Modeling Of COD Using Phytorid Sewage Treatment Plant

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ABSTRACT: *This study was conducted to investigate the COD removal from domestic sewage water using phytorid sewage treatment plant at agriculture College Maharaj bag, Nagpur during the year 2018-2019. The study was designed with an aim to study the effectiveness of the phytorid sewage treatment plant in reducing concentrations of COD from the domestic municipal wastewater and to determine the optimum condition with the help of the response surface methodology. For this purpose, we employed the Box - Behnken experimental design for Response Surface Methodology to find out relationship between the response functions i.e. removal of the COD from sewage water and variables. The effect of three independent variables such as hydraulic loading i.e. flow $(50 - 150\ m^3\ d^{-1})$, dilution (10 - 80 %) and spatial length (16 – 100 %) for COD removal from the sewage was investigated in bench mode of the experiment. Optimal conditions for COD removal were established at flow $134.84\ m^3/d$, dilution: 10% and spatial length 16 %. Under the experimental conditions, The experimental COD removal was $180mg/L^{-1}$. The equation of proposed model using RSM has show good agreement with the data of experiment. A correlation coefficient is 98.63%. These results revealed that optimized condition could be used for the efficient removal of the COD from the domestic sewage.*
Keywords*: Box-Behnken design, optimization, Pollutant, response surface modelling, sewage water.*

I-   INTRODUCTION

The contamination and pollution of water is of great concern in the developing countries like India where there is limited source of water. Appropriate use of wastewater of domestic origin can help in meeting a part of amount required for intensive cropping. (Herpin *et al.*, 2007). Recycled or treated wastewater is one such alternative, wherein many processes are designed in order to reduce pollutant load that nature can handle and can be used for agriculture. Also, it can reduce the burden on the fresh water It is necessary to treat the untouched source of sewage water through decentralized waste water management (Kretschmer et al., 2003; Toze., 2006).

Constructed wetlands (CWs) is innovative and promising natural technique for municipal and industrial wastewater treatment. It is low cost and technically simple to operate and negligible maintenance cost placing it as one of the preferred treatment technology in developing countries. (Babatunde, Zhao *et al.*, 2010). Phytorid technology is one such engineered solution that uses plant species with their root system along with natural attenuation process and can be easily implemented in cities as well as in rural areas for treatment of waste water. It combines chemical and physical process, works on gravity, no electric power requirement, scalable technology, easy to maintenance and cost effective (Singh et al., 2007). Over the years, different physio-chemical tests have been developed to determine the organic and inorganic content of wastewater (Metcalf & Eddy, 2003).

Chemical oxygen demand (COD) are most commonly used laboratory methods for the characterization of wastewater. COD is the total measurement of all chemicals (organics & in-organics) in the waste water. The COD concentration play an important role in the reuse of the waste effluents

particularly in the agriculture for irrigation purpose. Phytorid sewage treatment plant based on wetland engineering technology provided good potential BOD, COD, micronutrients, nitrogen and Phosphorus removal from domestic sewage water and to date it mainly focused on wastewater treatment for domestic sewage (Burchell *et al.,*2007)

The COD of waste water from coffee processing plant using activated made up of Avacado peels and showed significant reduction. In 2016 Navaghare et al showed significant reduction in COD levels from municipal wastewater using small scale phytorid bed technology. To date, research has mainly focussed on the use of phytorid sewage treatment plant for the treatment of domestic sewage water. Recent, research has shown that sewage treatment plant based on constructed or restored wetlands can remove sediments and nutrients from nonpoint sources, including agricultural discharges (Jorden et al, 2003). Response surface methodology (RSM) is a collection of mathematical and statistical techniques that are useful to explore the relative significance between several explanatory variables and one or more response variables in numerous chemical and biochemical process. Conventional optimization methods are "one-factor-at-a time" techniques often fails to identify the variables that give rise to the optimum response because the effects of factor interactions are not taken into account in such procedures (Deepak *et al*., 2008). RSM needed a fewer number of experimental trials to evaluate the interaction and is the most commonly used application where most of the variables are influencing the system (Myers and Montgomery, 2002).

Nagpur is the third largest city and winter capital of Maharashtra popularly known as orange city of India. Nag River is flowing through Nagpur. The average flow rate of sewage water in Nag River is 426 m3 hr-1 and it is the biggest reason its pollution. Phytorid sewage treatment plant based on wetland engineering technology was constructed in collaboration with NEERI technology was constructed at Maharajbag campus of Agriculture College, Nagpur to convert sewage water into water resource for irrigating the agricultural crops and gardening.

The present study was planned to investigate the COD removal from domestic sewage water through modified phytorid sewage treatment plant to enhance pollutant removal by physical chemical and biological processes at agriculture College Maharajbag, Nagpur during the year 2018-2019 and to determine the optimum condition with the help of the response surface methodology to understand the effect of various parameters and their interaction.

II- METHOLOGY

Details of the phytorid treatment plant:

Nag River is flowing through Nagpur and average flow rate of sewage water in it was 426 m3 hr1. Phytorid sewage treatment plant based on wetland engineering technology was constructed to convert sewage water into water resource for irrigating the agricultural crops and gardening at Maharaj bag campus of Agriculture College in collaboration with NEERI technology. The intake well was designed and constructed at the bank, as phytorid constructed wet land directly across flowing river requires huge funding and space as suggested by (Massuod *et al.,* 2009). The pump was selected as per designed capacity for lifting the raw sewage water of the treatment plant. The uniform flow of 1% was maintained from inlet through the length i.e from screening chambers and filter beds to the storage tank.

Design of phytorid treatment plant (Experimental Design)

Phytorid sewage treatment plant of design capacity 100 m^3d^{-1} was constructed. However, the hydraulic loading was made in the range of 50 to 150 $m^3d^{-1}$for sewage flow 10 - 80% for dilution and 16-100% for spatial length to optimize it for best purification efficiency for removal of COD concentration from the sewage treatment plant. The system was based on the specific plants species, such as Elephant grass, Cattails, Reeds, Cannas pp. and Yellow flag iris and some ornamental as well as flowering plants species such as Golden Dhuranda, Bamboo, Nerium, Colosia, normally found in natural wetlands with filtration and treatment capability.

In this study, the surface response modelling with Box-Behenken experimental design was chosen for finding out to optimize and understand the performance of parameters in any processes for the pre-treatment. RSM usage needed a

fewer number of experimental trials, lesser time and material sources to evaluate the interaction and is the most commonly used application where most of the variables are influencing the system. (Moghaddam *et al.,* 2011). Additionally, the analysis performed on the results are easily realized and experimental errors are minimized. Statistical methods measures the effects of change in operating variables and their mutual interactions on process through experimental design way.

Box-Behenken experimental design has the advantage of fewer trials (15 basic run) than that would be required in full factorial design (27 runs). Additionally, the analysis performed on the results is easily realized and experimental errors are minimized due to 3D response. Each factor was set at three different levels of low (-1), medium (0) and high (+1) respectively. The removal of COD concentration was taken as response (Y) of the experimental design. Statistical methods measured the effects of change in operating variables and their mutual interactions on process.

Response Surface Methodology

RSM is cluster of mathematical and statistical techniques was designed to obtain optimal response discovered by Box and Wilson in year 1951 to explore the relative significance between explanatory and response variables.

RSM has merits like (1) It offers More information than unplanned approaches per experiments; (2) It Minimizes cost and reduces number of tests; (3) It explores the relative significance between different variales studied explanatory and response variables; (4) It helps to find optimal operational settings to augment process. It is best application where system is influence by the various variables used (Myers and Montgomery, 2002).

Experimental design for absorption studies

In our study we chose the BBD and RSM to find out relation between response function i.e. removal of pollutant

from sewage water and variables (Hydraulic loading, Different Pollution concentration (dilution), and spatial length) for three different size fractions (50 to 150 m^3d^{-1} hydraulic loading i.e. flow, 10 to 80% dilution (initial concentration of sewage) and 16 to 100% is spatial length.

In statistics, Box–Behnken design is spherical rotatable 2nd designs based incomplete factorial designs that requires only three levels to run an experiment. The special arrangement of the Box–Behnken design levels allows the number of design points to increase at the same rate as the number of polynomial coefficients. In order to obtain the optimum condition for COD removal, three independent parameters were selected (Bhanarkar *et al.*, 2014).

Table 1. Experimental range and levels of variables

Variables	Unit	COD	Range and Levels		
			Low level	Centre	High level
Hydraulic Loading	$(m^3$	X_1	50	100	150
Dilution (Initial	(%)	X_2	10	45	80
Spatial length	(%)	X_3	16	58	100

In the above Table 1 is represented as were the ranges for hydraulic loading (X_1), dilution (X_2) and spatial length (X_3) were determined by an iterative method. Using BBD and RSM is used to determine the relation between the parameters and responses.

In our study, the experiment is consisted of 15 base run, and the independent variables at three different levels such as of low level (-1), medium level (0) and high level (+1). The Box-Behnken design presents an around rotatable design with only three levels per variable and combines a fractional factorial with incomplete block design excluding the extreme vertices (Aslan & Cebeci, 2007).

The Box-Behnken design has good performance with minimum error. The percentage of COD removal was taken as a response (Y) of the experimental design.

If all variables are assumed to be measurable, the response surface can be expressed as follows:

$Y = f(x_1; x_2; x_3; \ldots; x_k) \ldots (1)$

Where Y is the answer of the system, and xi are the variables of action called factors.

The aim is to optimize the response variable Y. It was suppose that the independent variables are non-stop and controllable by experiments with minor errors. It was required to find a acceptable (equation) for the true functional relationship between independent variables and the response surface (dependable variable). Generally, a second-order model is utilized in response surface methodology. In the optimization process, the responses can be simply related to chosen variables by linear or quadratic models. A quadratic model, which also includes the linear model, is given below:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i=1}^{k}\sum_{j=1}^{k} \beta_{ij} x_i x_j + \varepsilon$$

… (2)

Where,

Y = Response,

$x_1, x_2, .x_k$ = coded independent variables,

β_i, β_{ii} and β_{ij} = Linear, quadratic and interaction coefficients, respectively,

β_0 = Constant, and

ε =Random error.

Trials were performed in triplicate. Minitab 18 Free trial version software package for regression and graphical analysis were used for analyses of the data.

STATISTICAL ANALYSIS

With the help of ANOVA the significance of the independent variables and their interactions was tested. Evaluate the results using various illustrative statistics such as t-ratio, p-value, F-value, degrees of freedom (df), coefficient of variation (CV), coefficient of determination

(R^2), adjusted coefficient of determination (R^2adj), sum of squares (SS), mean sum of squares (MSS) statistic test to reflect the statistical significance of the quadratic model. The tabulated value of F statistic corresponding to df was obtained at desired probability level (i.e. 0.05 significance level or 95% confidence). The Design-Expert (trial version 8.0.5, Stat-Ease Inc., USA) software package was used for regression analysis of experimental data, and to plot response surface

Validation Experiments

The mathematical model obtained during RSM was demonstrate by conducting additional experiments for dissimilar combination of three independent variables in randomly fashion within its respective experimental field.

RESULTS AND DISCUSSION

The results of COD removal along with experimental conditions are given in Table 2. Uncoded function for COD concentration removal applicable for the treatment plant under study is given in following equation (Bhanarkar *et al.,* 2014).

COD = 270.4 - 1.315* X_1 - 4.093* X_2 - 0.650 X_3 +0.007876 X_1 *X_1+0.02343 X_2* X_2-   0.00500 X_3* X_3 - 0.00269 X_1* X_2 - 0.00239 X_1* X_3 +0.01653 X_2* X_3 ----- (2)

Where, Y is the pollutant concentration removal; and X_1 is the corresponding uncoded variable of flow (hydraulic loading), X_2 is the corresponding uncoded variable of dilution**,** X_3 is the corresponding uncoded variable of spatial length.

Table 2. Box-Behnken Experimental Design Matrix with Variable and Pollutant Removal

Factors: 3 ; Replicates: 2 ; Base runs: 15 ; Total runs: 30 ;

Base blocks: 1 ; Total blocks:1 Center points: 6 ;

Design Table (randomized)

Run order	coded variable			Uncoded variable			Response
	X1	X2	X3	Hydraulic Loading (Flow) (m³/day)	Dilution (%)	Spatial Length (%)	COD
1	0	-1	-1	100	10	16	164.1
2	-1	0	-1	50	45	16	82.08
3	-1	-1	0	50	10	58	133.9
4	0	0	0	100	45	58	34.56
5	-1	0	1	50	45	100	38.88
6	-1	0	-1	50	45	16	73.44
7	1	1	0	150	80	58	38.88
8	1	0	1	150	45	100	21.60
9	0	-1	1	100	10	100	47.52
10	0	0	0	100	45	58	52.92
11	1	-1	0	150	10	58	142.5
12	1	1	0	150	80	58	37.98
13	0	0	0	100	45	58	38.88
14	-1	1	0	50	80	58	49.68
15	0	1	1	100	80	100	18.36
16	0	-1	1	100	10	100	48.60
17	0	1	-1	100	80	16	29.16
18	0	0	0	100	45	58	46.44
19	1	-1	0	150	10	58	149.0
20	-1	-1	0	50	10	58`	138.2
21	-1	0	-1	50	45	100	23.76
22	0	0	0	100	45	58	49.68
23	0	1	-1	100	80	16	31.32
24	0	-1	-1	100	10	16	159.8
25	0	1	1	100	80	100	8.64
26	1	0	-1	150	45	16	82.32
27	0	0	0	100	45	58	38.90
28	1	0	1	150	45	100	20.52
29	-1	1	0	50	80	58	45.36
30	1	0	-1	150	45	16	92.88

MODEL STATISTICAL TESTS

To check the significance of the developed model the ANOVA was conducted to the data. As per ANOVA of the response model as in table 3 indicated that for model of the concentration removal of COD the model equation can be used adequately. The model F- value is 160.19 being greater than tabulated value (F_{tab}-4.1) that the model was significant. P-value less than 0.05 indicates that the quadratic model was highly significant.

Table. 3. Analysis of variance of the response surface quadratic model for the prediction of COD removal

Source	DF	Sum of Square	Mean Square	F-Value	P-Value
Model	9	62231.4	6914.6	160.19	0.000
Linear	3	47648.8	15882.9	367.97	0.000
H.L.m3/d	1	0.0	0.0	0.00	0.987
Dilution(%)	1	32806.3	32806.3	760.03	0.000
Spatial Length(%)	1	14842.5	14842.5	343.86	0.000
Square	3	9479.8	3159.9	73.21	0.000
H.L.m3/d*H.L.m3/d	1	2862.9	2862.9	66.33	0.000
Dilution(%)*Dilution(%)	1	6084.6	6084.6	140.96	0.000
Spatial Length(%)*Spatial Length(%)	1	574.2	574.2	13.30	0.002

2-Way Interaction	3	5102.8	1700.9	39.41	0.000
H.L.m3/d*Dilution(%)	1	176.9	176.9	4.10	0.056
H.L.m3/d*Spatial Length(%)	1	202.0	202.0	4.68	0.043
Dilution(%)*Spatial Length(%)	1	4723.9	4723.9	109.44	0.000
Error	20	863.3	43.2		
Lack-of-Fit	3	297.8	99.3	2.98	0.060
Pure Error	17	565.5	33.3		
Total	29	63094.7			

Description of Model

S	R-sq	R-sq(adj)	R-sq(pred)
6.56994	98.63%	98.02%	96.96%

Regression co-efficient R^2 was calculated for checking the goodness of fit of the model. The value of R^2 (98.63%) is suggests that maximum data of variation was explained by regression model.

Similarly high value of adjusted regression coefficient R^2adj (98.02%) indicates that the model have a capacity to satisfactorily describe the system behaviour win the range of operating parameters. Consistent result we are reported by (Can *et al* 2006; Zhang *et al.,* 2010).

When the term in the models are more and the sample size is small than R^2(adj) is very less than R^2 i.e.(R^2adj $\ll R^2$). But here the case is reverse it is not obtained in this study. Such type of similar pattern has been reported by (Aslan & Cebeci, 2007) in the box benhken model and (Liu *et al.,* 2004) in the central composite designs model for second order response surface methodology experiment.

Model Adequacy check

Checking of the model adequacy is important for the proposed model. When the adequacy of proposed model is good then it will give sufficient approximation to the check of the real system (Körbahti & Rauf, 2008).The normal probability of residuals presented in Fig.1. Indicates nearly no serious violation of the basic analysis, and established the normal assumption and independence of the residuals. Additionally, the differentiation of the residuals with the error variation show that none of the individual residuals be more than the value two times the square root of the error variance. Similar finding we are earlier reported by (Sen & Swaminathan, 2004).
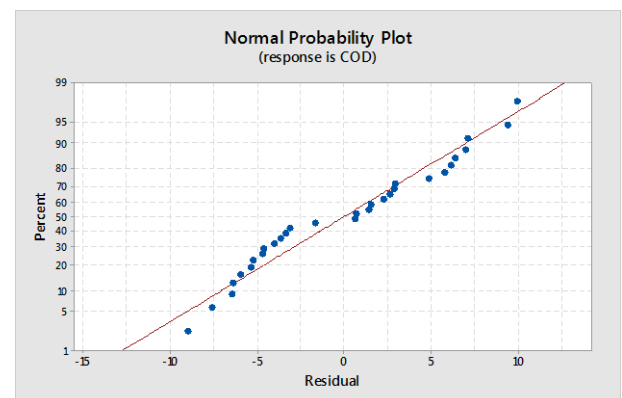

Fig.1. Normal probability plot of the residuals of COD

In Fig 2 represented that the assumption of constant variance. The points are randomly scattered, and all the values are lying within the range of -10 & +10.Values

beyond-10 & +10 are considered as the top & bottom outlier detection limits. Appropriately it was inferred that developed quadratic equation was appropriate & is successful for capturing the correlation between the influencing parameters of COD removal process.
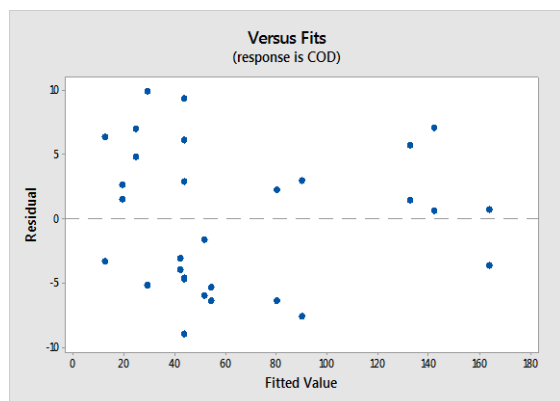

Fig.2. Internally studentied residuals vs. predicted value plot for COD

From Figure 3 the distribution graph of COD slightly skewed with for large value. The sample size was probably having very slight departure from the normality and homogeneity. The histogram was distributed in the residual value of -10 to +10. the maximum height of the graph depicting the maximum frequency for width residual -5 & +2.5 whereas minimum frequency observed in -10.
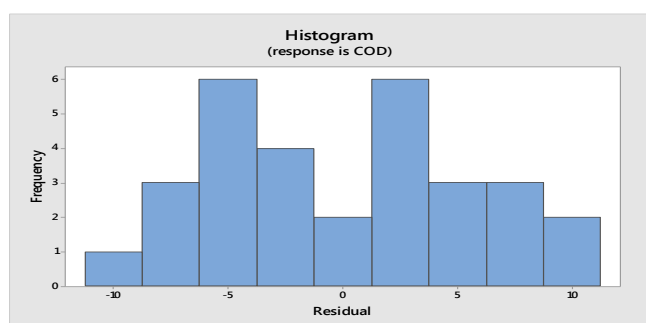

Fig.3. Internally studentied frequency vs. residuals plot for COD

The plots of residuals versus the order of the data presented in the fig.4. revealed that all the residual values were lying within the range of -10 & +10. They do not exhibit any serious departures from the homogeneity & the normal.

The large variation were recorded for the observation order no. 5 with flow $150 \ m^3 d^{-1}$ whereas minimum variation was observed for observation order no 11 with flow $50 \ m^3 d^{-1}$ the model successful in capturing the correlation between the influencing parameter of the COD removal process.
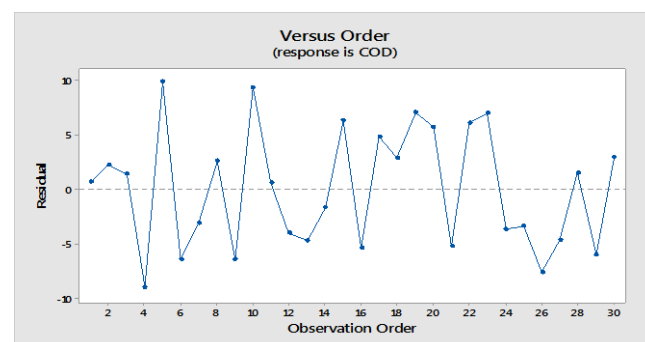

Fig.4. Plot between observation orders vs. residuals value plot

The Model Significance test

The result of t-test and p-value manage to assess the significance of the quadratic model coefficient are listed in Table 4. The t-value is the ratio of evaluate parameter effect, and evaluate parameter standard deviation. The parameter effect is estimated as two times the regression coefficient value for that parameter. To check the significance of the coefficient the p-value is used. The higher the magnitude of t value and lower the p value, significant is the corresponding parameter in the regression model as reported by (Yetilmezsoy *et al.,* 2009). Results showed that all the linear and quadratic terms were statistically significant ($p < 0.05$) terms except hydraulic loading i.e. flow (X_1). Similarly, all interactive terms were statistically significant, except hydraulic loading i.e. flow (X_1)*dilution(X_2).

Table 4. The result of multiple regression & significance of the components for the quadratic model of COD

Term	Coefficient	Standard Coefficient	T-Value	P-Value	VIF
Constant	43.56	2.68	16.24	0.000	
H.L.m3/d	0.03	1.64	0.02	0.987	1.00
Dilution(%)	-45.28	1.64	-27.57	0.000	1.00
Spatial Length(%)	-30.46	1.64	-18.54	0.000	1.00
H.L.m3/d*H.L.m3/d	19.69	2.42	8.14	0.000	1.01
Dilution(%)*Dilution(%)	28.70	2.42	11.87	0.000	1.01
Spatial Length(%)*Spatial Length(%)	-8.82	2.42	-3.65	0.002	1.01
H.L.m3/d*Dilution(%)	-4.70	2.32	-2.02	0.056	1.00
H.L.m3/d*Spatial Length(%)	-5.03	2.32	-2.16	0.043	1.00
Dilution(%)*Spatial Length(%)	24.30	2.32	10.46	0.000	1.00

quadratic term and dilution (X_2)* Spatial Length (X_3) is a interactive term was obtained the most significant component of the regression model for the available application, the hydraulic loading i.e. flow (X1) show the lower effect in removal of COD.

Optimization of experimental condition COD removal

It observed from fig. 5.(1)that COD removal increased with increasing dilution from 10 to 60 per cent, and the range of decrease of COD was from the 118.70 mg L^{-1} to 25.67 mg L^{-1} whereas no significant trend was obtained in the case of influence of flow on COD removal. COD removal slightly decreased with increasing flow rate from100 m^3 d^{-1} to 150 m^3 d^{-1}. The COD removal is increase with increase in the dilution may be due to the addition of the fresh water having very low concentration of COD and decrease in the COD removal may be due increase in flow of the sewage water having more concentration of COD.
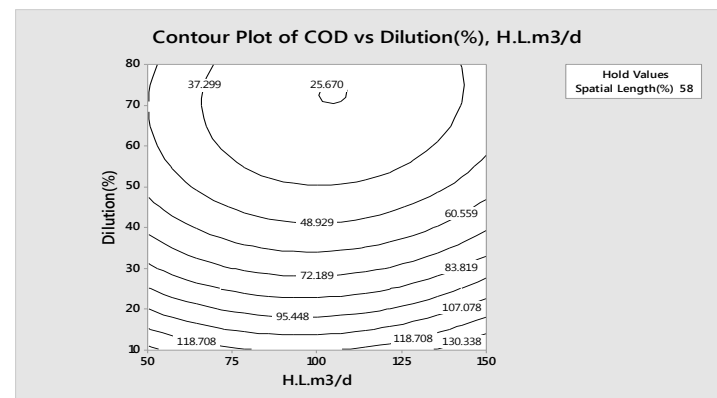

Fig.5 Contour plot showing effect of two independent variables(length (%) was held at their respective (centre level)

(1) Diltution (%) and Hydraulic Loading (flow) (m^{3}d^{-1})

As presented in Fig.5.(2) it is evident that the COD removal was increased with increasing the length however it was slightly decreased with increase in flow from 100 m^3 d^{-1} to 150 m^3 d The range of COD removal due to increase in

Additionally, In linear term i.e. dilution(X_2) and spatial length(X_3) obtained to be more significant than their respective quadratic effect $(X_2^2$ and $X_3^2)$. In dilution (X_2) was obtained to be nearly significant component of the regression model for available application, since amongst interactive term (hydraulic loading i.e. flow X_1 * dilution X_2) seen the minimum effect on COD removal. In Table 3 and Table 6.4.3 the p-value is indicate that the dilution(X_2) and Spatial length (X_3) have direct relation on the Removal of COD. Dilution (X_2) is a linear term, dilution (X_2^2) is a

Impact Factor Value 4.046   e-ISSN: 2456-3463
International Journal of Innovations in Engineering and Science, Vol. 4, No.6, 2019
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spatial length was from 64 to 8 mg L^{-1}. The COD removal was increased due to the addition of atmospheric oxygen by phytorid plants through the roots to flowing water along the length of phytori bed.
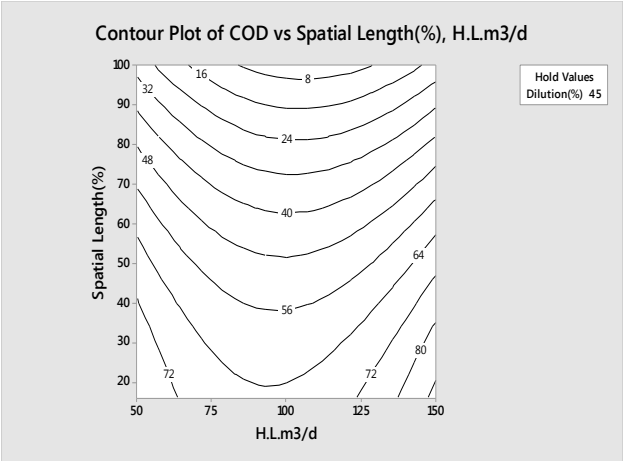

Fig.5 Contour plot showing effect of two independent variables (dilution (%) was held at their respective (centre level)

(2)   Spatial Length (%) and Hydraulic loading (Flow)(m^3d^{-1})

From the Fig.5 (3) it observed that removal of COD was increased with the dilution from 10 to 80 percent. Similarly the increase in length from 10 to 100 percent the COD removal also increased. The range of COD removal concentration due to dilution is 145 to 25 mgL^{-1} whereas due to length it is 145 to 55mg L^{-1}.

From the Fig 5.(3) plotted as dilution and Spatial length. The dilution plays an important role in removal of COD.
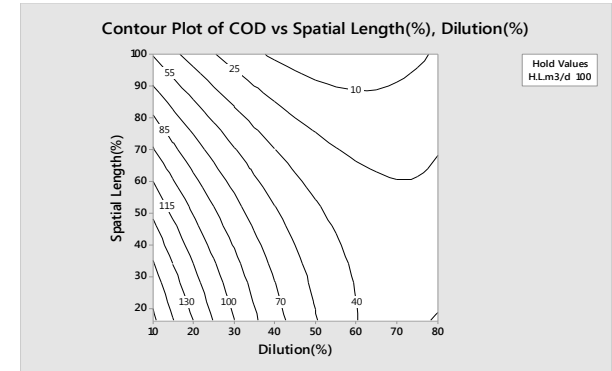

Fig.5 Contour plot showing effect of two independent variables (Hydraulic loading (m^3/d) was held at their respective (centre level)

(3)   Spatial length (%) and dilution (%)

Response Optimization of COD

In the optimization of COD using response optimizer was carried out for independent variable for the value of COD Parameters as 180 m^3d^{-1} as represented in fig. The global solution optimized for independent variable found was 134.848 m3d-1 of hydraulic loading, 10 percent dilution and 16 percent spatial length with Composite desirability = 0.999133.

Response	Goal	Lower	Target	Upper	Weight	Importance
COD	Target	8.64	180	250	1	1

Solution

Solution	H.L.m3/d	Dilution(%)	Spatial Length(%)	COD Fit	Composite Desirability
1	134.848	10	16	179.851	0.999133

Multiple Response Prediction

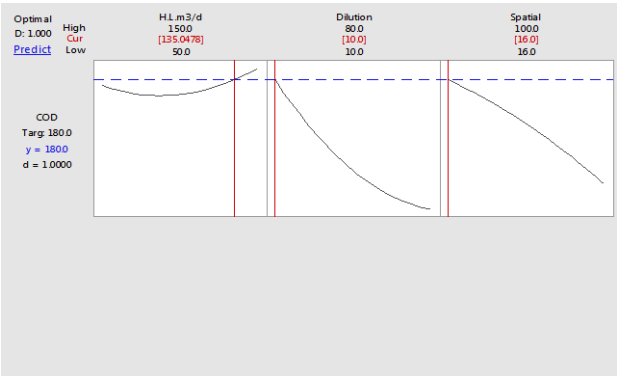| Response	Fit	SE Fit	95% CI	95% PI
COD	179.85	4.64	(170.18, 189.52)	(163.08, 196.63)

Fig. 6 Contour plot showing the optimizing condition of the COD

Predicted vs. Observed

In the fig. show that the experimental and predicated Concentration of COD removal value was used to evaluate the adequacy of the regression model. The experimental and predicted value of COD removal are show in good agreement. The point gather around the diagonal line indicated best fit of the model reported by (Ahmad et al., 2005) in optimize condition for parameter of COD.
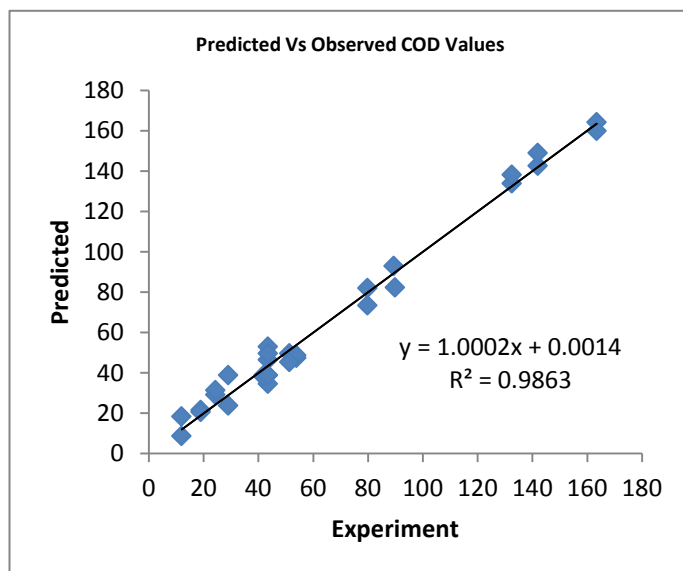

Fig 7. Plot showing the experimental observed value versus predicted value of the COD validation of the data

Validation of Data

In the developed model, extra five experiment we are conducted for separate combination of the three independent variables in random fasion every its respective experimental range and corresponding response variables for removal of COD was create model equation (2) and uncoded variables. The Following table represent the experimental condition through the predicted and experimental result of model. To determine the experimental response factor value for every five sets of variables were then used along with the predicted value to compute the R^2 values. A correlation (R^2=0.98) the

predicted and measured values of the response value of the response factor suggest for the adequacy of the proposed quadratic model in predicting the response variable.

Table 5. Experimental condition for model validation

Additional Experiment	Hydraulic loading $(m^3 d^{-1})$	Dilution (%)	Spatial length(%)	Predicted COD removal	Observed COD removal
1	100	10	16	164.58	163.49
2	50	45	16	38.88	28.98
3	150	45	16	82.32	89.94
4	100	45	16	49.68	43.56
5	150	10	58	149.04	148

with corresponding predicted and observed response.

Conclusion

COD concentration removal from sewage water is discussed with the help of Box- Behnken design and response surface methodology. In the box Behnken experimental design 3 level and 3 factorial was applied in the study. The COD removal of concentration of predicted values are obtained using model equation we are in good form. The value of Experimental R^2 is (R^2=0.98). The effect of the COD removal to gain the best understanding, and the predicted value we are represented as a counter graph. The Box Behnken design and RSM could be efficiently and economically used for modeling of removal of pollutant from phytorid sewage treatment plant.

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