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Biosorptive removal of lead using Borassus fruit waste and optimization using central composite design

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ABSTRACT

The removal of Pb^{2+} ions by biosorption using Borassus fruit waste was studied in a batch mode.

The cumulative effects of process parameters such as initial metal ion concentration (C_0), pH of the aqueous solution and biosorbent dosage (w) on the lead biosorption were analyzed using Central composite design (CCD). According to ANOVA results, the proposed quadratic model for CCD satisfactorily fitted to the experimental data. The optimized set of conditions for maximum percentage removal of lead is found to be pH= 5, dosage of biosorbent = 0.4 g/L, initial lead (II) ion concentration = 13.1820 mg/L. percentage of biosorption at optimized conditions was found to be 95.11%.

I.INTRODUCTION

Heavy metal pollution in the water bodies due to industrial run off has been a severe global concern. It is very clear that the industrial effluents contaminated with heavy metals have great adverse effect on human and aquatic life[1]. One of the most toxic heavy metals is lead and even in very low concentrations. The main sources of heavy metal contamination are industrial effluents, solid wastes, mining and pesticides. These are responsible for lead contamination in the fresh water bodies and also for domestic utilities[2]**.** Lead is a very toxic heavy metal and its target organs are bones, blood, kidneys and thyroid glands[3]**.** To reduce the risk of these conditions, it is essential to minimize the amount of lead ions in industrial runoff and wastewater. So many traditional methods such as chemical precipitation, ion-exchange, reverse osmosis and ultra filtration were utilized so far. But these methods are uneconomical and less efficient, especially at metal ion concentrations in the range of 10 - 100 mg/l[4]**.** These are not eco-friendly techniques to treat wastewater, which again may leads to pollution while disposing them[5]**.** Different approaches have been developed for the effective removal of heavy metals using bio-adsorbents such as different waste fruit cortexes[3], *Zalacca edulis* peel modify[4] , papaya seed[6], maize leaf[7], cattails (*Typha angustifolia)* leaves[8], Casuarina Leaf Powder[9], *Moringa oleifera* pods[10],. The aim of this work is to demonstrate the use of borassus fruit waste as an excellent source of bio-adsorbent to remove heavy metals like lead ions.

II.PREPERATION OF BIOSORBENT

Borassus fruit waste was collected in and around Etcherla village (Srikakulam, A.P, India). They were washed with distilled water to remove dust and micro algae and dried in a hot air oven. The dried *Borassus*, then grind well to get fine powder and sieved to various sizes ranging 75 to 212 µm.

III.PREPARATION OF METAL SOLUTION

Stock solutions of Pb (II) were prepared by dissolving 1.599 g of $Pb(NO_3)_2$ in 1 L of distilled water[8]. Few drops of 0.1 N HNO_3 were added to prevent precipitation of Pb (II)[2]. The working samples were prepared from the stock solutions to various concentrations ranging 10-50 mg/l. The pH of the solution was adjusted by adding 0.1 N HNO_3 or 0.1 N NaOH solutions.

IV.RESULTS AND DISCUSSION

4.1EXPERIMENTAL DESIGN AND DATA ANALYSIS

In the present work, optimization of lead biosorption on *Borassus fruit waste* was analyzed using Central Composite Design (CCD). CCD is a model, which is utilized to evaluate the interaction between experimental parameters and measured response at selected conditions.

Experimental runs to optimize the process parameters and percentage removal were obtained through Central Composite Design with factorial points (2^k design), central points and axial points. Experimental Design based on the above optimization method using Statistica 6.0 software. To optimize the biosorption of lead, the regression model equation is written in terms of % biosorption of lead (Y_{Pb}) as function of variables have great influence over the response i.e. C_0 (X_1), pH (X_2), w (X_3)[9].

To explain the response of process parameters, the data was subjected to the following second order empirical polynomial model shown below[11].

$$Y = \beta_0 + \sum_{i=1}^{3} \beta i Xi + \sum_{i=1}^{3} \beta ii Xi\, 2 + \sum_{i=1}^{3} \sum_{i=1}^{3} \beta ij Xi Xj + \in \quad \text{------- (1)}$$

Here, Y is the response, β_0 is the const. coefficient, X_i is non-coded variable, β_i is linear, β_{ii} is quadratic, β_{ij} is second order interaction coefficient, ϵ = residual term.

The final empirical model's equations for percentage removal of lead (Y_{Pb}) responses is given in the following equation

$$Y= -508.372 + 0.730\ X_1 + 194.047X_2 + 258.618\ X_3 - 0.030\ X_1^2 - 17.266\ X_2^2 - 399.893\ X_3^2 + 0.017\ X_1X_2 + 1.230\ X_1X_3 + 4.500\ X_1X_3 \quad \text{------------ (2)}$$

Here Y = % adsorption of chromium, X_1 =pH, X_2 = initial concentration, X_3 = dosage of adsorbent

The quadratic model was selected by the software for the three responses. ANOVA table explain the importance and how suitable the models is. The model terms with value of Prob. > F less than 0.05 are considered as significant. The model F-value is 22.30 and Prob. > F value of 0.003, justifying the model's significance[6].

The percentage removal of lead using *Borassus fruit* waste was visualized by response surface plots, which were plotted between any two process parameters.. From the surface plots the significant values of variables were optimized. The optimized adsorption conditions are pH 5, concentration of the metal solution 13.18 mg/l, dosage of adsorbent 0.4 g. The maximum percentage of adsorption of Cr (VI) at optimum conditions is 95.11.

Table.1: Experimental Design with coded values using central composite design

Experimental Run No.	Coded values			% Biosorption
1	-1.00000	1.00000	-1.00000	42.35
2	1.00000	1.00000	-1.00000	93.12
3	1.00000	-1.00000	1.00000	91.36
4	1.00000	1.00000	1.00000	93.23
5	-1.00000	-1.00000	1.00000	82.61
6	0.00000	0.00000	0.00000	90.23
7	0.00000	1.68179	0.00000	35.46
8	0.00000	0.00000	1.68179	75.22
9	-1.68179	0.00000	0.00000	81.89
10	0.00000	-1.68179	0.00000	85.23
11	1.68179	0.00000	0.00000	83.52
12	-1.00000	1.00000	1.00000	5.93
13	-1.00000	-1.00000	-1.00000	86.23
14	0.00000	0.00000	0.00000	48.07
15	1.00000	-1.00000	-1.00000	95.11
16	0.00000	0.00000	-1.68179	38.69

Table.2: Regression coefficients and their analysis for lead removal

Term symbol	**Regression**	**SE**	**t**	**p**
const	-508.372	59.3557	-8.5648	0.000139
X_1	0.730	1.1158	0.6539	0.537418
X_1^2	-0.030	0.0122	-2.4404	0.050446
X_2	194.047	13.8486	14.0120	0.000008

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X_2^2	-17.266	1.2163	-14.1950	0.000008
X_3	258.618	124.0734	2.0844	0.082234
X_3^2	-399.893	121.6342	-3.2877	0.016662
$X_1 X_2$	0.017	0.1309	0.1318	0.899460
$X_1 X_3$	1.230	1.3089	0.9397	0.383641
$X_2 X_3$	4.500	13.0892	0.3438	0.742728

SE = standard error

Table.3: ANOVA table for lead removal

Source	SS	DF	MS	F	p
X_1	305.68	1	305.675	22.3020	0.003250
X_2	81.63	1	81.626	5.9554	0.050446
X_3	7673.90	1	7673.898	559.8864	0.000000
X_1^2	2761.78	1	2761.784	201.4993	0.000008
X_2^2	0.49	1	0.492	0.0359	0.856045
X_3^2	148.15	1	148.147	10.8088	0.016662
$X_1 X_2$	0.24	1	0.238	0.0174	0.899460
$X_1 X_3$	12.10	1	12.103	0.8830	0.383641
$X_2 X_3$	1.62	1	1.620	0.1182	0.742728
Total SS	11095.46	15			

SS = sum of squares, DF = Degrees of freedom, MS = Mean squares,

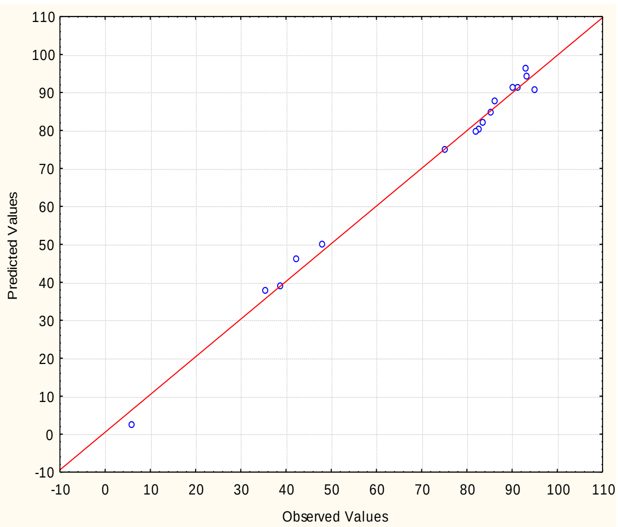

Fig.1. Plot of Experimental Vs predicted values of lead biosorption

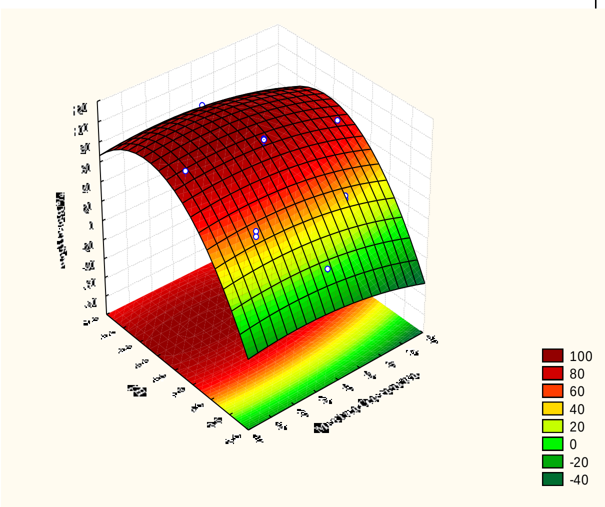

Fig.2: Plot of response surface of metal ion concentration Vs pH

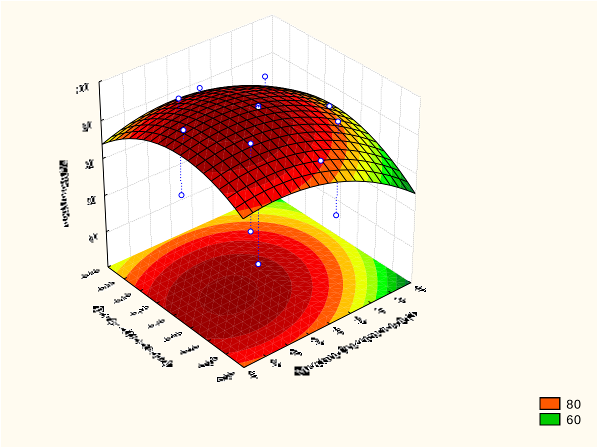

Fig.3: Plot of response surface of concentration Vs dosage of biosorbent

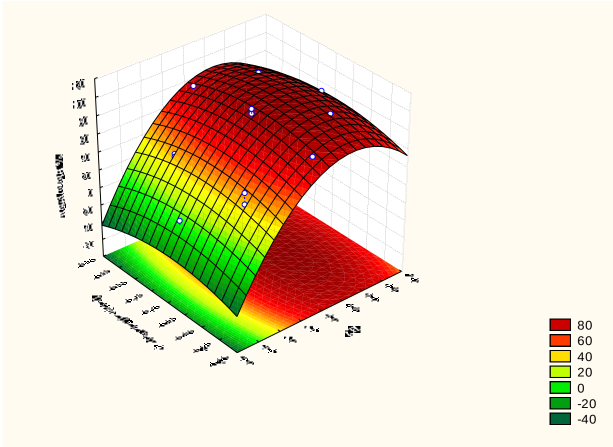

Fig.4: Plot of response surface of pH Vs dosage of biosorbent

V.CONCLUSION

The present study involves the application of statistical experimental design to optimize the process parameters for maximum biosorption of lead from aqueous solution with Central composite design,CCD. The CCD was successfully used to develop a mathematical model for predicting Pb (II) removal. The value of R^2 =0.9925 for the fitted quadratic model indicates the best correlation between the experimental value and predicted value of response by the mathematical model. The maximum biosorption of lead (95.11%) onto *Borassus fruit waste* is observed at the following optimized set of process parameters: pH = 5.0, Dosage of biosorbent (w) = 0.4 g/L, initial Pb(II) concentration(Co) =13.18 mg/L**.** Finally, it was concluded that *Borassus fruit waste* is a locally available and it has a scope as alternative for the effective removal of Pb (II) ions waste water.

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