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Carbon Dots Derived from Waste Fish Scale for Enhanced Removal of Levofloxacin Drug: Parametric Optimization, Isotherm and Kinetic Studies

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Abstract: *The public health and environmental protection have been facing a great challenge for efficient antibiotics' adsorption from aqueous solution. In this work, a carbon dots nanoparticle from biomass (fish scale) was synthesized and employed for antibiotic adsorption. The synthesized fish scale carbon dots (FCD) were characterized by means of the X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) and Fourier transform infrared (FTIR) analyses. Experiments on adsorption were performed to examine the capability of the synthesized adsorbent for adsorption of Levofloxacin. The optimum conditions were ascertained through the use of Response Surface Methodology (RSM) design to increase the effectiveness of levofloxacin removal, and there was 96.03% removal efficiency of 60 minutes contact time, 10 mg/L levofloxacin concentration and FCD dosage of 0.2 g/L. Also, the adsorption experiments indicated that at the lowest concentration of 10 mg/L, at time 45 min and 0.15 mg dosage the adsorption rate was high. For the kinetics data, the pseudo-second order model best fit the data. Furthermore, the Redlich-Peterson model fit isothermal data the best.*

Keywords*: Adsorption, Carbon dots, Synthesis, Antibiotics, Levofloxacin*

1. INTRODUCTION

In view of the fact that industrial effluents are hazardous and pose a risk to both human health and the environment, pollution from them is a serious concern. Because harmful components could infiltrate the food chains that affect humans and animals, there is general concern about the health concerns linked with the discharge of industrial effluents into water bodies [1]. Water is a naturally occurring resource that is essential to both human life and the health of the ecosystem, but owing to human involvement and climate change, it is becoming harder to find a safe supply [2]. Industrial wastewater discharge into the environment is one of the primary causes of environmental contamination because it has a substantial detrimental impact on the receiving water bodies [3]. Of particular concern is the presence of pharmaceutical debris in water, especially levofloxacin drug.

Levofloxacin (LEV) is widely used in hospitals and farms, which negatively impacts aquatic microorganisms. Due to the methods used for disposing of waste, treating municipal wastewater, and applying manure to farms, LEV usage in these settings undoubtedly leads to water contamination [4].

Various studies have shown that even low concentrations of levofloxacin in water can harm aquatic life and contribute to the development of antibiotic resistance. Furthermore, it can persist in water for extended periods, leading to long-term environmental damage [5]. Antibiotic resistance in microorganisms is anticipated to rise as a result of insufficient antibiotic removal by standard wastewater treatment technologies such as membrane filtration and biological treatment [6]. Antibiotic resistance develops as a result of overuse and inappropriate disposal of antibiotics, limiting drugs' capacity to successfully treat bacterial illnesses. The World Health Organization states that one of the main risks to public health, food security, and economic growth is antibiotic-resistant microorganisms [7, 8].

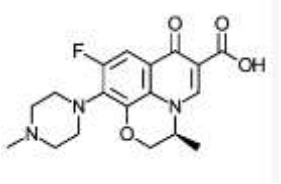
Levofloxacin (LEV) is a third-generation Fluoroquinolones (FQs) with the L-isomer of ofloxacin, its main characteristics is shown in Table 1. Levofloxacin is used to combat intracellular infections and is characterized by effective penetration of target tissues. The active antibiotic component of the medication is typically excreted from the body through

the kidneys. Levofloxacin is only minimally metabolized, and the inactive metabolites dimethyl levofloxacin and levofloxacin N-oxide make up lower than 5% of the applied dose. The antibiotic finds its way into the soil, surface and ground waters, and lake sediments once its being excreted [9]. Levofloxacin is an antibiotic belonging to the fluoroquinolone medication class that has the ability to directly impede the synthesis of bacterial DNA. Because levofloxacin inhibits DNA-gyrase in vulnerable organisms, which prevents supercoiled DNA from relaxing, it encourages the breakdown of DNA strands [10]. Antibiotic resistance has the potential to make standard surgeries and other contemporary medical procedures too dangerous if allowed to continue unchecked. Therefore, starting in 2050, antibiotic resistance might kill up to 10 million people annually [11]. As a result, developing an effective adsorbent is critical.

The investigation into effective water treatment technologies has increased due to the alleged extreme risks to man's health and the surrounding associated with water containing antibiotics. When it comes to eliminating antibiotics from water, one of the best treatment techniques has been suggested as adsorption, which has demonstrated its efficacy in the past [12, 13].

There have been recent attempts to produce carbon compounds from biomass wastes by using them as raw materials. Biomass waste is an organic carbon source found in nature and is mostly made up of protein, ash, cellulose, lignin hemicellulose, and some other components. For the manufacturing of carbon-dots, biomass waste provides an abundant, safe, renewable, and ecologically beneficial carbon source [14]. The biodegradable and less poisonous properties of carbon particles, particularly carbon nanomaterials, have attracted a lot of attention. Another reason is their ease of surface functionalization. The newest kind of fluorescent nanoparticles are called carbon dots (FCDs), dimensionless particles that are categorized as carbon nanomaterials larger than 10 nm [15]. It has recently been reported that fish scales can be used as biomass to create fluorescent nanomaterials with a variety of uses [16]. A study by [17] demonstrates the potential application of fish scale-derived CDs in detecting ferric ions in actual water samples and human serum. In the treatment of abattoir wastewater (AW), chito-protein made from fish scale is employed by another author [3] as a bio-coagulant. Additionally, there is a biological use for fish scale-derived CDs. For instance, [18] uses Lethrinus lentjan scales to simultaneously create hydroxyapatite and carbon nanoparticles that can be used for bone tissue engineering and bioimaging.

Table 1: Characteristics and chemical structure of Levofloxacin

Empirical Formular	Chemical Structure	Molecular Weight (g/mol)
$C_{18}H_{20}FN_3O_4$		361.37

The materials and compounds needed for long-term adsorption water treatment are still being studied by a diverse group of scientists. As a result, the importance of synthesizing compounds capable of successfully removing contaminants from the environment cannot be overstated. Many kinds of activated carbon have been in use in the past for a variety of adsorptive motives. Due to the limited surface area available for adsorption, bulk materials are ineffective for such uses [15]. Therefore, the objective of this research is to explore the adsorption task at the nanoscale utilizing fish scale carbon dots (FCD), where the adsorbent properties and removal performance for adsorption of many important water contaminants such as levofloxacin is being looked into.

2. MATERIALS AND METHODS

2.1 Materials and Instrumentation

The fish scale waste utilised for the production of carbon dots was acquired from Afe Babalola University's fish farm. The Levofloxacin was procured from Sigma Aldrich, Germany. Other reagent employed were of research grade. The surface functional groups on carbon dots adsorbent were assessed by Fourier transform infra-red (FTIR) spectrometer (Perkin Elmer 1750X, U.K.) of a 400 to 4000 cm^{-1} wavelength range under atmospheric circumstances. The XRD analysis for crystallinity was estimated and recorded using Cu Kα radiation in the 2θ range 4 to 90 degrees at room temperature. Energy dispersive x-ray spectroscopy (EDS) in conjunction with scanning electron microscopy (SEM, Hitachi S-3400N, Japan) was used to examine the structural and morphological characteristics of the as-synthesized carbon dots. Levofloxacin antibiotic concentration (at λ = 298 nm) was measured using a UV-visible spectrophotometer (Lambda 35PerkinElmer Life and Analytical Science, Singapore 139959, Singapore) following the adsorption process. Water that had been double-distilled was utilized for the experiment.

2.2 Synthesis of Carbon Dots

A prepared sample of fish scale, weighing 2 g, was combined with 100 mL of distilled water. It was thoroughly mix with magnetic stirrer for 15minutes for homogeneity, then transfer into a Teflon-lined autoclave and close tightly. Heat at 120^{o}C for 6 hours and allow to return to room temperature. The sediment was eliminated by centrifuging it for 60 minutes

at 2000 rpm. A 0.45 µm membrane filter is utilized to filter the refined CD solution. Dry the sediment at 120°C for 30 minutes and store for characterizations.

2.3 Batch Adsorption of Levofloxacin by Carbon Dots

Three important process parameters: the initial antibiotic concentration, the dosage of carbon dots, and the reaction time were optimized with the aid of Response surface methodology (RSM). Antibiotics adsorption studies in regard to central composite design (CCD) were mathematically modeled and optimized using software package Design-Expert 13. The sorption of LEV was assessed in this study using the following adsorption process variables: concentration (A: 10–50 mg/L), carbon dots dose (B: 0.1–0.2 g), and reaction time (C: 30-60 min). The aforementioned independent variables in CCD were chosen depended on prior research and potential actual industrial wastewater situations. With a three-variable, six-central-point experimental design, a total of twenty runs were obtained for LEV. Adsorption experiments were conducted in a 250 mL volume conical flask at 25 °C with a continuous stirring speed of 100 rpm.

Equations (1) and (2) were employed to determine the adsorption capacity and the percentage removal of the LEV antibiotic:

$$q_e = \frac{(Co-Ce)}{m} X V \quad (1)$$

$$R = \frac{(Co-Ce)}{Co} X 100 \quad (2)$$

where C_o is the initial levofloxacin concentration (mg. L^{-1}), C_e is the residual levofloxacin concentration (mg. L^{-1}) in the solution, R is the levofloxacin removal percentage, m is the adsorbent mass (g), q_e is the adsorption capacity of the adsorbent (mg/g) and V is the sample volume (L).

The equilibrium relationship between carbon dot as adsorbent and levofloxacin as an adsorbate were investigated using adsorption isotherms obtained using 10 – 50 mg. L^{-1} initial concentrations. The equilibrium studies were performed as follows: 20 mL of each solution was to a 250 mL Erlenmeyer flask containing 0.1 g of the adsorbent. The adsorption process was performed at room temperature for 1 hour, thereafter, the adsorbent and sample solution were separated by filtration and residual LEV concentration recorded. The Langmuir, Freundlich, and Redlich-Peterson isotherms as depicted in Equations 3, 4, and 5 respectively, were employed to analyse the equilibrium data obtained.

$$\frac{C_e}{q_e} = \frac{1}{K_L q_{max}} + \frac{C_e}{q_{max}} \quad (3)$$

$$\ln q_e = lnK_F + \frac{1}{n} lnC_e \quad (4)$$

$$\frac{C_e}{q_e} = \frac{1}{A} + \frac{B}{A} C_e^{\beta} \quad (5)$$

q_{max} indicates the adsorbent's monolayer adsorption capacity (mgg^{-1}), K_L denotes the Langmuir constant (Lmg^{-1}), and it's connected to adsorption energy and K_F is the Freundlich constant allied to adsorption capacity of adsorbent (mgg^{-1}). A is a constant with a unit of (Lmg^{-1}), B is the Redlich–Peterson isotherm constant (Lg^{-1}), and β is an exponential value ranging from 0 to 1. C_e represents the adsorbate's equilibrium liquid-phase concentration (mgL^{-1}), and q_e denotes the adsorbate's equilibrium loading onto the adsorbent (mgg^{-1}).

The sorption kinetics studies were investigated by placing 50 mL of 20 mgL^{-1} levofloxacin solution into 250 mL Erlenmeyer flask containing 0.1 g of carbon dot biosorbent. The solution was shaken for different time intervals within 0 to 60 min. At each contact time, content was filtered, and equilibrium LEV concentrations were recorded. The integral linearized form of pseudo-first order, pseudo-second order, Elovich, and Intra-particles (Equations 6,7,8,9), respectively were used for the analysis of the kinetic data:

$$\ln(q_e - q_t) = \ln(q_e) - k_1 t \quad (6)$$

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (7)$$

$$q_t = \frac{1}{\beta}\ln(\alpha\beta) + \frac{1}{\beta}\ln(t) \quad (8)$$

$$q_t = k_{IP} t^{0.5} + C_{IP} \quad (9)$$

Where k_1 and k_2 are the rate constants of pseudo first-order and pseudo-second-order respectively, while k_{IP} is the rate constant of intraparticle diffusion. C_{IP} denotes effect of boundary layer thickness, α and β are the Elovich constants that correspond to the rate of adsorption at zero coverage and the extent of surface coverage apiece, and represent the adsorption capacity at equilibrium and at time t.

3. RESULTS AND DISCUSSION

3.1 Characterization of Synthesized Carbon Dots

FTIR, XRD, and SEM methods were employed to depict the produced carbon dots adsorbent. The carbon dots' functional groups were analyzed and identified using the FTIR method, which was also employed to evaluate chemical structural changes that occurred after adsorption. In Figure 1, the spectra are shown. The regular absorption peaks at 3250 and 3257 cm^{-1} indicate that the synthesized sample of fish scale carbon dots contains carboxylic group (COO–), which is indicated by the in-plane twisting swing of O–H groups and stretching. The O-H group could act as π-electron acceptors for FCD during LEV sequestration [19]. The absorption band at 2937 and 2963 cm^{-1} are related with the C-H stretching group [20]. The presence of amino-containing groups, which is necessary for streptavidin conjugation, is indicated by the peak at 2117 cm^{-1} that is attributed to –C–N. The peak at 1625 cm^{-1}, corresponds to the C=O stretching vibrations carboxylate group [21]. The peak at 1021 and 1028 cm^{-1} is related to the stretching swings of the C–O stretching of primary alcohol groups inside the FCD, while the characteristic IR vibrations at 1598 cm^{-1} and 1408 cm^{-1} are allocated to the C=C and tertiary C=N stretching vibrations, apiece [22]. The FT-IR spectra of the produced fish scale carbon dots provide evidence of the presence of amino (N–H), carboxyl (COO–), aryl (C_6H_5), and hydroxyl (OH) groups on the surfaces of the FCDs.

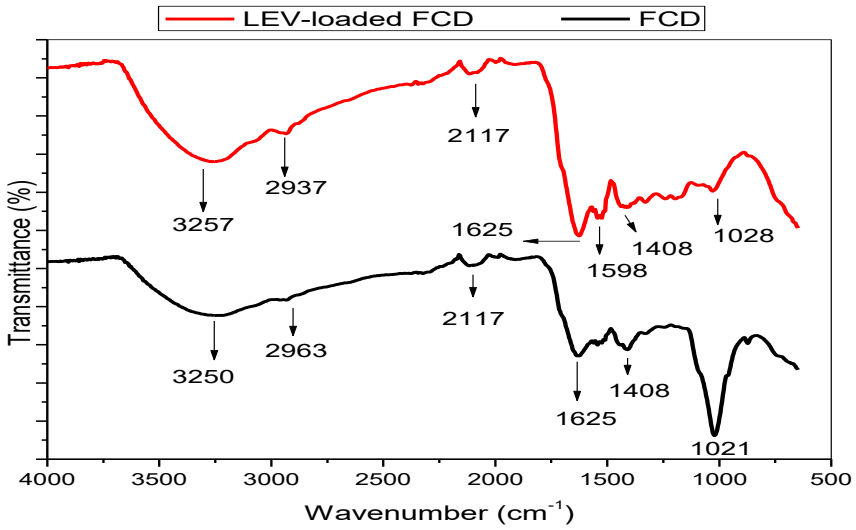


Figure 1: FTIR spectra of the synthesized FCD and LEV-loaded FCD

The X-Ray Power Diffraction is used to ascertain the mineral structure of the synthesized FCD and LEV-loaded FCD is depicted in Figure 2. Figure 2 displays peaks around 21.03 and 29.02° are corresponding to polymeric material and hydroxyapatite respectively. Athinarayanan [23] documented comparable findings on the production of carbon nanodots and hydroxyapatite nanoparticles from fish scale for use in biomedical applications. The peak at 29.02 for the FCD correspond to the (002) crystal plane where (002) denotes graphite (sp^2) like carbon. This is an indication that the FCD synthesized is largely crystalline [24]. LEV-loaded FCD diffraction pattern shows deviation and notable changes compared to FCD spectrum before LEV sequestration. Most of the peaks around 37.05, 50.62 and 60.89 were reduced or disappeared completely after LEV uptake process. This suggests there is strong interaction between the FCD biosorbent and the antibiotic.

SEM (scanning electron microscopy) images of the FCD and LEV-loaded FCD composites are displayed in Fig. 3. The picture of the unloaded FCD solids revealed a non-uniform and rough surface (Fig. 3(a)). A significant change in the structure of FCD is observed following the sequestration of LEV antibiotics (Fig. 3(b)). The cloud of LEV molecules that appears to be filling the empty pores is likely evidence of the circumscribed concentration of LEV bound and the heterogeneous distribution of polar functional groups on the FCD composite surface.

3.2 The Model Fitting and Statistical Analysis

Central composite design (CCD) structure combined with the experimental, predicted, and residuals in the LEV sequestration by FCD served as the basis for the optimization experiments that were carried out for levofloxacin uptake from liquid phase environments. A summary of the results obtained at various experimental conditions is presented in Tables 2. The removal efficiency ranged from 54.53% to 98.58%. Regression analysis was used to relate the association between the independent parameters and the response, bringing about a quadratic model expressed as equation 10.

$$\%Removal = 78.97 + 3.86A - 16.10B - 0.6271C - 0.3687AB - 1.45AC + 0.8762BC - 4.43A^2 - 2.68B^2 + 6.80C^2 \quad (10)$$

Here, *A*, *B*, and *C* represent the real independent variables values which include FCD dosage, initial LEV concentration and contact time, respectively. The experimental data of the normal distribution and correlation coefficient R^2 between the actual and predicted values for % LEV removal are key speculation taken into consideration for statistical analysis. The typical likelihood and normal probability plot for studentized residuals are shown in Figures 4a and 4b, respectively. The

residual distribution is regarded as normal if the experimental data are linear [25]. It is clear that the experimental points for LEV entrapment processes are on the normal line, regularly distributed, and free of outliers. The calculated correlation coefficient R^2 between the experimental and predicted values for LEV entrapment was 0.9533, meaning that the model could account for only 4.67% of the response's overall variation.

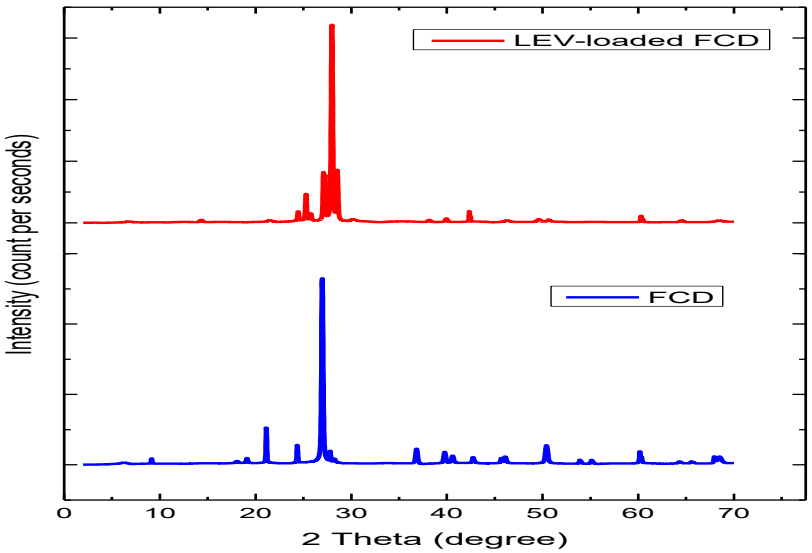


Figure 2: X-Ray power diffraction of the synthesized FCD and LEV-loaded FCD

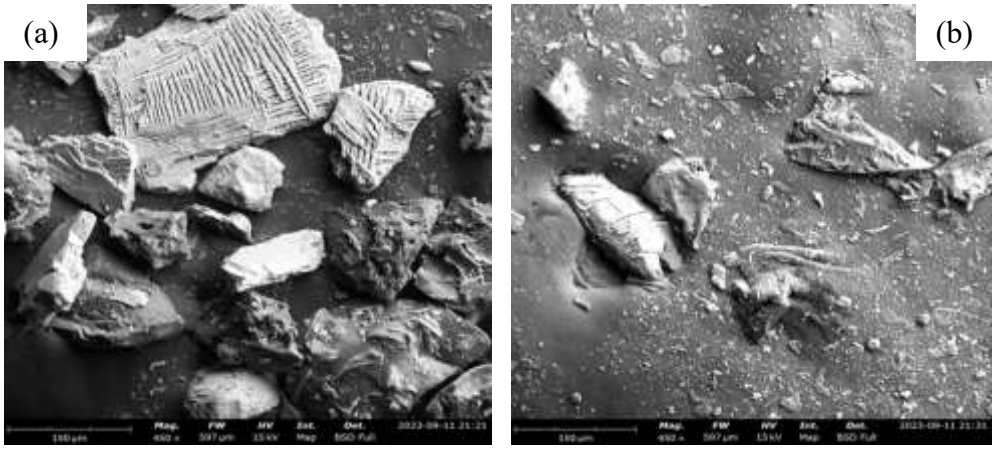


Figure 3**:** The scanning electron microscopy of (a) FCD before adsorption (b) FCD after adsorption

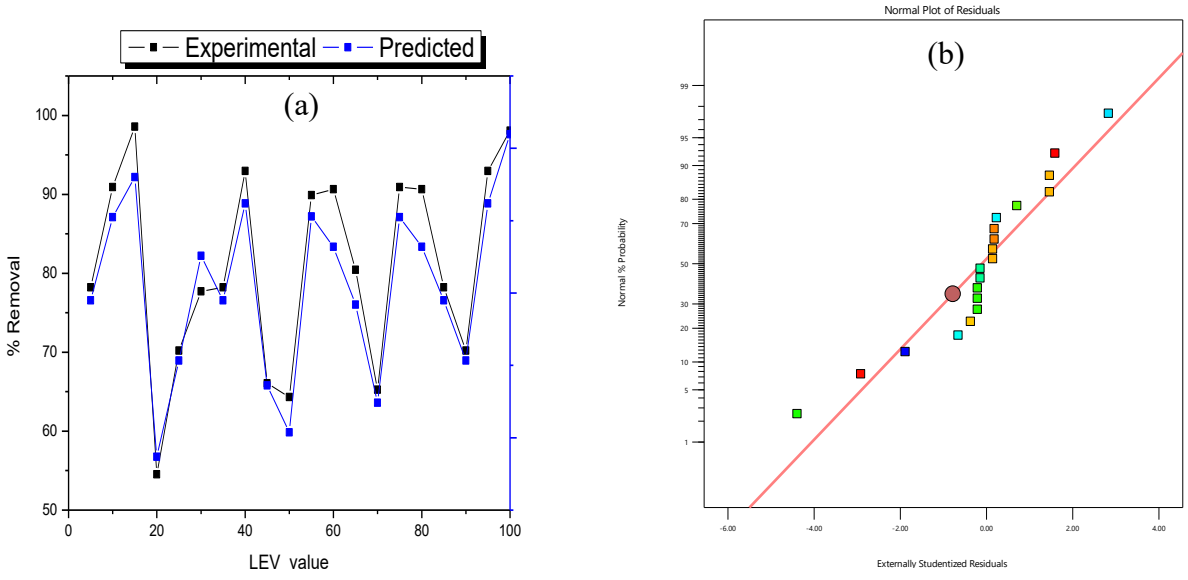


Figure 4: (a) Experimental vs Predicted value and (b) normal probability plot of residuals for % LEV Removal

Table 2: Experiment design of experimental and predicted results on LEV removal

	A: FCD dosage	B: Concentration	C: Reaction time	Removal extent (%)		
Run	G	mg/L	Min	Experimental	Predicted	Residual
1	0.15	30	45	78.22	78.97	-0.7460
2	0.1	10	60	90.91	90.47	0.4401
3	0.2	10	60	98.58	96.03	2.5500
4	0.1	50	30	54.53	57.36	-2.8300
5	0.1	30	45	70.21	70.68	-0.4659
6	0.15	30	60	77.71	85.13	-7.4200
7	0.15	30	45	78.22	78.97	-0.7460
8	0.15	10	45	92.95	92.39	0.5595
9	0.2	50	30	66.07	67.23	-1.1600
10	0.1	50	60	64.33	60.75	3.5800
11	0.1	10	30	89.89	90.58	-0.6941
12	0.15	30	30	90.66	86.39	4.2700
13	0.2	30	45	80.44	78.39	2.0500
14	0.2	50	60	65.25	64.84	0.4143
15	0.1	10	60	90.91	90.47	0.4401
16	0.15	30	30	90.66	86.39	4.2700
17	0.15	30	45	78.22	78.97	-0.7460
18	0.1	30	45	70.21	70.68	-0.4659
19	0.15	10	45	92.95	92.39	0.5595
20	0.15	10	30	98.07	101.93	-3.8600

3.2.1 Results of the analysis of variance

As demonstrated by the ANOVA analysis in Table 3, the p-value allows one to observe the significance value of each factor as well as the interaction between factors. The p-value designate each factor's significance value as well as the interaction between the factors. The connected factors are verified to have a significant impact on the answer if the absolute probability p-value displays a coefficient less than 0.05, indicating that the results have a confidence level of at least 95%. The F-value's model of 22.68 shows that it is substantial. The tendency of noise being the origin of this type of large F-value is 0.01%. Model terms of P-values less than 0.0500 are regarded significant. In this case, A, B, and C^2 represent the key model terms. Any value that is greater than 0.1000, rendered the model terms irrelevant. Adequate precision is employed to measure the signal to noise ratio. One prefers a ratio higher than 4. 16.658, the ratio, shows that the signal is sufficient. One way to channel the design space is with this suggested model.

Table 3: ANOVA table showing efficiency of LEV removal using FCD

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	2921.62	9	324.62	22.68	< 0.0001	significant
A	167.53	1	167.53	11.70	0.0065	
B	2312.62	1	2312.62	161.56	< 0.0001	
C	4.46	1	4.46	0.3116	0.5890	
AB	1.17	1	1.17	0.0817	0.7808	
AC	17.99	1	17.99	1.26	0.2885	
BC	6.60	1	6.60	0.4613	0.5124	
A^2	64.11	1	64.11	4.48	0.0604	
B^2	20.15	1	20.15	1.41	0.2628	
C^2	153.79	1	153.79	10.74	0.0083	
Residual	143.14	10	14.31			
Lack of Fit	143.14	4	35.79			
Pure Error	0.0000	6	0.0000			
Cor Total	3064.76	19				

R^2= 0.9533; Adjusted R^2 = 0.9113; Predicted R^2 = 0.7570; Adeq. Precision = 16.658

The interactions between the variables were ascertained and the ideal amount of LEV to produce the maximum adsorption value was confirmed by the use of a graphical representation of the response surface method for the percentage removal of antibiotics in respect to the three factors. The surface plots of the LEV strength vs the starting concentration, FCD dosage, and contact time are displayed in Figure 5. The impact on the LEV sequestration process of the following factors: FCD dosage and contact time at constant concentration, initial concentration and contact time at constant FCD dose, and adsorbent dosage and initial concentration at constant reaction time. An increase in FCD dose and decrease in concentration increase the % removal of LEV. As the FCD dose increases, reaction time decreases, and the adsorption rate increases. Also, the percentage removal of FCD increases at lower concentration and high reaction time.

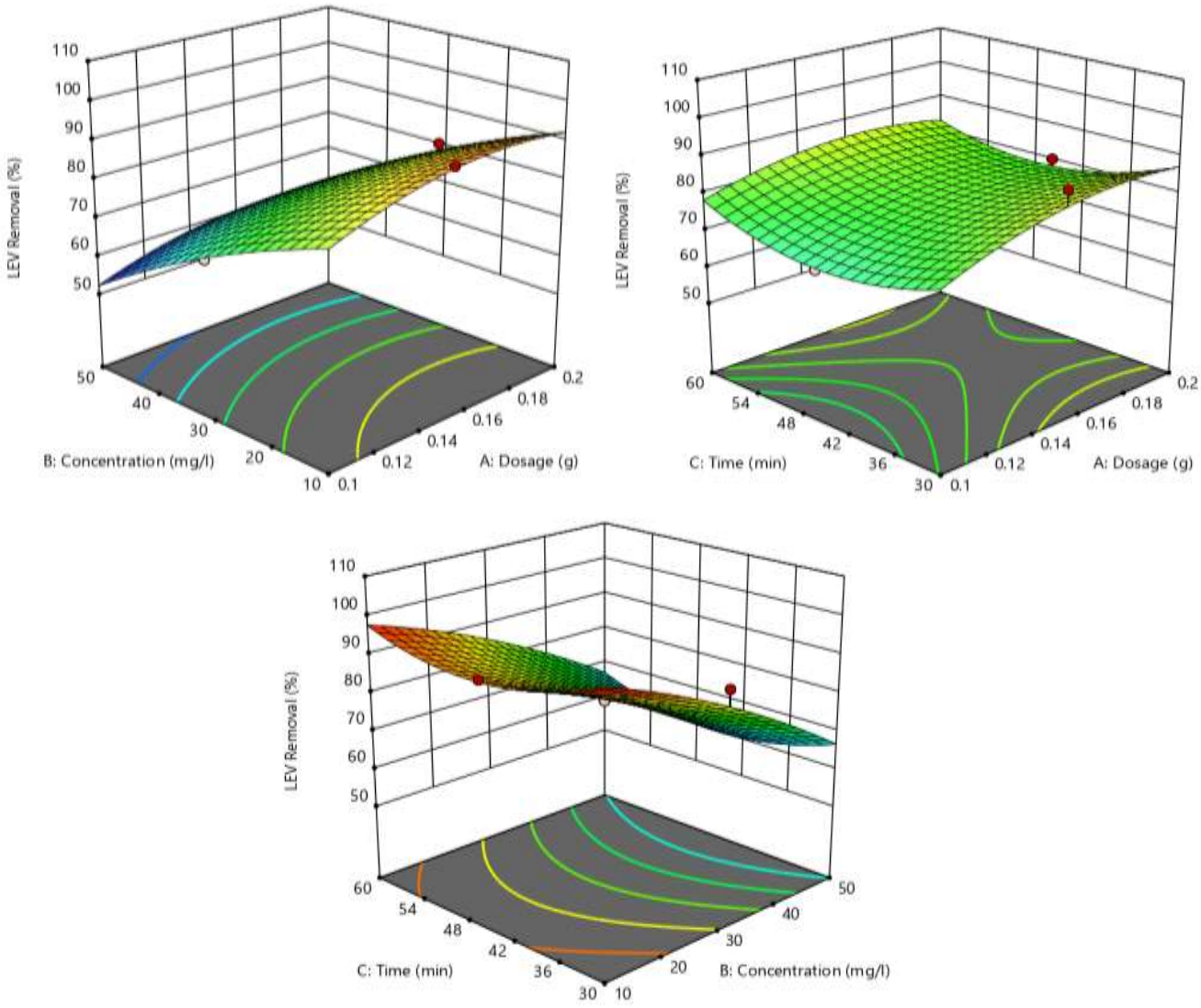


Figure 5: Three-dimensional response surface plot for % removal of Levofloxacin antibiotic as a function of initial concentration, FCD dose, and contact time.

3.2.2 Optimization condition of LEV sequestration process

Finding the ideal circumstances to maximize the LEV removal efficiency (R (%)) of FCD adsorbent is the primary goal of the current investigation. In order to achieve the maximum suitability function, Design-Expert software's numerical optimization menu was used to set the pH in range, FCD dosage in range, LEV concentration in ranges, and removal efficiency maximize. Figure 6 presents the desirability function and the optimal value of each variable. As it is seen, at the 60 minute's time, 0.2 g of FCD dosage, LEV concentration of 10 mgL^{-1} and removal efficiency of 96.03% were found to be optimum conditions for levofloxacin uptake. The desire function of 1.00 demonstrated favorable conditions for LEV removal by FCD adsorbent and supported the usefulness of the response surface methodology for determining ideal conditions and this is in accordance with [26].

To validate the model, replicate experiments were conducted in the laboratory under the projected optimal condition.

The optimum conditions for LEV were 10 mg/L of initial concentration, 0.2 g of FCD adsorbent dosage at 60 min with the predicted removal percentage of 96.028%. The experimental removal percentage of LEV (95.79%) was satisfied with the predicted LEV removal percentage of 96.028% with 0.238% error. This result reveals the suitability and validation of quadratic polynomial model adopted in optimising the sequestration of LEV antibiotic.

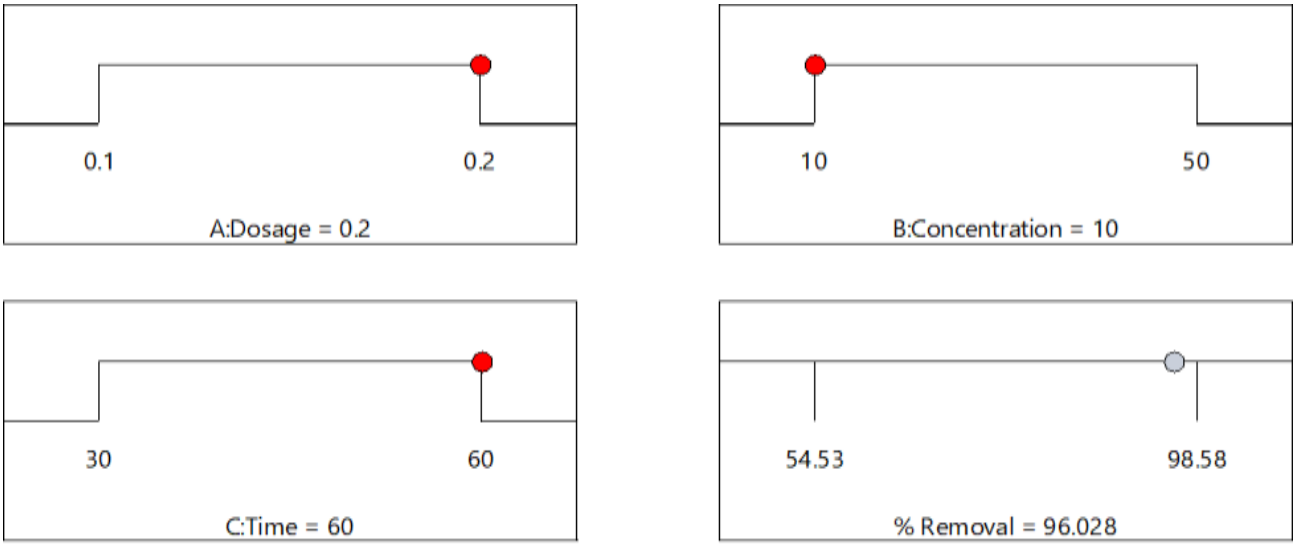


Figure 6: RSM design plot of optimal conditions for LEV sorption

3.3 Adsorption Equilibrium and Kinetic Analyses

The equilibrium study to determine the connection between the interactions between the FCD adsorbent and levofloxacin molecules, was analysed using three isotherms' models (Langmuir, Freundlich, Redlich-Peterson model). Figure 7 shows the Langmuir, Freundlich, and Redlich-Peterson isotherms plots representation of LEV adsorption. For the studied temperatures of 25^{o}C, the linear and nonlinear model parameters were estimated from slopes and intercepts of respective plots. The correlation coefficient (R^2), and other isotherm parameters procured from the fitting curves of the Langmuir, Freundlich, Redlich-Peterson models are shown in Table 4.

The Langmuir model is better suited to explain adsorption isotherms than the Freundlich model from the result. The outcomes demonstrate the single layer coverage of the adsorption film and the uniformity of the adsorbent. On the contrary, the total FCD capacity for LEV adsorption is the definition of the greatest single layer adsorption capacity, or qm. Furthermore, the entrapment process of LEV is advantageous when the intensity (n) value of adsorption is higher than 1 [24]. The Redlich-Peterson model, which has the largest R-square values, is the most appropriate isotherm for liquid phase LEV uptake. The Redlich-Peterson model which describes a hybrid homogeneous and heterogeneous system of adsorption makes the most plausible reason for the LEV antibiotic's sequestration in this investigation.

Significantly higher adsorption efficiencies are demonstrated by the produced FCD adsorbent, than other adsorbents as presented in Table 5, particularly for the removal of LEV. Contingent on the type of precursor and the experimental conditions employed, there may be discrepancies in the maximum adsorption capacity values reported by other reported investigations.

Table 4: Equilibrium parameters on removal of levofloxacin onto carbon-dot

Antibiotic	**Isotherm Models**					
	Langmuir		**Freundlich**		**Redlich-Peterson**	
Levofloxacin	q_m (mg.g^{-1})	4.23	K_F (L.g^{-1})	1.2250	K_{RP} (L.g^{-1})	1.2252
	K_L (L.g^{-1})	0.3120	N	3.023	α	1.0002
	R_L (L.mg^{-1})	0.1931			β	0.6692
	R^2	0.9600	R^2	0.9560	R^2	0.9930

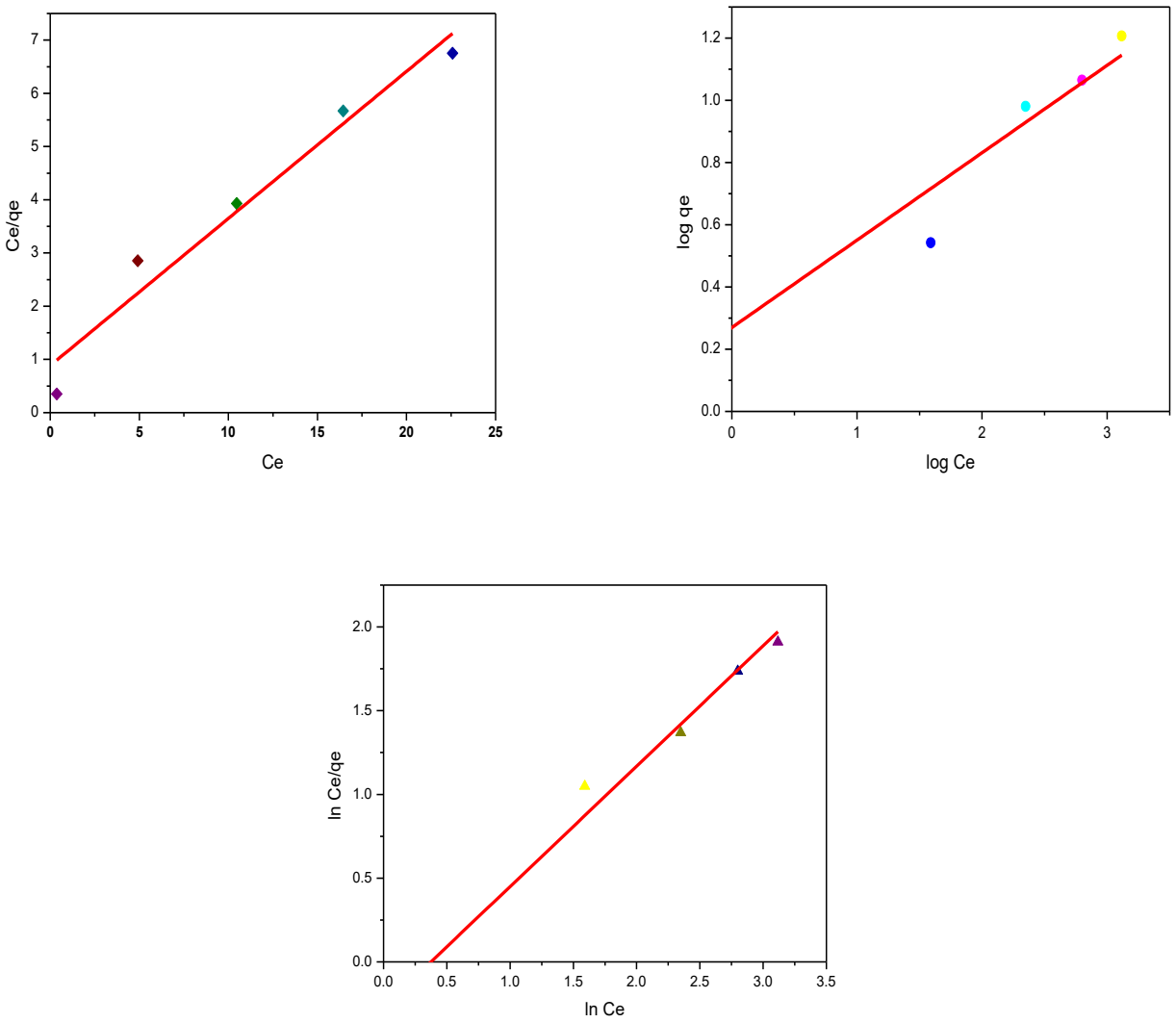


Figure 7: Adsorption Isotherm for Levofloxacin (a) Langmuir, (b) Freundlich, and (c) Redlich-Peterson

Table 5: Comparison of maximum adsorption capacity of various adsorbent for LEV

Adsorbent	Experimental conditions	Contact time (min)	Removal efficiency (%)	q_m (mg.g^{-1})	References
FCD	C_o = 10 mg/L, pH = 4, 0.2 g/L dose	60	96.03	4.23	Current study
Chitosan-walnut shells composite (Ch-W)	C_o = 4 mg/L, pH = 7, 0.5 g/L dose	45	75.7	7.43	[27]
	C_o = 2 mg/L, pH = 7, 0.5 g/L dose	45	94.2	3.77	
Green magnetic nanoparticle (Fe_3O_4)	C_o = 4 mg/L, pH = 7, 0.1 g/L dose	1440	86.15	22.47	[28]
Chemical magnetic nanoparticle	C_o = 4 mg/L, pH = 6.5, 0.1 g/L dose	240	80.2	6.09	
Zn@polyaniline/bentonite composite	C_o = 10 mg/L, pH = 8, 0.5 g/L dose	30	41.4	9.6	[29]
Mesoporous iron oxide nanoparticles	C_o= 10 mg/L, pH = 7.5, 0.4 g/L dose	10		33.10	[30]

The removal rate, the mechanism of adsorption, and the rate-determining phase were all investigated by an evaluation of the kinetic study of the process adsorption. The results of kinetic model for LEV adsorption with Pseudo-first order, Pseudo-second order, Elovich, together with intra-particles, are displayed in Figure 8 and model constants are summarised in Table 6. The discoveries are in good accord with the pseudo-second order kinetics, as evidenced by the great agreement between the estimated and experimental qe values. The highest R^2 value, nearly 1.00, was achieved for the pseudo-second order kinetics model, confirming the model's applicability and raising the possibility that LEV is absorbed by FCD by chemical adsorption. This is because valence forces are created when adsorbents and adsorbates share or exchange electrons. The elimination of the LEV may be accredited to the existence of multiple binding sites in the FCD, such as carboxylate, and hydroxyl groups, which can interact with it through hydrogen bonding and electrostatic contact. A multilayer adsorption is implied by correlation coefficient whose values greater than 0.9, indicates that the Elovich model also suit the experimental data ably. Besides, lower values of β than α support the model's feasibility and show that the adsorption rate was higher than the desorption rate [31]. Based on R^2 values, the intraparticle diffusion model was unable to produce a satisfactory match, even though the CIP's positive values suggest surface adsorption and a quicker starting rate (Table 6).

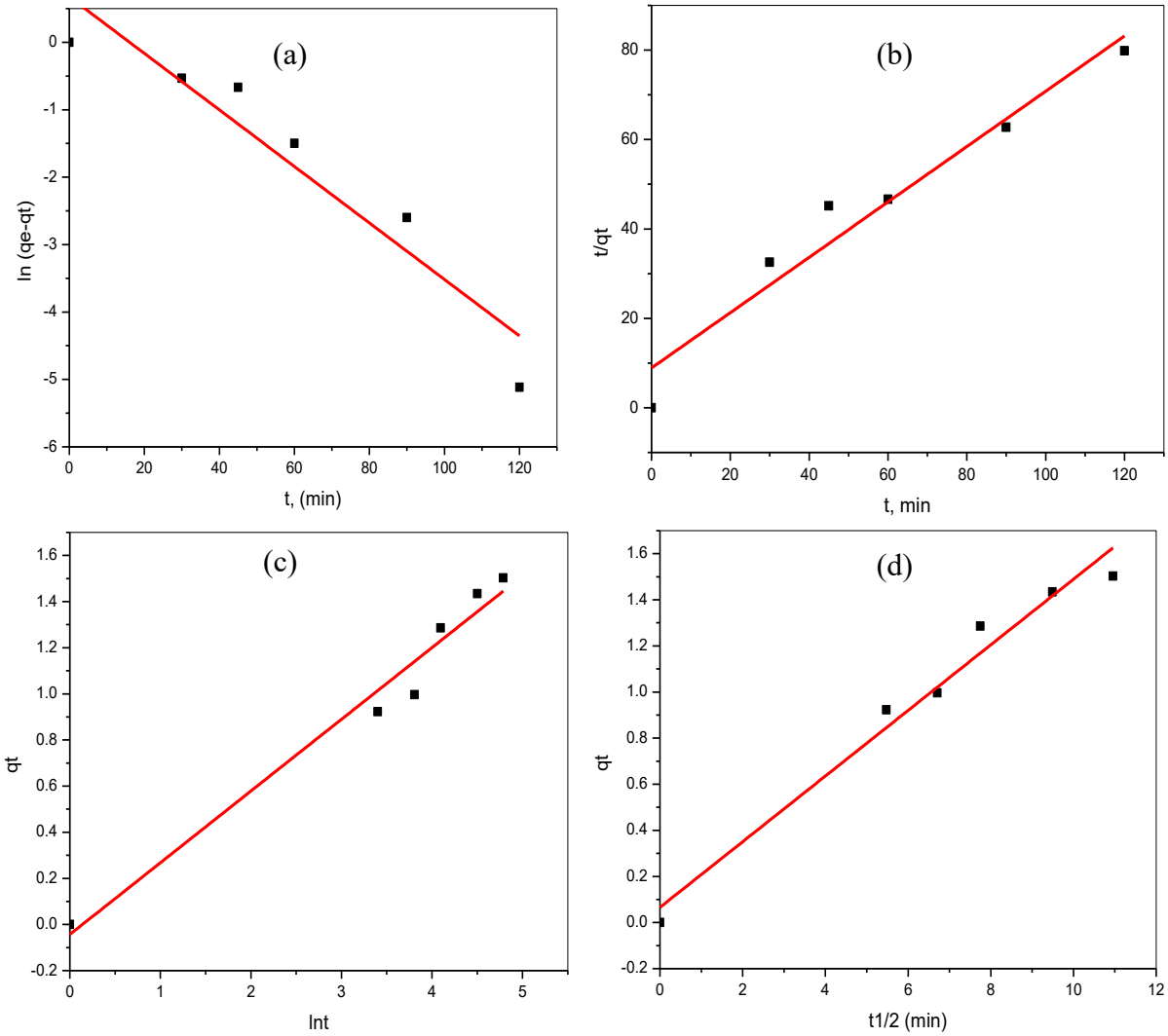


Figure 8: Kinetics model of Levofloxacin (a) PFO, (b) PSO, (c) Intra particle (d) Elovich

Table 6: Kinetic parameters for the removal of levofloxacin onto FCD

Kinetic Models							
PFO		**PSO**		**Elovich**		**IPD**	
$q_{e,1}$(mg.g^{-1})	1.96	$q_{e,2}$ (mg.g^{-1})	1.62	a(mg.g^{-1}.min^{-1})	3.2165	C (mg.g^{-1})	0.0658
k_1 (min^{-1})	0.0419	k_2 (g. mg^{-1}.min^{-1})	0.0431	b (g.mg^{-1})	0.2706	k_{id} (mg.g^{-1}.min^{-1})	0.1424
R^2	0.9348	R^2	0.9787	R^2	0.9439	R^2	0.9414

4. CONCLUSION

In this work, fish scale was utilised as precursor biomass for carbon dots preparation using a hydrothermal process. The synthesized fish scale carbon dot (FCD) was tested for adsorption of levofloxacin (LEV) from the aqueous solution. Response surface methodology (RSM) was utilized with central composite design to anticipate that FCD would display a high removal efficiency of 96.03% at 10 mg/L concentration of LEV with 0.2 g of FCD after 60 minutes. The defined ideal conditions for LEV antibiotic were ascertained accurate with a 0.23% error rate based on both predicted and experimental findings. The maximum Langmuir sorption capacity was 4.37 mg/g, and the Redlich-Peterson isotherm model parameters best fit the experimental results. Experimental data on kinetics fit a pseudo-second order model. Also, the FCD biosorbent that was synthesized showed promise in effectively removing LEV from a liquid phase environment. The results demonstrated that FCD was an extremely promising substitute adsorbent for treating wastewater that contained antibiotics.

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