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EFFECT OF 2D ELECTROCOAGULATION ON PHOSPHATE REMOVAL FROM UASBR TREATED SEWAGE

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ABSTRACT

Previous study showed that NaCl when employed in EC for UASBR sewage electrocoagulation shows insignificant effect on COD and turbidity removal. Further UASBR has limitation of un altered nutrient level in effluent hence this study was undertaken to analyze effect of NaCl addition on EC with respect to phosphate removal. Response surface methodology showed here significant effect of NaCl on phosphate removal which is quite different finding when compared to previous study. Hence thorough investigation for significance of process variables on focused parameter is always necessary in EC process'

KEYWORDS: electrocoagulation, UASB, phosphate, 2D

INTRODUCTION

Within the spectrum of anaerobic sewage treatment technologies, the upflow anaerobic sludge blanket (UASB) reactor offers great promise, especially in developing countries that usually have hot climates [1,2]. Effluent from UASB reactors, however, rarely meets disposal standards/guidelines especially in relation to organic content, suspended solids, nutrients and pathogen content [3,4]. The nutrients generally remain unaltered and the residual pathogen concentrations are high [1]. This necessitates post-treatment of UASB reactor effluent before its reuse in irrigation or discharge into natural water bodies [4-6]. Electrocoagulation (EC) has been successfully used for decades to treat the swine wastewater [8], cheese whey wastewater [9], humic acid solution [10], municipal wastewater [7] etc. EC involves in situ generation of coagulants by electrolytic oxidation of an appropriate sacrificial anode (for example, iron and aluminium) upon application of a direct current [12]. The metal ions generated during EC produce metal hydroxide ions and neutral metal hydroxides. The low solubility of these hydroxides mainly at pH values in the range of 6.0–7.0, promotes the generation of sweep flocs and the removal of pollutants by their enmeshment into these flocs [11,13]. EC process removes pollutants principally by coagulation, adsorption, precipitation and flotation [9,11]. Among several EC process variables current density, time and electrolyte addition are major variables which directly affect energy consumption. among these three variables, current density and time are always showing direct effect on EC process despite of type of effluent being treated but effect of electrolyte dose may vary with respect to effluent. Thus, the objective of this study was to understand effect of electrolyte addition on phosphate removal rate from UASBR treated sewage.

MATERIALS AND METHODS

Experimental

UASB effluent from Bamroli STP, Surat was used in this study.. The characteristics of the UASB effluent were analyzed and average values were given in Table 1 below. Fig. 1 shows electrocoagulation cell used in study. The electrocoagulator was made up of Plexiglas with the dimensions of 200 mm x 85 mm x 85 mm. Two electrodes were used, (one anode –one cathode) for RSM study. Both anode and cathodes were made from aluminium plates with dimension of 185 mm x 75 mm x 5 mm and interelectrode spacing of 15 mm. The electrodes were dipped into the cell containing UASB effluent with a 0.5 L working volume. The electrodes were connected to the digital DC power supply. All laboratory runs were performed at room temperature of 27 ±

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3 °C. Constant magnetic stirring was applied at 100 rpm. Before starting of each run, electrodes were washed with tap water to remove impurities present on the electrode surface.

Table 1 : Characteristics of UASB effluent

Parameter	Value *
COD (mg/Lit)	210-290
BOD (mg/Lit)	90-113
Phosphate (mg/Lit)	3.58-4.85
Turbidity (NTU)	157-178
Initial pH	7.51-7.73
SS (mg/Lit)	161-189

* Based on analysis of 3 samples

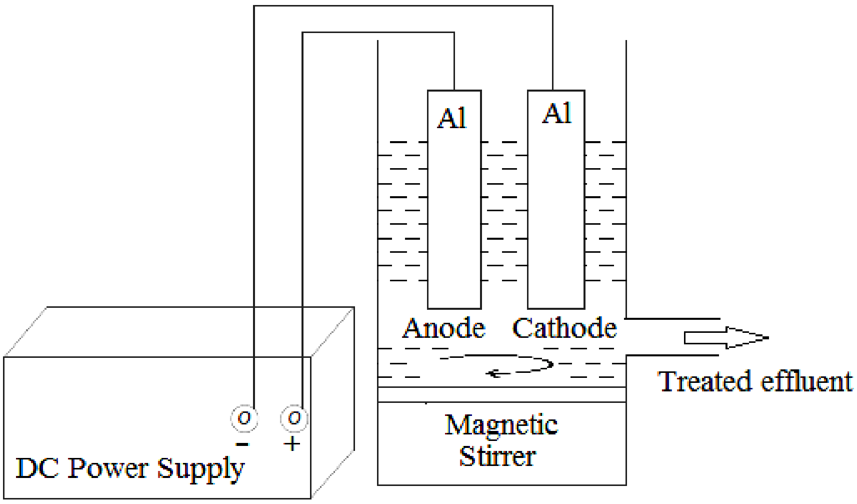

Fig. 1 Experimental set up for process optimization study (Makwana and Mansoor, 2017)

Experimental Design And Data Analysis

The Box-Behnken design (BBD) is an economical, efficient and rotatable quadratic design where factor combinations are at the midpoints of the edges and at the centre [15,16,19]. The central points are used to estimate the experimental error and to perform the model adequacy check.

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

Where y represents the predicted response; xi and xj are the independent variables, b0, bi, bii and bij are regression coefficients for intercept, linear, quadratic and interaction coefficients respectively, ε is the error and k is the number of variables studied.

Table. 2 shows the independent process variables used for RSM study in real and coded form. The BBD factorial design with five replicates at central point is presented in Table 3. To evaluate the contribution of the three variables, experimental data were analyzed and fitted to the following second-order polynomial model using Design Expert 8.0 software.

Table 2. Experimental range and levels of the independent variables

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Variable	Factors	Coded Factor Level		
		-1	0	1
CD (mA/cm^2)	x_1	1	6	11
Time (min)	x_2	1	6	11
NaCl dose (mg/L)	x_3	0	250	500

RESULTS AND DISCUSSION

Electrocoagulation process will be enhanced when applied current will be more due to more sacrificial metal ion dissolution in the EC cell. There is specific ratio between metal ion to pollution load for all wastewaters. Optimization of this ratio is necessary to avoid wastage of metal and for efficient treatment. Hence current density was taken as necessary parameter to be optimized. Further, electrocoagulation process involves destabilization of particulate impurities and their aggregation. Destabilization of pollutant is faster stage in EC process but aggregation stage needs more time for accomplishment. The first stage is usually short, whereas the second stage is relatively long [11,14]. Efficient pollutant removal is possible when both stages are done, this can be achieved by giving enough time to the treatment. Further NaCl is often used because the chloride ions significantly reduce the undesired effects of other anions such as HCO_3^- by avoiding precipitation of calcium ions contained in wastewater [17]. It is therefore recommended that among the anions present, there should be 20% Cl− to ensure a normal operation of electrocoagulation in water treatment [17]. The addition of NaCl would also lead to the decrease in power consumption because of the increase in conductivity (Chen, 2004). Moreover, the electrochemically generated chlorine was found to be effective in water disinfections [17]. Hence these parameters are taken into consideration and design matrix was developed as shown in Table 03.

Table 3: Design matrix along with observed and predicted response values

Std Run	Current density mA/cm^2	Time min	NaCl dose mg/L	Phosphate removal (%)	
				Actual	Predicted
1	-1	-1	0	55.45	47.55
2	1	-1	0	38.01	42.80
3	-1	1	0	.55.13	50.35
4	1	1	0	77.94	85.85
5	-1	0	-1	46.56	48.84
6	1	0	-1	74.14	64.22
7	-1	0	1	57.10	67.33
8	1	0	1	85.68	82.91
9	0	-1	-1	38.96	36.94
10	0	1	-1	50.18	59.86
11	0	-1	1	50.46	55.62
12	0	1	1	91.34	78.55
13	0	0	0	86.62	87.57
14	0	0	0	87.09	87.57
15	0	0	0	87.30	87.57
16	0	0	0	.89.22	87.57
17	0	0	0	87.60	87.57

Model Development and Validation

Obtained results of effluent phosphate removal (%) are presented in Table 03. Observed removal percentages were used to develop the model using second order polynomial as shown in equation (1) which shows main effect, interaction effect and quadratic effect of studied process variables. Following equation (2) represents model for % phosphate removal in terms of coded factors.

% Phosphate removal = $+14.89 + 4.59x_1 + 9.252x_2 + 0.1197x_3 + 0.402x_1 x_2 - 0.455x_1^2 - 0.78x_2^2 - (1.64\times10^{-4})x_3^2$ (2)

Table 3: Analysis of variance (ANOVA) test for effluent phosphate removal (%)

Model term	Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
	Model	5716.98	9	635.22	9.61	0.0035	significant
1	x_1-Current Density	473.19	1	473.19	7.16	0.0318	significant
2	x_2-Time	1051.09	1	1051.09	15.90	0.0053	significant
3	x_3-NaCl dose	698.18	1	698.18	10.56	0.0141	significant
4	x_1 x_2	405.07	1	405.07	6.13	0.0425	significant
5	x_1 x_3	0.26	1	0.26	3.91×10^{-3}	0.9519	Not significant
6	x_2 x_3	219.85	1	219.85	3.33	0.1110	Not significant
7	x_1^2	547.02	1	547.02	8.27	0.0238	significant
8	x_2^2	1606.26	1	1606.26	24.29	0.0017	significant
9	x_3^2	446.18	1	446.18	6.5	0.0355	significant
	Residual	462.82	7	66.12			

All model term - $R^2 = 0.8895$, $R^2_{adjusted} = 0.8035$.

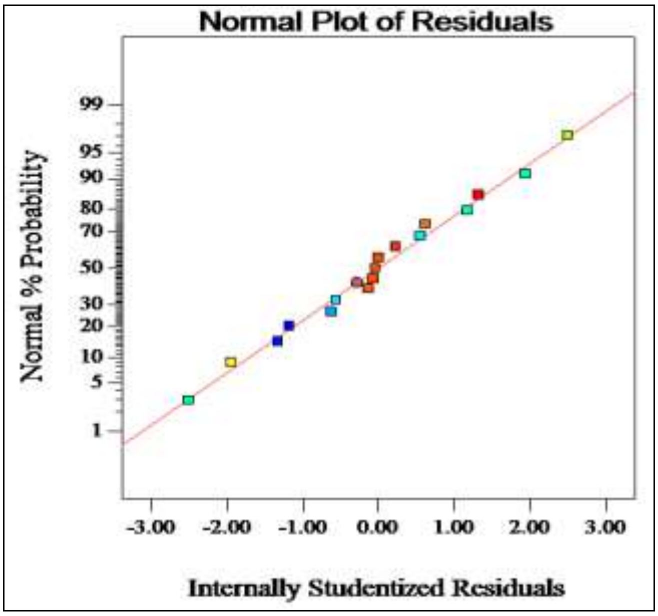

Fig. 02 Predicted v/s actual values for phosphate removal

Statistical fisher test was used to evaluate the significance of each factor and their interaction with each other. R^2 being the coefficient of determination, determines overall efficiency of model prediction. In this study R^2 and $R^2_{adjusted}$ ensures good correlation with each other. ANOVA test has given quadratic models for % phosphate removal. ANOVA results for effluent phosphate removal is represented in table 03. Equations (2) was developed after eliminating statistically insignificant term (x_1x_3, x_2x_3) based on p-value of coefficient for those terms. The *p*-value for all the model terms were less than 0.05 means model for % phosphate removal was found to be significant with 5% confidence interval. Values of "Prob > F" less than 0.0500 indicate model terms are significant (Montgomery, 2010, Nair et al., 2014). Coefficients with *p*-value greater than 0.1 were considered statistically insignificant and eliminated from the quadratic equations [18,19]. Fig 2 represents comparison of

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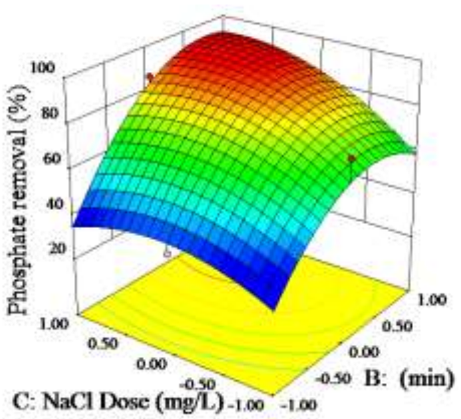
actual and predicted values of % phosphate removal with close agreement due to presence of all process variables which have significant effect on EC process.

Fig. 03 represents interaction effect of various process variables on phosphate removal efficiency. Fig. 03 (a) shows that increase in time and NaCl dose increases removal up to mid value and beyond that, removal decreases. Fig 03 (b) shows increase in removal with increase in current density and NaCl dose both, this is significant interaction effect. Being process of current and time, it is quite obvious that what is visible in Fig. 03 (c). Increase in CD and time shows increase in removal up to mid and beyond which further increase in both reduces removal hence proper understanding of all these parameters is necessary

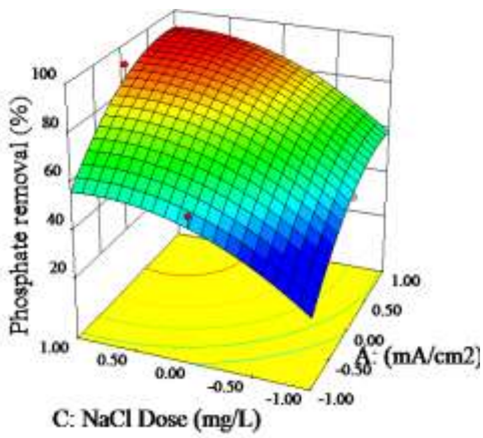
Process Optimization

Table 4. Optimum conditions for phosphate removal suggested based on RSM study

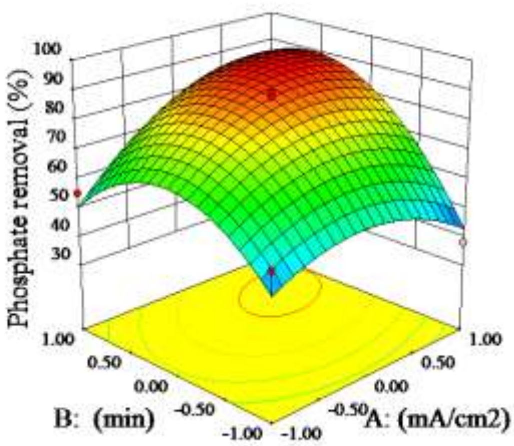
	Current density mA/cm^2	Contact time (min)	NaCl dose (mg/L)	Phosphate removal (%)	Desirability
Predicted	7.00	10.00	450.00	92.6	1.00
Observed	7.00	10.00	450.00	93.5	



(a)



(b)



(c)

Fig. 03 Contour plots for % phosphate removal as a function of (a) NaCl dose and time (b) current density NaCl dose (c) time and current density

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CONCLUSION

As per the conducted study it was observed that increase in current and time shows increase in removal. While presence of NaCl also showed significance on process. RSM suggested optimum condition of EC process as shown in table 04 for studied UASBR sewage.

Optimum time suggested is 10 min with 7 mA/cm^2 current density at 450 mg/L of NaCl dose, predicting 92.6 % phosphate removal from UASBR treated sewage. Triplicate test were performed and observed phosphate removal was found about 93.5% which is quite promising results to overcome limitation of UASB reactor of un-alteration of nutrients.

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