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Response Surface Methodology for the Removal of Chemical Oxygen Demand through Rotating Biological Contactor

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Abstract: Response Surface Methodology (RSM) is a significant Statistical instrument utilized to explore the optimum levels of contribution factor(s). Most important contribution originally in the field of Response Surface Methodology was done by Box and Wilson (1951) and Box and Hunter (1957) originated from British chemical Industry. The effect of two factors, hydraulic retention time and number of discs were observed on the elimination of Chemical Oxygen Demand (COD) through Rotating Biological Contactor (RBC) In the present study. In Response Surface Model (RSM) revealed that number of discs or disc area increment has significant effect on the removal of COD as; corresponding p-values are less than 0.01, while linear and quadratic effect of retention time has no significant effect on the removal of COD as the p values are 0.301 and 0.071 respectively. The best possible optimum level of COD with respect to removal was 51.53984. Furthermore, Response Surface Model elaborated as well, to demonstrate the effect of retention time and number of discs on the removal of COD

Keywords: Response Surface Methodology (RSM), COD, RBC.

1. INTRODUCTION

Response Surface Methodology (RSM) is a set of statistical and mathematical techniques helpful for the analysis and modeling and of problems in which a response of interest is influenced by a number of variables (Raymond Hyperlink "http://eu.wiley.com/WileyCDA/Section/id-302479.html?query=Raymond+H.+Myers".Hyperlink "http://eu.wiley.com/WileyCDA/Section/id-302479.html?query=Raymond+H.+Myers" (Myers *et al.*, 2016). G.E.P Box and K.B Wilson developed the technique in 1951. RSM is used to explore the association among descriptive variables and also one or more than one response variables. (Aziz *et al* 2007) distinct that (RSM) is a compilation of statistical and mathematical techniques extensively used to determined the effects of numerous variable and to optimize different biotechnological and chemical processes. Unfortunately, for RSM 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 (Sahaand Khuri). Consequently Response surface methodology 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 disjointed factor. The vector β of unknown parameters can be calculated from X matrix as $\boldsymbol{\beta = (X'X)^{-1}X'y}$ Showed by Box and Hunter (1957) and Mckee (1982).

Response Surface Methodology is a chronological method. We want to move rapidly from current point to optimum point with sequence, when we are on a point of response surface that is distant from optimum. Using a series of designed experiments, the purpose was, to achieve optimal solution (Montgomery, 1997). However optimization can be brought by applying a second degree model

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

Relationship between water quality parameters in rivers and lakes state 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 (Lee *et al* 2016). Both methods of analysis, however, have margins such as being time-consuming, imprecise and the Producer of chemical waste. Therefore, for organic pollutants Total organic carbon (TOC) analysis has been taken as a substitute analysis of BOD_5 or COD.

Under the topic "Evaluation of a cost effective and energy-efficient disc material for rotating biological contactors (RBC), and performance evaluation under

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varying condition of RPM (Rotations Per Minute) and submergence", (Tabraiz *et al.,* 2015) carried out this study to assess the appropriateness of polyethylene as disc stuff for rotating biological contactor (RBC).

Combining with (RSM), in order to maximize Pb(II) removal from aqueous solution by Antep pistachio (Pistacia vera L.) a three factor, three-level Box–Behnken experimental design and quadratic programming (QP) was employed. The optimum coded values of three test variables were computed as $x_1 = 0.125$, $x_2 = 0.707$, and $x_3 = 0.107$ by using a LOQO/AMPL optimization algorithm, and the corresponding Pb(II) removal efficiency was found to be about 100%. (Yetilmezsoy *et al.,* 2009)

Objectives of this study

For two contribution factors, Response surface methodology has been measured and literature is accessible accordingly. However, the objectives of the present study are:

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

2. MATERIALS AND METHODS

Response Surface Methodology was applied on RBC, which was being used in Simulation for Treatment of Wastewater, when elimination of pollutants was subjective by one or, more than one factors. For the present study, two factors were selected, to fit the quadratic response. The conduct experiment was observed on removal of Chemical Oxygen Demand through Rotating Biological Contactor to evaluate the effect of two factors; such are the hydraulic retention time and disc area increment.

Purpose and Development of Rbc Simulator

Rotating Biological Contactor (RBC) requires the occurrence of molecular oxygen for the metabolic movement of microorganisms. It is an attached growth aerobic treatment process. Elimination of colloidal particles was achieved, by the standard of physiochemical adsorption and than by the embarrassing circumstances of balanced particulate matters on the biological flocks. On the other hand, the elimination of soluble organic fractions like BOD_5 was reduces by bio degradation. These pollutants oxidized by microbes in to simpler end products i.e. water and carbon dioxide and synthesized new cells (Pathan *et al*).

Process applied to optimize the Response

For the treatment of greywater, In order to optimize the Hydraulic Retention Time (HRT), the RBC system was operated under three different HRTs

1 :- 2 hours, 0.42 l/min
2 :- 2.5 hours, 0.33 l/min
3 :- 3 hours, 0.28 l/min

Different conditions were applied during of treatment of Hydraulic Retention Time (HRT) and in order to optimize the results, of discs area increment. The system operated under multiple numbers of discs i.e. from forty to fifty-two, three different HRTs, 2 hours, 2.5 hours, and 3 hours. The data regarding chemical Oxygen Demand (COD), and interrelated information of grey water were collected from (NCEAC), Sindh University Hostel.

Development of Statistical Model for Water quality interaction of Time & Disc

Moreover the regression model representation is significant in illustration of the concept of interaction. A representation of regression model, for the two factors 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. Whereas x_1 and x_2 are distinct 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". Moreover "**ε"** is representing a random error term.

Statistical Analysis

In the present study, data was collected, tabulated, analyzed and interpreted. On the basis of the collected primary data, a Statistical Model is developed and the similar data is analyzed through Statistical software for Social Sciences (SPSS: 20), Mat lab, Ms Excel and Originpro version 7 to draw 3D plots. The developed statistical model is reliable and validated by way of the earlier experimental work done by the researchers.

3. RESULTS AND DISCUSSION

To get the response from RBC, present study was conducted to apply the RSM for getting optimum response. In terms of actual values, Response Surface model is given as follows:

$$y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 + \varepsilon \quad (1)$$

Removal = - 354 + 15.1 Time + 14.8 Disc - 4.43 time^2 - 0.148 disc^2 + 0.259 time disc (2)

Interpretation of the fitted Response Surface Model:

Model reveals, numbers of discs and retention time have linear positive effect on the removal of Chemical Oxygen Demand as the coefficient for retention time is 15.1 and 14.8 for number of discs respectively. Moreover, model further reveals that retention time and number of discs have positive effect over the removal on COD, however, as the time and number of discs increases the removal of Chemical Oxygen Demand tends towards decline as quadratic effect of retention time is -4.43 and **- 0.148 of number** of discs respectively.

The parameter for interaction of number of discs and retention time is positive. RSM model reveals that mutual increment of retention time and number of discs increases the removal of COD about **0.259**.

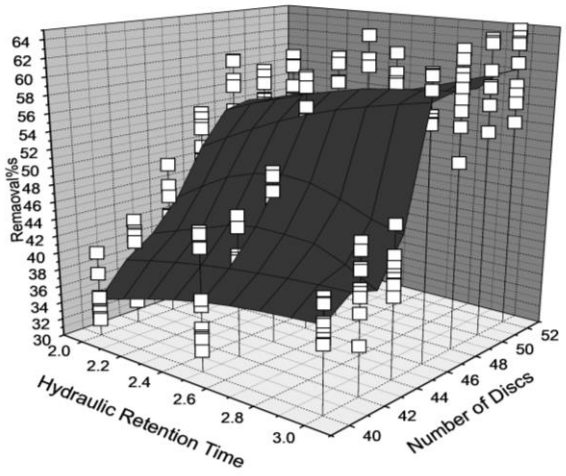

Fig. 1. Response Surface effect of Retention Time and Number of Discs on Removal of Chemical Oxygen Demand

Determination of the optimum response for the removal COD

To establish whether the point denoted by vector X_s, the nature of the response surface model must be known corresponds to a minimum, a maximum or a saddle point. The point where a minimum, a maximum or a saddle point occurs, for a second order fitted response surface, (X_s) is, $X_s = -1/2\ B^{-1}\ b^*$

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

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

Removal = - 354 + 15.1 Time + 14.8 Disc - 4.43 time^2 - 0.148 disc^2 + 0.259 timedisc

The surface X_s, as model indicates that is a maximum, now matrix B is requisite and the vector **b***, we obtain,

$$B = \begin{matrix} -1/2 & -4.43 & -0.1295/2 \\ & -0.1295/2 & -0.148 \end{matrix}$$

$$b^* = \begin{matrix} \mathbf{15.1} \\ 14.8 \end{matrix}$$

$$B^{-1} = \begin{matrix} -0.2317 & 0.2027 \\ 0.2027 & -6.9341 \end{matrix} \quad b^* = \begin{matrix} 15.1 \\ 14.8 \end{matrix}$$

$$\mathbf{X_s = -1/2\ B^{-1}\ b^* = 1.73} \qquad 50.84$$

The best possible predicted optimum Response Surface for COD at the stationary points of x_1 and x_2 are respectively= (COD) = X_s= 1.73 (Time) and 50.84 (Discs), as this is the close agreement with the location.

By substituting corresponding values, solving above equation of retention time and number of discs, the best possible optimum response of COD is 51.53984%.

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

Predictor	Coefficients	Standard Deviations	t-values	p-values (sig. level)
Constant	-354.32	49.85	-7.11	0.000
Time	15.12	14.58	1.04	0.301
Disc	14.784	1.939	7.62	0.000
time^2	-4.428	2.435	-1.82	0.071
disk^2	-0.14790	0.02055	-7.20	0.000
Timedisc	0.2590	0.1741	1.49	0.139

S = 3.976 R-Sq = 80.7% R-Sq(adj) = 80.2%

Table 2: Coefficients as well as their consequent t and p values for Response Surface Model

Predictor	Coefficients	Standard Deviations	t-values	p-values (sig. level)
Constant	-354.32	49.85	-7.11	0.000
Time	15.12	14.58	1.04	0.301
Disc	14.784	1.939	7.62	0.000
time^2	-4.428	2.435	-1.82	0.071
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S = 3.976 R-Sq = 80.7% R-Sq(adj) = 80.2%

Table 3: Analysis of Variance (Table containing F and p-values) showing the effect of intercept, retention time and number of discs on the removal of COD

Source	DF	SS	MS	F	P
Regression	**5**	**12283.2**	**2456.6**	**155.38**	**0.000**
Error	**186**	**2940.8**	**15.8**		
Total	**191**	**15224.0**			

Significant factors in the RSM and ANOVA Model

Significant factors in Response Surface and ANOVA models, by calculating t-values and consequent p-values, be capable of be acknowledged. A factor is considered as significant possesses p-value which is less than 0.05, if not, factor considered as not significant. In the above table, coefficients of the equation with their consequent t and p values are specified. The table reveals that linear and quadratic estimate of time is not significant effect on the removal of COD, as their values are greater than 0.05, however linear and quadratic estimates of number of discs are highly significant effect on the removal of COD, as their p-values are less than even 0.01. Consequently the interaction effect of retention time and number of discs is not significant, as the p-value of interactive effect is greater than 0.05. Coefficient of determination (r^2) reveals that data results are reliable as well as consistent more than 80 percent.

To analyze such kind of problems, Analysis of Variance (ANOVA), frequently, is used 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 COD through RBC, because the corresponding p-values are less than 0.01, while level of significance was 0.05.

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