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RESPONSE SURFACE MODELLING OF (N) FROM DOMESTIC SEWAGE BY PHYTORID SEWAGE TREATMENT PLANT: A STUDY USING THE BOX- BEHNKEN EXPERIMENTAL DESIGN

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KEYWORDS

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ABSTRACT

Removal of the excess nitrogen (N) from the sewage water by Phytoid sewage treatment plant has been studied at Agriculture College Maharajbag, Nagpur during 2012-2013. The objective of this investigation was to apply Box-Behnken experimental design and response surface methodology for modelling of excess N removal from sewage water through phytoid sewage treatment plant and to determine the optimal condition. The effect of three independent variables namely hydraulic loading i.e. flow (50 - 150 m³ d⁻¹), dilution (10 - 80 %) and spatial length (16 - 100 %) has been studied on the N removal. The optimal conditions of the N removal were found to be flow: 144.92 m³ d⁻¹, dilution: 69.69 per cent and spatial length: 99.98 per cent. Under these experimental conditions, the experimental N removal obtained was 7.2 mg L⁻¹. The proposed model equation has shown good agreement with the experimental data, with a correlation coefficient (R²) of 98.37 %. The result showed that optimised condition could be used for the efficient removal of the N. This study proved that Box-Behnken design and response surface methodology could economically and efficiently be applied for modelling of some pollutant concentration removal from the phytoid sewage treatment plant.

INTRODUCTION

Throughout the world, fluvial discharges of nutrients and sediments have increased due to increasing fertilizer applications to croplands (e.g., Turner and Ra-balais, 1991; Jordan and Weller, 1996), increasing concentration of livestock waste production (e.g., Sims and Wolf, 1994), and land-cover changes that enhance erosion (Woodward and Foster, 1997). The population increase has not only increased the fresh water demand but also increased the volume of wastewater generated (Upadhyay, 2004). Such nonpoint sources of pollutants have had significant detrimental effect on fresh water and coastal ecosystem. Nonpoint sources discharges contribute about two third of nitrogen and one quarter of the phosphorus inputs to Chesapeake Bay (Boynton *et al.*, 1995) one of the world's largest estuaries. Nitrate component that are soluble in water release nitrate ions which can affect human health and environmental effect. Input of nitrogen have led to excessive phytoplankton production (Gallegos *et al.*, 1992) that have contributed to the demise of submerged aquatic vegetation and increase in the extent of hypoxic waters (Howarth *et al.*, 2002). Excess nitrogen and phosphorous in effluents can leach and pollute groundwater under continuous sewage effluent use for long periods. Excess nitrogen can cause overstimulation of growth of aquatic plants and algae. Excessive growth of these organisms, in turn, can clog water intakes, use up dissolved oxygen as they decompose, and block light to deeper waters leading to a decrease in animal and plant diversity. Waste water generated also contains more concentration of nitrogen which is toxic (Jordan *et al.*, 1991a). Farmers having their farm adjacent to the wastewater flowing drains are directly using raw sewage water for irrigation. Such practice of sewage irrigation continues for longer period, without knowing pollutant load, may lead to chemical degradation of lands and possible entry of pollutants / toxicants in the food chain of people and animal consuming the farm produce of these lands which may cause health hazards. Excess nitrate in sewage causes the intestinal cancers in humans and animals. (Gupta *et al.*, 1998; Yadav *et al.*, 2002).

Sewage treatment plant based on CW's are now well-established methods for wastewater treatment in tropical climates (Burchell *et al.*, 2007; Pucci, 2003). 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 (Fleischer *et al.*, 1994; Mitsch, 1994; Whigham, 1995; Jordan *et al.*, 1999). Widespread restoration of wetlands has been suggested as part of a plan for reducing nitrogen releases from the Mississippi river basin (Mitsch *et al.*, 2000). Removal efficiency of constructed wetland with phytoplants (cattail and cyperus), plant density (4 and 22.5 m⁻²), and hydraulic retention time (2.2 and 6.6 days), for NO₃-N were in the range of 44.1-67.2 % (Yuan *et al.*, 2005). Nutrient removal by constructed wetlands has been extensively studied for their use in wastewater treatment (Hammer, 1989; Kadlec and Knight, 1996). Variability of water flow may diminish the ability of wetlands to remove nutrients and sediments, as removal capacities may be temporarily overwhelmed during short-lived high flow events (e.g., Kovacic *et al.*, 2000).

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The present work address the solution for removal of the excess pollutants from sewage water to convert it into water resource for agriculture which reduce the burden on limited fresh water, save the cost of the fertilisers and reduce the risk of health hazards due to toxicity in food chain in sustainable environment (Dash, 2012; Rai, 2008).

The objective of the present study is to find the optimum condition for efficient N removal from sewage water through phytoid sewage treatment plant by applying Box-Behnken design and response surface methodology to understand the effect of various parameters and their interaction.

MATERIALS AND METHODS

Treatment plant

The scientific study to convert sewage water into water resource for irrigating the agricultural crops and gardening was proposed (Jamwal and Mittal, 2010). It was decided to undertake a pilot project as a novel model (Anonymous, 2005) and the treatment plant was constructed at Maharajbag campus of Agriculture College, Nagpur. As the sewage water flow in the Nag river was $426 \text{ m}^3 \text{ hr}^{-1}$ in the month of May. It was not possible to construct the phytoid constructed wet land directly across the flowing river which was requiring huge amount of funding and space. Therefore to make the technology assessable as suggested by (Massuod, 2009) according to the water requirement, the intake well was designed and constructed at the bank of the river which was provided with the screen to avoid the entry of garbage material in the intake well. The pump was selected for lifting the raw sewage water as per designed capacity of the treatment plant. The uniform gradient was provided to the plant to flow the water from inlet through screening chambers and filter beds to the storage tank.

Design of phytoid treatment plant

The Phytoid sewage treatment plant was designed for $100 \text{ m}^3 \cdot \text{d}^{-1}$ capacity (Anonymous, 2005). However, for maximum removal of N from the sewage treatment plant, the independent variables ranges selected were $50\text{-}150 \text{ m}^3 \cdot \text{d}^{-1}$ for sewage water flow (hydraulic loading), $10\text{-}80\%$ for dilution and $16\text{-}100\%$ for spatial length of the sewage treatment plant (Korbhati and Rouf., 2008). Surface response modelling with Box-Behnken experimental design widely used for controlling the effects of parameters in any processes was used for the pre-treatment and optimization (Bhanarkar *et al.*, 2011, Khajeh, 2011, Liu *et al.*, 2004). Use of RSM decreased the number of trials, which otherwise would have been required in full factorial methods for the same object, thereby saving time and material resources (Moghaddam *et al.*, 2011). The experimental plan consisted of base run 15, and independent variables were studied at three different levels of low (-1), medium (0) and high (+1). Box-Behnken experimental design has the advantage of fewer trials (15 basic run) than that would be required 27 runs in full factorial design (Bhanarkar *et al.*, 2011).

Removal of N concentration was taken as response (Y) of the experimental design (Korbhati and Rouf, 2008). Furthermore, the analysis performed on the results is easily realized and experimental errors are minimized due to 3D response. Statistical methods measured the effects of change in operating

variables and their mutual interactions on process (Liu *et al.*, 2004). The N removal process from the domestic sewage water through the Phytoid sewage treatment plant through the phyto plants (Rai, 2008) is depicted in Fig.1. The design dimension, elevation and plan details of sewage treatment plant are given in Fig. 2(a) and 2(b) respectively.

Response surface methodology

Statistical designs are powerful tools used to study the main as well as the interactive effects of different process variables on a process. Among them, response surface methodology (RSM) is a collection of certain statistical techniques for designing experiments, building models, evaluating the effects of factors and searching for optimal conditions of desirable responses (Myers and Montgomery, 2002). The advantages of adopting RSM: (1) it provides more information on the experiment than unplanned approaches; (2) it reduces number and cost of experiments; (3) it makes possible to study the interactions among experimental variables within the range studied, leading to a better understanding of the process; (4) it facilitates to determine operating conditions necessary for the scale-up of the process. Its greatest applications have been in industrial research, particularly in situations where most of variables influencing the system feature (Myers and Montgomery, 2002, Khajeh, 2011, Sangeetha *et al.*, 2010).

Experimental design for absorption studies

In this study, the Box-Behnken experimental design was chosen for finding out the relationship between the response functions (N removal) and independent variables (Hydraulic loading, dilution indicating initial concentration of sewage and spatial length) of the sewage treatment plant for three different size fractions of $50\text{-}150 \text{ m}^3 \cdot \text{d}^{-1}$, $10\text{-}80\%$, $16\text{-}100\%$, respectively (Khajeh, 2011). In order to study the effects of three independent variables on pollutant concentration removal of N; batch runs were conducted at different combinations of the process parameters using Box-Behnken designed experiments (Yetilmezsoy *et al.*, 2009). The hydraulic loading i.e. flow range studied was between $50\text{ to }150 \text{ m}^3 \text{ d}^{-1}$, dilution (initial concentration of sewage) was kept between $10\text{ to }80\%$ and the spatial length was varied between $16\text{ and }100\%$ (Table 1). Box-Behnken design is rotatable second-order designs based on three-level incomplete factorial designs. 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 (Khajeh, 2011). In order to obtain the optimum condition for N removal, three independent parameters were selected (Bhanarkar *et al.*, 2011). These are presented in Table 1. The operating ranges for hydraulic loading i.e. flow (X_1), dilution (X_2) and spatial length (X_3) were determined by an iterative method.

The relationship between the parameters and responses were determined using Box-Behnken design under RSM. In this study, the experimental plan consisted of 15 base run, and the independent variables were studied at three different levels of low (-1), medium (0) and high (+1). Box-Behnken design presents an approximately rotatable design with only three levels per variable and combines a fractional factorial with incomplete block design excluding the extreme vertices (Aslan and Cebeci, 2007). The Box-Behnken design has good

performance with less error. The percentage of N 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:

$$Y = f(x_1, x_2, x_3, \dots, x_k) \dots \dots \dots (1)$$

Where Y is the answer of the system, and Xi are the variables of action called factors. The goal is to optimize the response variable Y. It was assumed that the independent variables are continuous and controllable by experiments with negligible errors. It was required to find a suitable approximation (equation) for the true functional relationship between independent variables and the response surface (dependable variable). Usually, a second-order model is utilized in response surface methodology. In the optimisation process, the responses can be simply related to chosen variables by linear or quadratic models (Myers and Monntgomery, 2002). A quadratic model, which also includes the linear model, is given below:

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

Where,

Y = Response,

x_1, x_2, \dots, x_k = Coded independent variables,

β_0, β_{ii} and β_{ij} = Linear, quadratic and interaction coefficients, respectively,

β_0 = Constant and

ϵ = Random error.

Trials were performed in triplicate. Minitab 16 Free trial version software package for regression and graphical analysis were used for analyses of the data. In all calculation, spreadsheets of Microsoft Excel 2007 were used as ODBC (Open Database Connectivity) data source running under windows.

Validation experiments

The mathematical model generated during RSM implementation was validated by conducting the additional experiments for different combination of the three independent variables in the random fashion, each within its respective experimental range (Wu *et al.*, 2009).

Statistical analysis

The significance of the independent variables and their interactions was tested by the analysis of variance (ANOVA) (Yetilmezsoy *et al.*, 2009). Results were assessed with various descriptive statistics such as t-ratio, p-value, F-value, degrees of freedom (df), coefficient of variation (CV), coefficient of determination (R²), adjusted coefficient of determination (R²adj), sum of squares (SS), mean sum of squares (MSS) 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).

RESULTS AND DISCUSSION

N removal

The results of N removal along with experimental conditions are given in Table 2. By applying multiple regression analysis on the design matrix and responses given in Table 2, approximate uncoded function for N concentration removal applicable for the treatment plant Under study is given in following equation (Bhanarkar *et al.*, 2011).

$$Y = 8.336 + 0.221X_1 - 4.855 \times 10^{-4}X_2 - 0.369 X_3 - 0.137 \times 10^{-2}X_1^2 - 5.173 \times 10^{-4} X_2^2 + 0.105 \times 10^{-2} X_3^2 - 6.96 \times 10^{-4} X_1 X_2 + 19.43 \times 10^{-4} X_1 X_3 + 0.092 \times 10^{-2} X_2 X_3 \dots \dots \dots (3)$$

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

Model statistical tests

The ANOVA was conducted as the analysis of variance, to test the significance of the developed model (Sen and Swaminathan, 2004). The summary of ANOVA of the regression model presented in Table 3 indicated that the model equation could be used adequately to describe the concentration removal of N under a wide range of operating conditions.

F-value of 134.27 being greater than the tabulated value (F tab-4.1) implied that the model was significant Liu *et al.* (2004). The probability value (p-model < F = 0.000, or below 0.0001) was less than 0.05, indicating that the quadratic model was highly significant. A fairly high value of R² (98.37%) suggested that most of the data variation was explained by the regression model. Moreover, high value of the adjusted regression coefficient (R²adj -95.84%) indicated the capability of the developed model to satisfactorily describe the system behaviour within the studied range of operating parameters (Can *et al.*, 2006; Zhang *et al.*, 2010). The value of R²adj was higher than that of R². A similar pattern has been reported by others for the second-order RSM experiments based on Box-Benhken (Khajeh, 2011) and central composite (Liu *et al.*, 2004) designs. Further, a relatively low value of the coefficient of variation (CV-8.098 %) indicated good precision and reliability of the conducted experiments, similar to earlier reported by (Ahmad *et al.*, 2005).

Model adequacy check

Adequacy check of the proposed model is an important part of the analytic procedure. Good adequacy can ensure the

Table 1: Experimental range and levels of variables

Variables	Unit	Code	Range and Levels		
			Low level(-1)	Centre(0)	High level(1)
Hydraulic Loading (flow)	(m ³ d ⁻¹)	X ₁	50	100	150
Dilution (Initial concentration of sewage)	(%)	X ₂	10	45	80
Spatial length	(%)	X ₃	16	58	100

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

Run order	Coded variable			Uncoded variable			Response N
	X1	X2	X3	Flow(m ³ /day)	Dilution (%)	Spatial (%)	
1	+	-	0	150	10	58	1.50
2	-	-	0	50	10	58	9.28
3	+	0	-	150	45	16	9.24
4	0	+	-	100	80	16	8.20
5	-	+	0	50	80	58	9.96
6	0	-	+	100	10	100	8.85
7	-	0	-	50	45	16	9.00
8	0	0	0	100	45	58	10.7
9	0	-	+	100	10	100	8.27
10	0	+	+	100	80	100	4.45
11	+	-	0	150	10	58	8.30
12	-	0	-	50	45	16	12.5
13	0	0	0	100	45	58	8.30
14	+	0	-	150	45	16	8.10
15	0	0	0	100	45	58	4.30
16	0	-	-	100	10	16	1.55
17	0	0	0	100	45	58	11.5
18	0	0	0	100	45	58	8.70
19	-	-	0	50	10	58	8.30
20	-	+	0	50	80	58	0.32
21	+	0	+	150	45	100	13.2
22	0	+	+	100	80	100	0.38
23	0	0	0	100	45	58	11.5
24	-	0	+	50	45	100	1.18
25	0	-	-	100	10	16	6.50
26	-	0	+	50	45	100	1.82
27	+	0	+	150	45	100	1.50
28	+	+	0	150	80	58	9.28
29	0	+	-	100	80	16	9.24
30	0	+	0	100	80	58	8.20

Factors: 3 Replicates: 2 Base runs: 15 Total runs: 30 Base blocks: 1; Total blocks: 1 Center points: 6 Design Table (randomized); Run Blk A B C

Table 3: Analysis of variance (ANOVA) of the response surface quadratic model for the prediction of N removal

Factor coded	DF	Sum of squares	Mean squares	F-value	p-value	Remark
Model	9	94.026	43.781	134.27	0.000	Significant
(X ₁)	1	29.133	29.133	89.35	0.000	Significant
(X ₂)	1	78.544	78.544	240.88	0.000	Significant
(X ₃)	1	3.940	3.940	12.08	0.002	Significant
X ₁ ²	1	92.943	87.450	268.19	0.000	Significant
X ₂ ²	1	4.474	2.966	09.10	0.007	Significant
X ₃ ²	1	25.274	25.274	77.51	0.000	Significant
X ₁ X ₂	1	11.858	11.858	36.37	0.000	Significant
X ₁ X ₃	1	133.25	133.25	408.66	0.000	Significant
X ₂ X ₃	1	14.607	14.607	44.80	0.000	Significant
Residual Error	20	6.521	0.326			
Lack-of-Fit	3	4.322	1.441	11.14	0.000	Significant
Pure Error	17	2.199	0.129			
Total	29	400.547				

S = 0.571026; SSe = 6.521; MSSe = 0.326; R-Sq = 98.37(%); R-Sq (pred) = 95.84(%) CV = 8.098(%)

model to provide an adequate approximation to the real system (Korbahti and Rauf, 2008).

The normal probability of the residuals depicted in Fig. 3 suggested that almost no serious violation of the assumptions underlying the analysis, and it confirmed the normality assumptions and independence of the residuals. Moreover, the comparison of the residuals with the error variance showed that none of the individual residual exceeded the value twice of the square root of the error variance as earlier reported by Sen and Swaminathan (2004).

The plot presented in Fig. 4 tests the assumption of constant variance. The points are randomly scattered, and all values were lying within the range of -1 and +1 (values beyond -1 and +1 are considered as the top and bottom outlier detection limits). Accordingly it was inferred that developed quadratic equation was appropriate and was successful for capturing the correlation between the influencing parameters of N concentration removal process.

As evident from the Fig. 5 the probability distribution of the residuals for N is within the range of -1.00 and +0.75 and

Table 4: Multiple regression results and significance of the components for the quadratic model of N

Factor coded	Coefficient	StandardError	Effect	t-ratio	PC
Intercept	8.24	0.2331	16.49		
X_1	1.35	0.1428	2.70	18.90	7.39
X_2	-2.22	0.1428	- 4.43	-31.03	19.93
X_3	-0.49	0.1428	- 0.99	-6.95	0.99
X_1^2	-3.44	0.2101	-6.88	-32.80	23.59
X_2^2	-0.63	0.2101	-1.27	-6.033	1.14
X_3^2	1.85	0.2101	3.70	17.61	6.41
$X_1 X_2$	-1.22	0.2019	-2.43	-12.06	3.00
$X_1 X_3$	4.08	0.2019	8.16	40.43	33.89
$X_2 X_3$	1.35	0.2019	2.70	13.38	3.70

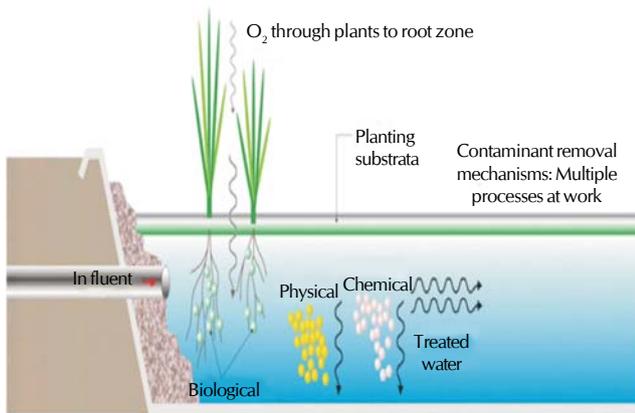


Figure 1: Contaminant removal process in the phytoid sewage treatment plant (Source: NEERI)

residual were centrally distributed slightly skewed for large value. As shown the distribution graph for the bin size of 0.00 having the maximum frequency equal to 10 whereas it was 1 for -0.75 bin size. As depicted the shape does not exhibit any serious departures from normality and homogeneity that the used response transformation was appropriate and successful in capturing the correlation between N removals and influencing parameter. As seen from the above plot, the standardized residuals are generally what we would label “well-behaved.” They do not exhibit any serious departures from normality.

Finally in the residual graph as depicted in Fig.6 all the residual values were laying within the range of -1 and +1. The large variation was recorded for the observation order no. 16 having the variable concentration 100:10:16 whereas minimum variation was observed for observation order no. 13 with the variable concentration 100:45:58 showing the model were capturing the successful correlation between the influencing parameter of the N concentration removal process.

Model significance test

The result of student t-test and p-value conducted to evaluate the significance of the quadratic model coefficient are listed in Table 4. The t-value is the ratio of estimated parameter effect, and estimated parameter standard deviation. The parameter effect is estimated as twice the regression coefficient value for that parameter. The p-value is used as a tool to check the significance of the coefficient. The larger the magnitude of t value and smaller the p value, significant is the corresponding

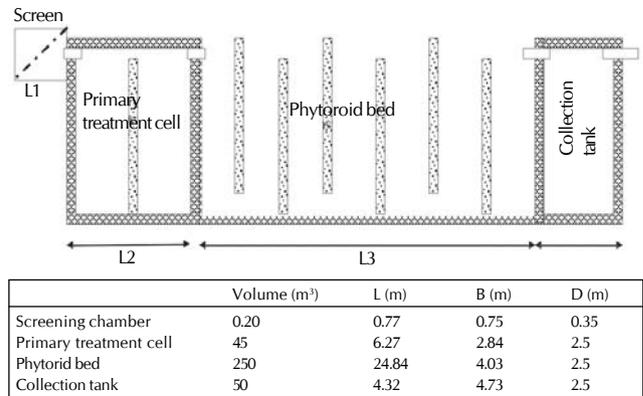


Figure 2(a):The design dimension, elevation of Phytoid sewage treatment plant

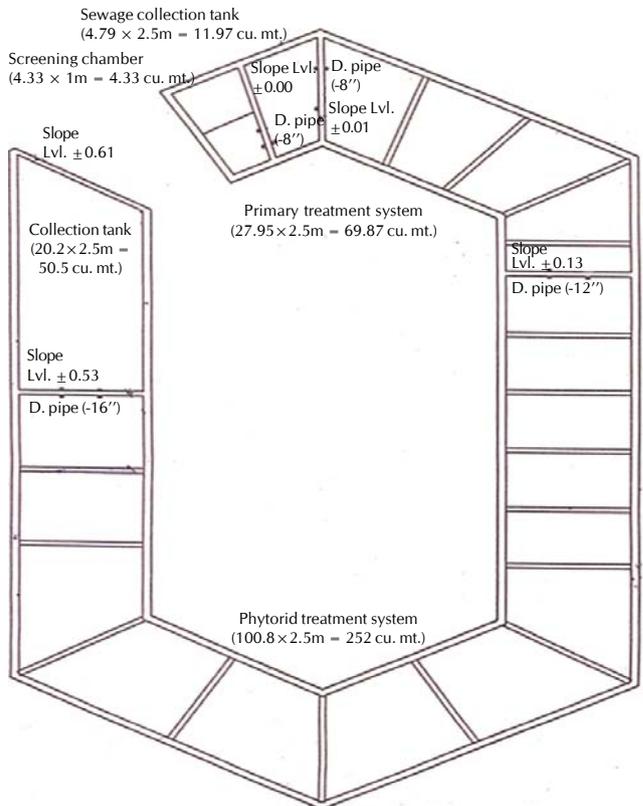


Figure 2(b): Plan of the phytoid sewage treatment plant

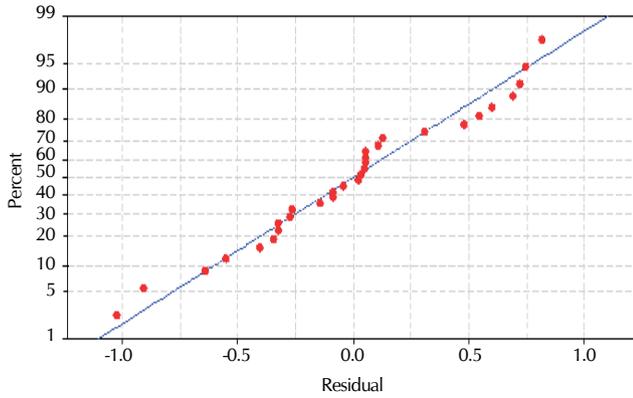


Figure 3: Normal probability plot of the residuals for N

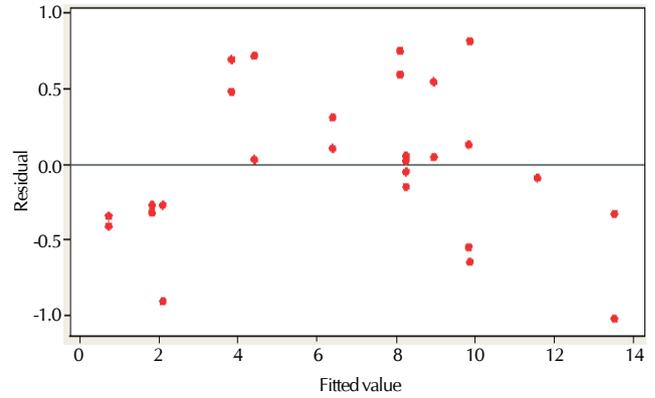


Figure 4: Internally studentied residuals vs. predicted value plot for N

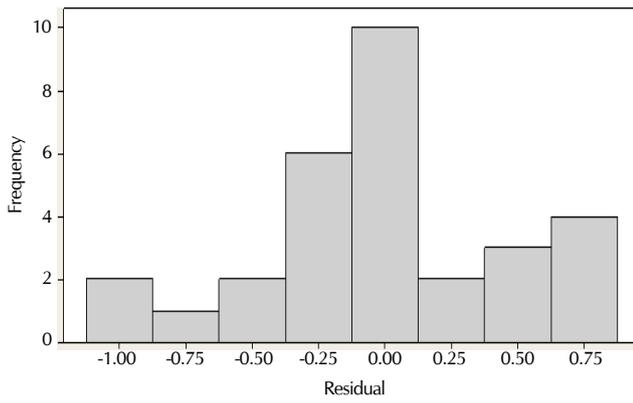


Figure 5: Internally studentied frequency vs. residuals value plot

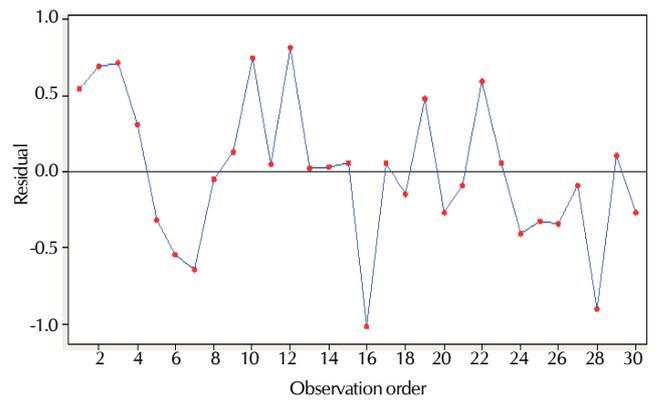


Figure 6: Plot between observation orders vs. residuals value plot

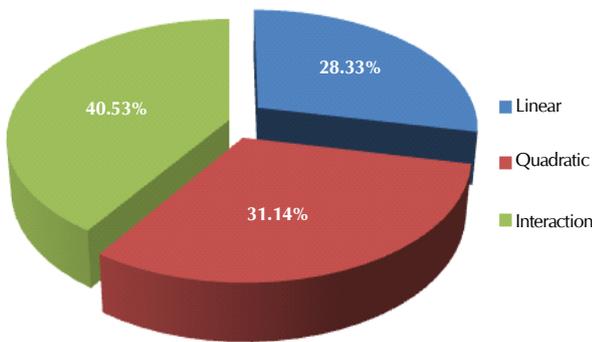


Figure 7: Schematic diagram showing percentage contribution of the component

parameter in the regression model as reported by Yeltilmezsoy *et al.* (2009).

Results showed that all the linear and quadratic terms were statistically significant ($p < 0.05$). Similarly all interactive terms were also found statistically significant. Moreover, interaction effect of independent variable found main effects and were found to be more significant than their respective quadratic effects (X_1^2 , X_2^2 and X_3^2) followed by first order main effect of all the three independent variables namely flow (X_1), dilution (X_2) and length (X_3). The t- and p-value (Table 3 and 4) revealed

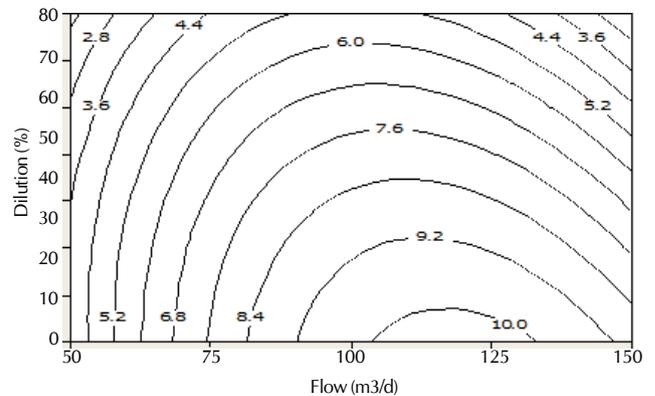


Figure 8a: Contour plot showing effect of two independent variables (Length (%) was held at their respective centre level) (a) Dilution (%) and flow ($m^3 d^{-1}$)

that the interactive terms flow(X_1)*length (X_3) was found to be the most significant component of the regression model for the present application, whereas, the linear term length (X_3) showed the lowest effect on the N removal.

Table 4 revealed the Percentage contribution (PC) of each of the individual terms in the final model computed using the sum of squares (SS) values of the corresponding term. The PC of the term is obtained as the ratio of SS of the terms as earlier suggested by Singh *et al.* (2011). As evident from Table 4, the interactive terms flow(X_1)*length (X_3) showed the highest level

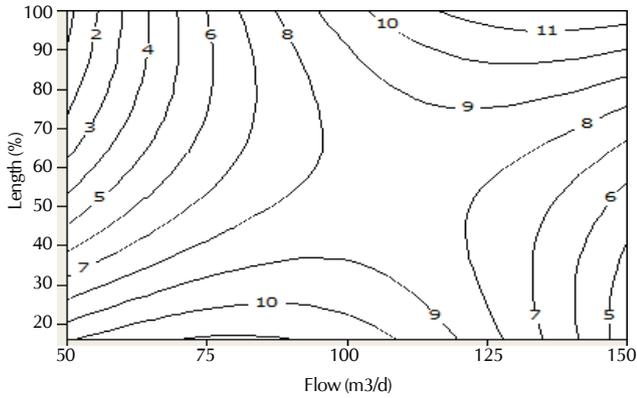


Figure 8b: Contour plot showing effect of two independent variables (Dilution (%) was held at their respective centre level) (b) Length (%) and flow ($\text{m}^3 \text{d}^{-1}$)

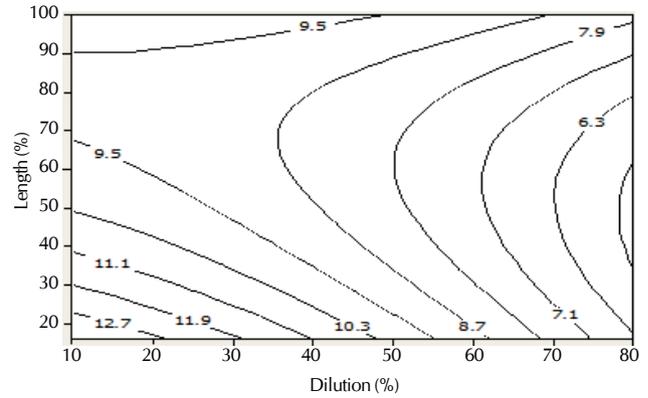


Figure 8c: Contour plot showing effect of two independent variables (Flow ($\text{m}^3 \text{d}^{-1}$) was held at their respective centre level) (c) Length (%) and dilution (%)

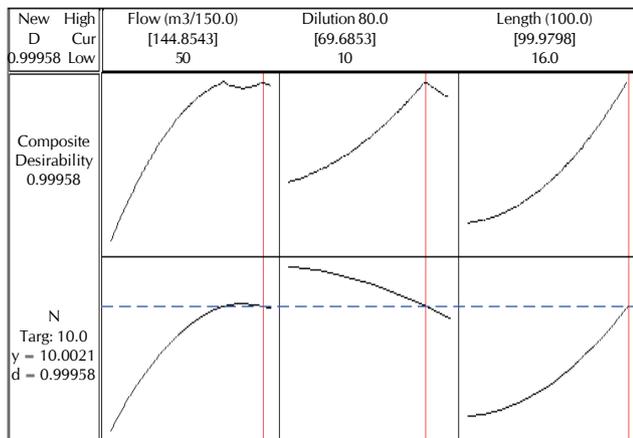


Figure 9: Contour plot showing the optimizing condition of the N

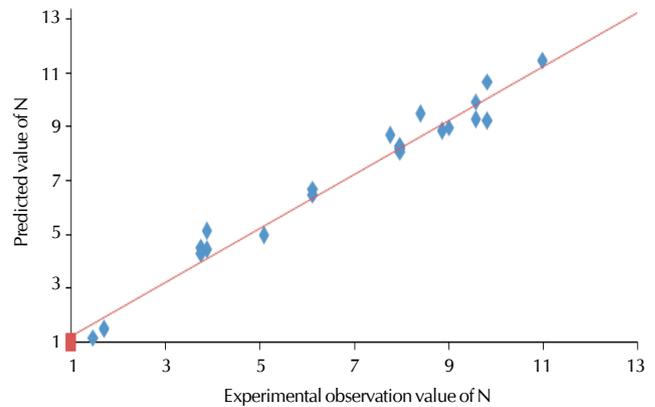


Figure 10: Plot showing the experimental observed value versus predicted value of the N.

of significance with a contribution of >33.89 per cent as compared to other components.

As depicted in Fig. 7 showing the total percentage contribution (TPC) of the possible first order, quadratic and interactive component (Meng *et al.*, 2007).

Results revealed that among the calculated TPC values, interactive terms had the highest level of significance with a total contribution of 40.53 per cent as compared to other TPC values. This was followed by the TPC of quadratic terms with a total contribution of 31.14 per cent. The TPC of first order terms showed the lowest level of significance with a total contribution of 28.33 per cent, indicated that the first order components showed a little effect in prediction of the N concentration removal. Hence, TPC values also proved that the interactive terms have a direct relationship on the dependent variable.

Optimization of experimental condition N removal

In order to gain better understanding of the influence of the independent variables and their interactions on the dependent variable, response contour plots for the measured responses were drawn based on the quadratic model. Fig.8 exhibits the response contour plots as the functions of two independent variables keeping other variable fixed at the centre level.

Fig. 8(a) revealed that N removal increased slightly with increased dilution from 40 to 80 percent whereas the reverse trend was obtained in the case of influence of flow on N removal. This increase in the N removal with increase in dilution might due to addition of the well water having lower value of N. N concentration increased with increasing flow rate to the extent of $100 \text{ m}^3 \text{d}^{-1}$ (Jordan *et al.*, 2003). A significant N removal was observed at flow rate $50 \text{ m}^3 \text{d}^{-1}$ and dilution more than 40 per cent.

From Fig. 8(b) it is evident that N removal increased with the length from 10 to 75 percent. The range of removal observed was 10 mg L^{-1} to 1 mg L^{-1} . Considerable N removal can be seen at 95 percent length and $50 \text{ m}^3 \text{d}^{-1}$ flows might be that due to uptake of the N by the phyto plants from the water passing along the length of filter media of the treatment plant (Sivaraman, 2011).

A significant removal of N concentration was obtained at $50 \text{ m}^3 \text{d}^{-1}$ flow and 75 percent length. The removal of N due to increased flow from $118 \text{ m}^3 \text{d}^{-1}$ to $150 \text{ m}^3 \text{d}^{-1}$ was with the range of 10 mg L^{-1} to 5 mg L^{-1} (Jordan *et al.*, 2003). Further, it is observed from the Fig 8(b) that at $50 \text{ m}^3 \text{d}^{-1}$ flow and length played an important role in N removal (Rai, 2008).

Fig. 8(c) revealed that N removal was increased slightly from

Table 5: Experimental condition for model validation with corresponding predicted and observed responses

Additional experiment	Flow(m ³ d ⁻¹)	Dilution(%)	Spatial(%)	Predicted N removal	Experimental N removal
1	100	80	16	6.470	6.912
2	50	45	16	9.907	9.160
3	150	10	58	9.128	8.767
4	90	45	58	7.915	7.443
5	140	45	16	6.349	6.824

12.7 to 9.5 mg L⁻¹ with increasing length percentage 23 to 67 percent and this might be due to uptake of N by the phyto plant along the length from the water passing through the filter media of the treatment plant (Dilshad *et al.*, 2010). Also it is evident from the Fig. 8(c) that there was increase in the N removal from 12.7 to 6.1 mg L⁻¹ with dilution from 20 to 80 percent. Increased N removal might due to addition of well water with lower concentration of N content similarly increased in N removal might due to chemical reaction of nitrification and denitrification occurring in the plant during detention period of treatment (Tegegne *et al.*, 2008).

Response Optimization

As presented in Fig.9 the optimization of N by using the response optimizer was carried out for independent variable for the value of N = 10.

The optimized global solution for the independent variable found was flow = 144.48 m³d⁻¹, dilution = 69.86 percent and spatial length = 99.98 percent with the composite desirability equal to 1.00. (Yus *et al.*, 2008).

Predicted vs. Observed

The diagnostic plot shown in Fig. 10 indicated the experimental and the predicted N concentration removal values and was used to estimate the adequacy of the regression model. Observed and predicted values of N removal were observed in well agreement. The points cluster around the diagonal line indicated developed quadratic model was successful in capturing the correlation between the influencing parameter of N removal (Ahmad *et al.*, 2005).

Validation of the Data

In order to verify the validity of the proposed model, additional five experiment were conducted for different combination of the three independent process variables in a random fashion (Wu *et al.*, 2009) each within its respective experimental range and corresponding response variable(N concentration removal) was generated using the uncoded variables and model equation (3).

Table 5 presents the experimental condition along with the model predicted and experimental results. Experimentally determined response factor values for each of the five sets of process variables were then used along with the model predicted values to compute the R² values. A correlation (R² =

0.984) among the predicted and measured values of the response values of the response factor suggest for the adequacy of the proposed quadratic model in predicting the response variable for the validation data set comprised of different combination of the process variables (Korbhati and Rouf, 2008).

CONCLUSION

Application of response surface methodology and Box–Behnken design from the point of view N concentration removal from domestic sewage water is discussed. Three-level three-factorial Box-Behnken experimental design was applied in the study. Predicted values of N concentration removal obtained using model equations were in good agreement with the experimental values (R² - 0.984). In order to gain a better understanding of the effect of the variables on N removal, the predicted models were presented as contour graphs. This study clearly confirmed that Box-Behnken design and response surface methodology could economically and efficiently be applied for modelling of some pollutant concentration removal from the phytoid sewage treatment plant.

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Parameter	Goal	Lower	Target	Upper	Weight	Import
N Target	0.32	10	15	1	1	1

Global Solution
 Flow (m³ d⁻¹) = 144.920
 Dilution (%) = 69.6853
 Length (%) = 99.9798

Predicted Responses;
 N = 10.00
 Desirability = 1.00
 Composite Desirability = 1.00

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