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USE OF NOVEL BIOSORBENT MIMUSOPS ELENGI FOR REMOVING ZINC IONS FROM AQUEOUS SOLUTIONS - PROCESS OPTIMIZATION USING CENTRAL COMPOSITE DESIGN

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ABSTRACT

The main target of the study was to optimize biosorption for the expulsion of zinc metal ions from the aqueous solutions using Mimusops elengi leaves as a proficient and cost-effective biosorbent. The impact of imperative parameters pH, metal concentration and biosorbent dosage was explored and the operating conditions were optimized using response surface methodology (RSM) taking into account a central composite design (CCD). A batch investigation of biosorption was performed at pH 5, concentration 20 mg/L, biosorbent dosage 0.1 g and temperature 303 K at an agitation time of 180 min. The optimal conditions for zinc biosorption were studied. A most extreme of 77.05 % of zinc was recouped under the ideal exploratory conditions. The proposed model using RSM has indicated a correlation coefficient, R^2 of 0.99. Experimental data were considered utilizing five isotherm models. Langmuir isotherm with a correlation coefficient of 0.992 was fitted well with the observational data.

Keywords: Zinc, biosorption, Mimusops elengi, Central Composite Design (CCD), correlation coefficient.

INTRODUCTION

The modern era of increasing consumerism has contributed to the establishment of various industries which resulted in pollution of the aquatic environment with heavy metals. These heavy metals are not biodegradable and are therefore bioaccumulated[1]. The heavy metals that are recognized as hazardous are cadmium, lead, nickel, copper, mercury, chromium and zinc[2]. Among all these heavy metals, zinc is taken care, because it plays an important role as an essential element for growth and metabolism of living organisms at certain concentrations. If the concentration exceeds beyond the required amount of biological functions, it may become toxic. According to World Health Organization (WHO), the acceptable concentration of zinc in drinking water is 3.0 to 5.0 mg/L[3]. Zinc present in excess may lead to health problems like respiratory distress syndrome, coughing, a decrease in oxygen uptake efficiency nausea, prostate cancer, neuronal death, etc.[4]

Many conventional methods such as chemical precipitation, conventional coagulation, reverse osmosis, ionic exchange, membrane based separation and carbon adsorption are available for the removal of zinc metal ions from the aquatic environment but are not cost effective[5]. The upcoming research for the use of ecofriendly and cost effective methods such as biosorption have proved that use of biological materials for the removal of heavy metals is one of the best alternative method[6]. These biosorbents have a metal sequestering property which can be utilized in the reduction of heavy metal ion concentration from part per million (ppm) to parts per billion (ppb) level in the aquatic solutions[7]. Extensive investigation has been done on the removal of heavy metals using biosorption. Published reviews on heavy metal biosorption focus on different aspects like the selection of biosorbent which is ecofriendly and cost effective, mechanism involved in the biosorption and large-scale experiment[8-17].

In the present study, the capability of Mimusops elengi was investigated for the expulsion of zinc metal ions from aqueous solutions. The impacts of different experimental parameters on the biosorption limit of Mimusops elengi were concentrated. Also, a few isotherms, were evaluated to comprehend the component included. The work additionally expected to survey the effects of independent variables such as pH, metal ion concentration and biosorbent dosage to distinguish the ideal conditions utilizing a central composite design (CCD).

EXPERIMENTAL

Preparation of the biosorbent

The leaves of Mimusops elengi were procured from the garden of GMRIT, Rajam, Andhra Pradesh, INDIA. The leaves were washed thoroughly with deionised water to get rid of soil and impurities The washing process was practiced till the wash water has no hints of soil specks. The fresh leaves were then completely dried in sunlight for about 10 days. The dried leaves were then powdered using a domestic mixer grinder. In the present study the powdered materials in the range of 75-212 µm average particle size were then directly used as biosorbents without any pre-treatment.

Batch biosorption procedure

Biosorption studies were carried out for 3 hours at an agitation speed of 180 RPM in a continuously stirred conical flasks containing 100 ml of zinc solution. After shaking, the samples were withdrawn at suitable time intervals and then analyzed for zinc concentration with AAS (GBC Avanta Ver 1.32, Australia) at a wavelength of 213.9 nm, slit width 0.2 nm and lamp current 5.0 mA for zinc. The zinc uptake capacities were calculated using a standard mass balance equation-

$$q_e = \frac{V(C_i - C_f)}{1000\, w} \qquad (1)$$

Experimental design

The work is focused on CCD for the optimization of parameters for zinc absorption onto Mimusops elengi as well as the determination of the significant single factors, interactions and quadratic terms using statistical analysis computer software with three factors is applied using STATISTICA 6.0. The design consisted of 16 runs performed twice to optimize the levels of parameters: pH of the solution, initial zinc concentration in the solution (C_o) and biosorbent dosage (w) of the solution. The scope of the variables was chosen based on preliminary observations.

Equilibrium Studies

Langmuir, Freundlich, Redlich and Peterson (R–P), Temkin and DubbinineRadushkevich (D-R) are the important isotherms that were applied to analyze the data and also anticipate the potential and biosorption capacity of the biosorbent used.

RESULTS AND DISCUSSION

The effect of contact time

The effect of contact time on zinc uptake capacity by Mimusops elengi was given in Fig. 1. Equilibrium was reached in 3 h for zinc and this contact time was more than enough to achieve equilibrium. After the equilibrium time, zinc ions were biosorbed and there was no significant change with further increment in time.

Effect of pH

pH of the medium is a decisive parameter for the biosorption experiments [18]. The influence of pH is more on the solubility of metal ions and the concentration of the counter ions on the functional groups (carboxylate, phosphate and amino groups) of the biosorbent cell walls[7]. Figure- 2 shows the effects of the initial pH on the absorption of zinc ions in aqueous solution. Maximum biosorption capacities were obtained from 2.0 to 5.0. At low pH value of 2, the biosorption capacity for the metal ions was observed to be moderate, due to the competition between hydrogen ions and zinc metal ions at the sorption sites. As the pH value increases, the availability of negatively charged cell surfaces will be more, allowing greater metal uptake [19]. If the pH value is > 5.0, the formation of insoluble zinc hydroxide precipates suppresses the contact of metal with the biosorbent.

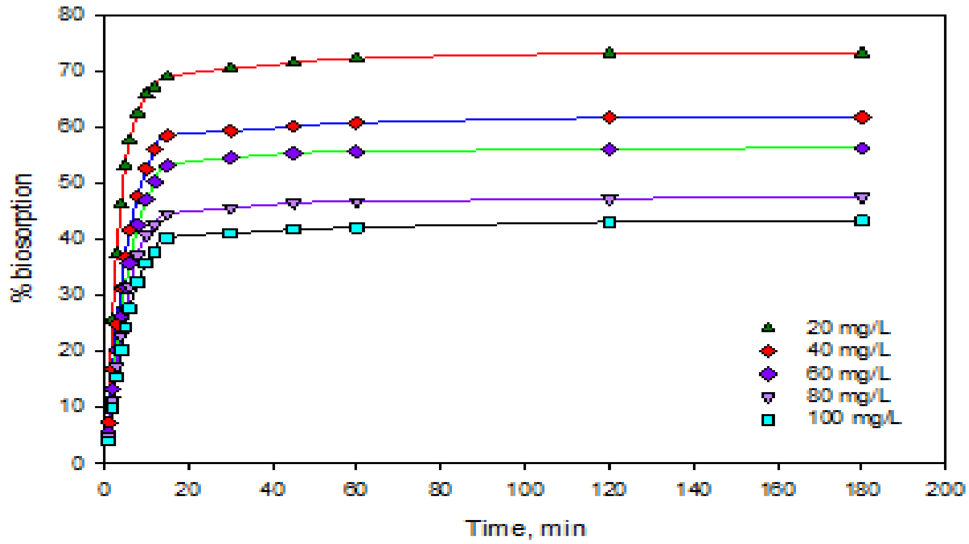

Fig.-1: Effect of contact time on biosorption of Zinc by Minusope elengi of 0.1g/ 30mL of biosorbent concentration

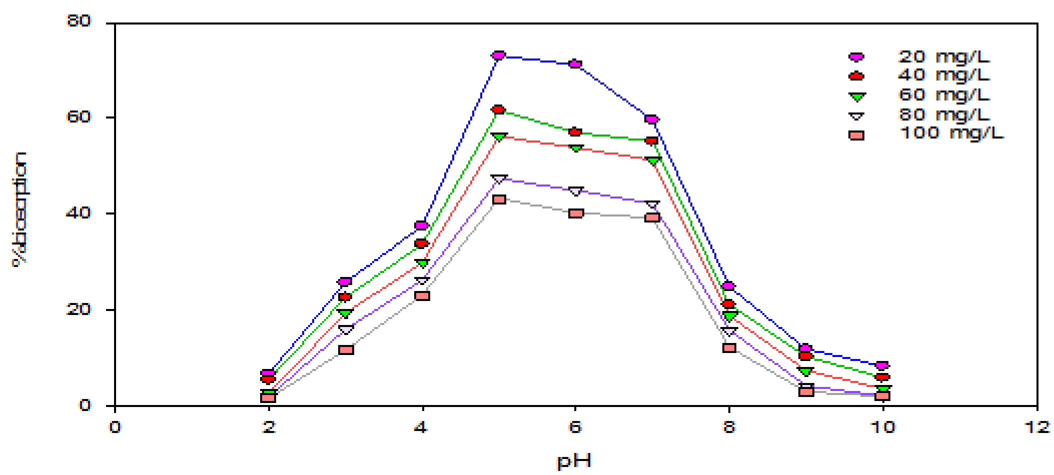

Fig.-2: Effect of pH on biosorption of Zinc by Mimusope elengi of 0.1g/30ml of biosorbent concentration

Effect of metal ion concentration

The experiments were taken out using various concentrations of zinc solution under the determined optimum pH values and contact time. The effect of zinc ion concentration was investigated in the range of 20–100 mg/L. The results are presented in Fig.-3. The zinc biosorption capacity of the biosorbent firstly increased with an increase in the initial concentration of zinc and then reached an equilibrium. Then the value did not significantly change with the initial zinc ion concentration. It was observed that with the high concentration of metal ions there is a competition between metal ions to adsorb on the active site of adsorbent because the least act of participating sites is available as compared to the metal ions. So there is a diminution in the adsorption efficiency with the increasing of metal ion concentration[20, 21].

The effect of biosorbent size

In order to examine the effect of biosorbent particle size on the removal of zinc metal ions from an aqueous solution, various sizes of 75 μm to 212 μm were introduced. Fig. 4 shows that as the biosorbent particle size increases, the charge per unit of biosorption decreases. This is because the surface area per unit volume is higher for smaller particles to increase in the binding sites and contact surfaces, which indicates that there is more rapid sorption and high mass transfer compared to the larger particles when they are used.

Effect of biosorbent dosage

Figure-5 shows the effect of biosorbent dosage on the biosorption capacity of the biosorbent Mimusops elengi. The dosage of the biosorbent added to the metal solution varied from 0.1 to 0.5 g. The quantity of zinc metal ions biosorbed per unit mass of Mimusops elengi increased with an increase in the concentration. Similar reports were also observed for zinc removal using Azadirachta indica as biosorbent[22-24].

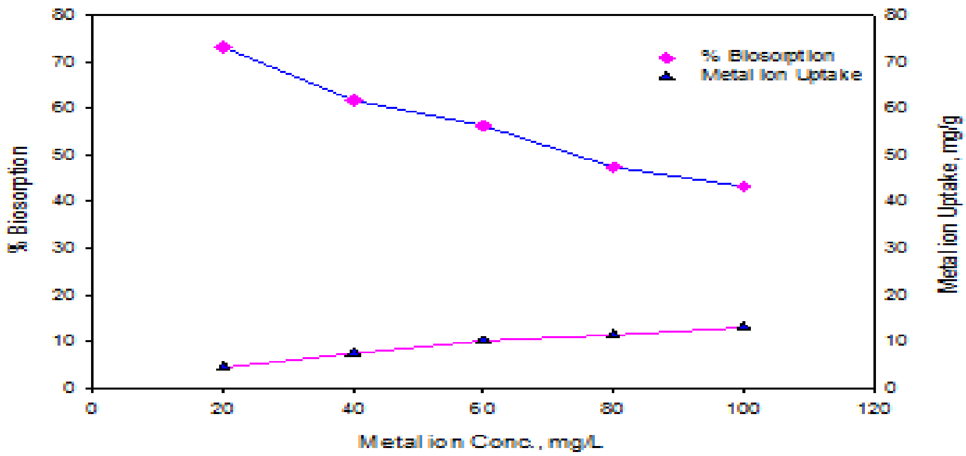

Fig.-3: Effect of metal ion concentration on biosorption capacity of Zinc by Minusope elengi of 0.1g/ 30mL of biosorbent concentration

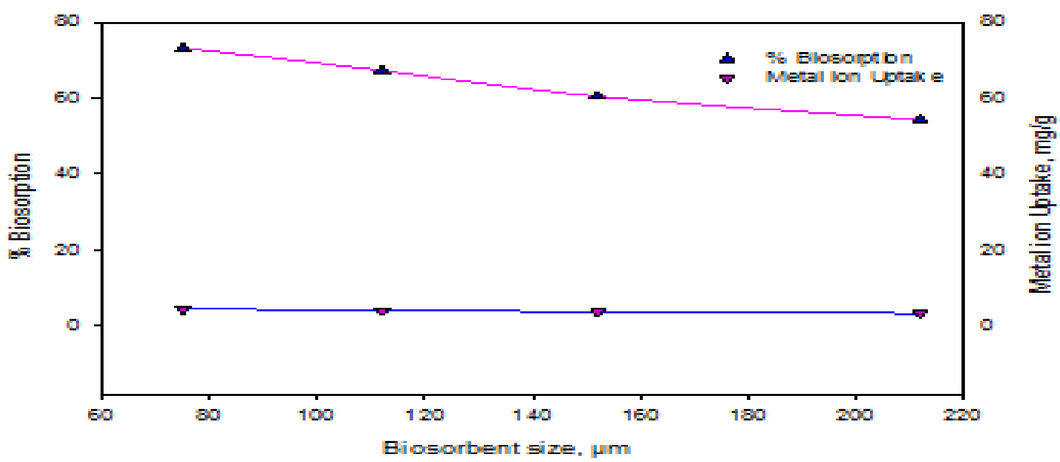

Fig.-4: Effect of biosorbent particle size on biosorption of Zinc for 20mg/L of metal and 0.1g/ 30mL of biosorbent concentration

Effect of Temperature

The equilibrium biosorption capacity of zinc onto Mimusops elengi were conducted at temperatures: 303, 313, 323 and 333 K. Results depicted in Fig.-6 shows that as the temperature increases the sorption capacity increases to a maximum value and then falls down gradually. This is because the biosorbent loses its properties at really high temperatures due to contamination [25]. From the present study also, it is reported that as the temperature increases biosorption capacity decreases.

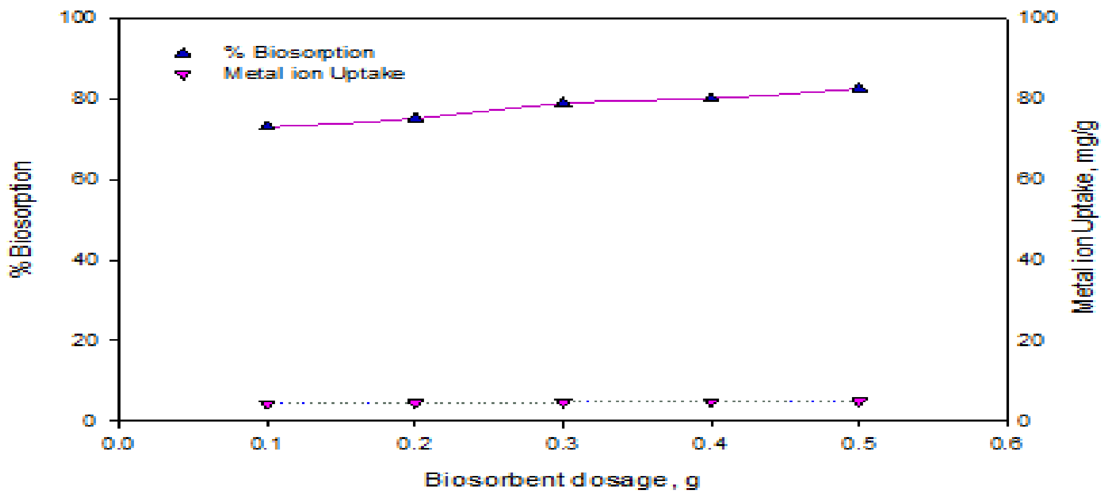

Fig.-5: Effect of Mimusops elengi dosage on biosorption of Zinc for 20mg/L of metal concentration

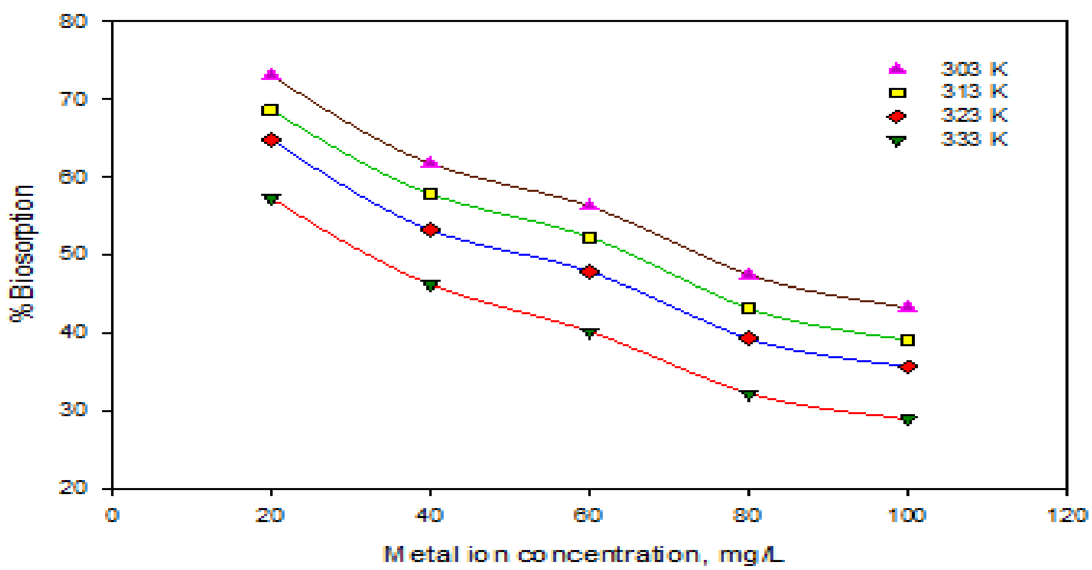

Fig.-6: Effect of temperature on biosorption of Zinc by Mimusops elengi for 0.1g/30mL of biosorbent concentration

Equilibrium Studies to fit experimental data

In this study, five isotherm models, Freundlich, Langmuir, Temkin, Redlich-Peterson (R–P) and Dubinin–Radushkevich (D–R) were used for linear regression analysis to describe (coefficient of determination, R^2) the equilibrium Zn (II) adsorbed onto Mimusops elengi.

Freundlich Isotherm

The Freundlich isotherm model assumes a heterogeneous biosorping surface and active sites with different energies [26]. The Freundlich isotherm model was picked to calculate the biosorption intensity of the sorbent towards the biosorbent. It is an empirical equation employed to describe the isotherm data given by-

$$q_{eq} = K_f C_{eq}^n \tag{2}$$

Where, Kf and n are Freundlich constants that affect the biosorption process of a system. K_f and n are an index for biosorption capacity and intensity, respectively. The slope and intercept obtained from the linear plot between *ln* q_{eq} and *ln* C_{eq} will be applied to compute the values of K_f and n [27]. The logarithmic plot gives a straight line with R^2close to unity (0.989). The value of *1/n* (0.462 g/L) and K_f (1.587 mg/g) were calculated from the slope and intercept of the straight line drawn in Fig.-7 and were tabulated in Table-1.

Table-1: Equilibrium constants for Zinc onto Mimusops elengi

Langmuir Isotherm			
$Q_{max}\,(mg/g)$	$b(L/mg)$	R^2	--
16.393	0.0601	0.992	--
Freundlich Isotherm			
$K_f\,(mg/g)$	$1/n\,(g/L)$	R^2	--
1.587	0.462	0.989	--
Redlich-Peterson Isotherm			
$A(L/g)$	$B(L/g)$	g	R^2
3.689	13.765	-0.81	0.275
Temkin Isotherm			
$A_T\,(L/mg)$	b_T	R^2	--
0.581	694.016	0.989	--
D–R Isotherm			
$K_d\,(Mol^2kJ^{-2})$	$Q_o\,(mg/g)$	R^2	$E(kJ/mol)$
0.0099	29.18	0.787	8.485

The high biosorptive capacity of Mimusops elengi at temperature 303 K and pH = 5.0 and from the values of K_f and *1/n*.

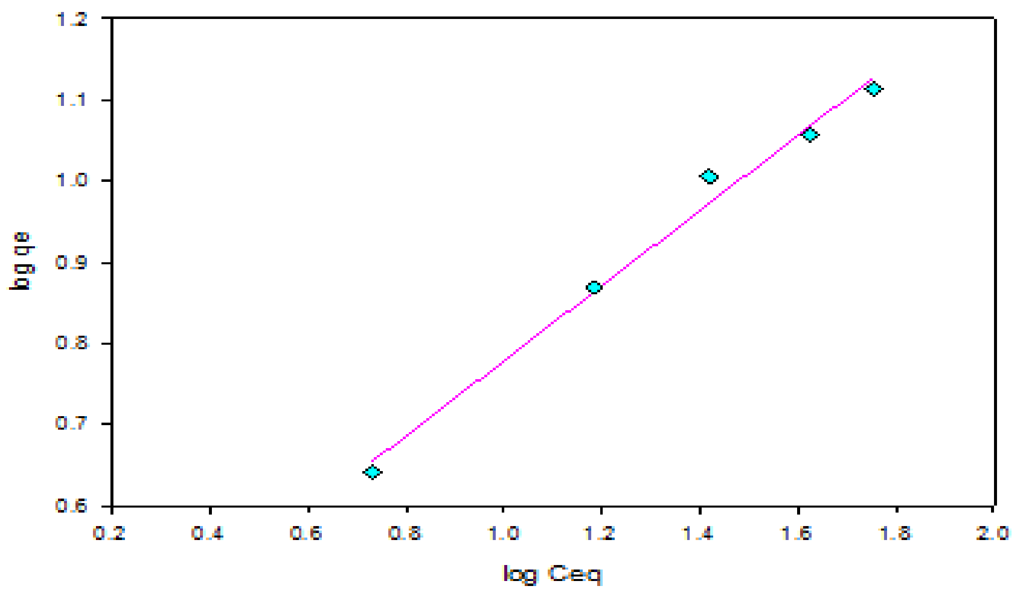

Fig.-7: Freundlich adsorption isotherms at 0.1g/30mL of biosorption concentration

Langmuir Isotherm

The Langmuir model assumes that a monomolecular layer is formed when biosorption takes place without any interaction between the adsorbed molecules[28]. The following Langmuir equation was used to analyze the data. The equation is given as-

$$\frac{1}{Q_e} = \frac{1}{Q_m} + \frac{1}{Q_m K_L}\left(\frac{1}{C_e}\right) \tag{3}$$

The Fig.-8, C_e/q_e plotted against C_{eq} gives a straight line with R^2 value 0.992 at temperature 303 K and pH = 5.0 indicating that biosorption data fitted well with the Langmuir model.

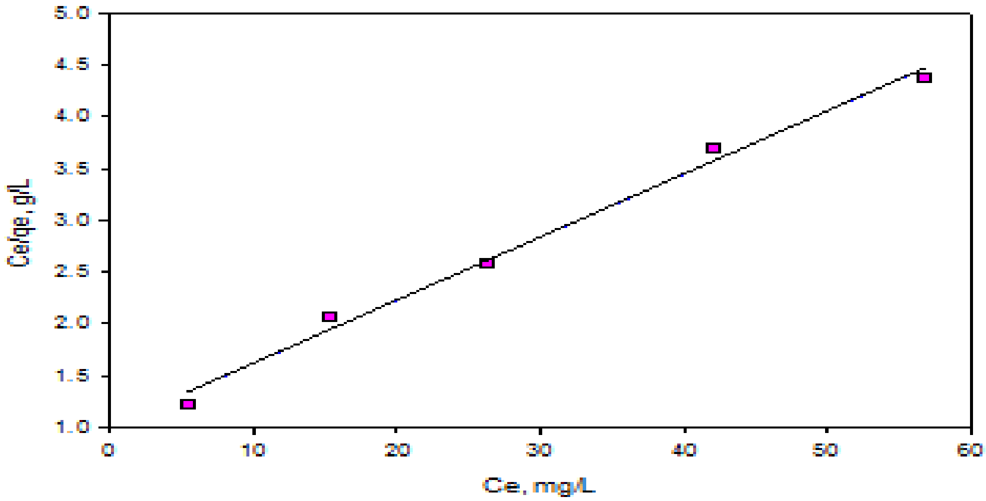

Fig.-8: Langmuir adsorption isotherms at 0.1g/30mL of biosorption concentration

The value of Q_{max} (16.393 mg/g) and b (0.0601) were derived from the slope and intercept of the linear plot respectively. The value of b is used in estimating K_R values using the equation

$$K_R = \frac{1}{1+bC_i} \tag{4}$$

Figure-9 and Table-2 gives the values of K_R at different concentrations. The estimated K_R values demonstrate that biosorption is higher at lower concentrations.

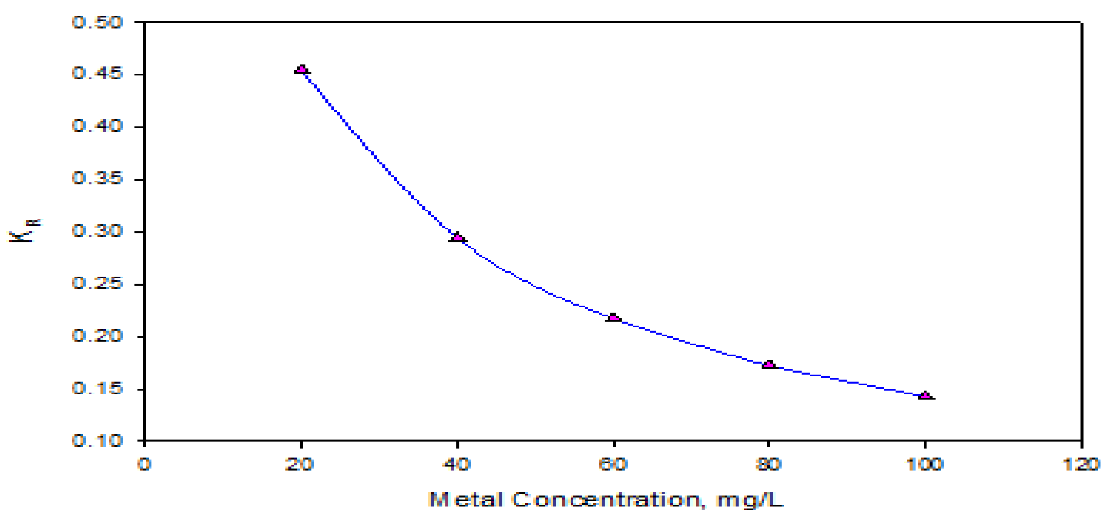

Fig.-9: Values of the separation factor, KR for the biosorption of zinc using Mimusope elengi

Table-2: K_R values at 303 K relating to the initial metal ion concentrations at pH 5.0

C_o (mg/L)	20	40	60	80	100
K_R Zinc	0.453968	0.2936	0.216995	0.172082	0.142572

Redlich-Peterson Isotherm

The R–P equation incorporated the features of the Langmuir and Freundlich isotherms and is written as a single equation.[29]

$$\ln\left(\frac{AC_e}{Q_e}-1\right)=g\ln C_e+\ln B \quad (5)$$

The plot, Fig.-10.- is drawn between $\ln\left(\frac{AC_{eq}}{q_{eq}}-1\right)$ and *ln* (C_{eq}). The estimated R-P constants and their corresponding R^2 values are shown in Table-1.

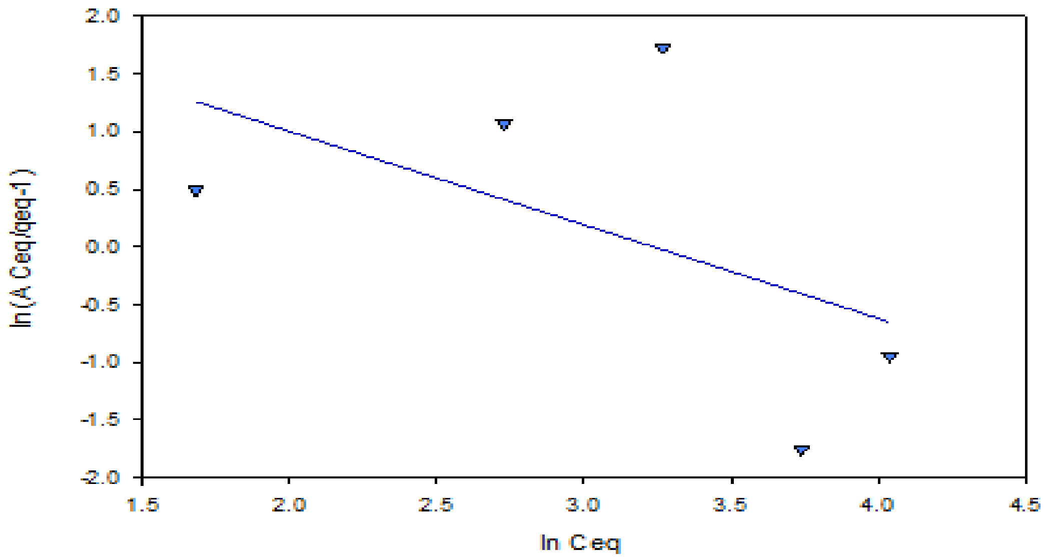

Fig.-10: Redlich-Peterson adsorption isotherms at 0.1g/30mL of biosorbent concentration

Temkin Isotherm

This isotherm takes into account the effects of indirect biosorbent-biosorbate interactions. The model presumes that the heat of adsorption of all the molecules in the layer would decrease linearly with coverage[30, 31]. The biosorption data was analyzed according to the linear form of the Temkin isotherm

$$q_e=\left(\frac{RT}{b_T}\right)\ln(A_T)+\left(\frac{RT}{b_T}\right)\ln(C_e) \quad (6)$$

The corresponding linear plots are shown in Figure-11. The linear isotherm constants and coefficients were determined from the slope and intercept and were tabulated in Table-1. From the data it is indicated that the Temkin isotherm provides a close fit to the zinc biosorption data.

D–R Isotherm

The D–R isotherm is more general than the Langmuir isotherm and is applied to express mechanism of biosorption with a Gaussian energy distribution onto a heterogeneous surface[32, 33]. It is also applied to

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distinguish the nature of biosorption as physical or chemical[34]. The D–R equation is obtained from the following relationship:

$$q_e = q_o e^{-K_d \varepsilon^2} \tag{7}$$

where q_e is the measure of the metal ions adsorbed at the equilibrium conditions, K_d identified with the mean free vitality of sorption, q_o is the infusion capacity obtained from the theoretical data, and ε is the Polanyi potential. The values of q_m and K_d can be obtained by plotting ln q_e versus ε^2.The mean free energy of adsorption (E), defined as the free energy change when one mole of ion is transferred from infinity in solution to the surface of the solid, was calculated from the K value using the following relation-[35, 36]

$$E = \frac{1}{\sqrt{2K_d}} \tag{8}$$

Where, K_d is expressed as the isotherm constant. ε can be computed using the following equation-

$$\varepsilon = RT \ln\left(1 + \frac{1}{C_e}\right) \tag{9}$$

Where R, T and C_e are the gas constant (8.314 J/mol K), absolute temperature (K) and biosorbate equilibrium concentration (mg/L), respectively.

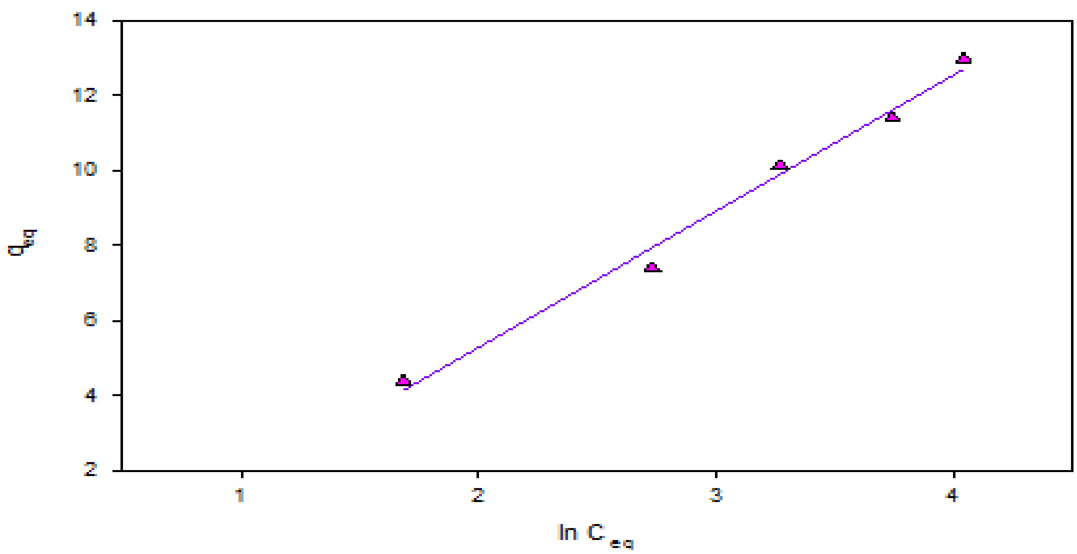

Fig.-11: Temkin adsorption isotherms at 0.1g/30mL of biosorbent concentration

The mean adsorption energy and the isotherm constants were tabulated in Table-1. E value was obtained as 8.485 kJ/mol for zinc and found that the biosorption process takes place through chemical ion-exchange mechanism. Similar observations were reported in other studies[37-39]. This explains that at low temperature physical adsorption is a dominant process involved and to increase in temperature chemical ion exchange mechanism could have taken the lead. The biosorption data at different temperatures are plotted as a function of the logarithm of the amount adsorbed ln q_e vs ε^2 the square of potential energy Fig.-12.

Experimental and optimization of biosorption of Mimusops elengi

An ideal condition for the biosorption of zinc by Mimusops elengi was controlled by the method CCD and RSM. The RSM comprises of a gathering of exact procedures committed to the assessment of the

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relationship existing between a bunch of controlled experimental factors and measured reactions as per one or more chose criteria. Optimization studies were completed by contemplating the impact of three variables, including pH, metal ion concentration and biosorbent dosage[40-42]. The picked free variables utilized as a part of this study were coded by using Equation (10).

$$x_i = \frac{X_i - X_0}{\Delta X} \tag{10}$$

The new intensity values (low and high) for every parameter are summed in this model[43]. For a full factorial-

$$\alpha = \left[2^k\right]^{\frac{1}{4}} \tag{11}$$

In the present work three parameters: pH, metal ion concentration and biosorbent dosage are considered and hence k=3 and α= 2 from Equation (11). Besides, the aggregate number of trail points (N) in a CCD is computed from the Equation (12).

$$N = 2k + 2k + X_o \tag{12}$$

Where X_o is the number of central points. Thus, total number of experimental runs, N= 16 and X_o = 1 from Equation (12).

In this manner, CCD with three variables is employed utilizing STATISTICA 6.0 with the limits of pH = 3–7, w = 0.1–0.5 g, C_0 = 20–100 mg/L as displayed in Table-3.

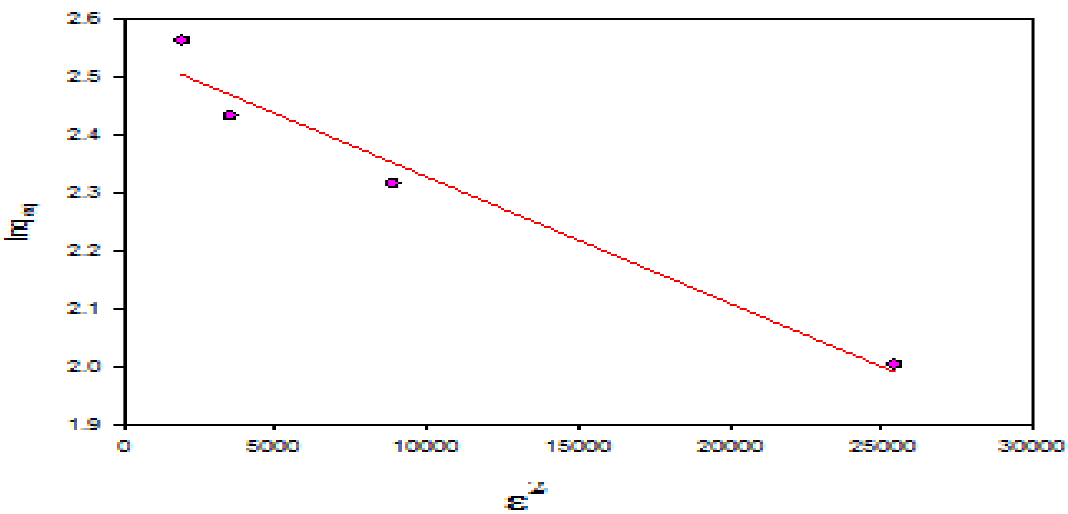

Fig.-12: Temkin adsorption isotherms at 0.1g/30mL of biosorbent concentration

Table-3: Process variables and their level

Factors	Name	Units	Low actual	High actual	Low coded	Middle coded	High coded
X_1	pH		3	7	-1	0	1
X_2	Initial concentration	mg/L	20	100	-1	0	1
X_3	Biosorbent dosage	g	0.1	0.5	-1	0	1

Based on the second-order polynomial model the behaviour of the system is explained using Equation (13):

$$y = \beta_o + \sum_{i=1}^{k}\beta_i x_i + \sum_{i=1}^{k}\beta_{ii} x^2{}_i + \sum\sum_{i<j}^{k}\beta_{ij} x_i x_j + \in \tag{13}$$

where *y* is the predicted response, β_0 is the intercept term or constant, β_i is the slope or linear effect of the input factor x_i, β_{ii} is the quadratic effect or the squared effect of input factor x_i, β_{ij} is the linear by linear interaction effect between the input factor x_i, and ϵ is the residual term[44-46]. The regression and graphical analysis of the obtained data is done using STATISTICA 6.0.
The work included the employment of central composite design to enhance the absorption because of its suitability to fit quadratic surface which often fits well for process optimization. The ideal values of the chosen variables were acquired by solving the regression equation at desired values of the process responses as the optimization criteria. Each of the parameters was coded at levels: $-\alpha$, −1, 0, +1 and +α [47]. The range and level of the variables are tabulated in Table-3. A design of 16 experiments with 1 replicate at the center point were planned to obtain the second-order polynomial model. The CCD experimental conditions along with the experimental values and predicted values are shown in Table-4.

Table-4: Experimental design in terms of coded factors

S.No.	pH	Concentration, mg/L	Dosage, g	% Biosorption
1	-1	-1	-1	64.82
2	-1	-1	1	70.14
3	-1	1	-1	48.67
4	-1	1	1	52.17
5	1	-1	-1	59.69
6	1	-1	1	67.23
7	1	1	-1	47.42
8	1	1	1	52
9	-1.68179	0	0	56.9
10	1.68179	0	0	52.66
11	0	-1.68179	0	75.23
12	0	1.68179	0	49.18
13	0	0	-1.68179	55.24
14	0	0	1.68179	61.73
15	0	0	0	73.11
16	0	0	0	71.24

Fitting the data using the CCD Model

Analysis of variance (ANOVA) which was used to assess the statistical significance[48] showed that the removal of zinc ions from aqueous solutions using Mimusops elengi was appropriately illustrated by quadratic model. The coefficients of the experimental model and their statistical analyses was calculated using the Design Expert Software, are presented in Table-5.

Table-5: ANOVA for the biosorption of Zinc

Source	SS	DF	Mean Square	*F*-value	*p*-value Prob > *F*
X_1	20.155	1	20.1551	34.138	0.001108
X_2	813.923	1	813.9234	1378.586	0
X_3	74.302	1	74.3019	125.849	0.00003

X_1^2	347.549	1	347.5486	588.662	0
X_2^2	113.476	1	113.4763	192.201	0.000009
X_3^2	214.788	1	214.7884	363.799	0.000001
$X_1 X_2$	5.478	1	5.478	9.278	0.022626
$X_1 X_3$	1.361	1	1.3612	2.306	0.179707
$X_2 X_3$	2.856	1	2.8561	4.837	0.070158
Error	3.542	6	0.5904		
Total	1326.313	15	R^2 = 0.99733; R^2 (Adj) = 0. 99332		

DF: degree of freedom; SS: sum of squares; F: factor F; P: probability.

Using the Software, the experimental data with multiple regression analysis was obtained for the biosorption of Zinc:

$$\% \text{ Removal } (Y) = -58.593 + 38.924X_1 + 0.335X_2 + 218.295X_3 - 4.253X_1^2 - 0.006X_2^2 - 334.380X_3^2 + 0.029X_1 X_2 + 2.865X_1 X_3 - 0.209X_2 X_3 \quad (14)$$

Where, X_1, X_2 and X_3 are the coded values for the independent variables pH, metal ion concentration and biosorbent dosage, $X_1 X_2$, $X_1 X_3$, $X_2 X_3$, X_1^2, $X_2^2$and X_3^2 are the significant model terms for the biosorption of Zinc. Table-5 presents the statistical significance of the second–order polynomial equation which is calculated using the Fisher's *F*-test of ANOVA. The adequacy of the model is indicated by Probability>*F* value. From the experimental data, a cubic equation with most extreme R^2 was significantly selected by the Design Expert software. The connected parameters impact and their interrelation on the removal, Equation (14) can be checked by *p*-value parameter. For every term, the user of the software can check the *p*-value column from the ANOVA, Table-5 accomplished from the software. Actually, a term with *p*-value <0.05 is noteworthy in the applied model while alternate terms with *p*-value >0.05 are overlooked. The *F*-value of 1378.586 and *p*-value of <0.0001 demonstrates that the model is significant. The interrelationship of the free variables and response can be illuminated by the regression model as shown in Table-6.

Table-6: Estimated regression coefficients and corresponding t and p values for the biosorption of Zinc

Term	Coefficient	SE Coefficient	*t*-value	*p*-value
Constant	-58.593	7.26727	-8.0627	0.000195
X_1	39.223	1.80777	21.697	0.000001
X_1^2	-4.253	0.17531	-24.2624	0
X_2	0.335	0.07754	4.3198	0.004984
X_2^2	-0.006	0.00045	-13.8637	0.000009
X_3	218.295	15.33601	14.2342	0.000008
X_3^2	-334.38	17.53113	-19.0735	0.000001
$X_1 X_2$	0.029	0.00951	3.0461	0.022626

$X_1 X_3$	2.865	1.88655	1.5184	0.179707
$X_2 X_3$	-0.209	0.09512	-2.1994	0.070158

The correlation R^2, 99.2% (0.992) value which is close to 1 determines that the model is well fitted[49]. In this model X_1, X_2 and X_3 corresponds the pH, Concentration and Dosage respectively. Table-7 gives a relationship between the experimental values and anticipated values by setting up the legitimacy of the model furthermore shows that they are in a nearby concurrence with one another. The actual and the predicted percentage biosorption of zinc are shown in Figure-13.

Table-7: The experimental values Vs. predicted values for biosorption of Zinc

S.No.	Experimental values of biosorption	Predicted values of biosorption
1	64.82	64.97
2	70.14	70
3	48.67	49.07
4	52.17	51.71
5	59.69	60.06
6	67.23	66.74
7	47.42	47.47
8	52.0	51.76
9	56.9	56.88
10	52.66	52.8
11	75.23	75.25
12	49.18	49.28
13	55.24	54.62
14	61.73	62.47
15	73.11	72.16
16	71.24	72.16

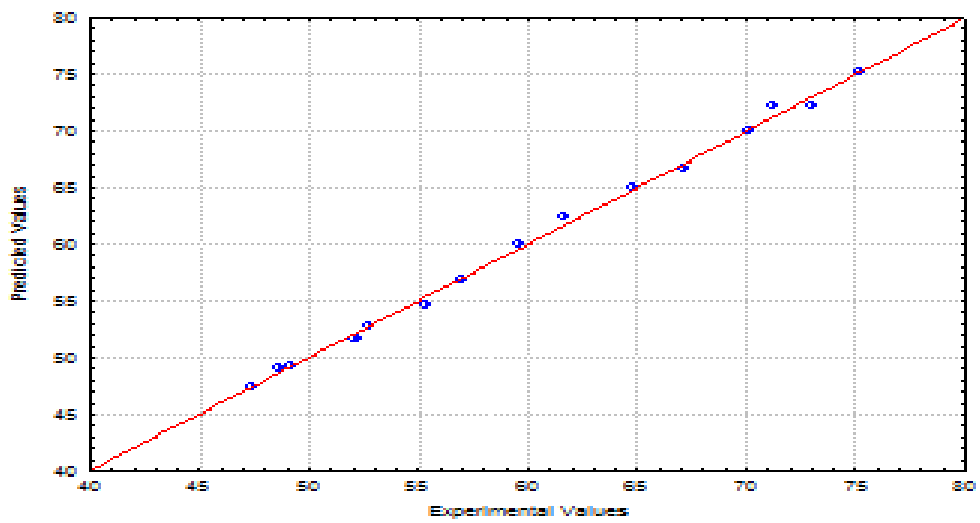

Fig.-13: Correlation plot of experimental values vs predicted values for the biosorption of Zinc

Interaction effects & Optimization by response surface modeling

The % biosorption of zinc with an appropriate combination of free variables is envisioned through a three-dimensional perspective of response surface plots Figs. 14-16. All the response surface plots display that at low and high levels of the variables, the % biosorption by the biosorbent Mimusops elengi is maximal; in any case, there exists a region where neither an increment nor a loss in the % biosorption is observed.

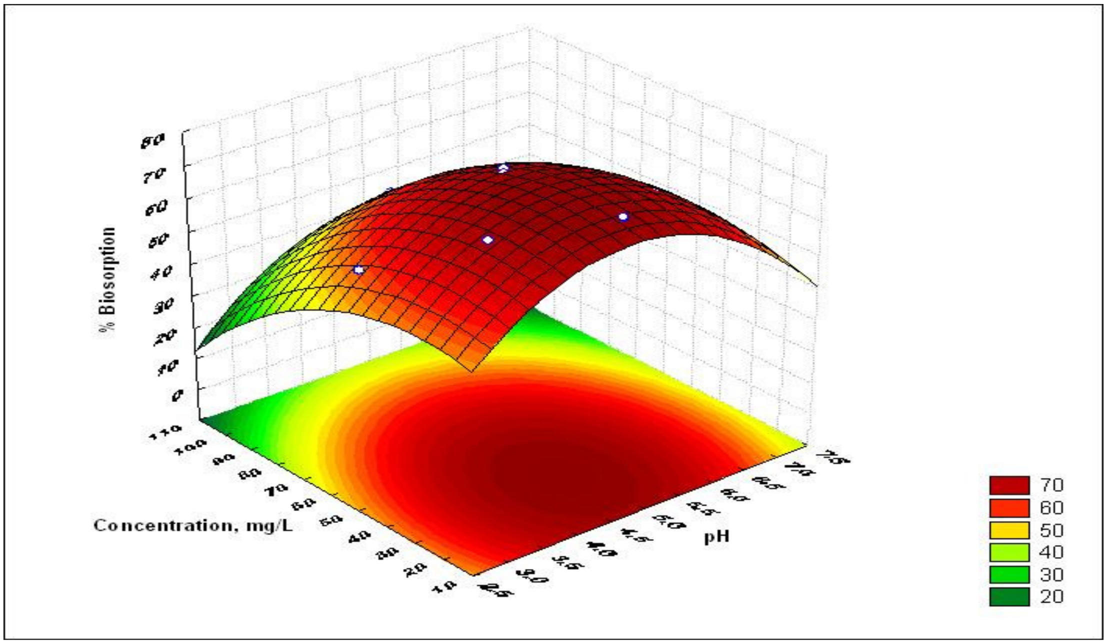

Fig.-14: Response surface plot of pH vs concentration for the biosorption of Zinc

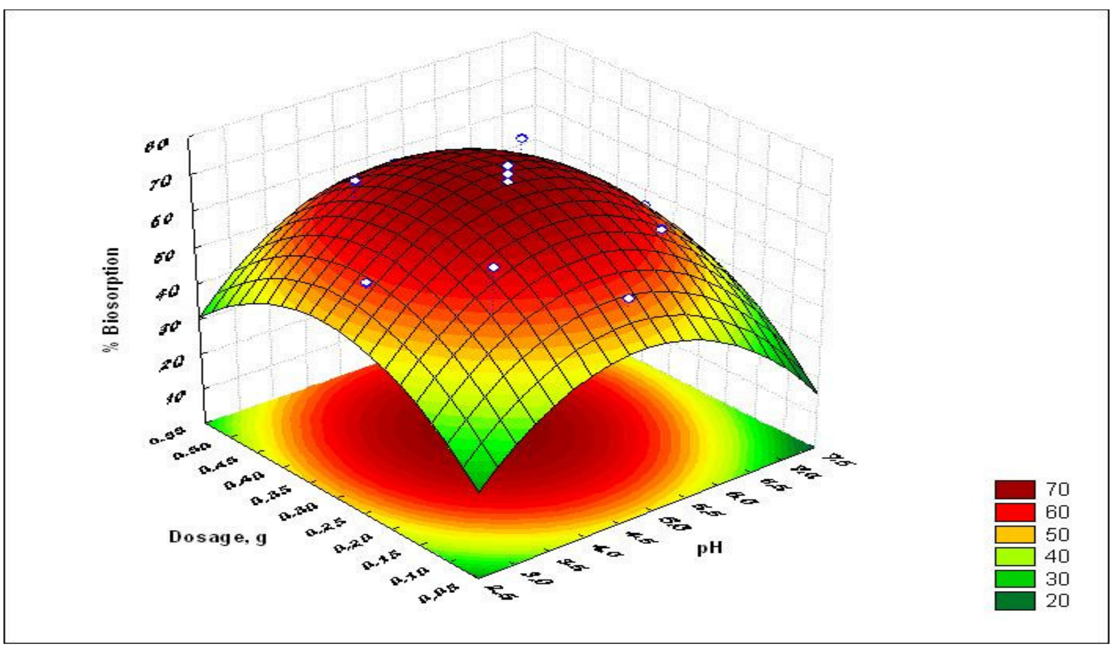

Fig.-15: Response surface plot of pH vs dosage for the biosorption of Zinc

This exemption affirms that there is a vicinity of perfect condition for the biosorption variables to support % biosorption. The pH predicts to be a critical parameter in % biosorption as is obvious from the plots Figs.-14 to 16. A moderately solid interaction was seen between pH with C_0 and w which is reflected by the comparing *P* values 0.022626, 0.179707and 0.070158 individually as found from the bend of the contour.

The ideal biosorption conditions set for the biosorbent Mimusops elengi are pH 4.8, metal ion concentration 32.6 mg/L, biosorbent dosage 0.37g. The model recommended has been portrayed at optimum levels of the process variables, foreseen by the model to attain the optimum % biosorption of 77.05.

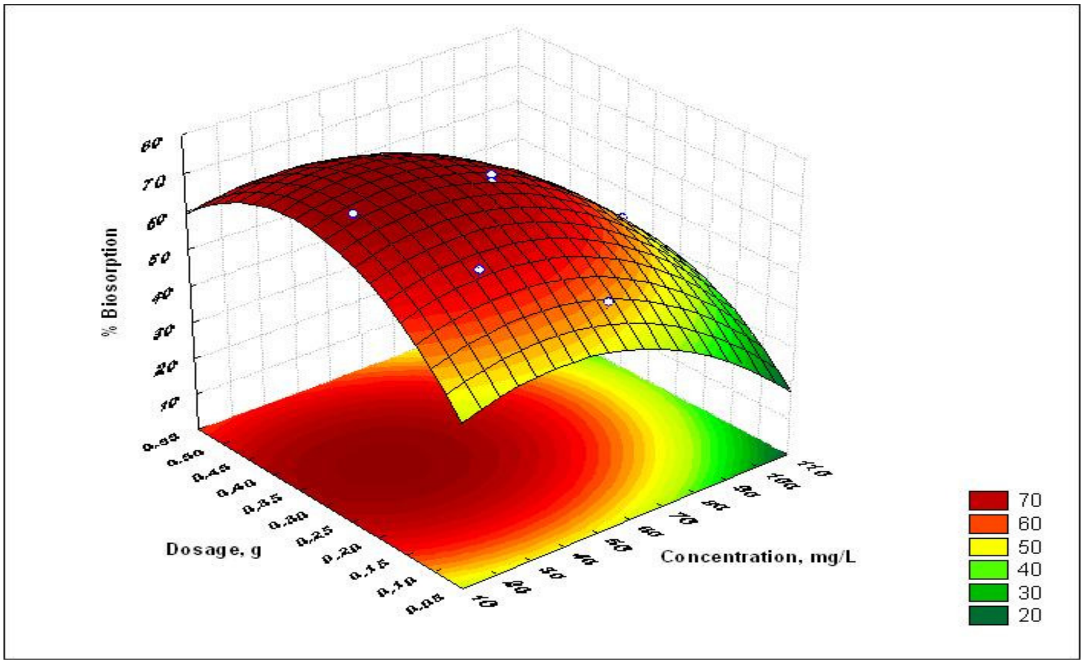

Fig.-16: Response surface plot of concentration vs dosage for the biosorption of Zinc

CONCLUSION

The aftereffects of present studies demonstrate that Mimusops elengi biomass was a productive biosorbent of zinc ions in a dilute aqueous environment. Analyses were executed as a component of solution pH, initial zinc metal ion concentration and biosorbent dosage. The acquired results demonstrated that Mimusops elengi is a better absorbing medium for zinc ions and had high absorption yields for the treatment of effluents containing zinc metal ions. In any case, optimization of biosorption from aqueous solutions by response surface methodology brought about 77.05 % zinc evacuation than that of the pre-enhanced condition. The level of the three variable, initial solution pH, 4.8; metal ion concentration of 32.6 mg/L; biosorbent dosage of 0.37 g, were observed to be ideal for better zinc metal ion removal. By perceptions biomass of Mimusops elengi is a suitable biosorbent for the removal of zinc from aqueous solutions.

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