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Kinetic studies on optimization of various operational parameters for the biosorption of textile waste water effluents using *Musa paradisiaca* and *Nymphaea nouchali*

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Abstract

The present research work was to compare the biosorption potential of two natural potential biosorbents. The stem portion of the plants namely *Musa paradisiaca* and *Nymphaea nouchali* were used for this study. The textile effluent was made to interact with the biosorbents in the aerobic sequential batch reactor (ASBR). Various operational parameters like pH, temperature, dye waste water to water ratio, and mixed liquor volatile suspended solids were optimized using the Box-Behnken design. The responses were recorded as percentage decolorization and percentage COD reduction. Of the two natural biosorbents, *Musa paradisiaca* showed the best biosorption potential. The R-sq and R-sq(adj) for percentage decolorization of *Musa paradisiaca* are 65.58% and 25.42%. And R-sq and R-sq(adj) for percentage COD reduction of *Musa paradisiaca* are 71.16% and 37.50%. The R-sq and R-sq(adj) for percentage decolorization of *Nymphaea nouchali* are 62.25% and 18.20%. The R-sq and R-sq(adj) values for percentage COD reduction of *Nymphaea nouchali* are 61.88% and 17.41%.

Keywords
Biosorption, *Musa paradisiaca, Nymphaea nouchali,* COD, ASBR.

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INTRODUCTION

Textile industries trace its own path almost from the ancient age. The textile dyes of 21st century comprise a predominant segment of the whole business in the chemical industry. Textile industry is one of the most important and the largest industrial sector and contributes to high economy to the country, contributing around 6% GDP, 16% to export and about 18% to industrial production. The dye and textile industry constitute a very greater part in the country's economy and development. Though textile dyeing is a simple process, it has greater attention towards the textile and fabric industries. But aside of economy, the textile dyes also lead to environmental

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graver and so an effective method for pacifying it is required (Perkins, 1856). There are several dyes such as azo dyes, vat dyes, reactive dyes, dispersive dyes etc. Dye molecules comprise of 2 key components: The chromophore, accountable for manufacturing the color, and also the auxochromes, which may not solely supplement the group however additionally render the molecule soluble in water and provides increased affinity (to attach) toward the fibers. Dyes exhibit goodly structural diversity and are classified in many ways in which. These may be classified each by their chemical structure and their application to the fiber kind. Dyes may additionally be classified on the premise of their solubility: soluble dyes that embody acid, mordant, metal advanced, direct, basic and reactive dyes; and insoluble dyes as well as early, sulfur, vat and disperse dyes.

Besides this, either a major group linkage or Associate in anthraquinone unit additionally characterizes dyes with chemicals. It's worth noting that the group dyes are the one most generally used and accounts 65–70% of the total dyes produced. Though, the classification of dyes on basis of structure is an appropriate system and has many advantages, like it readily identifies dyes as belonging to a group and having characteristic properties, e.g., azo dyes (strong, good all-round properties, cost-effective) and anthraquinone dyes (weak, expensive), there are a manageable number of chemical groups (about a dozen) (Eswaramoorthi S. Dhanapal et al., 2008). Besides these, both the synthetic dye chemist and the dye technologist use this classification most widely (Kant et al., 2012). However, the classification based on application is advantageous before considering chemical structures in detail because of the complexities of the dye nomenclature from this type of system. It is also worth to point that classification by application is the principal system adopted by the Color Index (C.I.).

Many physical and chemical methods involving adsorption (Bestani et al., 2008), precipitation/coagulation/flocculation (Verma et al., 2012; Ebeling et al., 2003) Zhou et al. 2008), filtration (Avlonitis et al. 2008), oxidation (Gupta and Suhas 2009), ozonation (Wu et al. 2007), advanced oxidation processes, ultra violet photolysis and sonolysis techniques (Bandala 2008) have been commercially deployed for the treatment of textile dye effluents. Advanced technology and methods such as ultrafiltration, nanofiltration and microfiltration and reverse osmosis have also been additionally deployed for the dye removal process (Avlonitis et al. 2008). Adsorption is one of cost-effective techniques for textile dye decolorization (Garg et al., 2003; Mishra and Shukla 2016). Phytoremediation could be the possible method for biosorption (Bedabati and Gupta, 2016; Han *et al.,* 2010).

MATERIALS AND METHODS

Plant samples *Musa paradisiaca* and *Nymphaea nouchali,* stems were collected from various places around the district of Chennai, Tamilnadu (Biplab Kumar *et al.,* 2013; Kemi Dadimola *et al.,* 2017; Rezania *et al.,* 2016). The collected stem was tightly packed with Polyethene bag and then transfer to the laboratory. Then it was washed with distilled water twice and kept under room temperature for two weeks in dark condition. Then it was made into powder using blender.

Aerobic Sequential batch reactor (ASBR)

Two ASBRs are utilized for leading the exploration work. The reactors are indistinguishable in all perspectives. The elucidating schematic of one of the four reactors is appeared in Fig. 1. For treatment with plant materials exclusively, the acrylic tank alone is utilized. For blended plant material treatment, the plant material is put in their individual openings as appeared in the figure. The limit of the Acrylic Tank is 5 liters. The example that will be dealt with is permitted to enter the Acrylic tank through a valve. The stream rate of the example (gushing) is 5ml/min. The plant materials are exposed to the treatment of around 36 hours each. The subsequent gushing is presently permitted to respond with crab shell powder.

ASBR inoculation and start-up

The two ASBR reactors are filled with the textile dye industry effluent. The reactor is inoculated with the mixed culture obtained from textile dye wastewater treatment pond and the pH is maintained at the optimum value of 7.2. Temperature is maintained at 32±1°C. The textile dye industry wastewater is pumped into the reactor regularly and the COD reduction, mixed liquor volatile suspended solids (MLVSS) concentration and biogas production are monitored regularly in all the four ASBR.

Experimental procedure for optimization studies in ASBR's

Amid the fill time frame, material color wastewater is sustained into the reactor. The response is done for determined time as appeared in the Table 1. At that point slop is permitted to settle. After the bio-slop is completely settled, the supernatant must be expelled amid the withdrawal time. From that point onward, crisp material color wastewater is brought into the reactor and the above activity is rehashed.

To control the stable bio-muck fixation in the ASBR, the overabundance bio-ooze is expelled from the base of the ASBR. Every one of the trials is performed utilizing CCD and the decolorization, slime volume file (SVI) and COD are dissected for each condition according to standard techniques for examination, APHA (1992). At the enhanced conditions, all the four SBR's exhibitions are contemplated as far as decolorization and COD decrease.

Table 1 Operating procedure of ASBR

Steps	Cycle time, h		
	12	24	36
Fill, h	0.5	1	1
React, h	10	20	32
Settle, h	1	2	2
Withdrawal, h	0.5	1	1

Table 2 Levels of variables for the textile dye industry effluent treatment using *Musa paradisiaca* and *Nymphaea nouchali* Stem

Variables	Code	Levels		
		-1	0	+1
pH	A	6.5	7.5	8.5
Temperature	B	28	32	36
Waste water dilution ratio	C	1:0	1:1	1:2
MLVSS, mg/L	D	4500	6000	7500

Table 3 Characteristics of textile dyeing industry effluent

Parameters*	Method of detection	CETP Standards	Textile Dye Effluent without treatment
pH	IS: 3025 part 11-1983 (Reaff: 2002)	5.5 – 9.0	7.35
Color	Hazen Units	25	500
TSS	IS: 3025 part 17-1984 (Reaff: 2002)	100	221
TDS	IS: 3025 part 15-1984 (Reaff: 2003)	2100	3381
BOD	IS: 3025 part 44-1993 (Reaff: 2003)	100	168
COD	IS: 3025 part 58-2006	250	699
Sulphates (as SO_4^{2-})	APHA 22nd EDN-4500-SO_4^{2-}E	1000	1905
Chlorides (as Cl^-)	IS: 3025 part 32-1988 (Reaff: 2003)	1000	1200
Sodium	Calculation Method	60	73.98
Total Kjedahl Nitrogen	APHA 22nd EDN-4500-Norg	100	153.2
Oil & Grease	IS: 3025 part 39-1991 (Reaff: 2003)	20	16
Sulphide (as S^{2-})	APHA 22nd EDN-4500-S^{2-}	2.8	6.3
Copper (as Cu)	APHA 22nd EDN 3111 B	3.0	0.26
Cadmium (as Cd)	APHA 22nd EDN 3111 B	2.0	0.2
Chromium (as Cr)	APHA 22nd EDN 3111 B	2.0	0.1
Lead (as Pb)	APHA 22nd EDN 3111 B	1.0	0.1
Selenium (as Se)	APHA 22nd EDN 3111 B&C	0.05	0.02
Zinc (as Zn)	IS: 3025 part 49 (Reaff: 2003)	15	0.36
Nickel (as Ni)	APHA 22nd EDN 3111 B	3.0	0.22

*** All values except pH and color are in mg/L**

Table 4 Details of peaks denoting different functional groups in FTIR analysis

Peaks for *Musa paradisiaca* Stem	Peaks for *Nymphaea nouchali* Stem
3303.46- PHENOLS ALCOHOLS, O-H	3306.36- Phenols
	2926.45- CH_2, CH
2922.59- CH_2, CH	2855.1- CH_2, CH
2853.17- CH_2.CH	1725.98- C=0 (acid)
1732.73- C=O ACID	1650.77- C=C
1637.27- C=C	1617- C=C
1446.35- ALPHA CH_2 BEND	1536.02 C=C
	1446.35- ALPHA CH_2 BEND
1375.96- O-C	1351.86- O-C
1323.89- O-C	
1247.72-C-O PHENOLS, C-O ACID	

Table 5 BBD based experimental conditions and results of decolorization and COD of *Musa paradisiaca* stem against Textile Dying Industry Effluent

Run no.	A B C D	Decolorization, %		COD reduction, %	
		Experimental	Predicted	Experimental	Predicted
1	1 -10 0	41.6	61.7	49.8	61.8
2	0 1 -10	39.2	52.7	46.0	53.1
3	1 0 -10	34.5	53.7	42.9	57.4
4	1 0 0 1	41.4	47.9	50.4	47.3
5	0 1 0 1	45.6	43.9	53.2	44.8
6	0 -11 0	56.1	43.7	57.6	45.2
7	-1-10 0	43.4	52.8	46.9	53.7
8	0 0 1 -1	52.1	36.6	60.9	39.3
9	0 0 1 1	59.8	48.8	64.5	51.6
10	-10 0 -1	42.6	43.2	48.6	45.4
11	0 0 0 0	48.9	51.5	52.6	56.3
12	1 0 0 -1	42.1	42.3	49.2	43.7
13	-11 0 0	37.2	54.9	39.8	53.9
14	0 0 -11	46.7	56.9	54.0	55.9
15	-10 0 1	48.3	55.1	49.6	54.0
16	1 1 0 0	39.2	40.3	42.3	41.8
17	1 0 1 0	49.1	58.3	59.5	59.8
18	0 -1-10	39.7	55.7	42.3	56.9
19	0 0 0 0	46.8	54.9	54.3	59.3
20	0 1 0 -1	45.8	42.7	51.0	43.4
21	0 1 1 0	48.6	50.0	53.8	47.8
22	0 -10 1	33.2	39.8	36.3	42.3
23	0 0 -1-1	41.1	47.1	46.3	48.9
24	0 -10 -1	40.0	44.5	45.7	44.3
25	-10 -10	48.6	47.1	55.7	46.7
26	0 0 0 0	46.7	42.4	51.3	51.7
27	-10 1 0	39.4	49.5	44.5	48.5

Table 6 ANOVA for Evaluation of *Musa paradisiaca* stem against Textile Dying Industry Effluent Using Box Behnken design – Decolorization

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	14	623.519	44.537	1.63	0.200
Linear	4	202.855	50.714	1.86	0.182
pH	1	136.688	136.688	5.01	0.045
Temperature	1	1.763	1.763	0.06	0.804
Waste Water Dye Ratio	1	9.363	9.363	0.34	0.569
MLVSS	1	55.041	55.041	2.02	0.181
Square	4	291.674	72.919	2.67	0.084
pH*pH	1	2.001	2.001	0.07	0.791
temperature*temperature	1	51.253	51.253	1.88	0.196
WWDR*WWDR	1	7.363	7.363	0.27	0.613
MLVSS*MLVSS	1	147.701	147.701	5.42	0.038
2-Way Interaction	6	128.990	21.498	0.79	0.596
pH*temperature	1	14.440	14.440	0.53	0.481
pH*WWDR	1	1.960	1.960	0.07	0.793
pH*MLVSS	1	33.062	33.062	1.21	0.292
temperature*WWDR	1	71.403	71.403	2.62	0.132
temperature*MLVSS	1	0.002	0.002	0.00	0.993
WWDR*MLVSS	1	8.122	8.122	0.30	0.595
Error	12	327.287	27.274		
Lack-of-Fit	10	192.701	19.270	0.29	0.929
Pure Error	2	134.587	67.293		
Total	26				

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
5.22245	65.58%	25.42%	1412.78	0.00%

Table 7 ANOVA for Evaluation of *Musa paradisiaca* stem against Textile Dying Industry Effluent Using Box Behnken design – COD

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	14	826.673	59.048	2.11	0.100
Linear	4	256.972	64.243	2.30	0.118
pH	1	180.188	180.188	6.45	0.026
Temperature	1	8.333	8.333	0.30	0.595
Waste Water Dye Ratio	1	24.367	24.367	0.87	0.369
MLVSS	1	44.083	44.083	1.58	0.233
Square	4	329.096	82.274	2.95	0.066
pH*pH	1	3.891	3.891	0.14	0.715
temperature*temperature	1	37.689	37.689	1.35	0.268
WWDR*WWDR	1	9.071	9.071	0.32	0.579
MLVSS*MLVSS	1	196.290	196.290	7.03	0.021
2-Way Interaction	6	240.605	40.101	1.44	0.279
pH*temperature	1	62.410	62.410	2.33	0.161

pH*WWDR	1	11.560	11.560	0.41	0.532
pH*MLVSS	1	51.122	51.122	1.83	0.201
temperature*WWDR	1	100.000	100.000	3.58	0.083
temperature*MLVSS	1	3.610	3.610	0.13	0.725
WWDR*MLVSS	1	11.902	11.902	0.43	0.526
Error	12	335.106	27.925		
Lack-of-Fit	10	164.979	16.498	0.19	0.971
Pure Error	2	170.127	85.063		
Total	26				

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
5.28446	**71.16%**	**37.50%**	**1333.07**	**0.00%**

Table 8 BBD based experimental conditions and results of decolorization and COD of *Nymphaea nouchali* stem against Textile Dying Industry Effluent

Run					%Decolorization		COD reduction	
no.	A	B	C	D	Experimental	Predicted	Experimental	Predicted
1	0	0	1	1	62.4	61.7	69.6	61.8
2	1	0	0	1	51.2	52.7	58.1	53.1
3	0	-1	1	0	63.5	53.7	64.6	57.4
4	0	1	0	1	56.4	47.9	48.2	47.3
5	1	-1	0	0	42.3	43.9	44.3	44.8
6	1	0	0	-1	59.2	52.8	47.4	45.2
7	1	0	1	0	46.1	36.6	62.0	53.7
8	1	1	0	0	43.2	48.8	46.1	39.3
9	-1	1	0	0	52.9	43.2	47.2	51.6
10	0	0	-1	-1	40.6	51.5	39.6	45.4
11	-1	0	1	0	43.1	42.3	56.7	56.3
12	0	0	-1	1	36.4	54.9	42.7	43.7
13	-1	0	0	1	57.3	56.9	52.2	53.9
14	0	-1	0	-1	50.5	55.1	51.1	55.9
15	0	0	0	0	42.6	40.3	45.9	54.0
16	1	0	-1	0	48.4	58.3	49.3	41.8
17	0	0	0	0	37.6	55.7	42.0	59.8
18	0	0	0	0	38.9	54.9	46.2	56.9
19	0	-1	0	1	46.7	42.7	53.0	59.3
20	0	-1	-1	0	55.6	50.0	51.6	43.4
21	0	1	1	0	40.4	39.8	42.8	47.8
22	-1	-1	0	0	52.1	47.1	55.3	42.3
23	0	1	-1	0	51.9	44.5	60.5	48.9
24	-1	0	-1	0	59.3	47.1	60.1	44.3
25	0	1	0	-1	47.7	42.4	40.2	51.7
26	-1	0	0	-1	54.1	49.1	58.8	43.5
27	0	0	1	-1	45.2	54.7	45.8	48.7

Table 9 ANOVA for Evaluation of *Nymphaea nouchali* stem against Textile Dying Industry Effluent Using Box Behnken design – Decolorization

Analysis of Variance

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Model	14	1038.64	74.188	1.41	0.277
Linear	4	492.12	123.031	2.34	0.114
pH	1	163.54	163.541	3.12	0.103
Temperature	1	123.52	123.521	2.35	0.151
WWDR	1	202.54	202.541	3.86	0.073
MLSVV	1	2.52	2.521	0.05	0.830
Square	4	369.82	92.456	1.76	0.201
pH*pH	1	84.62	84.624	1.61	0.228
temperature*temperature	1	44.34	44.339	0.84	0.376
WWDR*WWDR	1	16.96	16.961	0.32	0.580
MLSVV*MLSVV	1	114.91	114.907	2.19	0.165
2-Way Interaction	6	176.69	29.448	0.56	0.754
pH*temperature	1	2.56	2.560	0.05	0.829
pH*WWDR	1	23.52	23.523	0.45	0.516
pH*MLSVV	1	3.24	3.240	0.06	0.808
temperature*WWDR	1	69.72	69.723	1.33	0.272
temperature*MLSVV	1	14.44	14.440	0.28	0.609
WWDR*MLSVV	1	63.20	63.202	1.20	0.294
Error	12	629.91	52.493		
Lack-of-Fit	10	596.42	59.642	3.56	0.239
Pure Error	2	33.49	16.743		
Total	26	1668.55			

Model Summary

S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**
7.24518	**62.25%**	**18.20%**	**0.00%**

Table 10 ANOVA for Evaluation of *Nymphaea Nouchali* stem against Textile Dying Industry Effluent Using Box Behnken design – COD reduction

Analysis of Variance

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Model	**14**	**998.75**	**71.339**	**1.39**	**0.286**
Linear	**4**	**494.22**	**123.556**	**2.41**	**0.107**
pH	**1**	**263.58**	**263.578**	**5.14**	**0.043**
Temperature	**1**	**77.83**	**77.826**	**1.52**	**0.241**
dye to WWDR	**1**	**145.81**	**145.812**	**2.84**	**0.117**
MLSVV	**1**	**7.01**	**7.007**	**0.14**	**0.718**
Square	**4**	**346.33**	**86.582**	**1.69**	**0.217**
pH*pH	**1**	**122.65**	**122.645**	**2.39**	**0.148**
temperature*temperature	**1**	**10.39**	**10.385**	**0.20**	**0.661**
WWDR*WWDR	1	9.25	9.246	0.18	0.679
MLSVV*MLSVV	1	97.85	97.850	1.91	0.192
2-Way Interaction	6	158.20	26.366	0.51	0.787

pH*temperature	1	0.46	0.462	0.01	0.926
pH*WWDR	1	41.60	41.603	0.81	0.385
pH*MLSVV	1	10.24	10.240	0.20	0.663
temperature*WWDR	1	50.41	50.410	0.98	0.341
temperature*MLSVV	1	0.20	0.202	0.00	0.951
WWDR*MLSVV	1	55.28	55.279	1.08	0.320
Error	12	615.17	51.264		
Lack-of-Fit	10	601.22	60.122	8.62	0.108
Pure Error	2	13.95	6.973		
Total	26	1613.92			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
7.15988	**61.88%**	**17.41%**	**0.00%**

Table 11 Performance of the Sorbents at their optimum conditions

Plant Sample	pH	Temperature ºc	WWDR	MLSVV	% Decolorization	% COD
Musa paradisiaca stem	7.5	33.5	1:2	7000	62.3	65.4
Nymphaea nouchali stem	7.0	34	1:1	6500	70.3	72.6

Batch study

All the batch studies are carried out in 250cc Erlenmeyer flasks. Sterilized batch reactors are used to carry out the experiments (Arrojo et al., 2004). All the reactors are maintained same Environmental Conditions according to the required parameters.

Response Surface Methodology (RSM)

Design of experiment (DOE)

The RSM has a few classes of structures, with its very own properties and qualities. Focal composite structure (CCD) and Box– Behnken plan (BBD) are the most mainstream plans connected by the scientists. An earlier learning with comprehension of the related bioprocesses is important for a sensible displaying approach. In this examination, BBD is utilized in bunch reactor and also in SBR. This plan is utilized to contemplate the impacts of the factors towards their reactions and hence in the streamlining ponders. This strategy is appropriate for fitting a quadratic surface and it improves the viable parameters with a base number of investigations, and in addition to dissect the cooperation between the parameters. So as to decide the presence of a connection between the elements and the reaction factors, the information gathered are investigated in a measurable way, utilizing relapse. A relapse configuration is regularly utilized to demonstrate a reaction as a numerical capacity (either known or observational) of a couple of nonstop factors and great model parameter gauges are wanted.

Model fitting and statistical analysis

The relapse and graphical investigation with factual importance are completed utilizing Minitab 18 (Minitab is an insights bundle created at the Pennsylvania State University, a measurable examination program by NIST). So as to picture the connection between the exploratory factors and reactions, the reaction surface and shape plots (3D) are created from the models. The ideal estimations of the procedure factors are acquired from the polynomial condition.

The sufficiency of the model is additionally legitimized through examination of difference (ANOVA). Absence of-fit is an exceptional symptomatic test for ampleness of a model that looks at the unadulterated mistake, in light of the repeat estimations to the next absence of fit, in light of the model execution. F-esteem, determined as the proportion between the absence of-fit mean square and the unadulterated mistake mean square, is the measurement parameter used to decide if the absence of-fit is critical or not, at an essentialness level.

Experimental Procedure for Batch Reactor

The range and dimension of the factors are given in Table below. Investigations are completed by the Box-Behnken plan. The pH of the example is balanced by including corrosive or base as required. Sulphuric corrosive and sodium hydroxide are utilized as corrosive and base individually. The underlying centralization of color wastewater is fluctuated as 1:1 and 1:2 by weakening with water. The bunch contemplates are completed by differing the temperature in water shower shaker. The unsettling rate of the shaker is kept consistent at 50 rpm. From the outcomes, the best plant test acquired is utilized for the treatment of material coloring industry emanating in ASBR (Abdulgader et al., 2009).

Analysis

Dye concentration is measured in Bio-spectrophotometer (Model: BL-200, ELICO, India) at a wavelength of 395 nm. COD of the sample is analyzed using the procedure given in APHA. The percentage COD reduction is calculated by the following equation.

$$\text{COD \%}=\frac{\text{Initial COD-Final COD}}{\text{Initial COD}}*100$$

RESULTS AND DISCUSSION

Characteristics of Textile Dyeing Industry Effluent

The effluent collected from textile dyeing industry is characterized by analyzing pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), Sulphates, Chlorides, Sodium, Potassium, Total kjedahl Nitrogen, Oil& Grease, Sulphides, Calcium, Magnesium, Copper, Cadmium, Chromium, Lead, Selenium, Zinc, Nickel (Lavid et al., 2012). The results obtained are given in Table.

The textile dye industry effluent collected is slightly basic and yellowish brown in color. The increase in TDS indicates that the textile effluent contains various chemicals like Chloride, Nitrogen, Sulphate, Sulphide, but there is a very low Concentration of heavy metals like Selenium, Cadmium, Lead, Chromium and Nickel (M P and Kousar, 2016).

FTIR analysis of the sorbents

The confirmation of the functional groups present in the sorbents has been done using the FTIR analysis. The FTIR of the samples revealed functional groups present in them due to phytoconstituents like phenolic, flavonoids, tannins, carbohydrate compounds present in them. Bands at 3303.36, 3306.46, 3356 cm^{-1} are due to presence of alcohols or phenolic compounds, as the qualitative test showed presence of phenolic compounds in the plant, this bending must be due to presence phenols and flavonoids. The other absorption bands of IR spectrum like C-O (1351.86 cm^{-1}), C=C, C-H (2950-2800 cm^{-1}), =CH were in consistent with presence phytoconstituents analysis. From IR and qualitative analysis of plants, presence of many O groups must be attributing to the phytoremediation property of the plants, as plants in general, use flavonoids, amino acids, polysaccharides, phenols as growth and support supplements, in a form of intermediates which makes pollutants to bind them and make them bioavailable for microbes to degrade them. Besides sometimes plants transfer the contaminants to shoots, leaves or flower for accumulation.

Parameter optimization and Efficiency Evaluation of *Musa paradisiaca* stem against Textile Dying Industry Effluent Using Box Behnken design

$$\text{Decolorization, \%} = 341 - 59.0\,A - 12.6\,B + 105.4\,C + 0.0274D + 3.98\,A^2 + 0.180\,B^2 + 7.1\,C^2 - 0.000002\,D^2 + 0.200\,A*B - 4.85\,A*C - 0.00060\,A*D - 2.09\,B*C + 0.000317\,B*D - 0.00530\,C*D$$

$$\text{COD reduction, \%} = 150 - 57.8\,A - 3.1\,B + 112.1\,C + 0.0376\,D + 4.80\,A^2 + 0.087\,B^2 + 5.3\,C^2 - 0.000002\,D^2 - 0.085\,A*B - 6.45\,A*C - 0.00107\,A*D - 1.78\,B*C + 0.000038\,B*D - 0.00496\,C*D$$

Where A, B, C and D are the coded values of the process variables, pH, temperature (^oC), wastewater dilution ratio (WWDR) and MLVSS concentration respectively.

Experimental results are analyzed using Analysis of Variance (ANOVA) and are given in Table 6 and 7 respectively, for decolorization and COD reduction. From the ANOVA, model F-value of 1.63 and 2.11 for decolorization and COD reduction respectively, shows the significance of the model.

To investigate the interactive effect of two factors on the decolorization and COD reduction of textile dyeing wastewater by *Musa paradisiaca* stem, response surface methodology is used, and contour plots are drawn. Response surface plots as a function of two factors at a time, maintaining all other factors at fixed levels are more helpful in understanding both the main and the interactive effects of two factors. The response surface curves for the decolorization and COD reduction of textile dye wastewater are shown in Fig.3 to 14. The nature of the response surface curves shows the interaction between the variables. The elliptical shape of the curve indicates good interaction between the two variables and circular shape indicates no interaction between the variables. From the figures it is observed that the elliptical nature of the contour in graphs depicts the mutual interactions of all the variables. There is a relative significant interaction between every two variables, and there is a maximum predicted yield as indicated by the surface confined in the smallest ellipse in the contour diagrams.

Fig.3 shows the interactive effect of pH and temperature on textile dye decolorization. From the figure, it is inferred that increase in pH (up to 7.3) increases the dye decolorization efficiency. After that the decolorization efficiency decreases. Similar trend is observed in Fig.4 and Fig.5. The pH has a major effect on the efficiency of dye decolorization, and the optimal pH for color removal is often between 6.5 and 7.5 and response gets reduced as the pH moves towards alkaline for most of the dyes. It is clear from Fig.3 that percentage decolorization of dye increased with an increase in temperature from 30 to 33.5^{o}C. The percentage decolorization of dye decreased with further increase in temperature. Decolorizing activity is significantly lowered at higher temperatures. From Fig.5, it is observed that, the decolorization percentage increases is maximum in the 1.5 dilution ratio. The increase in MLVSS up to 7000 mg/L increases the decolorization efficiency.

pH is one of the important factors in the treatment of textile dye wastewater by *Musa paradisiaca* stem. The effect of interaction between pH and temperature on biodegradation of textile industry wastewater effluent is shown in Fig.9. From the figure it is observed that increase in pH up to 7.2 increases the COD reduction. Further increase in pH leads to decrease in COD levels. The interactive effects of other parameters are shown in Fig.9-Fig.14.

The second order polynomial equation is solved in MATLAB 7.0 to find the optimum conditions. The optimum condition for the maximum decolorization and COD reduction is found to be: pH-7.5, temperature-33.5^{0}C, wastewater dilution ratio 1:2, and MLVSS-7000mg/L. The optimal conditions predicted using RSM has been validated using experiments. At the optimized condition, the maximum decolorization and COD reduction are found to be 62.3% and 65.4% respectively.

Parameter optimization and Efficiency Evaluation of *Nymphaea nouchali* stem against Textile Dying Industry Effluent Using Box Behnken design

The effect of pH, temperature, wastewater dilution ratio (WWDR) and MLVSS on decolorization and COD reduction are studied. The experimental and predicted values of percentage decolorization and COD reduction are given in Table 8. The coefficients of second order equation are found using the Minitab for decolorization and COD reduction. The equation is given below.

$$\text{Decolorization, } \% = 341 - 59.0\,A - 12.6\,B + 105.4\,C + 0.0274\,D + 3.98\,A{*}A + 0.180\,B{*}B + 7.1\,C{*}C - 0.000002\,D{*}D + 0.200\,A{*}B - 4.85\,A{*}C - 0.00060\,A{*}D - 2.09\,B{*}C + 0.000317\,B{*}D - 0.00530\,C{*}D$$

$$\text{COD reduction, } \% = 150 - 57.8\,A - 3.1\,B + 112.1\,C + 0.0376\,D + 4.80\,A{*}A + 0.087\,B{*}B + 5.3\,C{*}C - 0.000002\,D{*}D - 0.085\,A{*}B - 6.45\,A{*}C - 0.00107\,A{*}D - 1.78\,B{*}C + 0.000038\,B{*}D - 0.00496\,C{*}D$$

Where A, B, C and D are the coded values of the process variables, pH, temperature (^{o}C), wastewater dilution ratio and MLVSS concentration respectively. The results are analyzed by Analysis of Variance (ANOVA) and are given in Table 9 and 10. The ANOVA of the quadratic regression model indicates the model is significant. In this work, the model F-value 1.41 and 1.39 for decolorization and COD reduction implies that the models are significant.

Response surface plots as a component of two factors at any given moment, keeping up every other factor at settled dimensions are progressively useful in understanding both the primary and the intelligent impacts of two elements. The reaction surface bends for the decolorization and COD decrease of material color wastewater are appeared in Fig.15- Fig.26. Figure 15 demonstrate the intelligent impact of pH and temperature on material color decolorization. From the figure, it is gathered that expansion in pH (up to 7.5) builds the color decolorization effectiveness. It is obvious from Fig.17 that rate decolorization of color expanded with an augmentation in temperature from 28 to 34°C. From Fig.18, it is seen that, the level of decolorization decline with increment in weakening proportion. The expansion in MLVSS up to 6500 mg/L expands the decolorization productivity. This is plainly portrayed in Fig. 12, 13 and 15. The intuitive impacts of different parameters are appeared in Fig.21 – Fig.27. The pattern watched for different parameters is like the decolorization profile.

The second order polynomial equation obtained from RSM is used to find the optimum conditions. Equation is solved in MATLAB 7.0. The optimum condition for the maximum decolorization and COD reduction is: pH–7.0, temperature–34^{0}C, wastewater dilution ratio 1:1, and MLVSS–6500 mg/L. The optimal conditions predicted using RSM has been validated using experiments. At the optimized condition, the maximum decolorization and COD reduction are found to be 70.3% and 72.6% respectively.

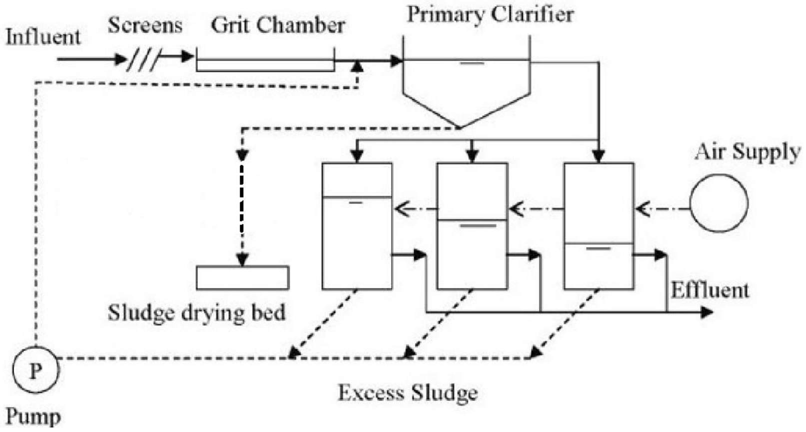

Fig.1 Schematic diagram of ASBR set up modified from Domestic system wastewater treatment by Ketchem et al., 1979.

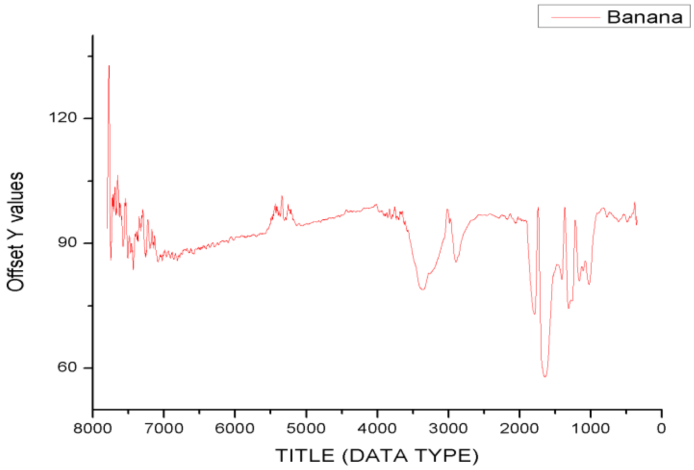

Fig. 2 FTIR graph of *Musa paradisiaca* stem

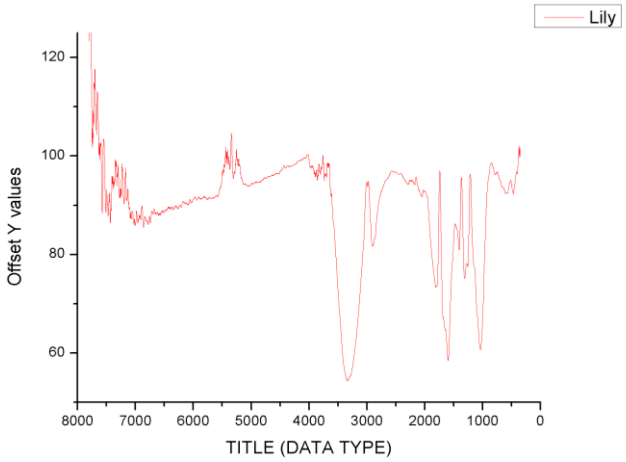

Fig.3 FTIR graph of *Nymphaea nouchali* stem

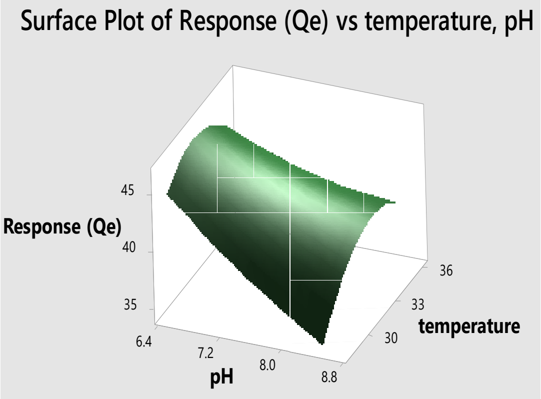

Fig.4 Interactive effect of pH and temperature on decolorization by *Musa paradisiaca* stem

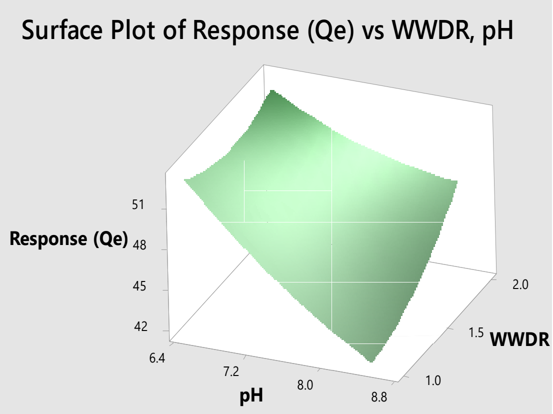

Fig.5 Interactive effect of pH and WWDR on decolorization by *Musa paradisiaca* stem

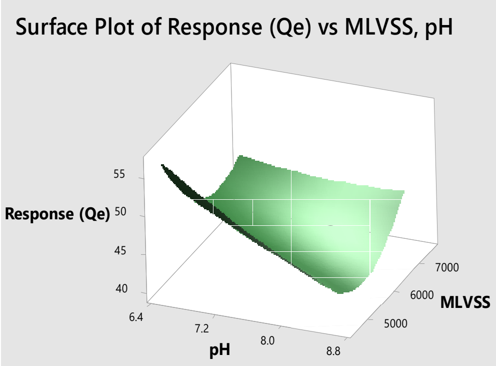

Fig.6 Interactive effect of pH and MLVSS on decolorization by *Musa paradisiaca* stem

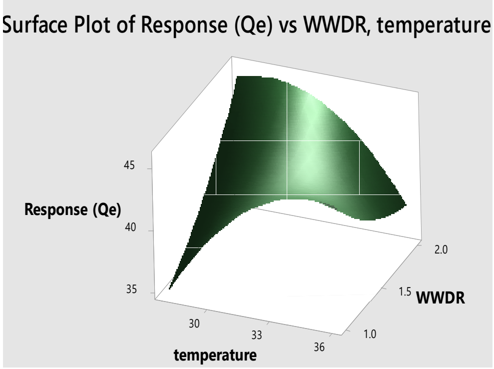
Surface Plot of Response (Qe) vs WWDR, temperature

Fig.7 Interactive effect of temperature and WWDR on decolorization by *Musa paradisiaca* stem

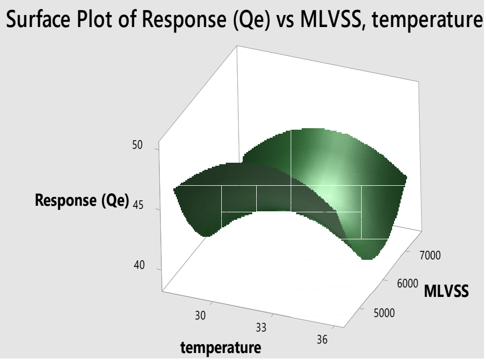
Surface Plot of Response (Qe) vs MLVSS, temperature

Fig.8 Interactive effect of temperature and MLVSS on decolorization by *Musa paradisiaca* stem

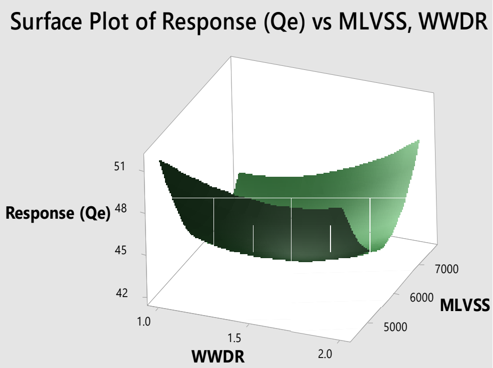
Surface Plot of Response (Qe) vs MLVSS, WWDR

Fig.9 Interactive effect of WWDR and MLVSS on decolorization by *Musa paradisiaca* stem

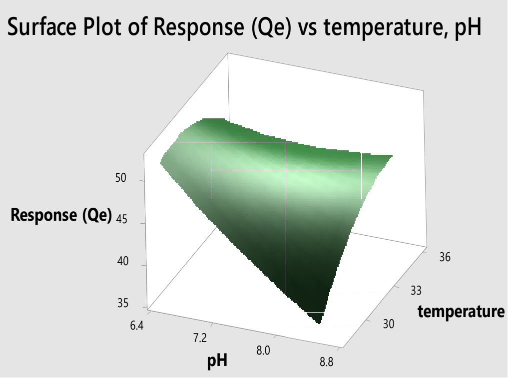
Surface Plot of Response (Qe) vs temperature, pH

Fig.10 Interactive effect of pH and temperature on COD reduction by *Musa paradisiaca* stem

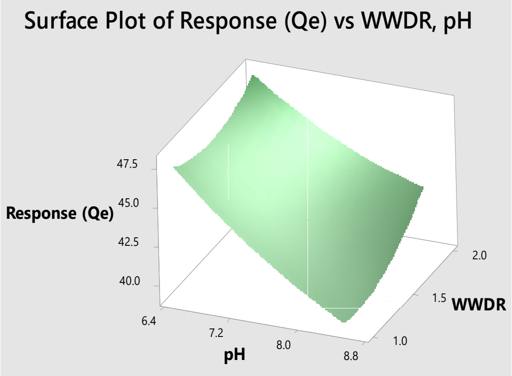

Fig.11 Interactive effect of pH and WWDR on COD reduction by *Musa paradisiaca* stem

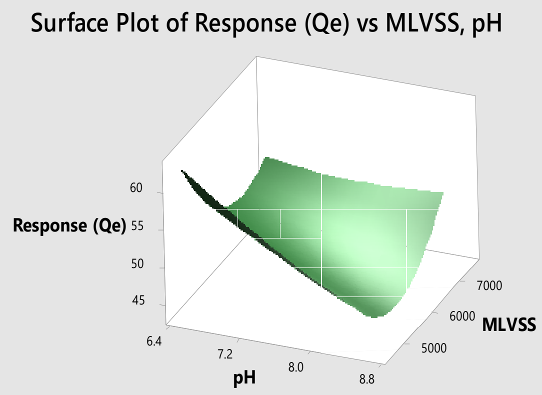

Fig.12 Interactive effect of pH and MLVSS on COD reduction using by *Musa paradisiaca* stem

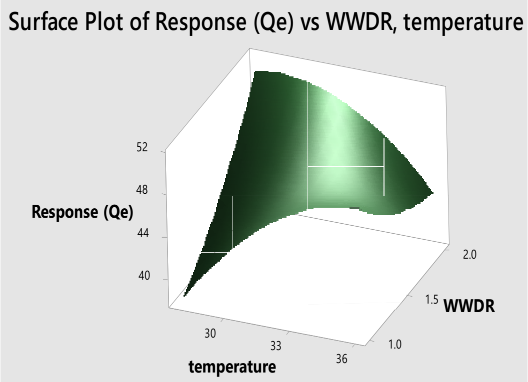

Fig.13 Interactive effect of temperature and WWDR on COD reduction by *Musa paradisiaca* stem

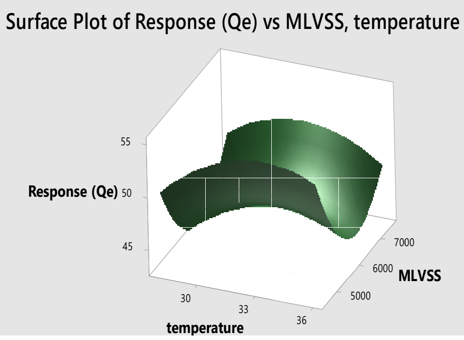

Fig.14 Interactive effect of temperature and MLVSS on COD reduction by *Musa paradisiaca* stem

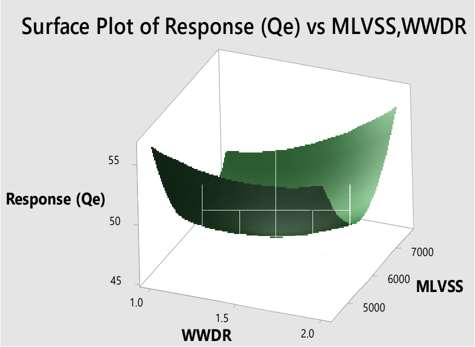

Fig.15 Interactive effect of WWDR and MLVSS on COD reduction by *Musa paradisiaca* stem

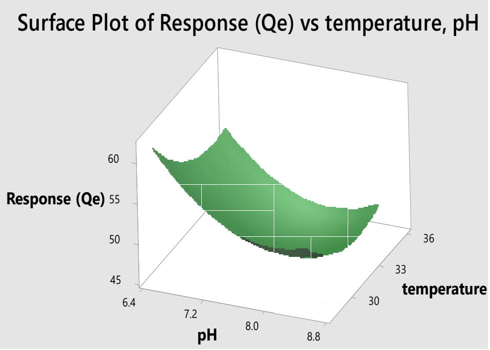

Fig. 16 Interactive effect of pH and temperature on decolorization by *Nymphaea nouchali* stem

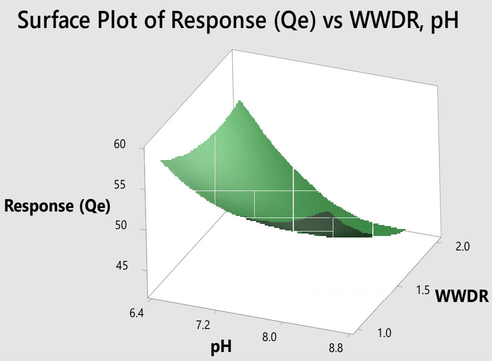

Fig. 17 Interactive effect of pH and WWDR on decolorization by *Nymphaea nouchali* stem

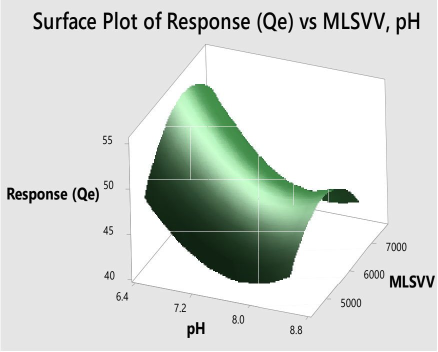

Fig. 18 Interactive effect of pH and MLVSS on decolorization by *Nymphaea nouchali* stem

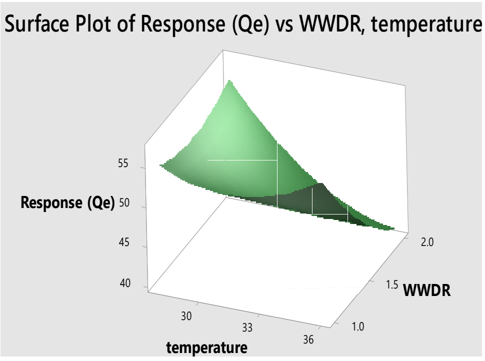

Fig. 19 Interactive effect of temperature and WWDR on decolorization by *Nymphaea nouchali* stem

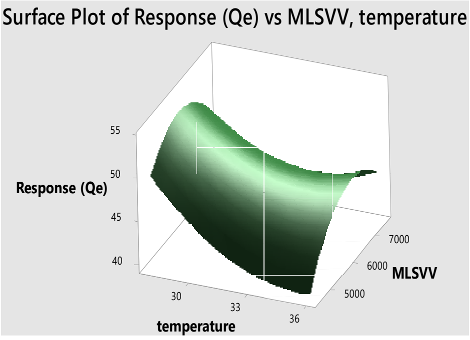

Fig. 20 Interactive effect of temperature and MLVSS on decolorization by *Nymphaea nouchali* stem

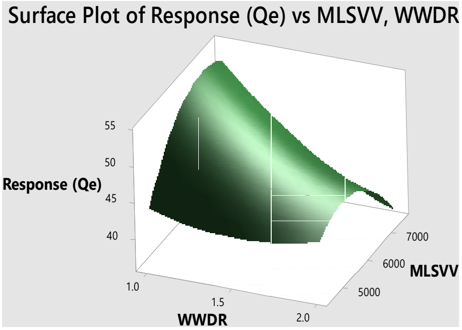

Fig. 21 Interactive effect of WWDR and MLVSS on decolorization by *Nymphaea nouchali* stem

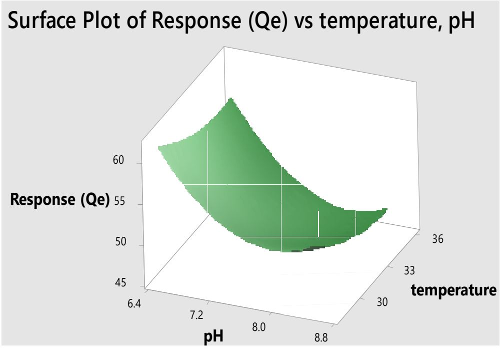

Fig. 22 Interactive effect of pH and temperature on COD reduction by *Nymphaea nouchali* stem

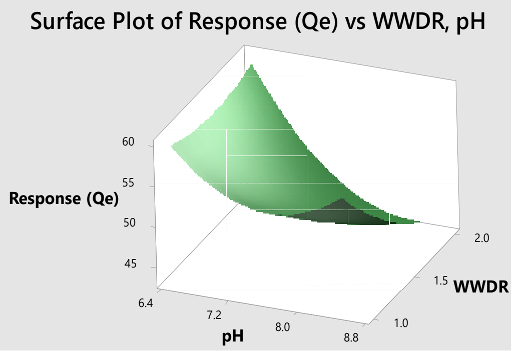

Fig. 23 Interactive effect of pH and WWDR on COD reduction by *Nymphaea nouchali* stem

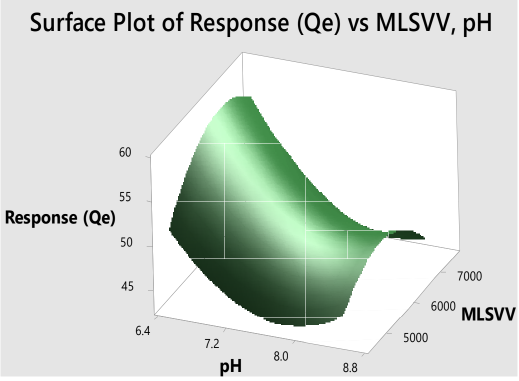

Fig. 24 Interactive effect of pH and MLVSS on COD reduction by *Nymphaea nouchali* stem

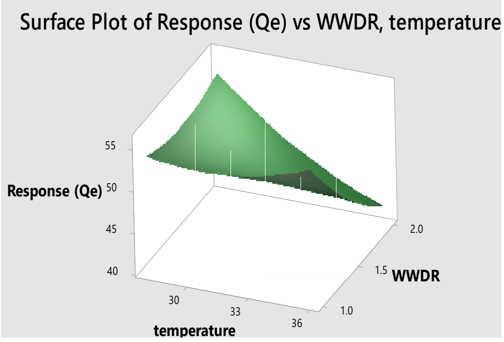

Fig. 25 Interactive effect of temperature and WWDR on COD reduction by *Nymphaea nouchali* stem

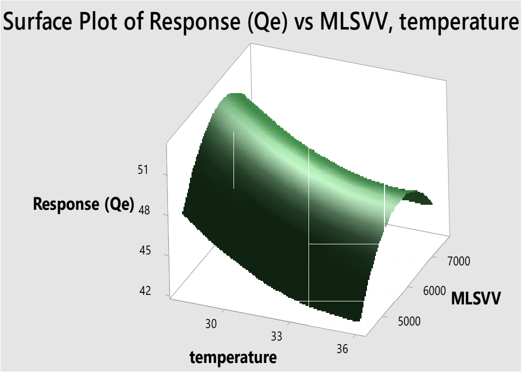

Fig. 26 Interactive effect of temperature and MLVSS on COD reduction by *Nymphaea nouchali* stem

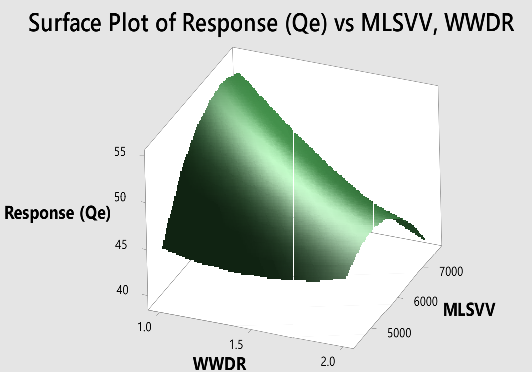

Fig. 27 Interactive effect of WWDR and MLVSS on COD reduction by *Nymphaea nouchali* stem

CONCLUSION

Biosorption is a cost-effective technique used to decolorize the of textile dye effluents. The stem regions of *Musa paradisiaca* and *Nymphaea nouchali* and their adsorption potentials were studied. The experiment was performed in aerobic sequential bioreactor. Various operational parameters such as pH, temperature, dye waste water to water ratio, and mixed liquor volatile suspended solids were optimized using the Box-Behnken design. Responses were recorded in terms of percentage decolorization and percentage COD reduction. The R-sq and R-sq (adj) for percentage decolorization of *Musa paradisiaca* are 65.58% and 25.42%. And R-sq and R-sq (adj) for percentage COD reduction of *Musa paradisiaca* are 71.16% and 37.50%. The R-sq and R-sq (adj) for percentage decolorization of *Nymphaea nouchali* are 62.25% and 18.20%. The R-sq and R-sq (adj) values for percentage COD reduction of *Nymphaea nouchali* are 61.88% and 17.41%. *Musa paradisiaca* showed high biosorption potential when compared to *Nymphaea nouchali* and is due to the presence of charged functional groups present on its surface. The results concluded that Musa paradisiaca could be used as potential biosorbent for large-scale decolorization of toxic textile effluents.

The parameters optimization using the Box Behnken design for the stem *Musa paradisiaca* using the ANOVA analysis model f value was found to be 1.63 for decolorization and 2.11 for COD reduction from which RSM and contour plots were drawn, from which it was inferred after plotting as function of two factors at a time, while other factors were maintained at the fixed level, the data obtained for optimum condition for maximum decolorization and COD reduction was found to be at pH 7.5, temperature 33.5 °C and wastewater dilution ratio to be 1:2 and MLVSS-7000mg/L, which removed about 62.3 % of decolorization and 65.4% COD reduction. Similarly, for the stem of *Nymphaea nouchali,* optimum conditions were found to be at pH 7.0, temperature 34°C, waste water dilution 1:1 and MLVSS at 6500 mg/L with removal of color was 70.3 % and COD was reduc10ed about 72.6%. This proved that *Nymphaea nouchali* can be used aa potential biosorbent on larger scale.

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