SindhUniv. Res. Jour. (Sci. Ser.) Vol. 50 (004) 591-594 (2018)

http://doi.org/10.26692/sujo/2018.12.0095

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Response Surface Methodology for removal of Biological Oxygen Demand (BOD) through RBC

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Received 11th March 2017 and Revised 27th June 2018

Abstract: Response Surface Methodology (RSM) is a powerful Statistical instrument utilized to explore the optimum levels of contribution factor(s), while the response is influenced by input factors. First major contribution in Response Surface Methodology was made by Box and Wilson (1951) and Box and Hunter (1957) originated from British chemical Industry. In the present study, the effect of two factors, hydraulic retention time and number of discs were tested on the removal of Biological Oxygen Demand through Rotating Biological Contactor. The Response Surface Model revealed that both, the retention time and number of discs have highly significant effect on the removal of BOD as; corresponding p-values are less than 0.01. Consequently the results obtained from Analysis of Variance are very much consistent with that of Response Surface Methodology. The optimum level of BOD with respect to removal was 78.99767. Furthermore, Response Surface Model was also elaborated to show the effect of retention time and number of discs on the removal of BOD.

Keywords: Response Surface Methodology (RSM), BOD, RBC),

1. INTRODUCTION

Response Surface Methodology (RSM) is used to explore the association among descriptive variables and also one or more than one response variables. G.E.P Box and Wilson developed the technique in 1951. Response surface methodology (RSM) is a set of statistical and mathematical techniques helpful for the analysis, modeling and for problems in which a response of interest is influenced by a number of variables and the objective is to optimize the response (Raymond *et al* 2007). Unfortunately, for RSM models having random block effects of the prediction variance depend, on an unidentified parameter that is the ratio of two unknown variance components. The assessment of the design effect on the prediction variance as a result depends on the value of the unknown parameter (Saha, and Khuri.) Aziz *et al* (2007) distinct that (RSM) is a collection of statistical and mathematical techniques extensively used to determined the effects of numerous variable and to optimize different biotechnological and chemical processes. Consequently RSM is compilation of mathematical and Statistical techniques helpful for improving, developing and optimizing processes. Moreover the response surface method is a functional technique to establish the optimum prescribed amount of each factor disjointedly. Box and Hunter (1957), Mckee (1982) showed that the vector β of unknown parameters can be calculated from X matrix as under.

$$\beta = (X'X)^{-1}X'y$$

Response Surface Methodology is a sequential technique. When we are on a point of response surface that is distant from optimum and we want to move rapidly from current point to optimum point with sequence. The purpose was using a series of designed experiments to achieve optimal solution (Montgomery, 1997) however optimization can be brought by applying a second degree model

$$\hat{y} = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \varepsilon$$

Jaewoong *.et al.*, (2016) environmental Monitoring and Assessment, relationships between water quality parameters in rivers and lakes states that Biological oxygen demand (BOD_5) or chemical oxygen demand (COD) analysis is extensively used to estimate organic pollutants in system of water as well as the effectiveness of treatment plants of wastewater. Both methods of analysis, however, have margins such as being imprecise, insensitive, time-consuming, and the fabrication of chemical waste. Total organic carbon (TOC) analysis therefore, for organic pollutants has been measured for a substitute analysis as an alternative of BOD_5 or COD.

Shamas *et al* (2015) carried out this study under the topic "Evaluation of a cost effective and energy-efficient disc material for rotating biological contactors

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(RBC), and performance evaluation under varying condition of RPM (Rotations Per Minute) and submergence", to assess the appropriateness of polyethylene foam as disc stuff for rotating biological contactor (RBC).

2. OBJECTIVES OF THIS STUDY

Response surface methodology to two contribution factors has been considered and consequently literature is accessible. However, the objectives of the present study are:

1. Development of Statistical Model for Water quality interaction of retention Time & number of Discs.
2. To explore optimum level of retention time & number of discs for BOD_5.
3. To study the interactive effect of retention time & number of discs on water quality parameter.

3. MATERIALS AND METHODS

Response Surface Methodology is used on "Rotating Biological Contactor" which is in actually used in Simulation for Treatment of Wastewater, when removal is influenced by one or more than one factors. For the present study, to fit the quadratic response, two factors were chosen. This experiment was conducted on Rotating Biological Contactor for elimination of Biological Oxygen Demand, to analyze the effect of two factors; such are the hydraulic retention time and multiple numbers of discs.

4. Purpose and Development of RBC simulator:

Rotating Biological Contactor (RBC) is an attached growth aerobic treatment process. It requires the occurrence of molecular oxygen for the metabolic movement of microorganisms. Removal of colloidal particles were achieved first, in this process by the standard of physiochemical adsorption and secondly by the embarrassing situation of balanced particulate matters on the biological flocs. On the other hand, the removal of soluble organic fractions like BOD_5 was talented by microbial bio combination (Pathan 2015). The RBC works on the standard of bio amalgamation. These pollutants are transformed by microbes in to simpler end products i.e. water and carbon dioxide and create them possess cells.

5. STUDY REGION

At National Center of Excellence in Analytical Chemistry (NCEAC), University of Sind, Jamshoro, a hall of Residence was chosen as study area in this investigate work. Maximum accommodation provides by this hostel up to 27 bachelor students in 9 rooms.

6. Procedure applied to optimize the Response:

In order to optimize the results, different procedures were applied i.e. Hydraulic Retention Time (HRT) and multiple numbers of discs for greywater treatment through (RBC). The system operated under three different HRTs,2 hours, 0.42 **liter per min**, 2.5 hours, (0.33 **l/min**) and3 hours, (**0.28 l/min)** and multiple numbers of discs i.e. from forty to fifty-two. 40 numbers of discs representing 0% area increment, 42 disks representing 5% area increment, 44 as 10%, 46 as 15%, 48 as 20%, 50 as 25% and 52 numbers of discs representing 30% area increment respectively. The primary information regarding quantities of Biochemical Oxygen Demand (BOD_5), and related information of grey water were collected from Sindh University Hostel after processed into Rotating Biological Contactor (RBC) so that we can collect different quantities of pollutant levels in grey water by different procedures regarding the discs area, and the hydraulic retention time.

7. Development of Statistical Model for Water quality interaction of Time & Disc:

Response surface methodology (RSM) is a group of statistical methods that is important for the modeling and investigation of problems. In which a response of attention is affected by numerous objective variables and objective is to optimize the response. The regression model representation is also important in illustration of the concept of interaction. A regression model representation of the two factor factorial experiment could be written as:

$$y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 + \varepsilon$$

Where, y is the response, β is the parameter whose value is to be determined and x_1 and x_2 are the variables that represent factors "Time" and "Disc" respectively and "**ε"** is a random error term. Whereas x_1 and x_2 are defined on coded scale from -1 to +1 (representing the level as low and high of "Time" and "Discs"), and the interaction is represented by x_1 x_2 of "Time" and "Disc".

8. Statistical Analysis:

Data collected, tabulated, analyzed and interpreted in the present work. On the basis of the collected data, a Statistical model is developed and the same data analyzed through Statistical software for Social Sciences (SPSS: 20), Mat lab, Ms Excel and Originpro version 7 is used to draw 3D plots. The developed statistical model validated with the previous experimental work by the researchers.

9. RESULTS AND DISCUSSION

Present study was conducted to apply the Response Surface Methodology for getting removal of Biological Oxygen Demand data from grey water taken from (NCEAC). Response Surface model in terms of actual values is given as follows:

Source	DF	SS	MS	F	P
Regression	2	27857	13928	272.37	0.0000
Error	189	9665	51		
Tottal	191	37522			

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 + \varepsilon$$

Removal = - 807 + 53.1 time + 32.2 disc+ 0.73 time^2 - 0.290 disc^2 - 1.09 time disc

10. Interpretation of the fitted Response Surface Model:

The output indicates in the above model, that, retention time and number of discs have linear positive effect on the removal of Biological Oxygen Demand. The coefficients for retention time, number of discs are 53.1 and 32.2 respectively. The quadratic effect of retention time is 0.73. It intends that as the time increases the removal of Biological Oxygen Demand be also increased. The model further reveals that number of discs has positive effect on the removal of Biological Oxygen Demand; however, after some level of increment of discs, it tends towards decline, as, the quadratic response of number of discs is -0.290.

The parameter for interaction of retention time and number of discs is negative. Mutual interface of retention time and number of discs decreases the removal about 1.09. It reveals that after a specific position curvature tend towards decline.

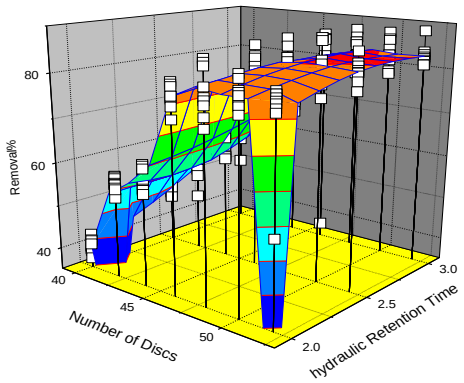

Fig. 1. following figure showing Response Surface effect of Retention Time and Number of Discs on Removal of Biological Oxygen Demand (BOD_5)

11. Determination of the optimum response for the removal BOD

The nature of the response surface must be known to establish whether the point denoted by vector X_s, corresponds to a minimum, a maximum or a saddle point. For a second order fitted response surface, the point where a minimum, a maximum or a saddle point occurs (X_s) is,

$X_s = -1/2 \; B^{-1} b^*$

By substituting the values in the model and simplifying the matrix the quadratic response is obtained under,

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 + \varepsilon$$

Removal = - 807 + 53.1 time + 32.2 disc+ 0.73 time 2-0.290 disc 2 -1.09 time disc

As model indicates that the surface X_s is a maximum, now matrix B is required and the vector **b***, we obtain,

$$\mathbf{B} = -1/2 \begin{bmatrix} 0.73 & -1.09/2 \\ -1.09/2 & -0.290 \end{bmatrix}$$

$$\mathbf{b^*} = \begin{bmatrix} \mathbf{53.1} \\ 32.2 \end{bmatrix}$$

$X_s = -1/2 \; B^{-1} b^* = \begin{matrix} 2.1131 \\ \mathbf{51.5460} \end{matrix}$

The predicted Optimum Response Surface (BOD_5) at the stationary points of x_1 and $x_2$respectively= X_s = 2.1131 (Time) and 51.5460 (Discs), as this is the close agreement with the location.

Removal = - 807 + 53.1 time + 32.2 disk + 0.73 time2 - 0.290 disk2 - 1.09 time disk

By solving above equation by substituting corresponding values of retention time and number of discs, the optimum response of BOD is 78.99767%.

Table 1: coefficients as well as their consequent t and p values for Response Surface Model

Preditor	Coefficient	Standard Deviations	t-values	p-values (sig. level)
Constant	**-807.00**	**70.65**	**-11.42**	**0.000**
Time	**53.09**	**20.66**	**2.57**	**0.011**
Disc	**32.237**	**2.748**	**11.73**	**0.000**
time^2	**0.731**	**3.451**	**0.21**	**0.832**
Disc	**-0.28971**	**0.02913**	**-9.95**	**0.0000**
Timedisc	**-1.0861**	**0.2467**	**-4.40**	**0.0000**

Table 2: Regression Equation, Regression Analysis and Analysis of Variance (Table containing t and p-values) showing the effect of intercept, retention time and number of discs on the removal of BOD_5

Predictor	Coef	StDev	T	P
Constant	-79.995	6.684	-11.97	0.000
Time	6.881	1.264	5.44	0.000
Disk	2.9008	0.1278	22.70	0.000

The regression equation is
Removal = - 80.0 + 6.88 time + 2.90 disk
S = 7.151 R-Sq = 74.2% R-Sq(adj) = 74.0%

12. Analysis of Variance

Significant factors in the RSM Model:

The factors be capable of be acknowledged as significant by calculating t-values and consequent p-values. A factor possesses p-value which is less than 0.05 is considered as significant, if not, factor considered as not significant. The coefficients of the above equation with their consequent t and p values are specified in the table. The table reveals that linear estimate of time and disc are significant as their values are less than 0.05, however linear and quadratic estimates of number of discs are highly significant as their p-value are less than 0.01. Moreover quadratic estimate of retention time is not significant as its p-value is greater than 0.05. Consequently the interaction effect of retention time and number of discs is also highly significant as the p-value of interactive effect is less than 0.01.

Analysis of Variance (ANOVA), frequently, is used to analyze such kind of problems, data obtained from factorial experiments, F-values are calculated and hypothesis is tested. ANOVA table was constructed to confirm the results obtained by applying Response Surface Methodology. Table 2 shows that retention time and number of discs have highly significant effect on removal of BOD through RBC, because the corresponding p-values are less than 0.01, while level of significance was 0.05. Consequently the results obtained from Analysis of Variance are very much consistent with that of Response Surface Methodology.

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