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A Comparative and Optimization Study for Efficient Heavy Metals (Pb and Cu) Removal Using Keratin-Based Coconut Coir Activated Carbon Composite

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Abstract

Heavy metals in water pose a significant health risk globally, disproportionately affecting underdeveloped nations. This study aimed to optimize and compare lead (Pb) and copper (Cu) removal efficiency using keratin-based activated carbon from coconut coir. The keratin used in this study was extracted from chicken feathers through pre-treatment and precipitation, and then combined with carbonized and activated coconut coir. To optimize the adsorption process, Response Surface Methodology (RSM) was utilized, specifically employing Central Composite Design (CCD) to investigate the effects of heavy metal concentration, contact time, and adsorbent dosage on adsorption efficiency, with experimental design and analysis conducted using Design Expert version 13. The results of the study were promising. The keratin extraction process yielded 70%, while the lead (Pb) removal efficiency reached 97.55 % for coconut coir activated carbon and 99.26 % for keratin-based coconut coir activated carbon. Copper (Cu) removal efficiency was also significant, at 86.74% for coconut coir activated carbon and 97.53% for keratin-based coconut coir activated carbon. Optimal conditions for removal were identified as 5.41 mgL^{-1}, 71.31 mins, and 7.35 gL^{-1} for Pb, and 6 mgL^{-1}, 70 mins, and 6 gL^{-1} for Cu. The coefficient of determination (R^2) values, ranging from 0.9838 to 0.9910, indicated a strong correlation between the variables, confirming the effectiveness of keratin-based coconut coir activated carbon in heavy metal adsorption. This solution aligns with the sustainable development goals, ensuring clean water, sanitation, good health, and wellbeing. The findings demonstrate the potential of keratin-based coconut coir activated carbon to address the global issue of heavy metal contamination in water.
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1. Introduction

Clean water is a critical social, economic, environmental, and political concern in globally. The earth's crust is made up of 70.9 per cent water, majorly in the form of oceans and seas [1] The necessity of water in the globe and its economy cannot be overemphasized. Approximately 70% of the water used by people is used for agriculture [2]. Most long-distance resource trading is carried out by boats (such as oil, naturally occurring gas, and industrial goods) across waterways, canals and lakes. Large volumes of water are used for heating and cooling in both homes and businesses in the form of ice and steam. Additionally, water is frequently used in industrial processes, in laundry and cooking, electric generating plants, the Pulp and paper milling industry, chemical plants, petroleum refining industry, iron and steel milling industry, aluminium smelters and food processing facilities. With the development of more industries, water pollution is on the increase.

Water pollution from chemicals like heavy metals, dyes, and radioactive materials poses significant health and environmental risks. Heavy metals, in particular, accumulate in the food chain, harming aquatic life and potentially humans, with toxic effects exacerbated at higher trophic levels [3–7] Traditional heavy metal removal methods, including liquid membrane separation and chemical precipitation, are costly and inefficient, producing toxic sludge and disposal issues [8]. Stricter global regulations, such as the World Health Organization (WHO's) 0.2 mg L^{-1} aluminium threshold, exacerbate the need for cost-efficient alternatives, particularly in developing nations with limited equipment capacity [9–11]. Adsorption is an efficient and economical technology for removing contaminants from wastewater, with minimal sludge production while exhibiting high efficacy in extracting metal ions from wastewater [12]. Various adsorbents, including activated carbon, are effective in extracting metal ions, but their high cost and disposal challenges limit widespread use [12–14].

Generally, researchers aim to replace activated carbon with inexpensive, locally sourced agricultural and industrial by-products (e.g., rice hulls, scrap tires) to create cost-effective adsorbents for wastewater treatment [12]. This approach can reduce disposal challenges, minimize industrial waste disposal costs, and provide an economic alternative to traditional activated carbon. Biosorption, a cost-effective and energy-efficient method, utilizes waste biomass or deceased biomass to extract heavy metals from wastewater through physical-chemical or metabolic processes [15,16]. This approach offers substantial energy conservation, reduced operational hours, and economic feasibility due to the low cost and wide availability of waste biomass, making it a viable method for industrial wastewater treatment.

In this study, a novel keratin-based activated carbon (from coconut coir) composite was developed and evaluated as a hybrid adsorbent for removing lead (Pb) and copper (Cu) from wastewater. Comparative batch experiments revealed its superior adsorption capacity over traditional activated carbon. Central Composite Design (CCD) under Response Surface Methodology (RSM) was employed to optimize the adsorption process. This study contributes to the United Nations' Sustainable Development Goals (SGDs), specifically promoting good health and wellbeing (SDG 3), clean water and sanitation (SDG 6), and preserving aquatic life.

2. Methodology

2.1 Materials

The coconut coir and chicken feathers were obtained from the local market in Benin City, Edo state, Nigeria. The chemicals used were analytical grade diethyl ether (98%), sodium sulphide (90%), hydrochloric acid (95%), potassium hydroxide (98%), Lead nitrate (98%), copper (II) sulphate pentahydrate (98%).

2.2 Preparation of coconut coir activated carbon

Coconut coir was converted to activated carbon (CCAC) through a multi-step process: drying (2 h at 110℃) [17], KOH soaking (10 %), washing, drying (24 h at 105 ± 5 ℃), carbonization at 900℃ in N_2 presence (0.5 h), activation with 10% HCl, and final drying (24 h at 105±5 ℃) [18]. The resulting CCAC was then ground and used for adsorption testing.

2.3. Pre-treatment, extraction and preparation of keratin from chicken feathers

Chicken feathers were cleaned and pre-treated with detergent, diethyl ether, and distilled water, then dried under sunlight for 48 h [19]. Keratin extraction was performed using alkaline hydrolysis with 0.5M sodium sulphide solution at 50°C and pH 10 - 13 for 5h, followed by filtration, centrifugation, and supernatant filtration [20].

2.4.Precipitation and purification of Protein

The filtrate solution from alkaline hydrolysis was treated with HCl solution, and the resulting solid particles were collected, washed repeatedly with deionized water until neutral pH, and dried at 45°C for 5h to produce keratin powder [20] .

2.5. Calculation of keratin yield

The percentage of keratin yield was determined using Eq. (1) presented below.

$$\text{Amount of keratin yield (Yield \%)} = \frac{Total\ weight\ of\ obtained\ keratin}{Total\ weight\ of\ waste\ chicken\ featherts} \times 100 \qquad (1)$$

2.6. Preparation of keratin-based activated carbon composite

The synthesis of the keratin-based activated carbon composite was performed by modifying the existing method reported in literature [21]. This involved mechanical blending, where keratin and activated carbon powders were combined in a 1:1 ratio and mechanically processed to create a uniform mixture. The resulting powder blend was then used for the adsorption process.

2.7. Preparation of the contaminated lead and copper solution

Stock solutions of Pb (1000 mg L^{-1}) and Cu (1 g L^{-1}) were prepared by dissolving $Pb(NO_3)_2$ and $CuSO_4 \cdot 5H_2O$, respectively, in distilled water [22]. These stock solutions were then diluted to create working solutions with varying concentrations of Pb (2 - 10 mg L^{-1}) and Cu (2 - 10 mg L^{-1}).

2.8. Batch Adsorption Experimental Study

Batch adsorption studies were conducted to investigate the effects of heavy metal concentration (2 - 10 mg L^{-1}), contact time (20 - 120 min), and adsorbent dosage (2-10 g L^{-1}) on Pb and Cu removal [23]. 100 mL simulated solutions were shaken with varying adsorbent dosages, and residual metal ions were quantified using atomic absorption spectroscopy (AAS). This procedure was repeated for both coconut coir activated carbon and keratin-based coconut coir activated carbon composite.

3. Results and Discussion

3.1 Adsorbent characterization

3.1.1 Fourier transform infrared spectroscopy (FTIR) analysis

FTIR analysis (500 - 4000 cm^{-1}) revealed the presence of various functional groups on the surface of the adsorbent materials. Coconut coir activated carbon in Fig. 1a showed C-H, S-C/N, N=C=S, and O-H stretches, while keratin-based coconut coir activated carbon composite in Fig. 1b exhibited C-H, N=C=N, and C=C stretches, indicating the presence of C-H stretching alkene, thiocyanate, isothiocyanate, carbodiimide (N = C = N), and cyclic alkene groups (C = C).

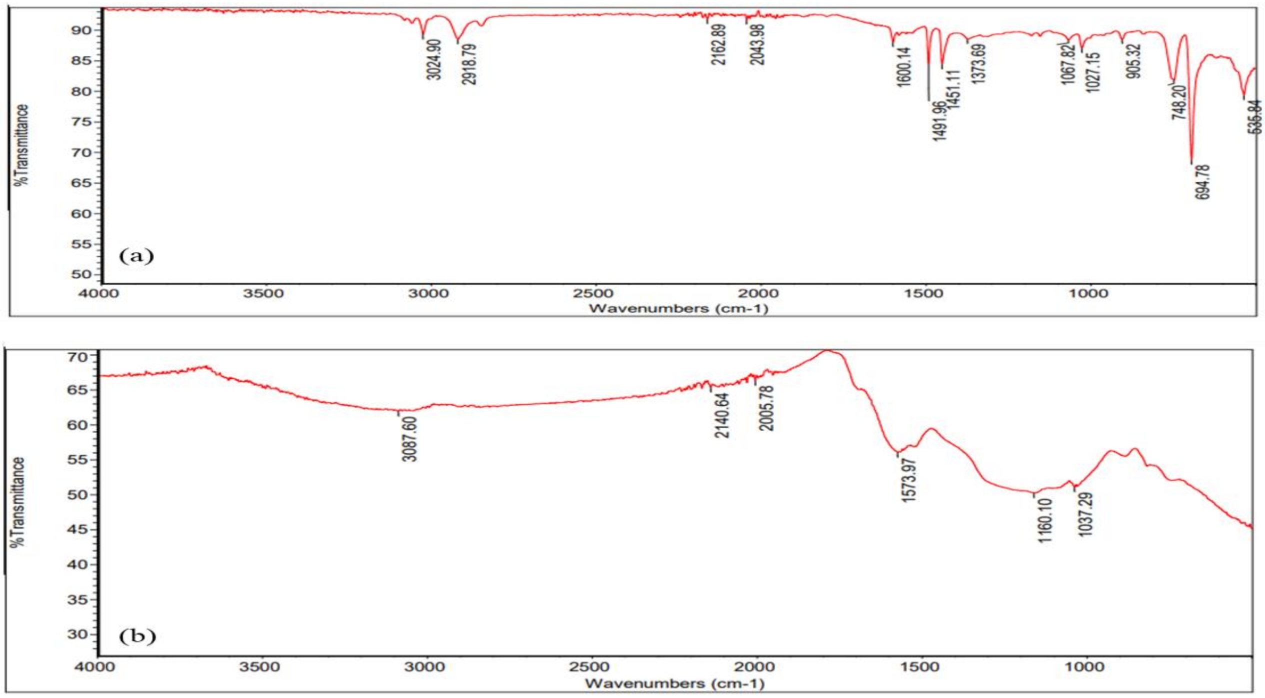

Fig.1: FT-IR spectra for (a) coconut coir activated carbon (b) keratin-based coconut coir activated carbon composite.

3.1.2 Scanning Electron Microscopy (SEM) analysis

SEM analysis (500 × magnification) revealed the surface morphology of the coconut coir activated carbon and keratin-based coconut coir activated carbon composite (Fig. 2). Coconut coir activated carbon (Fig 2a) showed a highly porous structure (5-10 µm pore size), while the composite (Fig. 2b) exhibited a smooth surface with a uniform keratin distribution, retaining a significant porous framework favourable for heavy metal adsorption.

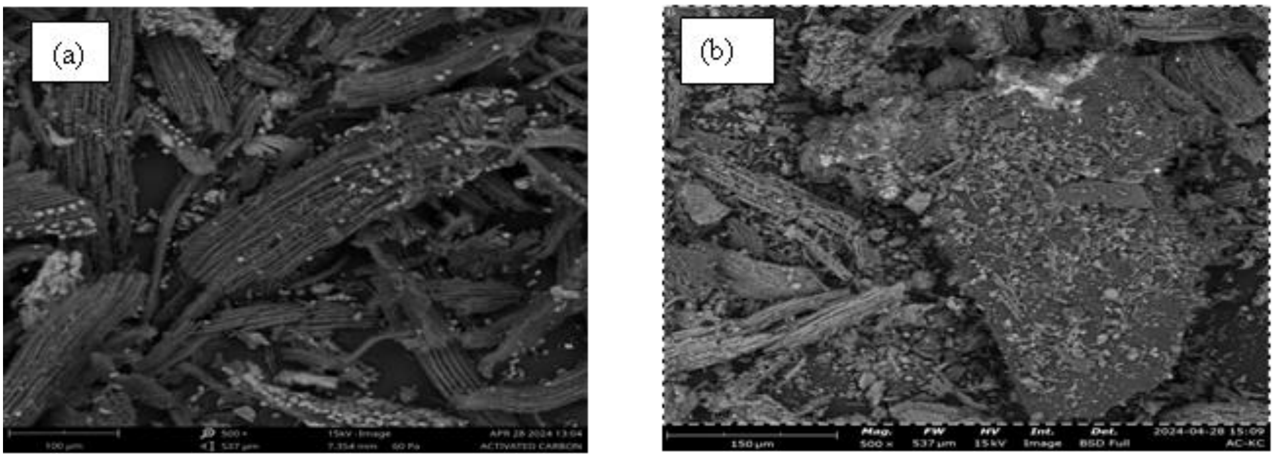

Fig. 2: Scanning Electron Micrograph (a) activated carbon and (b) keratin-based activated carbon composite.

3.1.3. Energy dispersive X-ray (EDX) analysis

The elemental compositional analysis of the coconut coir activated carbon and the keratin-based coconut coir activated carbon composite samples using the EDX analysis are shown in Table 1.

Table 1: EDX analysis of the synthesized adsorbents.

Atomic Number	Element Symbols	Element Name	Weight % of Coconut Coir Activated Carbon. (%)	Weight % of Keratin-based coconut coir activated carbon. (%)
6	C	Carbon	86.00	65.59
14	Si	Silicon	8.45	6.73
7	N	Nitrogen	3,29	13.28
26	Fe	Iron	1.21	0.00
13	Al	Aluminium	0.42	0.25
20	Ca	Calcium	0.23	0.10
22	Ti	Titanium	0.11	0.07
16	S	Sulphur	0.09	13.71
17	Cl	Chlorine	0.05	0.00
19	K	Potassium	0.09	0.00
12	Mg	Magnesium	0.05	0.09
11	Na	sodium	0.00	0.18

3.1.4. Textural Analysis

The textural properties of coconut coir activated carbon and keratin-based coconut coir activated carbon composite were analysed. The results showed that the composite had a higher surface area (488.1 m^2g^{-1}), pore size (2.46 nm), and pore volume (23.95 cc g^{-1}) compared to activated carbon (385.809 m^2g^{-1}, 2.136 nm, and 0.190 cc g^{-1}) and existing literature [24]. This suggests that the composite is a more effective adsorbent for heavy metal adsorption.

3.2.Effect of Process Parameters

Using Response Surface Methodology (RSM), the effects of adsorbent dosage, contact time, and heavy metal concentration on metal ion removal were investigated. The results showed that all three parameters significantly impacted the removal of lead (Pb) and copper (Cu) from a simulated aqueous solution, informing the development of a suitable treatment method and adsorbent.

3.2.1. Effect of contact time

The effect of contact time (20 - 120 mins) on Pb and Cu removal from aqueous solutions (2 -10 mgL^{-1}) was investigated and presented in Fig. 3. Results showed that Pb removal rate increased until 84 mins, then decreased (Fig. 3a, coconut coir activated carbon; Fig. 3c, keratin-based coconut coir activated carbon composite). Cu removal rate increased until 70 mins, then decreased (Fig. 3b, coconut coir activated carbon; Fig. 3d, keratin-based coconut coir activated carbon composite).
The initial high removal rates were attributed to the concentration gradient and available adsorbent surface sites, which decreased as contact time increased.

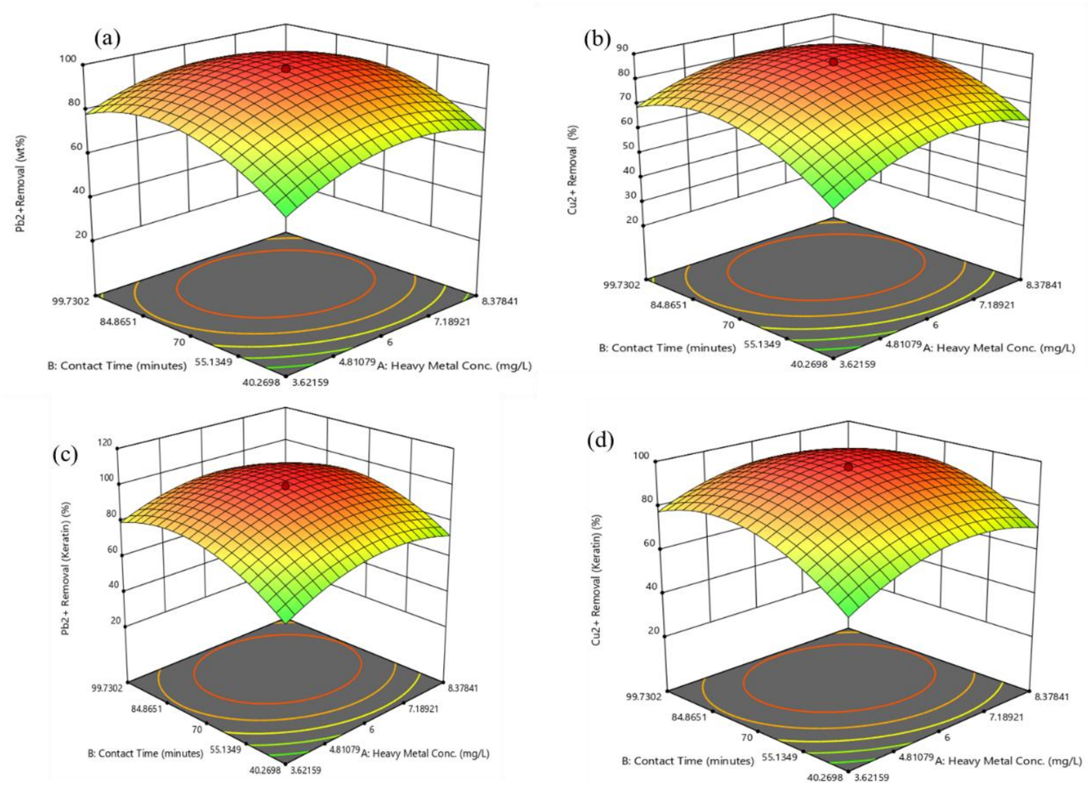

Fig. 3: 3D Response surface of effects of contact time on the concentration of (a) Pb^{2+} (b) Cu^{2+} removal using coconut coir activated carbon (c) Pb^{2+} and (d) Cu^{2+} removal using keratin-based activated carbon composite.

3.2.2 Effect of adsorbent dosage

The effect of adsorbent dosage (2 - 10 g L^{-1}) on Pb^{2+} and Cu^{2+} removal was investigated and represented in Fig. 4. Results showed that metal uptake increased with dosage up to 6 g L^{-1}, then declined due to mass transfer limitations. The optimal adsorbent dosage was 6 g L^{-1} (using heavy metal concentration of $7mgL^{-1}$) for both coconut coir activated carbon (Fig. 4a, and b) and keratin-based coconut coir activated carbon composite (Fig. 4 c, and d). This finding is consistent with previous research highlighting the importance of adsorbent dosage in optimizing heavy metal removal from industrial wastewater using biomass-based materials [25].

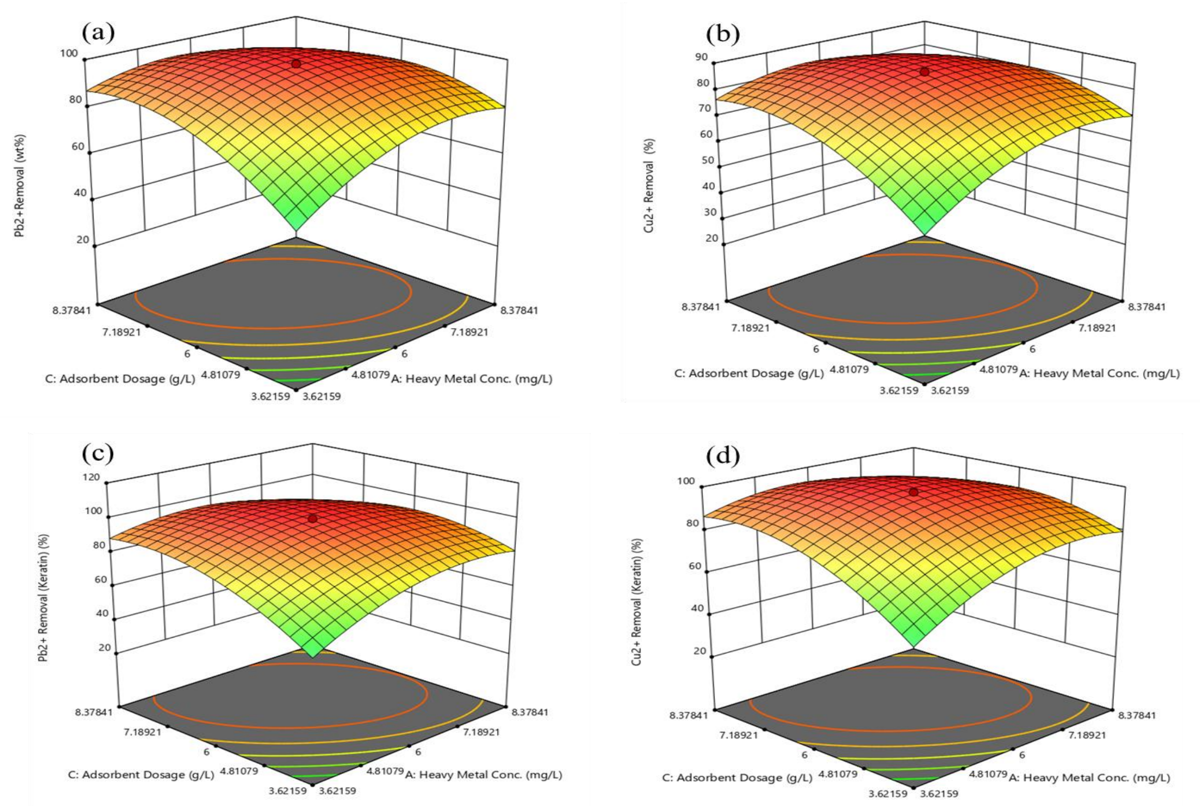

Fig. 4: 3D Response surface of effects of adsorbent dosage on the concentration of (a) Pb^{2+} and (b) Cu^{2+} removal using coconut coir activated carbon (c) Pb^{2+} and (d) Cu^{2+} removal using keratin-based coconut coir activated carbon composite.

3.2.3 Analysis of contact time and adsorbent dosage

Fig. 5(a - d) gives the optimization result on three-dimensional (3D) plots showing the relationship between the effectiveness of the adsorbates removal (Pb^{2+} and Cu^{2+}), the adsorbent dosage and the contact time for the coconut coir activated carbon (Fig. 5a (Pb^{2+}), Fig. 5b (Cu^{2+}) and the keratin-based activated carbon composite Fig. 5c (Pb^{2+}) and Fig. 5d (Cu^{2+}). The optimal removal efficiencies for Pb^{2+} and Cu^{2+} were achieved at specific contact times and adsorbent dosages. For activated carbon, the highest removal efficiency for Pb^{2+} occurred at 74 mins with an adsorbent dosage of 7.1 gL^{-1}, while Cu^{2+} removal was maximized at 70 mins with a dosage of 6 gL^{-1}. Similarly, the keratin-based activated carbon composite achieved its highest removal efficiency for Pb^{2+} at 70 mins with a dosage of 6 gL^{-1}, and for Cu^{2+} at 71.34 mins with a dosage of 7.3 $g\ L^{-1}$. The plot indicates a positive correlation between contact duration, adsorbent dosage, and removal efficiency, suggesting that increasing these parameters enhances removal efficiency.

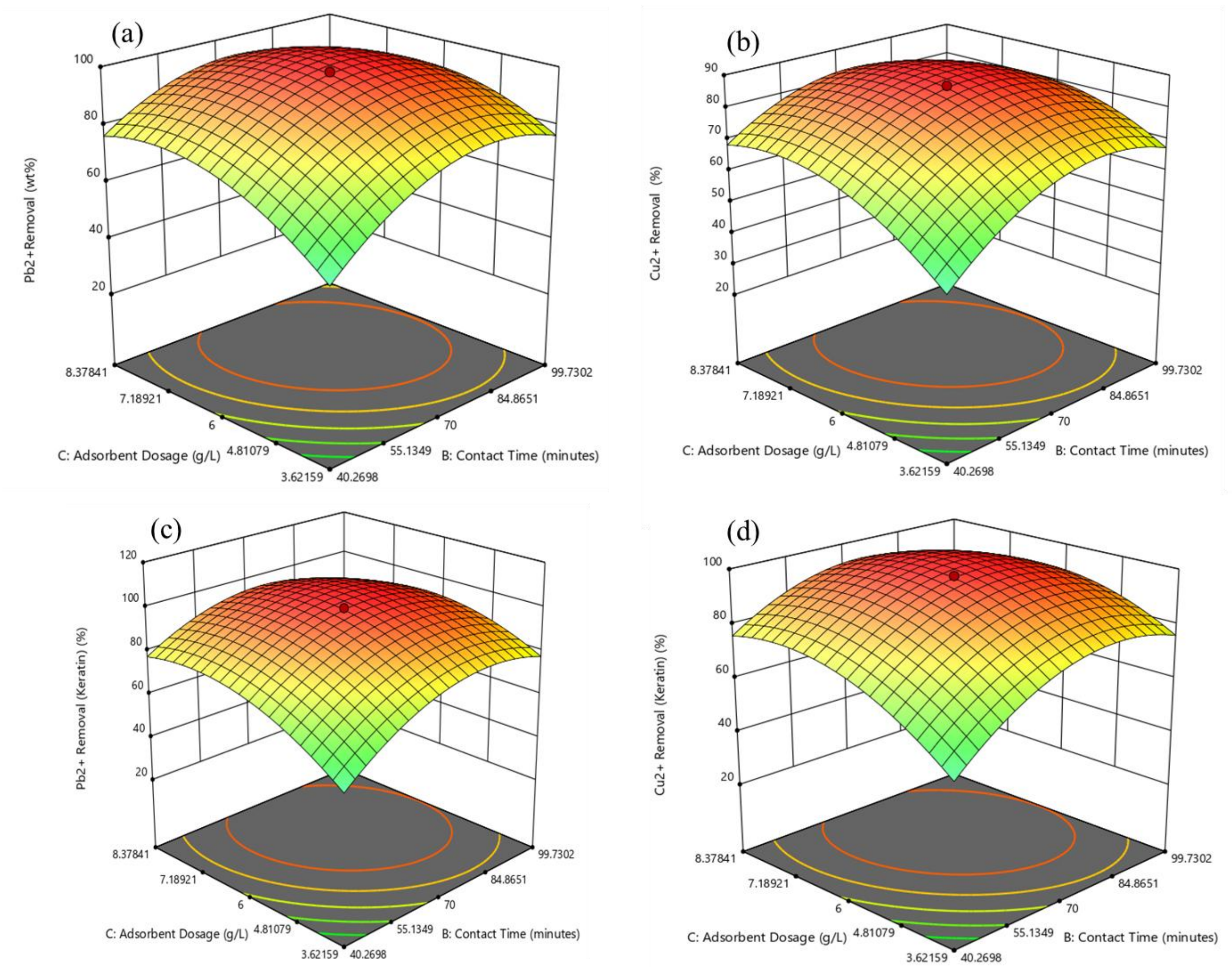

Fig. 5: 3D plots of the effect of contact time in relation to adsorbent dosage for (a) Pb^{2+} (b) Cu^{2+} Coconut coir activated carbon and (c) Pb^{2+} (d) Cu^{2+} keratin based activated carbon composite.

3.3. Analysis of Variance

3.3.1. Pb^{2+} ions

3.3.1.1 Analysis of variance using coconut coir activated carbon and keratin-based coconut coir activated carbon.

Regression analysis was used to model the removal efficiency of Pb^{2+} using coconut coir activated carbon and keratin-based coconut coir activated carbon composite as a function of heavy metal concentration, contact time, and adsorbent dosage. For the coconut coir activated carbon, the resulting model, presented in Eq. (2), had an F-value of 100.28 (p-value = 0.01%) and significant predictors (p-values < 0.0500), indicating a good fit with a Lack of Fit F-value of 2.78. The responses for Pb^{2+} removal using coconut coir activated carbon are presented in Table 2. A similar regression analysis was performed for the keratin-based coconut coir activated carbon composite, with the model presented in Eq. (3) having an F-value of 67.51 and significant predictors as presented in Table 3. However, the Lack of Fit F-value of 4.85 suggests a 5.40 % chance of noise contributing to lack of fit, which is slightly concerning but below the 10% threshold.

Final model in terms of coded factors (activated carbon composite)

$$Y = +97.41 + 3.35A + 7.10B + 7.00C - 1.66AB - 8.03AC - 4.433BC - 10.54A^2 - 13.91B^2 - 11.33C^2 \quad (2)$$

Final model in terms of coded factors (keratin-based activated carbon composite)

$$Y = +98.91 + 4.13A + 7.75B + 7.65C -1.81AB -8.29AC - 4.523BC -10.73A^2 -14.53B^2 -11.53C^2 \quad (3)$$

Table 2: ANOVA Response for Pb^{2+} ions using coconut coir activated carbon.

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	7447.35	9	827.48	100.28	< 0.0001	Significant
A-Heavy Metal Conc.	170.43	1	170.43	20.65	0.0011	
B-Contact Time	687.95	1	687.95	83.37	< 0.0001	
C-Adsorbent Dosage	669.64	1	669.64	81.15	< 0.0001	
AB	22.02	1	22.02	2.67	0.1334	
AC	516.42	1	516.42	62.58	< 0.0001	
BC	149.84	1	149.84	18.16	0.0017	
A^2	1601.26	1	1601.26	194.05	< 0.0001	
B^2	2788.19	1	2788.19	337.89	< 0.0001	
C^2	1850.84	1	1850.84	224.30	< 0.0001	
Residual	82.52	10	8.25			
Lack of Fit	60.66	5	12.13	2.78	0.1434	not significant
Pure Error	21.85	5	4.37			
Cor Total	7529.87	19				

Table 3: Response 2 for Pb^{2+} ions removal using keratin-based coconut coir activated carbon composite.

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	8009.83	9	889.98	67.51	< 0.0001	Significant
A-Heavy Metal Conc.	232.92	1	232.92	17.67	0.0018	
B-Contact Time	820.20	1	820.20	62.22	< 0.0001	
C-Adsorbent Dosage	799.89	1	799.89	60.68	< 0.0001	
AB	26.30	1	26.30	2.00	0.1882	
AC	549.38	1	549.38	41.68	< 0.0001	
BC	163.67	1	163.67	12.42	0.0055	
A^2	1659.45	1	1659.45	125.89	< 0.0001	
B^2	2885.97	1	2885.97	218.93	< 0.0001	
C^2	1917.42	1	1917.42	145.46	< 0.0001	
Residual	131.82	10	13.18			
Lack of Fit	109.29	5	21.86	4.85	0.0540	not significant
Pure Error	22.53	5	4.51			
Cor Total	8141.65	19				

The fit statistics for Pb^{2+} removal using activated carbon and keratin-based activated carbon, presented in Table 4, demonstrate a high degree of correlation between the predicted and actual values, as evident from the high R^2 values. Notably, the difference between the adjusted R^2 and predicted R^2 values is minimal, measuring less than 0.2, suggesting a strong agreement between the two metrics. Furthermore, the R^2 values are close to 1, indicating a desirable fit. The adequate precision metric, which evaluates the signal-to-noise ratio, exceeds the preferred threshold of 4, confirming the reliability of the model. Overall, these results suggest that the models effectively predict Pb^{2+} removal using both activated carbon and keratin-based activated carbon.

Table 4: Fit statistics for Pb^{2+} ions removal

Activated Carbon			
Standard Deviation.	2.87	R^2	0.9890
Mean	72.97	Predicted R^2	0.9254
C.V. %	3.94	Adjusted R^2	0.9792
		Adeq Precision	33.2003
Keratin-based Activated Carbon			
Standard Deviation.	3.63	R^2	0.9838
Mean	74.05	Predicted R^2	0.8771
C.V. %	4.90	Adjusted R^2	0.9692
		Adeq Precision	27.4890

3.3.1.2 Parity plot for Pb^{2+} ions removal

Fig. 6 presents a parity plot illustrating the correlation between actual and predicted Pb^{2+} ions removal concentrations for (a) coconut coir activated carbon and (b) keratin-based coconut coir activated carbon. The data points approach a straight line, indicating a strong correlation (R^2 value near unity) between the data and the model. This suggests that the model provides a reliable estimate of the system's reaction within the investigated boundaries, enabling its use to predict responses instead of independent input factors.

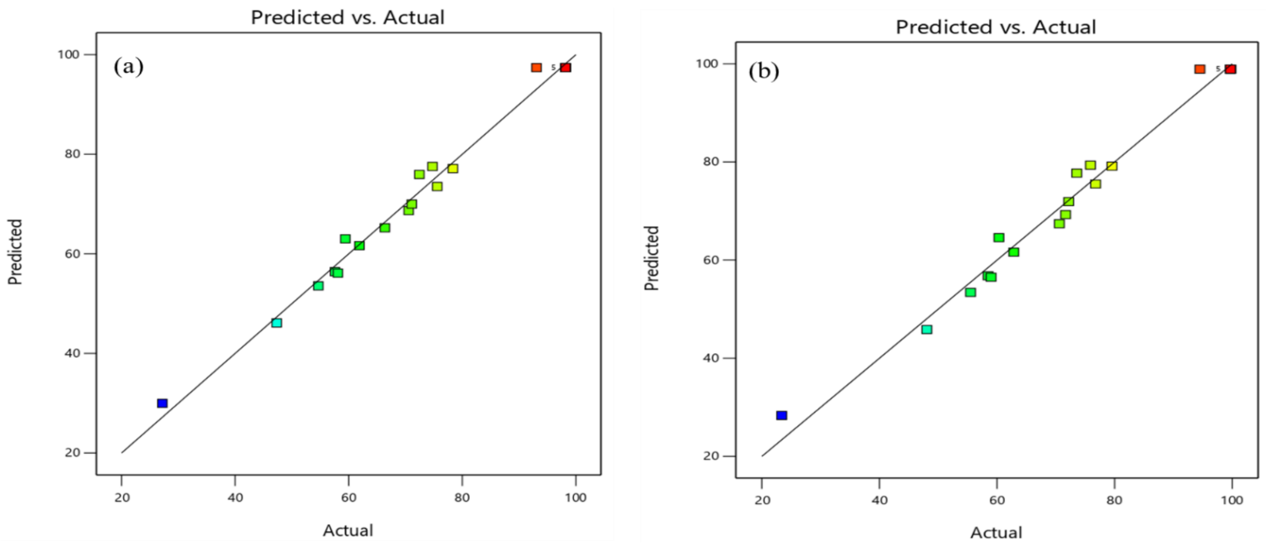

Fig. 6: Parity plot of predicted against actual Pb^{2+} ions removal for (a) coconut coir activated carbon and (b) keratin-based coconut coir activated carbon composite.

3.3.2. Cu^{2+} ions

Two models for Cu^{2+} removal were developed, one using coconut coir activated carbon (Eq. 4, Table 5,) and the other using keratin-based coconut coir activated carbon (Eq. 5, Table 6). The activated carbon model demonstrated statistical significance with an F-value of 121.78 (p-value = 0.01%) and significant model terms (P-values < 0.0500), with a Lack of Fit F-value of 2.05 indicating a good fit. Similarly, the keratin-based activated carbon model showed statistical significance with an F-value of 67.51 and significant model terms (P-values < 0.0500), except for terms with P-values > 0.1000, and a Lack of Fit F-value of 4.85 indicating a good fit.

Final model in terms of coded factors (using activated carbon)

$$Y = 86.02 + 3.58A + 6.19B + 6065C - 1.56AB - 6.26AC - 3.92BC - 9.41A^2 - 12.11B^2 - 9.84C^2 \quad (4)$$

Final model in terms of coded factors (using keratin-based activated carbon)

$$Y = +96.75 + 4.04A + 7.58B + 7.49C - 1.77AB - 8.11AC - 4.42BC - 10.50A^2 - 13.84B^2 - 11.28C^2 \quad (5)$$

The equations are presented in the form of coded factors enabling the anticipation of the reaction for specific levels of individual elements.

Table 5: Analysis of Variance (ANOVA) for the Response Surface Quadratic Model for Cu^{2+} ions removal using coconut coir activated carbon.

Source	Sum of Squares	Mean Square	Df	F-value	p-value	
Model	5707.86	634.21	9	121.78	< 0.0001	Significant
A-Heavy Metal Conc.	175.20	175.20	1	33.64	0.0002	
B-Contact Time	523.09	523.09	1	100.44	< 0.0001	
C-Adsorbent Dosage	603.40	603.40	1	115.86	< 0.0001	
AB	19.43	19.43	1	3.73	0.0822	
AC	314.00	314.00	1	60.29	< 0.0001	
BC	122.68	122.68	1	23.56	0.0007	
A^2	1202.97	1202.97	1	230.99	< 0.0001	
B^2	2114.23	2114.23	1	405.97	< 0.0001	
C^2	1394.21	1394.21	1	267.71	< 0.0001	
Residual	52.08	5.21	10			
Lack of Fit	35.02	7.00	5	2.05	0.2243	not significant
Pure Error	17.06	3.41	5			
Cor Total	5759.93		19			

Table 6: Analysis of Variance (ANOVA) for the Response Surface Quadratic Model for keratin-based coconut coir activated carbon composite for Cu^{2+} removal.

Source	Sum of Squares	Mean Square	Df	F-value	p-value	
Model	7663.69	851.52	9	67.51	< 0.0001	Significant
A-Heavy Metal Conc.	222.85	222.85	1	17.67	0.0018	
B-Contact Time	784.76	784.76	1	62.22	< 0.0001	
C-Adsorbent Dosage	765.32	765.32	1	60.68	< 0.0001	
AB	25.16	25.16	1	2.00	0.1882	
AC	525.63	525.63	1	41.68	< 0.0001	
BC	156.60	156.60	1	12.42	0.0055	
A^2	1587.74	1587.74	1	125.89	< 0.0001	
B^2	2761.26	2761.26	1	218.93	< 0.0001	
C^2	1834.56	1834.56	1	145.46	< 0.0001	
Residual	126.12	12.61	10			
Lack of Fit	104.56	20.91	5	4.85	0.0540	not significant
Pure Error	21.56	4.31	5			
Cor Total	7789.81		19			

Table 7 presents the fit statistics for Cu^{2+} removal using coconut coir activated carbon and keratin-based coconut coir activated carbon. The difference between the adjusted R^2 value (0.9828) and the predicted R^2 value (0.9413) is less than 0.2, indicating a good agreement between the two metrics. For the fit statistics for Cu^{2+} removal using keratin-based activated carbon, the difference between the adjusted R^2 value (0.9838) and the predicted R^2 value (0.9692) is less than 0.2, indicating a good agreement between the two metrics.

Table 7: Fit statistics for the removal of Cu^{2+} ions

Activated Carbon			
Standard Deviation.	2.28	R^2	0.9910
Mean	64.80	Predicted R^2	0.9413
C.V. %	3.52	Adjusted R^2	0.9828
		Adeq Precision	36.7123
Keratin-based Activated Carbon			
Standard. Deviation.	3.55	R^2	0.9838
Mean	72.43	Predicted R^2	0.8771
C.V. %	4.90	Adjusted R^2	0.9692
		Adeq Precision	27.4890

3.3.2.1.Parity plot for Cu^{2+} removal

Fig. 7 shows the correlation between the actual and predicted concentrations of Cu^{2+} ions removal (a) using coconut coir activated carbon (b) using keratin-based coconut coir activated carbon. The distribution of the data points tends to assume a straight line. This points to a strong fit between the data and the model as well as a reliable estimate of the system's reaction within the investigated boundaries, thereby suggestive of a high correlation (R^2 value close to unity) for both adsorbents.

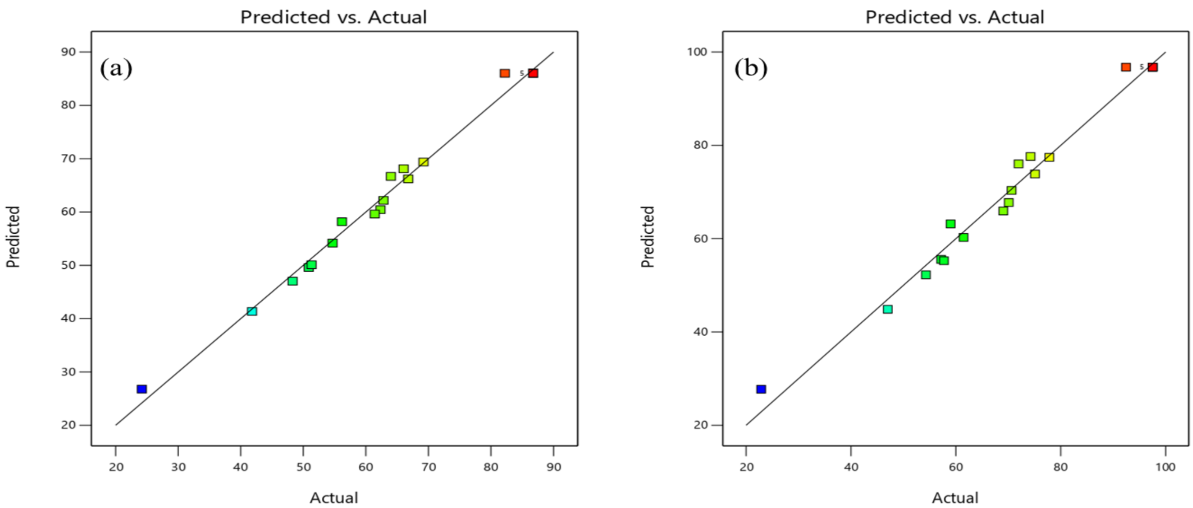

Fig. 7: Parity plot of predicted against actual Cu^{2+} ions concentrations for (a) activated carbon (b) keratin-based activated carbon composite.

4. Conclusions

Activated carbon which is widely known to be a low-cost effective absorbent has been combined with keratin to determine its effectiveness in heavy metal removal for waste water treatment. Herein, the performance of activated carbon and a keratin-based activated carbon composite was compared for the adsorption of lead (Pb^{2+}) and (Cu^{2+}) ions with boundaries set using three factors of contact time, adsorbent dosage and heavy metal concentration. The activated carbon was obtained from coconut coir while the keratin was obtained from chicken feathers with adsorbent samples characterized by FTIR, BET, SEM, and EDX to confirm formation of the adsorbent samples.

Keratin extraction process gave a yield of 70 %. For coconut coir activated carbon, the optimal values were heavy metal concentration: 5.41 mg L^{-1}, contact time: 71.31 mins, and adsorbent dosage 7.35g L^{-1}, while the keratin-based coconut coir activated carbon composite had values of heavy metal concentration: 6mg L^{-1}, contact time: 70mins, and absorbent dosage: 6 g L^{-1}. Under the same experimental conditions, coconut coir activated carbon gave an optimal removal efficiency of

97.55% and 86.75% for Pb^{2+} ions for Cu^{2+}ions removal while the keratin- based coconut coir activated carbon composite had optimal removal efficiency of 99.26 % and 97.53% for Pb^{2+} ions and Cu^{2+}ions, respectively, implying better efficiency of the keratin- based activated carbon composite.

The coefficient of determination (R^2) for Pb^{2+} ions removal using activated carbon and keratin-based activated carbon composite was 0.9890 and 0.9838, respectively, while that for Cu^{2+} ions were 0.9910 and 0.9838 for coconut coir activated carbon and keratin-based coconut coir activated carbon composite, respectively. Based on the closeness to unity, the experiment yielded desired results which leads to the conclusion that keratin activated carbon composite is fit for the adsorption of heavy metals.

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