows the effect of the CKD dosage with the initial concentration of copper and its effect on the removal rate Since the dosage of the to CKD was within (5, 20, and 35) g / l at an initial concentration of copper metal (20, 60 and 100) (ppm) The response surface plot (5-a) illustrates that it currently has a significant effect on copper removal efficiency as it increases with increasing dosage of CKD at 35 g / l.

While the removal efficiency decreased as the focus increased. The corresponding contour piece (5-b) confirms that the maximum value of copper removal efficiency lies in a small area where the CKD dosages about 35 g / l and the copper ion concentration is about 20 ppm.

3.3. 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 Copper so the 'maximum' field with corresponding 'weight'1.0 was chosen. 35.59% was taken as the lowest limit for the removal efficiency while 100.00% was taken as the upper limit. Under these settings and boundaries, the optimization procedure was conducted and the results are displayed in **Table 3** with the desirability function of (1). Results of optimization recommended using the initial concentration of copper (20 ppm), shaking rate 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 copper 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 7**. A removal efficiency of 100% 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 copper.

Response	Goal	Lower	Target	Upper	Weight	Importance
RE%	Maximum	35.59	100	100	1	1

Response	Fit	SE Fit	95% CI	95% PI
RE%	119.82	9.14	(101.00; 138.64)	(98.36; 141.27)

Solution

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	119.819	1

Table 7. Confirmation of the optimum conditions for copper 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	99.78	99.79
RUN 2	20	35	300	8	90	99.80	99.79

4. Conclusions

It has been demonstrated that the removal of copper from a simulated solution of wastewater can be successfully performed using CKD as an absorbent material. The RMS methodology is applied effectively to improve process parameters and to know the optimum levels of these parameters for copper removal resulting in increased removal efficiency. ANOVA analysis showed a high value of R^2 (0.951) as a correlation coefficient indicating good compatibility between the quadratic model and experimental results. Based on RSM analysis, it can be concluded that copper concentration has the greatest influence on the efficiency of copper removal compared to other factors. The optimum values obtained from the improvement were a preliminary Cu (II) concentration of 20 ppm, pH 8, a shaking rate 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 Cu (II) from 20 ppm to less than 0.04 ppm (RE = 99.8%) at a time of 90 minutes.

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