Chapter 10
Analysis of Hedychium Flavum Waste Powder as a Potent Heavy Metal Adsorbent

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Abstract *Hedychium flavum,* a medicinal, edible, and ornamental plant, is widely cultivated in India. Essential oils from the plant are used for various medical purposes and the leftover plant residue after oil extraction is discarded as a waste. An attempt was made to explore the used of this waste to remove heavy metals from wastewater was analysed. Result shows that the waste powder can be used effectively for metal removal. *Hedychium flavum* sequence was submitted to the NCBI database to procure accession numbers MN988619.

Keywords *Hydicum flavum* · *RSM* · Optimization software · Metal removal · Modelling

10.1 Introduction

Agricultural residues are a renewable resource that can help alleviate our planet's pressing environmental issues sustainably and economically. Numerous studies have shown that this type of agricultural waste, both cheap and abundant, has great promise as an adsorbent for removing various contaminants from waste streams. Hazardous metal contamination in water has long persisted as a severe concern to human health and aquatic life due to the persistence of heavy metals in nature. Heavy metals are released into water sources typically caused by leakage of chemical pollution, mineral processing, and many other forms of manufacturing activity. Although trace amounts of various transition metals, e.g., copper, nickel, and lead, are required for live organisms, their excessive levels may induce detrimental effects, including neurological diseases, respiratory failure, birth deformities, or even death in extreme

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cases. Conventional treatment procedures, such as oxidation/reduction, coagulation/flocculation, reverse osmosis/membrane filtering, ion exchange, and electrochemical approaches, are either too expensive or too inefficient to be widely used for the decontamination of heavy metals.

However, the adsorption process using activated carbon as an adsorbent is particularly favored because of its high efficiency, simple operation, immunity to harmful chemicals, reusability, and scope of use. Adsorption process efficiency is very sensitive to adsorbents' properties and the choice of optimal operating conditions. The characteristics of the input materials and the method of manufacture often govern the former. In contrast, the latter demands selecting an optimal combination of several influencing parameters, typically established by extensive experimentation. However, the number of experiments required can be drastically cut down by using optimization techniques. One of the most important multivariate techniques used in analytical optimization is response surface methodology (RSM), which is a collection of mathematical and statistical methods based on fitting empirical models to the experimental data collected from a set of predefined trials. To determine which experiments need to be conducted in the investigated experimental region to assess the independent variable effects and their interactions with the fewest possible trials, BBD is the most frequently used matrix design among those with a wide range of potential properties and characteristics.

The Hedychium plant genus is ornamental and ethnomedicinal, encompassing around 90 species, disseminated across South-East Asia. *Hedychium* species are a potent origin of numerous components with medical and allied industrial appliances. After extraction of oil and other components the wastes of the plant parts are discarded. The current work focused on the use of Hedychium waste on the metal adsorption capabilities (Raj et al. 2013; Thomas et al. 2015).

10.2 Materials and Methods

10.2.1 Materials

Processed Hedychium waste was collected from a local industry. The waste was washed with distilled water and sun dried.

10.2.2 Adsorption Experiments

Adsorption experiments were carried out in the flasks containing 50 mL of aqueous solution of chromium metal ion. The heavy metals levels were confirmed by AAS analysis. The removal efficiency and the adsorption capacity were calculated as follows:

Table 10.1 Design parameters

Factor	Name	Units	Minimum	Maximum
A	pH		1	5
B	Adsorbent dosage	g/L	0.100	1.0
C	Cr concentration	mg/L	50	500

$$\text{Chromium removal } (\%) = [(\text{Ci} - \text{Cf})/\text{Ci}] * 100 \qquad (10.1)$$

where Ci and C f are the initial and equilibrium M (II) concentrations (ppm) respectively.

10.2.3 RSM-BBD Experiemntal Design

In order to obtain responses across the entire factor space and determine the region of optimal or near-optimal response via a sequence of designed experiments, response surface methodology is widely applied due to its potency as a powerful tool that combines the benefits of mathematical and statistical techniques. To identify the best conditions for the adsorption process, the current research used response surface methodology (RSM) along with Box Behnken design (BBD). The adsorption capacity of the adsorbent was used as the output variable, with the concentration of metal ions (Chromium) (A), the dosage of the adsorbent (B), and the pH (C) serving as the input factors (Table 10.1).

Analysis of variance (ANOVA) of the quadratic polynomial re- gression models was utilized to identify the significance of input variables as well as the relationship between the responses and the influential factors. In this study, the ANOVA was calculated using Design-Expert version 11.

10.3 Results and Discussions

Experimental design was created to explore the contribution of three influential factors: pH, meatal ion concentration and adsorbant concentration (Factor a, b, c) on the sorption capabilities of *Hedychium flavum* waste powder on chromium metal (Response R) [Table 10.2]. The response metal sorption % was caluated using Eq. 10.1.

To prove the model fitness, the analysis of variance (ANOVA) was done (Table 10.3). The R (%) response was statistically significant with F–value of 56.61 and p–value of 0.0001. The results elucidated that adsorbant dosage (*Hedychium flavum* waste powder) considerably impacts the R (%) response followed by AC: pH with the combination of meatl concentraiton). There was good congruity of the outcome

Table 10.2 Experimental runs and metal sorption response

	Factor A	Factor B	Factor C	Response R
Run	A: pH	B: Adsorbent dosage	C: Cr concentration	%removal
		g/L	mg/L	
1	5	0.55	50	80
2	5	0.1	275	41
3	1	0.55	50	62
4	3	0.55	275	72
5	3	1	50	88
6	5	1	275	90
7	5	0.55	500	69
8	3	0.55	275	73
9	3	0.55	275	73
10	3	0.1	50	40
11	3	0.55	275	73
12	3	1	500	85
13	3	0.55	275	73
14	1	0.1	275	55
15	1	0.55	500	82
16	3	0.1	500	53
17	1	1	275	91

of the 17 experimental runs which can be observed in the normal plot (Fig. 10.1). The relationship between actual and predicted values of R (%) response is illustrated in Fig. 10.2.

For optimization of the variables, the BBD-RSM was utilized, and 17 runs of experiments were created. By the quadratic model (Eq. 10.2) the meatal sorption percentage (R %: response) for optimized values of the factors can be calculated using Eq. 10.2.

$$\%removal = 72.8 + -1.25 * A + 20.625 * B + 2.375 * C + 3.25 * AB + -7.75 * AC + -4 * BC + 1.6 * A^2 + -5.15 * B^2 + -1.15 * C^2 \tag{10.2}$$

The 3D surface and contour plots of the interaction of pH with adsorbant dosage and metal concentration on the metal sorption capacity are depicted in Figs. 10.3, 10.4 and 10.5). For maximal adsorption of the metal using the sorbent the optimal pH was 2.7 and the adsorant dosage was 0.89 g a maximal removal of 97.5% was achieved which was validated with an independent run.

Table 10.3 ANOVA table RSM BBD design

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	3934.07	9	437.12	56.61	< 0.0001	significant
A-pH	12.50	1	12.50	1.62	0.2439	
B-adsorbent dosage	3403.12	1	3403.12	440.74	< 0.0001	
C-Cr concentration	45.13	1	45.13	5.84	0.0463	
AB	42.25	1	42.25	5.47	0.0519	
AC	240.25	1	240.25	31.11	0.0008	
BC	64.00	1	64.00	8.29	0.0237	
A^2	10.78	1	10.78	1.40	0.2760	
B^2	111.67	1	111.67	14.46	0.0067	
C^2	5.57	1	5.57	0.7212	0.4238	

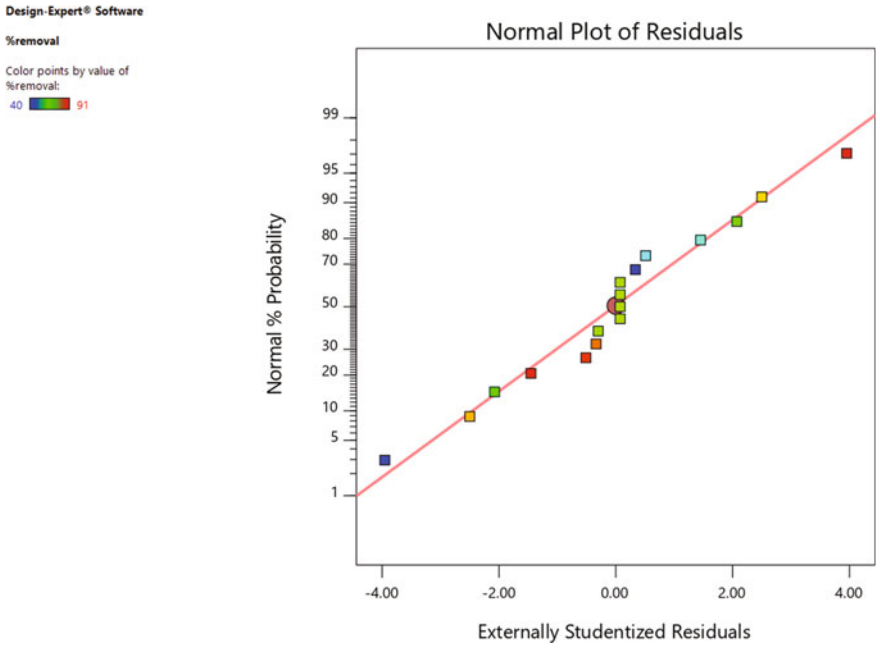

Fig. 10.1 Normal plot

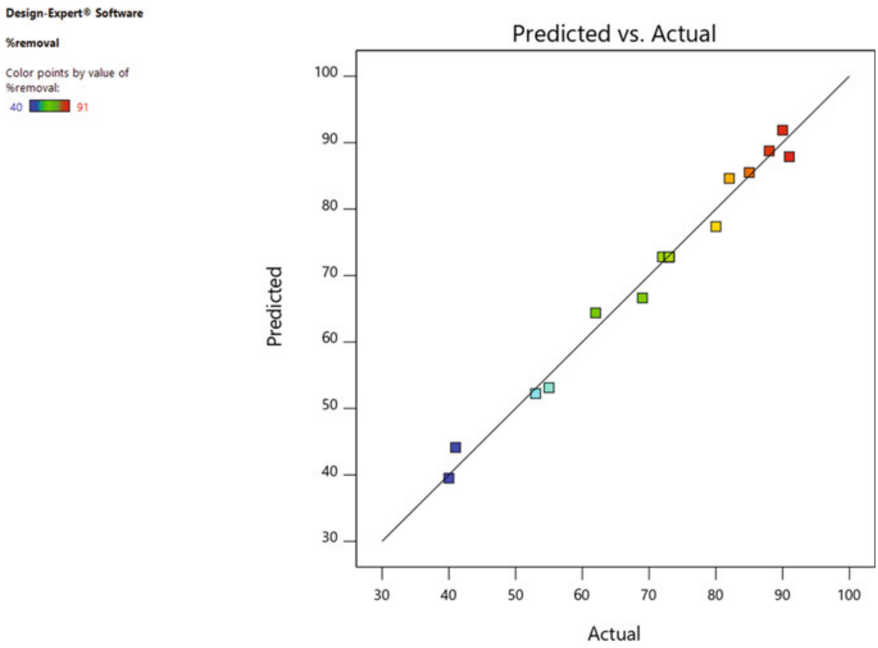

Fig. 10.2 Actual versus predicted

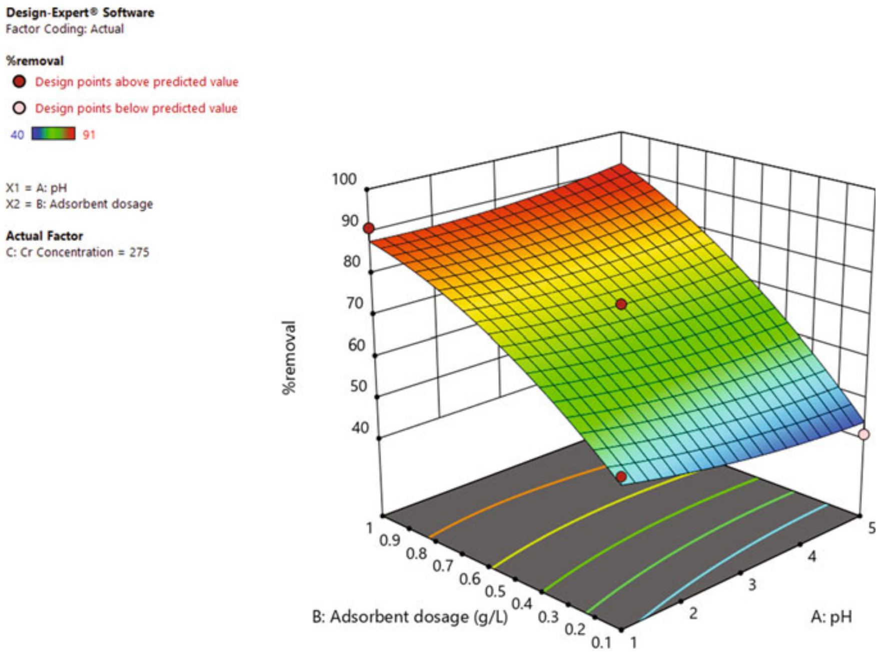

Fig. 10.3 Adsorbant dosage and pH impact on metal sorption.

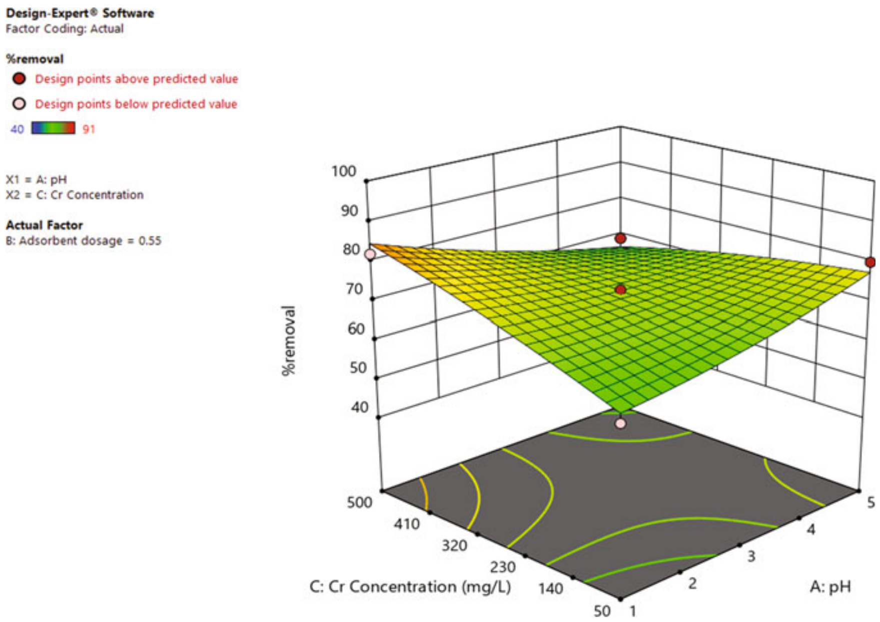

Fig. 10.4 Metal concentration and pH impact on sortion

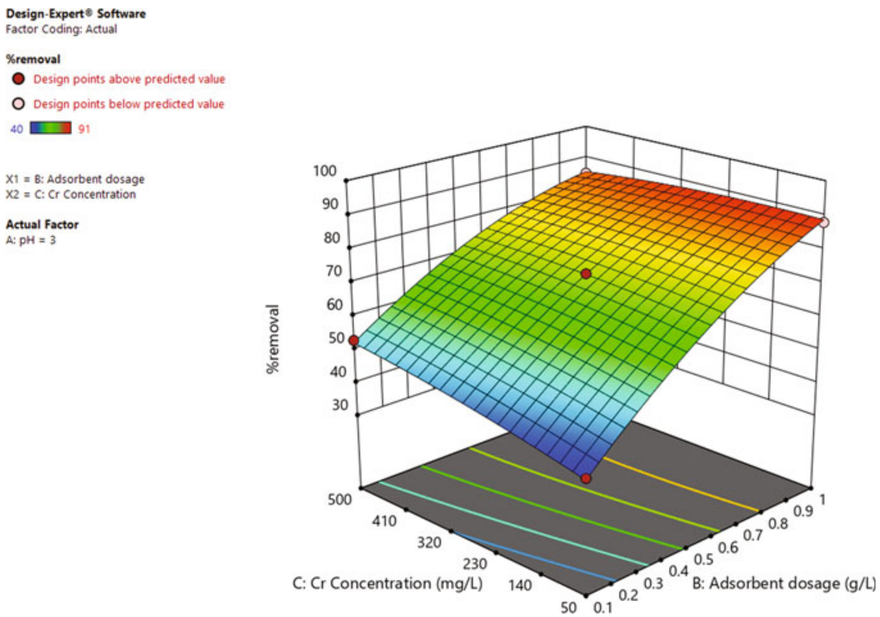

Fig. 10.5 Metal concentration and adsorant dosage impact on sorption

10.4 Conclusion

This study is the first to show that the waste from *Hydicum flavum* can be a good adsorbant to remove metals from waste streams as a maximal removal of 97.5% of metal removal can be achieved under the optimal pH of 2.7 and adsorbant dosage of 0.89 g.

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