

تصميم العامل وتحسين مسحوق بذور نبات الورد كمخثر طبيعي لمياه الصرف الصناعي

د. محمد شادي صالح أبو جزر

كلية مجتمع الأقصى المتوسطة، جامعة الأقصى، غزة

د. محمد محمود أبو عودة

قسم الأحياء، كلية العلوم، جامعة الأقصى، غزة

(تاريخ الاستلام 2022/11/25، تاريخ القبول 2023/01/09)

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

Dr. Mohammed Shadi S. Abujazar

Al-Aqsa Community Intermediate College, Al-Aqsa University

Dr. Mohamad M. Abou Auda

Department of Biology, Faculty of Science, Al-Aqsa University, Gaza

(Received 25/11/2022, Accepted 09/01/2023)

E-mail address: shadiabujazar@gmail.com - د. محمد شادي أبو جزر - كلية مجتمع الأقصى، جامعة الأقصى، غزة، فلسطين

E-mail address: mohamadmahmoudabouauda@gmail.com - د. محمد محمود أبو عودة - قسم الأحياء، كلية العلوم، جامعة الأقصى، غزة، فلسطين



الملخص:

تهدف هذه الدراسة إلى فحص كفاءة مسحوق بذور نبات الورد لمعالجة المياه العادمة الخارجة من مصنع الحديد والصلب ولإثبات جدوى استخدام مسحوق بذور نبات الورد في معالجة العادمة الخارجة من مصنع الحديد والصلب وتحسين المعايير التشغيلية. باستخدام 1 جم / لتر من بذور نبات الورد كعامل تحكم، ودرجة الرقم الهيدروجيني، ووقت الاستقرار، تم استخدام منهجية سطح الاستجابة (RSM)، وهو تصميم تجريبي إحصائي، لتحسين COD وNH₃-N وكفاءة النسبة المئوية لإزالة المعادن الثقيلة. كان الحد الأقصى لإزالة COD واللون وNH₃-N وFe وMn وAl وCu وNi عند الرقم الهيدروجيني 8 87.1% و78.1% و72.1% و93.2% و94.8% و97.1% و81.3% و91.7% على التوالي. باستثناء Fe (0.0170)، Mn (0.0021)، وCu (0.0024)، تم تحديد النماذج التربيعية للمعاملات المحددة لتكون ذات دلالة إحصائية (>0.001). كشفت نتائج الدراسة أن مسحوق بذور نبات الورد يمكن استخدامه كمخثر طبيعي لمعالجة مياه الصرف الصحي الناتجة عن صناعات الحديد والصلب.

Abstract:

In order to ascertain the viability of using rosehip seed powder in wastewater treatment and optimize operating parameters, this research aims to examine the effectiveness of rosehip seed powder for iron and steel industry wastewater treatment. Using 1 g/l rosehip as a controlling factor, pH, and settling time, the Response Surface Methodology (RSM), a statistical experimental design, was used to increase the COD, NH₃-N, and heavy metals removal percentage efficiencies. At pH 8, the highest percentages of COD, color, NH₃-N, Fe, Mn, Al, Cu, and Ni were removed, respectively, by 87.1%, 78.1%, 72.1%, 93.2%, 94.8%, 97.1%, 81.3%, and 91.7%. The quadratic models for the given parameters were found to be statistically significant (0.001), with Fe (0.0170), Mn (0.0021), and Cu being the exceptions. According to the study's conclusions, rosehip powder can be used to treat wastewater which produced by metallurgy of iron as a natural coagulant.

Keywords: Industrial Wastewater, Natural Coagulant, Rosehip Seed Powder, Treatment, Removal, Heavy Metals

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

1. Introduction

Water is required for all forms of life, all areas of socioeconomic growth, and the preservation of healthy ecosystems. It is also used for cleaning, agriculture, industry [1], and producing wastewater in which the industrial revolution and other forms of modernity boost wastewater discharge [2]. Moreover, world's growing population, high living standards, varying consumption styles, and the expansion of irrigation systems are reflexively considered the other effective key drivers of increased worldwide water demand. By 2050, approximately 6 billion people will be affected by the lack of safe water due to the increased water demand and reduced water supplies in addition to the increased water pollution which is encountered due to huge population and economic expansion [3,4].

Inappropriate or poorly treated wastewater, which contains contaminants such as suspended particles, microbes, nutrients, and toxic substances, is hazardous to the environment and contributes to several environmental issues [5,6]. Furthermore, waterborne infections harm public health and are responsible for approximately 80% of all illnesses [7,8]. Therefore, cleaning and reusing wastewater is the most effective technique in combating freshwater scarcity and waterborne diseases [9,10].

It is worth mentioning that the result of growing industrialization, the creation of effluents in many industrial processes have created significant environmental problems [11,12]. The indiscriminate discharge of these effluents can consequently contaminate water and soil. Besides, the impacts of abiotic ingredients such as water and soil substantially influence living beings health [13].

Discharged wastewater from iron and steel factories contains heavy metal and organic chemicals [14]. This highlight that polluted wastewater interacts with the environment, contraposing both human health and ecosystem at risk. Also, non-biodegradable materials such

as heavy metals can cause cancer [15–18], heavy metal pollution is a long-lasting health danger to both mankind and environmental health, and it can at the same time harm living organisms [6,19].

Here, various methods have been developed to enhance the removal of organic matter (expressed as COD) and heavy metals from manufacturing effluent. Moreover, physical, chemical, and biological remedies, or a mix of these processes, are the most significant. However, these methods have considerable drawbacks, such as being costly, sophisticated, time-consuming, and necessitating the hiring of professional personnel, resulting in an incomplete removal, extreme energy consumption, and development of noxious sludge [20–30]. Accordingly, physicochemical techniques like coagulation-flocculation have been shown to reduce contamination and offer clean water reuse while remaining simple and cost-effective [31,32].

Therefore, inorganic, synthetic organic, or natural organic coagulants are often used [33]. Recent research has emphasized the significance of natural coagulants; because they can perform coagulation mechanisms such as colloidal particle charge neutralization and polymer bridging to function as coagulants [34–36]. The main advantages of natural coagulants are presented in renewability, biodegradability, nontoxicity, cost-effectiveness, less sludge generation, and avoiding pH changes in treated water. These studies have already proved the effectiveness of natural coagulants in wastewater treatment applications [37,38].

Hence, this treatise objectivizes to evaluate and review the utility of rosehip powder as a natural-based coagulant for iron and steel factory wastewater and its efficiency for removal of heavy metals. The ideal experimental parameters and the statistical relationship between variables and response are evaluated for the use of rosehip powder as a

plant-based natural coagulant in industrial wastewater treatment.

2. Materials and Methods

This study was conducted at Karabuk University's College of Engineering, the Department of Environmental Engineering, in an environmental laboratory. Industrial wastewater samples were collected from the Karabuk iron and steel factory, which is located near Karabuk University and has the coordinates 41° 11' N, 32° 38' E. The collected samples were placed in dark brown plastic bottles at the discharge point and transported to the laboratory in a cool box within one hour of collection and used. In the case of the not immediate use, the samples were kept at 25°C in the dark until use.

2.1 Preparation of Rosehip Seeds Powder

The rosehip seeds were obtained from a farm closed to the Turkish Karabük University. The rosehip seeds were washed with distilled water to remove suspended impurities and then dried at room temperature before being placed in an oven for eight (8) hours at 50°C; this was done to make it easier to smash the rosehip seeds; by using a mortar and pestle. Then, the rosehip seeds were crushed to reduce their size. The crushed seeds were processed in a (Retsch RS 200) grinder to generate rosehip seed powder, which was utilized as a coagulant in the tests (Fig.1).



Figure 1: rosehip seeds and powder

2.2 Experimental Procedure

To model the coagulation-flocculation process, an orbital shaker (PSU-10i, Latvia) and three 0.5 liter beakers were utilized, with the impact of rosehip seed powder dose taken into account. Each beaker contained 200 ml of wastewater sample. The automated controller of

the shaker equipment was implemented to alter the time and speed for rapid and slow mixing. In this experiment, rapid and slow mixing was running for 5 minutes at 200 rpm and 15 minutes at 90 rpm, respectively, with one hour of settling for further COD, color, NH₃-N, and heavy metal removal efficiency tests. The

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

sample's initial pH (8) was left uncorrected throughout this experiment, and coagulation was evaluated based on COD and NH₃-N elimination efficiency.

Before the coagulation-flocculation process, pH was adjusted by 1M HCl and 1M NaOH. The appropriate rosehip powder dose from the previous experiment was examined regarding the effect of pH (5-10) on removal efficiency for the stated parameters. Iron and steel wastewater samples were strongly agitated

previously to coagulation; removal efficiency is expressed as bellows:

$$efficiency\ removal\ (\%) = \left[1 - \left(\frac{C_f}{C_i} \right) \right] * 100 \quad (1)$$

where C_i and C_f represent the starting and ending values of each parameter

Table 1 shows the specifications of the iron and steel plant effluent utilized in these tests.

Table 1: “Characteristics of industrial (iron and steel factory) wastewater”

Industrial parameters	wastewater	Units	Results
pH		--	8
Color		Pt-Co	865.6
TSS		mg/L	110
COD		mg/L	840.24
Ammonia-nitrogen NH ₃ -N		mg/L	42.8
Manganese "Mn"		mg/L	6.27
Iron "Fe"		mg/L	5.30
Zinc "Zn"		mg/L	5.44
Aluminium "Al"		mg/L	0.38
Nickel "Ni"		mg/L	0.15

2.3 Factorial Design and Optimization

According to Central Composite Design (CCD) and Response Surface Methodology (RSM) for statistical design and data analysis, "a mathematical and statistical approach for determining the optimal process parameter values in experimental designs" was used [39,40]. Equation (2) depicts the relationship and interplay of process input constraints and their responses.

$$Y = f(X_1, X_2, X_3, \dots, X_k) \pm \epsilon \quad (2)$$

Where x₁, x₂, x₃,...x_k are the variable input quantity that may impact the outcome and the random error.

The Design Expert Software generated a set of designs in response to the design parameters. Besides, the ability of the designs to predict higher-order terms varies. The quadratic model is only useful for the vast majority of designs. The second-order model is represented by equation (3).

$$Y = \beta_0 + \sum_{j=1}^k \beta_j X_j + \sum_{j=1}^k \beta_{jj} X_j^2 + \sum_{i < j=2}^k \beta_{ij} X_i X_j \quad (3)$$

In this equation, Y represents the outcome, X_i and X_j are the variable quantity, as the regression coefficient, k is the numeral of components examined and improved in the testing, and e is the random error.

RSM seeks an approximation function for anticipating future responses and factor values that maximize the response function.

The independent variables are assumed to be continuous and controlled by low-error trials, which is a key assumption. As a result, the issue is determining a reasonable approximation for the exact functional link between the independent variables and the response surface [40].

The F-test was implemented to confirm the statistical implication of the coefficient of determination (R²) value, which was termed to assess the superiority of the suitable polynomial

typical. Moreover, the P-value (probability) through a 95% confidence limit was used to assess model terms.

CCD and RSM were employed to adjust and examine the connection between two essential independent variables: (1) rosehip powder dose and (2) pH, as illustrated in Table 2.

Table 2: INDEPENDENT VARIABLES OF THE CCD DESIGN

Level of Value	A: Rosehip seeds powder (g)	B: pH
-1	1	5
0	3	7.5
+1	5	10

The removal efficiencies of COD, color, NH₃-N, Mn, Fe, Zn, Al, and Ni in effluent wastewater were explored as dependent variables (response). The efficiency removal of COD and NH₃-N was used to assess the process's effectiveness. The treatment efficiencies for the above constraints were demonstrated to assess the process's efficacy. Based on the literature [41], each independent variable was modified across three levels

ranging from 1 to +1 at the stated ranges, generating a total of 13 trials (=2k+2k⁵) for the two factors (k=2). Table 3 details the exponential design matrix of the coagulation process.

Table 3. The volume of rosehip powder and pH number for each experiment are summarized in the experimental matrix

Run	Type	Factor 1 A: Rosehip dosage	Factor 2 B: pH
		g/L	
SR1	Center	3.00	7.50
SR2	Fact	5.00	5.00
SR3	Fact	1.00	10.00
SR4	Center	3.00	7.50
SR5	Axial	1.00	7.50
SR6	Fact	1.00	5.00
SR7	Center	3.00	7.50
SR8	Axial	3.00	5.00
SR9	Center	3.00	7.50
SR10	Center	3.00	7.50
SR11	Fact	5.00	10.00
SR12	Axial	5.00	7.50
SR13	Axial	3.00	10.00

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

3. Results and Discussion

3.1 Scanning Electron Microscopy (SEM) Characterization of Rosehip Seed Powder

Before and after coagulation, the rosehip seed powder morphological surface structure was tested and showed a shortened crystalline brick-shaped assembly, shown in Fig 2a. The structure performed as an add-on point for

suspended elements and cations [42,43]. As shown in Fig 2b, the coagulant combined the elements, resulting in larger flocs that dropped easily. Consequently, rosehip seed powder SEM imaging one study discovered that bridging might remain in charge of the powder's superior coagulation properties [42,44,45].

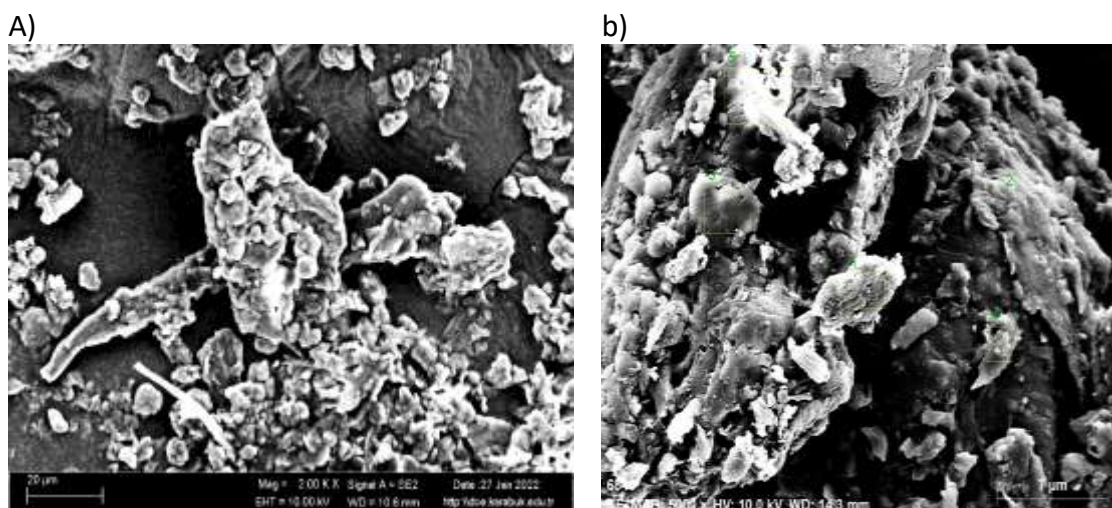


Figure 2: Microscopic image (2 μm) for rosehip seeds powder (a) before (b) after the coagulation process observed by scanning electron microscopy

3.2 Fourier Transformed Infrared (FTIR) Analysis

The same IR was constructed via FTIR to extra inspect existence of the major possible efficient groups in crushed rosehip seeds, as shown in Fig. 3. The FTIR investigation was acceptable for shortening and perhaps accenting the key purposeful groups. The band's range was preferred to examine the IR spectra formed for rosehip seeds powder for its efficient clusters could emphasize through the limit of wavelength points. The existence of durable amine salts (N-H), which are implicated in the

particle linking throughout the coagulation method and could boost ammonia and organics removal efficiency from polluted water, might explain the observed highest in the 3000-2500 cm^{-1} region.

In other words, the highest among 1750-1650 cm^{-1} demonstrates the C-N connection, whilst the one between (1650-1550) cm^{-1} confirms a prime amine N-H or the aromatic C=C. The green ultimate ranging 1300-1250 cm^{-1} corresponds to an aromatic ester C-O pledge, whilst the one ranging 1200-1000 cm^{-1} corresponds to an N-H aliphatic amine [45,46].

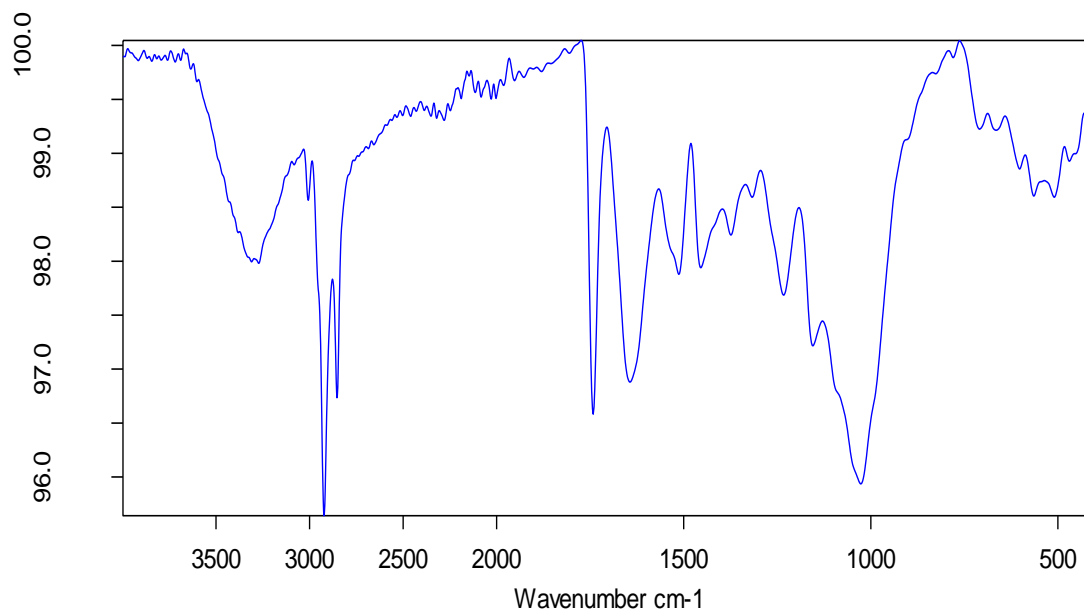


Figure 3: Rosehip seed powder Fourier transformed infrared (FTIR) spectroscopy curve.

Table 4: Overview of an experimental matrix for wastewater coagulation utilizing rosehip seed powder.

Run	Type	Factor 1 A:Rosehip dosage	Factor 2 B:pH	Response 1 COD	Response 2 Color	Response 3 NH ₃ -N	Response 4 Mn	Response 5 Fe	Response 6 Zn	Response 7 Al	Response 8 Ni
		g/L		%	%	%	%	%	%	%	%
1	Center	3.00	7.50	80.6	72	66	88	89	91	74	87
2	Fact	5.00	5.00	77	69	62	84	85	89	72	84
3	Fact	1.00	10.00	85	74	69	92	91	93	78	89
4	Center	3.00	7.50	80.6	72	66	88	89	91	74	87
5	Axial	1.00	7.50	87	78	71	92	94	96	81	91
6	Fact	1.00	5.00	84	76	69	90	92	94	79	89
7	Center	3.00	7.50	80.6	72	66	88	89	91	74	87
8	Axial	3.00	5.00	78	68	60	84	83	86	69	83
9	Center	3.00	7.50	80.6	72	66	88	89	91	74	87
10	Center	3.00	7.50	80.6	72	66	88	89	91	74	87
11	Fact	5.00	10.00	76	67	58	77	82	80	64	73
12	Axial	5.00	7.50	76	68	61	82	84	87	70	82
13	Axial	3.00	10.00	77	66	60	83	83	84	71	82

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

Adding rosehip seed powder to the wastewater solution in various amounts changed the testing conditions. Consequently, the removal results varied from 76.0-85.0 % for COD, 66.0-78.0 % for color, 58.0-71.0 % for NH₃-N, and 77.0-92.0 % for Mn. The Fe removal ratio is 82.0 % to 94.0 %, the Zn removal ratio is 80.0 % to 96.0 %, the Al removal ratio is 64.0 % to 81.0 %, and the Ni removal ratio is 73.0 % to 91.0 %. According to the findings, rosehip seeds powder has a high efficacy in removing COD and Zn throughout the processing procedure, while the treatment rate in NH₃-N was acceptable; this was attributed to the cohesiveness of these elements' molecules, which resulted in less removal effectiveness, as illustrated in Table 4.

The regression parameters of the projected response area exponential models and additional statistical parameters for ANOVA for COD, color, NH₃-N, Mn, Fe, Zn, Al, and Ni, are shown in Table 5. According to the table underneath, all models were weighty and significant at the 5% sureness limit based on the P rate. The R² (coefficients of determination) principles discovered in this study were for (COD, color, NH₃-N, Mn, Fe, Zn, Al, and Ni). R² values are as follows: 0.96, 0.92, 0.92, 0.96, 0.91, 0.95, 0.93, and 0.92. Which is more than 0.80 to fit the model fully; a value of R² near to one implies that the expected and calculated outcomes correspond well. Typical terms were excluded from the study (they were irrelevant), and despite their minor effect, six quadratic models were shown in Table 6.

3.3 Variance Investigation

Table 5: ANOVA (Analysis of Variance) for parameter removal

	Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	Remarks
COD Removal (%)	Model	138.73	5	27.75	30.47	0.0001	significant
	A	121.50	1	121.50	133.42	< 0.0001	
	B	0.17	1	0.17	0.18	0.6816	
	A2	10.12	1	10.12	11.11	0.0125	
	B2	12.02	1	12.02	13.20	0.0084	
	AB	1.00	1	1.00	1.10	0.3295	
	Residual	6.37	7	0.91			
	Pure Error	0.000	4	0.000			
	Cor Total	145.11	12				
	Std. Dev.	0.95	R ²	0.9561			
	Mean	80.23	Adj R ²	0.9247			
	C.V.	1.19	Pred R ²	0.6233			
	Color removal (%)	Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model		138.86	5	27.77	16.98	0.0009	significant
A		96.00	1	96.00	58.70	0.0001	
B		6.00	1	6.00	3.67	0.0970	
A2		19.98	1	19.98	12.22	0.0101	
B2		30.27	1	30.27	18.51	0.0036	

	AB	0.000	1	0.000	0.000	1.0000	
	Residual	11.45	7	1.64			
	Pure Error	0.000	4	0.000			
	Cor Total	150.31	12				
	Std. Dev.	1.28	R²	0.9238			
	Mean	71.23	Adj R²	0.8694			
	C.V.	1.80	Pred R²	0.4137			
NH ₃ -N removal (%)	Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	Remarks
	Model	179.44	5	35.89	16.07	0.0010	significant
	A	130.67	1	130.67	58.51	0.0001	
	B	2.67	1	2.67	1.19	0.3107	
	A2	13.03	1	13.03	5.84	0.0464	
	B2	40.46	1	40.46	18.12	0.0038	
	AB	4.00	1	4.00	1.79	0.2226	
	Residual	15.63	7	2.23			
	Lack of Fit	15.63	3	5.21			
	Pure Error	0.000	4	0.000			
	Cor Total	195.08	12				
	Std. Dev.	1.49	R²	0.9199			
	Mean	64.62	Adj R²	0.8626			
C.V.	2.31	Pred R²	0.4251				
Mn removal (%)	Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	Remarks
	Model	211.11	5	42.22	36.41	< 0.0001	significant
	A	160.17	1	160.17	138.11	< 0.0001	
	B	6.00	1	6.00	5.17	0.0571	
	A2	0.89	1	0.89	0.77	0.4090	
	B2	23.73	1	23.73	20.46	0.0027	
	AB	20.25	1	20.25	17.46	0.0041	
	Residual	8.12	7	1.16			
	Pure Error	0.000	4	0.000			
	Cor Total	219.23	12				
	Std. Dev.	1.08	R²	0.9630			
	Mean	86.46	Adj R²	0.9365			
	C.V.	1.25	Pred R²	0.7348			
Fe removal (%)	Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	Remarks
	Model	158.44	5	31.69	13.34	0.0018	significant
	A	112.67	1	112.67	47.42	0.0002	
	B	2.67	1	2.67	1.12	0.3246	
	A2	13.03	1	13.03	5.49	0.0517	
	B2	40.46	1	40.46	17.03	0.0044	

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

	AB	1.00	1	1.00	0.42	0.5372	
	Residual	16.63	7	2.38			
	Pure Error	0.000	4	0.000			
	Cor Total	175.08	12				
	Std. Dev.	1.54	R²	0.9050			
	Mean	87.62	Adj R²	0.8371			
	C.V.	1.76	Pred R²	0.3012			
	Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	Remarks
Zn removal (%)	Model	213.78	5	42.76	26.14	0.0002	significant
	A	121.50	1	121.50	74.29	< 0.0001	
	B	24.00	1	24.00	14.67	0.0065	
	A2	13.24	1	13.24	8.10	0.0248	
	B2	51.31	1	51.31	31.38	0.0008	
	AB	16.00	1	16.00	9.78	0.0167	
	Residual	11.45	7	1.64			
	Pure Error	0.000	4	0.000			
	Cor Total	225.23	12				
	Std. Dev.	1.28	R²	0.9492			
	Mean	89.54	Adj R²	0.9129			
	C.V.	1.43	Pred R²	0.6087			
	Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	Remarks
Al removal (%)	Model	222.80	5	44.56	19.16	0.0006	significant
	A	170.67	1	170.67	73.39	< 0.0001	
	B	8.17	1	8.17	3.51	0.1031	
	A2	15.19	1	15.19	6.53	0.0378	
	B2	27.50	1	27.50	11.82	0.0109	
	AB	12.25	1	12.25	5.27	0.0554	
	Residual	16.28	7	2.33			
	Pure Error	0.000	4	0.000			
	Cor Total	239.08	12				
	Std. Dev.	1.52	R²	0.9319			
	Mean	73.38	Adj R²	0.8833			
	C.V.	2.08	Pred R²	0.3365			
	Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	Remarks
Ni removal (%)	Model	234.00	5	46.80	15.66	0.0011	significant
	A	150.00	1	150.00	50.19	0.0002	
	B	24.00	1	24.00	8.03	0.0253	
	A2	1.59	1	1.59	0.53	0.4895	

B2	29.02	1	29.02	9.71	0.0169
AB	30.25	1	30.25	10.12	0.0155
Residual	20.92	7	2.99		
Pure Error	12.80	4	3.20		
Cor Total	254.92	12			
Std. Dev.	1.73	R²	0.9179		
Mean	84.92	Adj R²	0.8593		
C.V.	2.04	Pred R²	0.6105		

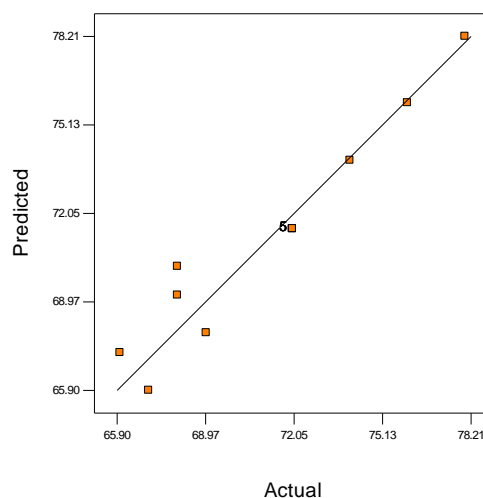
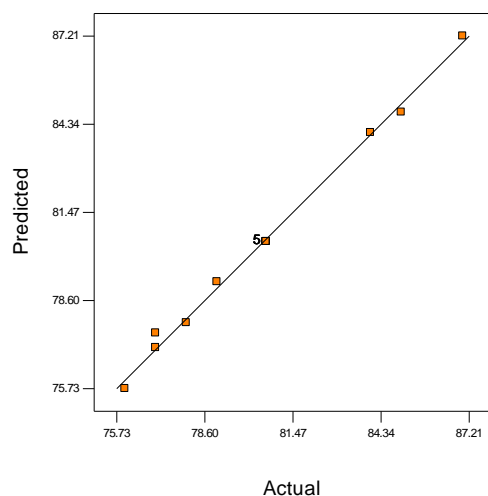
3.4 Treatment Efficiency

The chosen model is shown to contest the current scheme using Design Expert 6.0.7 software by generating emblematic defense plots for definitive diagnoses and residues. Probability plots created with the Design Expert 6.0.7 software were used to analyze the models. Figure 4 shows the probability plots of the standardized residues for COD, color, NH₃-N, Mn, Fe, Zn, Al and Ni. As a result, some models' responses to the data can be considered to be continuously distributed.

As illustrated in Fig. 5, the Design Expert 6.0.7 database was utilized to examine

the interacting connections among independent components and the responses of various replicas which demonstrating that the powdered rosehip powder is 1 g/L. The pH is 9.0, and the percentages of COD, color, and NH₃-N removal were 85%, 74%, and 69%, correspondingly. The elimination percentages for Mn, Fe, Zn, Al, and Ni were 90.9%, 91.9%, 93%, 79%, and 89%, respectively. According to these response charts, the quantity of treatment required is dictated by the amounts of these constituents in the wastewater and the experimental conditions (pH level).

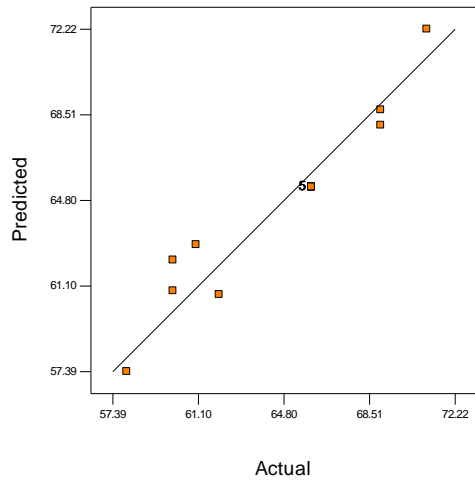
Predicted vs. Actual
COD) Color)



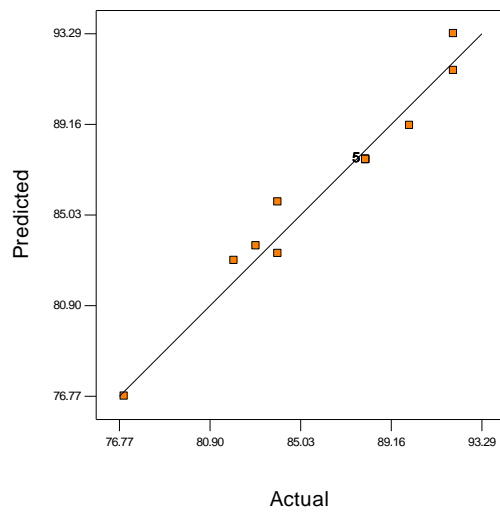
NH₃-N)

Mn)

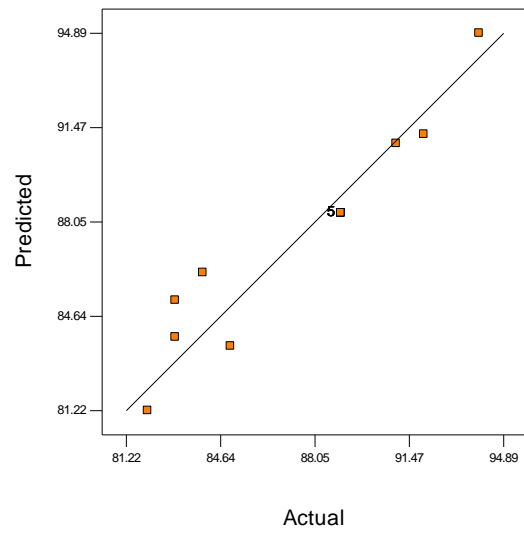
Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater



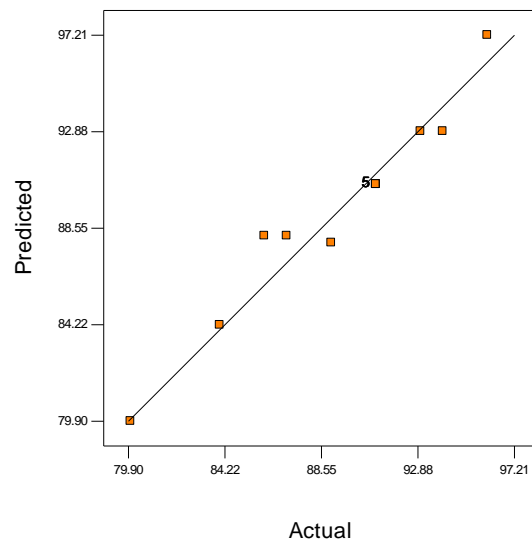
Fe)



Zn)



Al)



Ni)

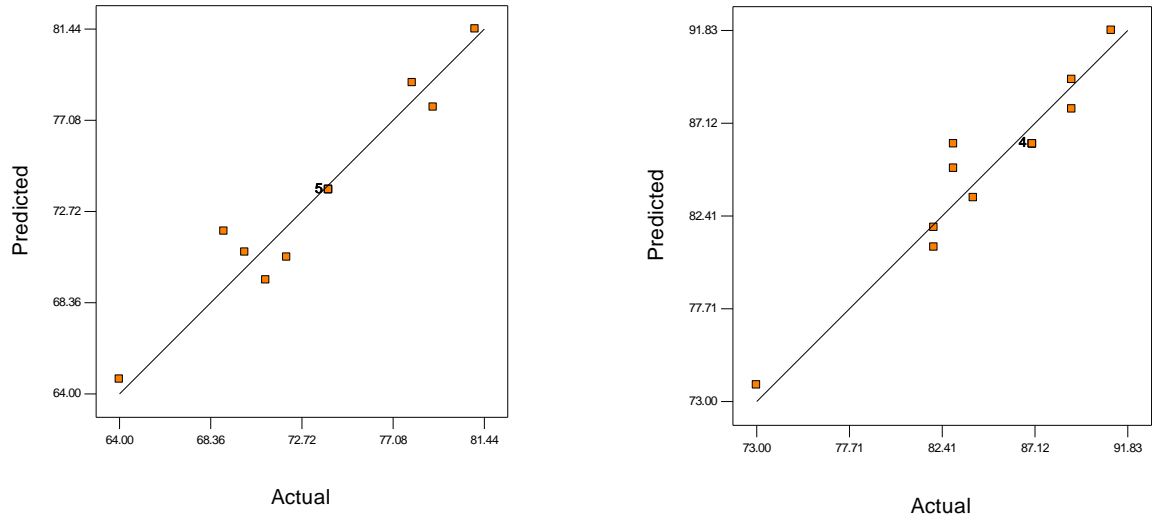
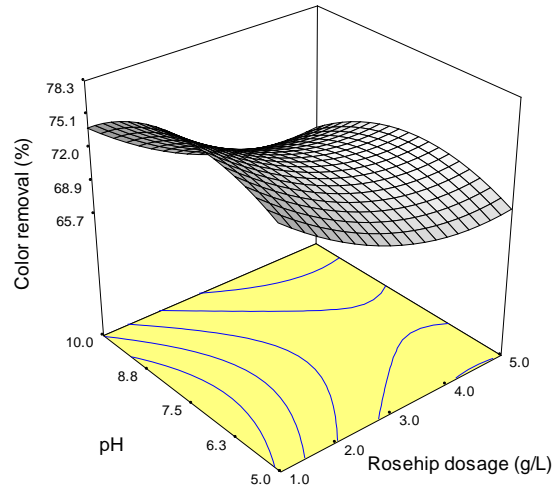
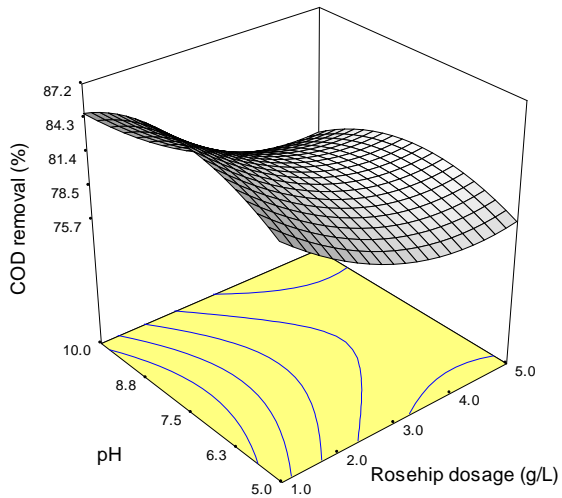


Figure 4: Normal probability plots for a (COD, color, and NH₃-N, Mn, Fe, Zn, Al, and Ni) removals.

Response surface curves

COD)

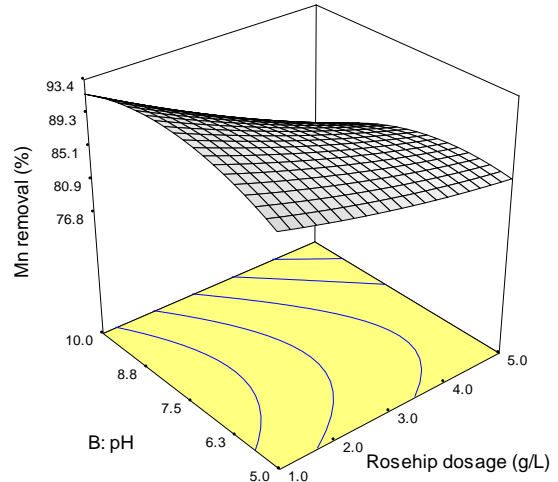
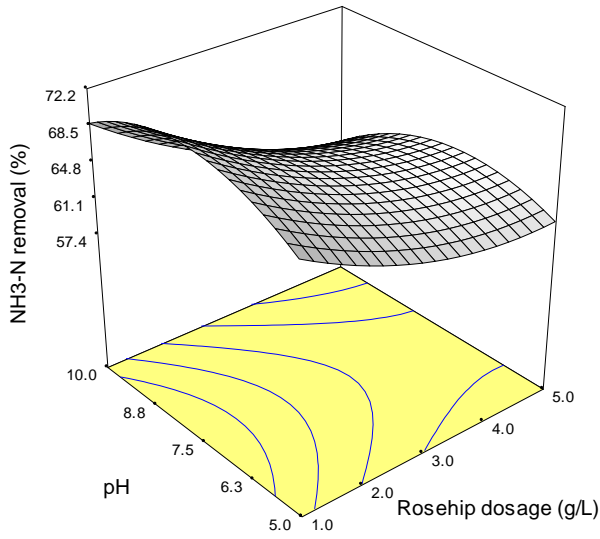
Color)



NH₃-N)

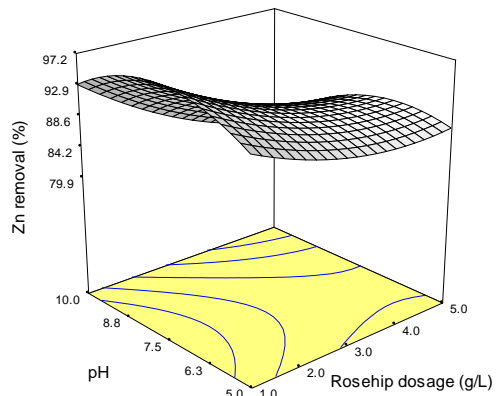
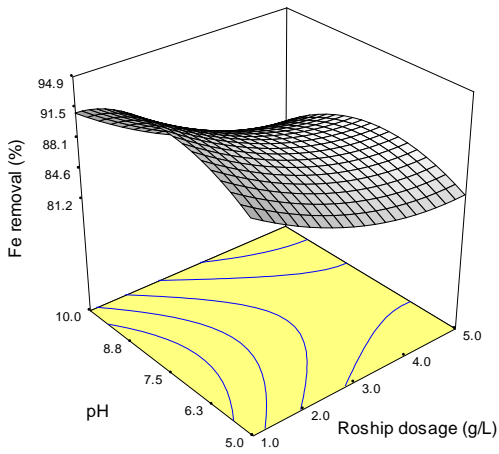
Mn)

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater



Fe)

Zn)



Al)

Ni)

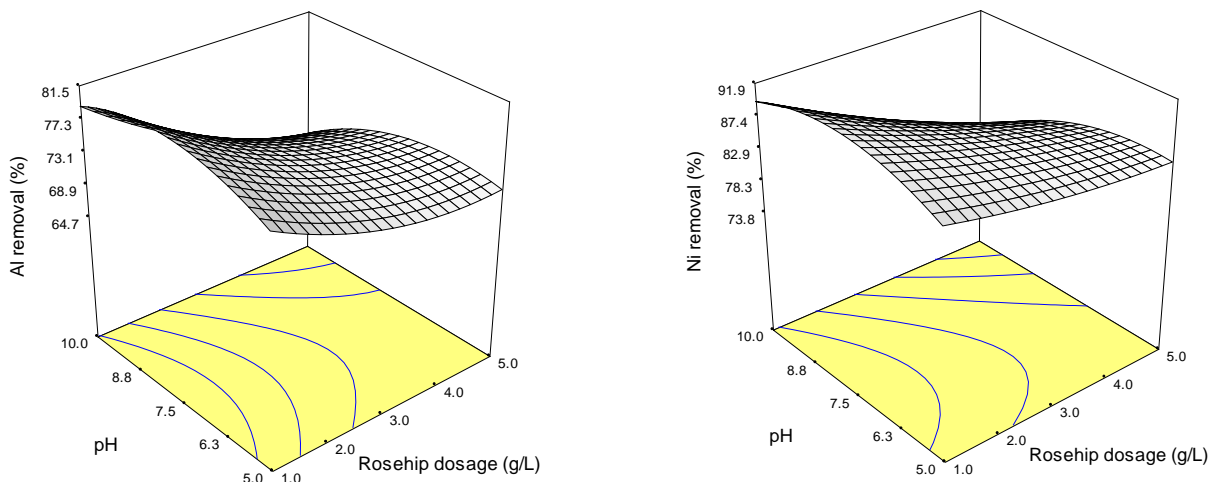


Figure 5: Response surface Plots for a (COD, color, and NH₃-N, Mn, Fe, Zn, Al, and Ni) removals

3.5 Optimization Operational Conditions

The Design Expert 6.0.7 tool was used to obtain the optimum value for dealing with COD, color, NH₃-N, Mn, Fe, Zn, Al, and Ni wastewater. Consequently, the experimental circumstances for each case (pH concentration and crushed rosehip dosage) were computed. The answers were discovered to be the ideal limits for attaining the greatest treatment value. Besides, individual preferences are aggregated into a single value, which the computer then attempts optimization with a referee to the

response objective. As a result, the perfect working settings and per cent removal effectiveness, as shown in Table 6, were determined.

Based on ideal working circumstances, it is expected to remove 87.1%, 78.1%, 72.1%, 93.2%, 94.8%, 97.1%, 81.3%, and 91.7% of COD, color, NH₃-N, Mn, Fe, Zn, Al, and Ni (rosehip powder 1g, pH 8). Testing was done in the laboratory to check the validity of the ideal outcomes, and the experiment results matched the predicted response value.

Table 6: OPTIMAL RESPONSE RESULTS FROM MODEL PREDICTION AND LABORATORY.

	Rosehip (g/l)	pH	COD removal (%)	Color removal (%)	NH ₃ -N removal (%)	Mn removal (%)	Fe removal (%)	Zn removal (%)	Al removal (%)	Ni removal (%)	Desirability
Predicted	1	8	87.1	78.1	72.1	93.2	94.8	97.1	81.3	91.7	1.0
Lab. Experiment			86.1	78	71.0	92	91.7	96.6	80.7	90.5	

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

4 Conclusion

The effective removal of COD, color, TSS, NH₃-N, Mn, Fe, Zn, Al and Ni by rosehip seed powder showed great potential as a natural plant-based coagulant in iron fabrication and steel mill processing. The experiment showed powerful coagulation properties of Shoshana. FTIR analysis also revealed the presence of multiple functional groups involved in the coagulation process. At 1g/l, the rosehip seed powder eliminated a large proportion of COD, color, NH₃-N, Fe, Mn, Al, Cu, and Ni from effluent at pH 8, with percentages of 87.1%, 78.1%, 72.1%, 93.2%, 94.8%, 97.1%, 81.3%, and 91.7%, respectively.

Due to the rosehip seed powder's organic structure, the pH of the wastewater discharge remained constant following its addition. Consequently, no pH adjustment was done throughout the treatment when rosehip seed powder was used as a coagulant.

5 Acknowledgements:

“The authors wish to express sincere thanks to the many individuals and organizations for their kind support, in particular, Karabuk University Turkey, Scientific Research Projects Coordination Unit through its KBÜBAP-22-YL-033 funding, as well as the Institute of International Education-Scholar Rescue Fund, (IIE –SRF). New York, NY 10007 USA, in supporting this work.”

References:

- [1] M.S.S. Abujazar, S. Fatihah, A.E. Kabeel, Seawater desalination using inclined stepped solar still with copper trays in a wet tropical climate, *Desalination*. 423 (2017) 141–148. <https://doi.org/10.1016/j.desal.2017.09.020>.
- [2] H. Panchal, P.K. Shah, Investigation on solar stills having floating plates, *Int. J. Energy Environ. Eng.* 3 (2012) 8. <https://doi.org/10.1186/2251-6832-3-8>.
- [3] X. Zhu, C. Lei, J. Qi, G. Zhen, X. Lu, S. Xu, J. Zhang, H. Liu, X. Zhang, Z. Wu, The role of microbiome in carbon sequestration and environment security during wastewater treatment, *Sci. Total Environ.* 837 (2022) 155793. <https://doi.org/10.1016/j.scitotenv.2022.155793>.
- [4] M.M. Mekonnen, A.Y. Hoekstra, Four billion people facing severe water scarcity, *Sci. Adv.* 2 (2016) 1–7. <https://doi.org/10.1126/sciadv.1500323>.
- [5] A. Mukherjee, T. Mandal, A. Ganguly, P.K. Chatterjee, Lignin degradation in the production of bioethanol—a review, *ChemBioEng Rev.* 3 (2016) 86–96. <https://doi.org/10.1002/cben.201500016>.
- [6] M.Y.D. Alazaiza, A. Albahnasawi, N.K. Coptly, M.J.K. Bashir, D. Eddin, T. Al, S.S. Abu, M. Shadi, S. Abujazar, Nanoscale zero-valent iron application for the treatment of soil, wastewater and groundwater contaminated with heavy metals: a review, *Desalin. Water Treat.* 253 (2022) 194–210. <https://doi.org/10.5004/dwt.2022.28302>.
- [7] J. Lundqvist, G. Mandava, S. Lungu-Mitea, F.Y. Lai, L. Ahrens, In vitro bioanalytical evaluation of removal efficiency for bioactive chemicals in Swedish wastewater treatment plants, *Sci. Rep.* 9 (2019) 1–9. <https://doi.org/10.1038/s41598-019-43671-z>.
- [8] S.N. Ugwu, A.F. Umuokoro, E.A. Echiegu, B.O. Ugwuishiwu, C.C. Enweremadu, Comparative study of the use of natural and artificial coagulants for the treatment of sullage (domestic wastewater), *Cogent Eng.* 4 (2017) 1–13. <https://doi.org/10.1080/23311916.2017.1365676>.
- [9] M.S.S. Abujazar, S. Fatihah, E.R. Lotfy, A.E. Kabeel, S. Sharil, Performance evaluation of inclined copper-stepped solar still in a wet tropical climate, *Desalination*. 425 (2018) 94–103.

- <https://doi.org/10.1016/j.desal.2017.10.022>.
- [10] J. Hubeny, M. Harnisz, E. Korzeniewska, M. Buta, W. Zieliński, D. Rolbiecki, J. Giebułtowicz, G. Nałęcz-Jawecki, G. Płaza, Industrialization as a source of heavy metals and antibiotics which can enhance the antibiotic resistance in wastewater, sewage sludge and river water, *PLoS One*. 16 (2021) e0252691. <https://doi.org/10.1371/journal.pone.0252691>.
- [11] Q. Mahmood, S. Shaheen, M. Bilal, M. Tariq, B. Saima, Z. Zahid, Chemical pollutants from an industrial estate in Pakistan: a threat to environmental sustainability, *Appl. Water Sci.* 9 (2019) 1–9. <https://doi.org/10.1007/s13201-019-0920-1>.
- [12] M.S.S. Abujazar, S.U. Karaağaç, H. Ramadan, S.S. Abu Amr, M.Y.D. Alazaiza, Application of pinecones powder as a natural coagulants for sustainable treatment of industrial wastewater, *Desalin. WATER Treat.* 269 (2022) 57–64. <https://doi.org/10.5004/dwt.2022.28749>.
- [13] P.K. Chhonkar, S.P. Datta, H.C. Joshi, H. Pathak, Impact of industrial effluents on soil health and agriculture - Indian experience: Part I - Distillery and paper mill effluents, *J. Sci. Ind. Res. (India)*. 59 (2000) 350–361.
- [14] N.A.A. Qasem, R.H. Mohammed, D.U. Lawal, Removal of heavy metal ions from wastewater: a comprehensive and critical review, *Npj Clean Water*. 4 (2021). <https://doi.org/10.1038/s41545-021-00127-0>.
- [15] Y. Wu, Z. Zhang, P. He, H. Ren, N. Wei, F. Zhang, H. Cheng, Q. Wang, Membrane fouling in a hybrid process of enhanced coagulation at high coagulant dosage and cross-flow ultrafiltration for deinking wastewater tertiary treatment, *J. Clean. Prod.* 230 (2019) 1027–1035. <https://doi.org/10.1016/j.jclepro.2019.05.139>.
- [16] K.E. Lee, N. Morad, T.T. Teng, B.T. Poh, Development, characterization and the application of hybrid materials in coagulation/flocculation of wastewater: A review, *Chem. Eng. J.* 203 (2012) 370–386. <https://doi.org/10.1016/j.cej.2012.06.109>.
- [17] K.E. Lee, M.M. Hanafiah, A.A. Halim, M.H. Mahmud, Primary Treatment of Dye Wastewater Using Aloe Vera-aided Aluminium and Magnesium Hybrid Coagulants, *Procedia Environ. Sci.* 30 (2015) 56–61. <https://doi.org/10.1016/j.proenv.2015.10.010>.
- [18] Y. Zou, X. Wang, A. Khan, P. Wang, Y. Liu, A. Alsaedi, T. Hayat, X. Wang, Environmental Remediation and Application of Nanoscale Zero-Valent Iron and Its Composites for the Removal of Heavy Metal Ions: A Review, *Environ. Sci. Technol.* 50 (2016) 7290–7304. <https://doi.org/10.1021/acs.est.6b01897>.
- [19] Y. Birhanu, S. Leta, G. Adam, Removal of chromium from synthetic wastewater by adsorption onto Ethiopian low-cost Odaracha adsorbent, *Appl. Water Sci.* 10 (2020) 227. <https://doi.org/10.1007/s13201-020-01310-3>.
- [20] A. Aghababai Beni, A. Esmaeili, Y. Behjat, Invent of a simultaneous adsorption and separation process based on dynamic membrane for treatment Zn(II), Ni(II) and, Co(II) industrial wastewater, *Arab. J. Chem.* 14 (2021) 103231. <https://doi.org/10.1016/j.arabjc.2021.103231>.
- [21] M. Alazaiza, A. Albahnasawi, G. Ali, M. Bashir, D. Nassani, T. Al Maskari, S. Amr, M. Abujazar, Application of Natural Coagulants for Pharmaceutical Removal from Water and Wastewater: A Review, *Water*. 14 (2022) 140. <https://doi.org/10.3390/w14020140>.
- [22] G. Wu, Z. Li, Y. Huang, F. Zan, J. Dai,

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

- J. Yao, B. Yang, G. Chen, L. Lei, Electrochemically assisted sulfate reduction autotrophic denitrification nitrification integrated (e-SANI®) process for high-strength ammonium industrial wastewater treatment, *Chem. Eng. J.* 381 (2020) 122707. <https://doi.org/10.1016/j.cej.2019.122707>.
- [23] M.A.N. Camacho, A.I.G. López, A. Martínez-Ferez, J.M. Ochando-Pulido, Increasing large-scale feasibility of two-phase olive-oil washing wastewater treatment and phenolic fraction recovery with novel ion exchange resins, *Chem. Eng. Process. - Process Intensif.* 164 (2021) 108416. <https://doi.org/10.1016/j.cep.2021.108416>.
- [24] G. Han, Y. Du, Y. Huang, S. Yang, W. Wang, S. Su, B. Liu, Efficient removal of hazardous benzohydroxamic acid (BHA) contaminants from the industrial beneficiation wastewaters by facile precipitation flotation process, *Sep. Purif. Technol.* 279 (2021) 119718. <https://doi.org/10.1016/j.seppur.2021.119718>.
- [25] Y. Jiao, L. Liu, Q. Zhang, M. Zhou, Y. Zhang, Treatment of reverse osmosis concentrate from industrial coal wastewater using an electro-peroxone process with a natural air diffusion electrode, *Sep. Purif. Technol.* 279 (2021) 119667. <https://doi.org/10.1016/j.seppur.2021.119667>.
- [26] A.A. Owodunni, S. Ismail, Revolutionary technique for sustainable plant-based green coagulants in industrial wastewater treatment—A review, *J. Water Process Eng.* 42 (2021) 102096. <https://doi.org/10.1016/j.jwpe.2021.102096>.
- [27] G.L. Muniz, A.C. Borges, T.C.F. da Silva, Performance of natural coagulants obtained from agro-industrial wastes in dairy wastewater treatment using dissolved air flotation, *J. Water Process Eng.* 37 (2020) 101453. <https://doi.org/10.1016/j.jwpe.2020.101453>.
- [28] P.J.M. Martins, P.M. Reis, R.C. Martins, L.M. Gando-Ferreira, R.M. Quinta-Ferreira, Iron recovery from the Fenton's treatment of winery effluent using an ion-exchange resin, *J. Mol. Liq.* 242 (2017) 505–511. <https://doi.org/10.1016/j.molliq.2017.07.041>.
- [29] N. Meunier, P. Drogui, C. Montané, R. Hausler, G. Mercier, J.-F. Blais, Comparison between electrocoagulation and chemical precipitation for metals removal from acidic soil leachate, *J. Hazard. Mater.* 137 (2006) 581–590. <https://doi.org/10.1016/j.jhazmat.2006.02.050>.
- [30] P. Ostermeyer, L. Bonin, K. Folens, F. Verbruggen, C. García-Timmermans, K. Verbeke, K. Rabaey, T. Hennebel, Effect of speciation and composition on the kinetics and precipitation of arsenic sulfide from industrial metallurgical wastewater, *J. Hazard. Mater.* 409 (2021) 124418. <https://doi.org/10.1016/j.jhazmat.2020.124418>.
- [31] S. Manhokwe, C. Zvidzai, Post-treatment of yeast processing effluent from a bioreactor using aluminium chlorohydrate polydadmec as a coagulant, *Sci. African.* 6 (2019) 4–11. <https://doi.org/10.1016/j.sciaf.2019.e00125>.
- [32] M.F. Mohd Amin, S.G.J. Heijman, L.C. Rietveld, The potential use of polymer flocculants for pharmaceuticals removal in wastewater treatment, *Environ. Technol. Rev.* 3 (2014) 61–70. <https://doi.org/10.1080/21622515.2014.966784>.
- [33] L. Zhou, H. Zhou, X. Yang, Preparation

- and performance of a novel starch-based inorganic/organic composite coagulant for textile wastewater treatment, *Sep. Purif. Technol.* 210 (2019) 93–99. <https://doi.org/10.1016/j.seppur.2018.07.089>.
- [34] A. Hariz Amran, N. Syamimi Zaidi, K. Muda, L. Wai Loan, Effectiveness of Natural Coagulant in Coagulation Process: A Review, *Int. J. Eng. Technol.* 7 (2018) 34. <https://doi.org/10.14419/ijet.v7i3.9.15269>.
- [35] A. Ahmad, S.R.S. Abdullah, H.A. Hasan, A.R. Othman, N. 'Izzati Ismail, Plant-based versus metal-based coagulants in aquaculture wastewater treatment: Effect of mass ratio and settling time, *J. Water Process Eng.* 43 (2021) 102269. <https://doi.org/10.1016/j.jwpe.2021.102269>.
- [36] M. Shadi, S. Abujazar, S. Ugurlu, S.S. Abu, S. Fatihah, M.J.K. Bashir, M.Y.D. Alazaiza, E. Ibrahim, The effectiveness of rosehip seeds powder as a plant-based natural coagulant for sustainable treatment of steel industries wastewater, *Desalin. Water Treat.* 270 (2022) 44–51. <https://doi.org/10.5004/dwt.2022.28782>.
- [37] S.K. Rifi, S. Souabi, L. El Fels, A. Driouich, I. Nassri, C. Haddaji, M. Hafidi, Optimization of coagulation process for treatment of olive oil mill wastewater using *Moringa oleifera* as a natural coagulant, CCD combined with RSM for treatment optimization, *Process Saf. Environ. Prot.* 162 (2022) 406–418. <https://doi.org/10.1016/j.psep.2022.04.010>.
- [38] S. Nimesha, C. Hewawasam, D.J. Jayasanka, Y. Murakami, N. Araki, N. Maharjan, Effectiveness of natural coagulants in water and wastewater treatment, *Glob. J. Environ. Sci. Manag.* 8 (2022) 101–116. <https://doi.org/10.22034/gjesm.2022.01.08>.
- [39] S. Ghafari, H.A. Aziz, M.J.K. Bashir, The use of poly-aluminum chloride and alum for the treatment of partially stabilized leachate: A comparative study, *Desalination.* 257 (2010) 110–116. <https://doi.org/10.1016/j.desal.2010.02.037>.
- [40] S. Yi, Y. Su, B. Qi, Z. Su, Y. Wan, Application of response surface methodology and central composite rotatable design in optimizing the preparation conditions of vinyltriethoxysilane modified silicalite/polydimethylsiloxane hybrid pervaporation membranes, *Sep. Purif. Technol.* 71 (2010) 252–262. <https://doi.org/10.1016/j.seppur.2009.12.005>.
- [41] C. Tizaoui, L. Bouselmi, L. Mansouri, A. Ghrabi, Landfill leachate treatment with ozone and ozone/hydrogen peroxide systems, *J. Hazard. Mater.* 140 (2007) 316–324. <https://doi.org/10.1016/j.jhazmat.2006.09.023>.
- [42] H. Salehizadeh, S.A. Shojaosadati, Extracellular biopolymeric flocculants Recent trends and biotechnological importance, *Biotechnol. Adv.* 19 (2001) 371–385. [https://doi.org/S0734-9750\(01\)00071-4](https://doi.org/S0734-9750(01)00071-4).
- [43] F.V. Adams, A.F. Mulaba-Bafubiandi, Application of rice hull ash for turbidity removal from water, *Phys. Chem. Earth.* 72–75 (2014) 73–76. <https://doi.org/10.1016/j.pce.2014.09.010>.
- [44] N. He, Y. Li, J. Chen, S. Lun, Identification of a novel bioflocculant from a newly isolated *Corynebacterium glutamicum*, *Biochem. Eng. J.* 11 (2002) 137–148. [https://doi.org/S1369-703X\(02\)00018-9](https://doi.org/S1369-703X(02)00018-9).
- [45] S. Vishali, R. Karthikeyan, Cactus *opuntia (ficus - indica)*: an eco-friendly alternative coagulant in the treatment of paint effluent, *Desalin. Water Treat.* 56 (2015) 1489–1497. <https://doi.org/10.1080/19443994.2014.945487>.

Factorial Design and Optimization of Rosehip Seed Powder as a Natural Coagulant for Industrial Wastewater

- [46] B. Kakoi, J.W. Kaluli, P. Ndiba, G. Thiong'o, Banana pith as a natural coagulant for polluted river water, *Ecol. Eng.* 95 (2016) 699–705. <https://doi.org/10.1016/j.ecoleng.2016.07.001>.