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Original scientific paper

Treatment of sugar industry effluent using an electrocoagulation process: Process optimization using the response surface methodology

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Abstract: Wastewater of sugar industries has a high pollutant load due to the presence of organic and inorganic materials. Discharge of untreated or partially treated wastewater has a negative effect on the environment and on the life of humans, plants and animals. In our present studies, it was attempted to treat sugar industry effluent (SIE) by an electrocoagulation process (ECP) using mild steel (MS) as the electrode material. For this purpose, three process parameters, namely pH (5–9), current density (j = 34.7–104 A m^{-2}) and treatment time (t_R = 20–100 min), were selected to optimize the process using the response surface methodology (RSM). The optimum conditions were pH 6.66, j = = 104 A m^{-2} and $t_{R\,=}$ 100 min. The maximum chemical oxygen demand (*COD*) removal of 75.98 % was achieved under the optimum conditions. The predicted model by RSM showed R^2 = 0.9515. After treatment of the effluent, the sludge content in the treated water was separated effectively by filtration and settling.

Keywords: chemical oxygen demand; total dissolved solids; filtration; sedimentation; current density.

INTRODUCTION

The sugar industries are one of the most important agro-based industries and their contribution to the economy is large in many countries. Brazil, India, the European Union, Thailand, China, the USA, Pakistan, Russia, Mexico and Australia are the main sugar producing countries in the world. The total contributions by these countries were about 150 million metric tons in the year 2017–2018.[1] Sugar is produced from sugar beet and sugarcane, of which the contribution of sugarcane is more than 70 %. The polluted water produced by sugarcane-based sugar industries are more complex as compared to sugar beet-based ones.[2] In

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sugarcane-based sugar industries, 1500–2000 dm^3 water are consumed and 1000 dm^3 of wastewater are generated for per ton of cane crushed.[3] The wastewater has high organic load of 2000–6000 mg dm^{-3} of chemical oxygen demand (*COD*) and total dissolved solids (*TDS*) and in organics in the range of 940–1650 mg dm^{-3}. The composition of wastewater reported by some investigators and that in the present study are given in Table S-I of the Supplementary material to this paper. Due to the large quantity and highly polluted nature of sugar industry effluent (SIE), effective treatment methods are required. Various process applied to treat SIE were reported in brief by Kushwaha[4]. These processes include coagulation,[5] electrocoagulation,[6-9] anaerobic biological treatment,[10] microbial treatment,[11] membrane separation,[12] *etc.*, and each have their merits and demerits. The biological processes are cost effective, but the extent of organic pollutant removal is not significant, hence, a second stage treatment is required to reduce pollution. Furthermore, most of the biological processes only remove organic pollutants and the removal of inorganic pollutants remains an issue. The membrane separation process gives good quality of treated water but suffers from high installation and operation costs. Coagulation is a low-cost process, but the level of pollutant removal is not large. The EC method has been found to be effective for the removal of pollutants present in distillery wastewater,[13] textile wastewater,[14] Acid Yellow 36 wastewater,[15] poultry slaughterhouse wastewater[16] and pulp and paper mill wastewater.[17] Due to its versatility, it was used in the present study. A significant reduction of pollutants was obtained by the process. Ease of operation, low treatment cost, environmental compatibility, versatility, amenability of automation, high energy efficiency and no secondary pollutant generation are some of the advantages of this process.[18] Apart from this, EC can additionally remove oil, grease, complex organics, heavy metals, and destroy bacteria, cysts and viruses.[19] Electrode replacement due to its dissolution, and slowdown of electrode efficiency due to deposition of oxide layer on electrode surface are the disadvantages of the process.[19]

In the open literature, process optimization by RSM for treatment of SIE using an iron electrode was not found. Moreover, in this work, an attempt was made to treat SIE by EC and the desired set of experiments were performed avoiding futile experiments. For this, experiments were designed based on RSM and optimum operating conditions, namely pH, treatment time and current density, was determined. The treated effluent was in slurry form, from which the solid and water were separated by filtration and sedimentation processes.

MATERIALS AND METHODS

Materials

The SIE was collected from Bhoramdev Sahkari Shakkar Utpadak Karkhana Maryadit, Kawardha (C.G.), India. It was kept in a deep freezer at about 4 °C to preserve it. The composition of SIE is presented in Table S-I of the Supplementary material. The laboratory and analytical grade chemicals were purchased from Rankem Ltd., India. The MS plate was obtained from a local market.

Experimental methods

The EC experiments were performed in an electrochemical reactor (ECR) made of Perspex glass (Fig. 1). The total volume of the reactor was 1.7 dm^3. The specification of the reactor and electrode material are given in Table S-II of the Supplementary material. The 1.5 dm^3 SIE was taken in the ECR and the electrodes were dipped in it and then, it was fitted to direct current (DC) power supply unit. A magnetic stirrer with speed of 200 rpm was used to keep the concentration of the solution in the ECR uniform throughout the experiments. Lower speeds caused insufficient mixing, and higher speed caused breaking of flocks and sludge formed during process, which is not desirable. Breaking of sludge resulted in its separation being difficult. After a certain time, a wastewater sample was taken from the ECR and analyzed for various parameters. The *COD*, phosphate, chloride, *TDS* and *TSS* were determined using standard methods.[20] The pH was measured using a pH instrument (EI, India).

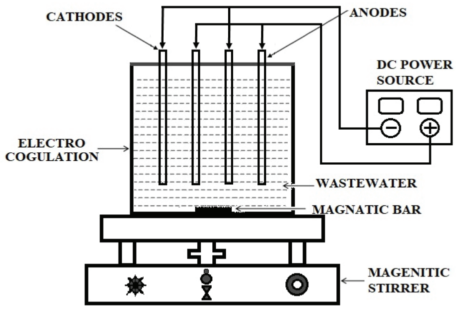

Fig. 1. Electrochemical reactor.

Electrocoagulation mechanism

In EC, when current is supplied to electrodes, the dissolution of metal take place. The metal cations generated from wide range of coagulant species at various pH. These coagulated species mostly have positive charge, which destabilizes the opposite charged suspended and dissolved particles. The coagulant species, especially metal hydroxide polymers adsorb the contaminants contained in the effluent and form a heavy mass of coagulant species-pollutants complex ions, which settled down. Furthermore, it also removes pollutants by sweeping during the settling. In the EC process, the H_2 gas generated at the cathode float the pollutants at top of reactor and aid pollutant removal. Thus, in the EC process, pollutant removal involves four mechanisms, *i*) charge neutralization, *ii*) adsorption, *iii*) sweeping and *iv*) flotation.

In the EC process, aluminum and iron are most widely used as the electrode. A few works also reported on the use of copper electrodes.[9,21] In the present studies, MS was used as electrode. In the process, less dissolution of iron into the effluent was found as compared to aluminum and copper. After a few runs, flacks of metals had formed in the case of aluminum and copper and due to this, loss of metal occurs. The separation of the sludge formed using iron electrode is easy due to its heavy mass. The use of iron is also encouraged due to its low cost. For iron electrodes, the following reactions occur at the electrodes. When a current is applied, sacrificial anodic metal Fe is dissociated and metal cations are formed according to the following reaction:

$$\mathrm{Fe} \rightarrow \mathrm{Fe}^{2+} + 2\mathrm{e}^- \tag{1}$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^- \quad (2)$$

At the cathode, H_2 gas is liberated by the following reaction:

$$3H_2O + 3e^- \rightarrow 1.5H_2 + 3OH^- \quad (3)$$

OH^- generated at the cathode attaches chemically to the electrode material, especially at high pH of the solution:

$$2Fe + 6H_2O + 2OH^- \rightarrow 2Fe(OH)_4^- + 3H_2 \quad (4)$$

The H_2 liberated in Eqs. (3) and (4) aids the removal of pollutants by floatation at the top of electrochemical reactor (ECR). The metal cations, Fe^{2+}/Fe^{3+}, and OH^-, react and form metal hydroxide flocks in the solution, which is summarized as:[22]

$M^{3+}, M^{2+} + OH^- \rightarrow$ monomeric metal hydroxide cations $\rightarrow$ polymeric metal hydroxide cations $\rightarrow$ polymeric amorphous metal hydroxide:

$$M_n(OH)_{3n} \rightarrow M(OH)_3 \quad (5)$$

In case of MS electrode, monomeric species: $Fe(OH)^{2+}$, $Fe(OH)_2^+$, $Fe(OH)_4^-$ and $Fe(H_2O)^{2+}$, and polymeric species: $Fe(H_2O)_5OH^{2+}$, $Fe(H_2O)_4(OH)_2^+$, $Fe(H_2O)_8(OH)_2^{4+}$ and $Fe_2(H_2O)_6(OH)_4^{2+}$, and iron hydroxide $Fe(OH)_3$, are produced. The rate of formation of these different species depends on the pH of the solution and types of ion present, which play significant role in the EC process.[23] The coagulant species participate in coagulation and the pollutants are removed by ther four mechanisms discussed above.

RESULTS AND DISCUSSION

Design of experiments

In the ECT of various effluents, the pH, j and t_R have been found to be highly influential[13] and therefore, these variables were considered for statistical analysis. Three independent variables in the range of pH 5–9, j = 34.7–104 A m^{-2} and t_R = 20–100 min were chosen at level –1, 0 and 1. The values of variables are presented in Table I. A set of 14 data were designed as per an earlier report,[24] which are presented in Table II.

TABLE I. Process parameters and their level for EC treatment using MS

Parameter	Variable	–1	0	1
j / A m^{-2}	x_1	34.72	69.44	104.16
pH	x_2	5	7	9
t / min	x_3	20	60	100

Polynomial studies could be performed using the models linear, interactive, quadratic and cubic. In the present studies, the quadratic model was chosen. To find the response (Y) of input parameters, a mathematical model was established by Montgomery,[25] which is given by Eq. (6).

$$Y = \alpha_0 + \sum \alpha_i x_i + \sum \alpha_{ii} x_{ii} + \sum \alpha_{ij} x_i x_j + \varepsilon \quad (6)$$

where Y is response, α_i, α_{ii} and α_{ij} are the coefficient of linear, interaction and quadratic terms, ε is residual error, and x_i, x_j are independent variables values that impact on the response (Y). The experimental data was fitted by regression method using analysis of variance (ANOVA). The relation obtained among the variables in term of encoded factor for *COD* removal is shown by Eq. (7):

$$Y = 59.78 + 6.0975x_1 - 3.9x_2 + 15.305x_3 - 1.6225x_1^2 - 17.44325x_2^2 - \\ - 3.5225x_3^2 - 1.025x_1x_2 - 0.53x_1x_3 - 0.825x_2x_3 \quad (7)$$

TABLE II. Design of RSM and its actual and predicted values

Standard order	j / A m^{-2}	pH	t / min	*COD* removal, %	
				Actual	Predicted
1	104.16	7	100	80.41	75.51
2	69.44	7	60	63.1	59.78
3	34.72	9	60	32.1	31.75
4	104.16	9	60	41.3	41.90
5	34.72	5	60	38.10	37.50
6	69.44	5	100	54.3	58.86
7	104.16	5	60	51.4	51.75
8	69.44	9	100	45.1	38.45
9	69.44	5	20	30.90	26.60
10	104.16	7	20	42.0	45.96
11	69.44	9	20	25.0	20.45
12	34.72	7	20	27.8	32.70
13	34.72	7	100	68.33	64.37
14	69.44	7	60	58.12	59.78
15	69.44	7	60	58.12	59.78

The values of *COD* removal calculated by Eq. (7) are given in Table III. The difference in experimental values and calculated values are within a maximum 4.9 %. The data of experiments and predicted values calculated (Y) by model are presented in Fig. 2. The dotted values are near to the line, which affirms that the result of the ANOVA analysis is correct.

The coefficient of determination $R^2 = 0.9515$ and adjusted $R^2 = 0.8642$ were obtained from RSM, which showed the validity of model, as a large value of R^2 is desirable. The value of $R^2(j)$ is generally lower than R^2. The low $R^2(j)$ indicates that extra variables are included in the model but in the present case $R^2(j)$ is sufficiently high. The Fischer distribution (F value) and null hypothesis test (P value) are other parameters that evaluate the significance of the regression model. The F value predicts the model quality by considering all design variables simultaneously. Value of F should be large, and P should be small (<0.05).

There is interrelation between the value of P and F and the value of P is used to estimate the value of F. In present case, the overall value of P is 0.009, which is less than 0.05, and value of F is 10.90, which is sufficiently high to show that the model is statically significant.[7] The ANOVA analysis (Table III) also show that the linear ($P = 0.03$, $F = 28.78$) and square ($P = 0.013$, $F = 10.85$) have a significant effect, while the interaction ($P = 0.97$, $F = 0.08$) was found to have a smaller effect on the response, *i.e.* COD value evaluation, by Eq. (7). Overall, pH 6.66, $j = 104.16$ A m^{-2} and time = 100 min was found to be optimum and under these operating condition, a *COD* removal of 75.98 % was obtained.

TABLE III. ANOVA for COD removal quadratic model

Source	*DF*	Sum of squares (*SS*)	*j SS*[a]	Mean square	*F*	*P*
Regression	9	3440.91	3440.91	382.32	10.90	0.009
Linear	3	2293.06	2293.06	764.35	21.78	0.003
j	1	297.44	297.44	297.44	8.48	0.033
pH	1	121.68	121.68	121.68	3.47	0.122
Time	1	1873.94	1873.94	1873.94	53.41	0.001
Square	3	1139.80	1139.80	379.93	10.83	0.013
j×*j*	1	0.06	9.72	9.72	0.28	0.621
pH×pH	1	1093.93	1122.06	1122.06	31.98	0.002
Time×Time	1	45.81	45.81	45.81	1.31	0.305
Interaction	3	8.05	8.05	2.68	0.08	0.970
j×pH	1	4.20	4.20	4.20	0.12	0.743
j×Time	1	1.12	1.12	1.12	0.03	0.865
pH×Time	1	2.72	2.72	2.72	0.08	0.792
Residual error	5	175.44	175.44	35.09		
Lack-of-Fit	3	158.91	158.91	52.97	6.41	0.138
Pure error	2	16.53	16.53	8.27		
Total	14	3616.35				

[a] Adjustable sum of squares

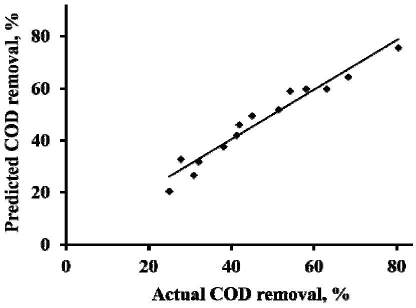

Fig. 2. Actual *COD* removal *vs*. the predicted value.

The three-dimensional plot obtained by RSM for operational variables pH, *j* and t_R is presented by surface and contour plots in Fig. S-3 of the supplementary material. In the EC, Fe^{2+} are generated, which are converted to Fe^{3+} and metal hydroxides monomer and polymer, as given by Eq. (5). At low pH Fe^{2+} and Fe^{3+} are present in predominant amounts, which are relatively less active coagulant species as compared to metal hydroxide monomers and polymers. The metal hydroxide monomers and polymer species are present in greater amounts at pH values 5–8 and because of this, removal of pollutants by the: adsorption, charge neutralization and sweeping mechanism were prevalent in this pH range. At higher pH values, $Fe(OH)_3$ and $Fe(OH)_4^-$ are formed, which are not so active coagulant species. Poor performance under high acidic and basic conditions has been reported by some investigators.[12–14] The SIE contained colloidal suspensions of meloinodin, protein and carbohydrate, which have negatively charged functional groups.[26] The positively charged coagulants, *i.e.*, metal cations and metal hydroxide cations, neutralize these and form dense compounds, which settle at the bottom of the reactor. Removal of pollutants is enhanced due to their enmeshment in the amorphous flock and swapping during settling of solid neutralized mass. The *COD* reduction was found to increase with time, due to availability of more coagulant species that participate in coagulation. With increasing time, metal dissolution leads to an increase in coagulant species. The contour plot in Fig. S-3 of the Supplementary material shows a *COD* reduction of between 60–70 % in near neutral pH at lowest time of 60 min. A *COD* removal of more than 70 % could be observed after 90 min in near neutral pH.

The j and time are also surrogated parameters highly affected by pollutant removal from the effluent. The effect of j and t_R on *COD* removal at constant pH 7 is presented in Fig. S-3. With increasing time and j, the *COD* removal also increased. At j= 40 A m^{-2} and t_R = 80 min, a more than 60 % reduction *COD* could be seen. This reduction continued with decreasing t_R but simultaneous increase in j. At t_R = 100 min and j = 60 A m^{-2}, more than 70 % reduction in *COD* was found. The same reduction could be seen in a shorter time, t_R = 80 min, but with j greater than 100 A m^{-2}.

The experimental data of *COD* reduction and the *COD* reduction values predicted by RSM model are also listed in Table III. These data show that the experimental values are similar to the predicted values with a maximum deviation of 4.9 %, which validated the model.

With increasing j and time, the *COD* removal was increased, which is attributed to the formation of more Fe^{2+} and iron hydroxides cations. The relation between ions production with variation of j and time during electrolysis has been represented by well-known Faraday's law of electrolysis, Eq. (8),[27] It shows the metal ions produced by dissolution of the electrode is directly proportional to j and time. Similarly, the current efficiency can be calculated by Eq. (9):[28]

$$W = \frac{j\,t\,M}{Z\,F} \tag{8}$$

$$\phi = \frac{100 m_a}{ItM / nF} \tag{9}$$

where W is the mass of dissolved metal, g; j is the current density, A m^{-2}; t is the contact time, s; M is the atomic mass of Fe, g mol^{-1}; Z is number of electrons involved in the reaction (Z = 2 for Fe), F is Faraday's constant (96500 C mol^{-1}),

m_a is the mass of iron released to the solution, *g*; *I* is the applied current, A; and *n* is the oxidation state of iron. The number of ions generated also depends upon the initial pH of the effluent (alkali or acidic). At acidic pH values, more ions are generated as compared at basic pH values.

For a 2 A current, in 50 min, 1.17 g iron was released from mild steel in water and thus, a value of ϕ = 67.19 % could be evaluated. For other current values, similar calculations could be performed. The effects of *j* and pH at a constant time of 60 min are presented in Fig. S-3. *COD* removal was increased at all *j* values with increasing pH from 5 to 6.7, after that the *COD* reduction decreased. At pH 7, the *COD* removal was found to be higher at all *j* values (Fig. S-3). As already discussed, slightly acidic to slightly basic pH values were found suitable for treatment of effluent, because active coagulant species are generated in this pH range.

Separation of solid and liquid from slurry

Settling process. Various processes, such as settling, filtration, centrifuge and membrane separations, have been applied to separate the solid and liquid in a slurry obtained from water treatment. If solid contained in the slurry has sufficient specific gravity and the materials to be separated are inexpensive, settling is the most preferable industrial choice. Settling is a very low cost process and due to this, it was undertaken in the present studies. After the EC process, the treated effluent was taken in 1 dm^3 cylindrical jar, which had a height 245 mm and diameter 72 mm. The effluent was stirred initially then interfacial height between solid and liquid was noted at different time intervals. The height of the interface decreased with time because of settling of solid mass, which is presented in Fig. 3 as a plot of H/H_0 *vs.* time, where *H* is the height of interphase between the clear liquid (water) and the sludge from the bottom of the settler at any time during settling, and H_0 is the height of sludge water mixture at the start the settling. Fig. 3 shows that initially for a very short period (< 2 min) the sedimentation was slow, because of Brownian motion of the particles. Then, the sedimentation rate was fast for a period of 8 min, which is called zone settling. After

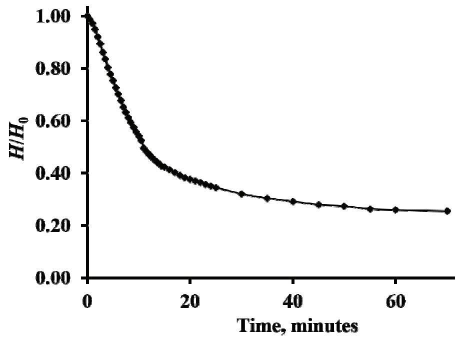

Fig. 3. Settling characteristic of electrocoagulation using an MS electrode.

this zone, the sedimentation settling rate was slow for a period 8–18 min, called transition settling, in which the slope changed rapidly. After the transition zone, the settling occurred at a very low rate. In 50 min, about 78 % settling was observed, which shows the settling process could be applied for the separation of the sludge and liquid.

Area for sedimentation and height of the settling chamber could be evaluated from the settling data presented in Table IV, in which, u_c is the under flow settling velocity of the sludge, determined by drawing a tangent in the graph between H (at the ordinate) *vs.* time (at the abscissa). The C_u is the final concentration of solid when settling of the sludge had almost stopped. It could be seen that in 23rd and 24th min, the concentration of the solid is 33.399 kg m^{-3}, means the settling of solids had almost stopped corresponding to 33.399 kg m^{-3}, calculated to be 37.26 m^2 s kg^{-1}. The area of sedimentation tank could be calculated by Eq. (10):[29]

$$A = Q_0 C_0 \left(\frac{1/C - 1/C_u}{u_c} \right)_{\max} \tag{10}$$

TABLE IV. Settling characteristics of slurry obtained by EC of SIE using MS electrode

No.	t min	H mm	u_c μm s^{-1}	C kg m^{-3}	$(C^{-1}-C_u^{-1})$ m^3 kg^{-1}	$((C^{-1}-C_u^{-1})/u_c)_{\max}$ m^2 s kg^{-1}
1	0	244	0.000	9.718	-	-
2	2	224.5	239.44	10.563	0.064725	270
3	4	196	214.91	12.098	0.052706	245
4	5	171	202.08	13.867	0.042163	209
5	6	149	179.26	15.915	0.032886	183
6	8	132	158.47	17.964	0.025717	162
7	10	115	141.88	20.620	0.018548	131
8	12	106	101.03	22.371	0.014752	146
9	14	103	71.60	23.022	0.013487	188
10	15	100.5	51.82	23.595	0.012433	240
11	16	91.5	47.05	25.916	0.008637	184
12	18	88.5	37.23	26.794	0.007372	198
13	20	85.5	26.52	27.735	0.006107	230
14	22	84.5	25.26	28.063	0.005685	225
15	24	82	22.85	28.918	0.004631	203
16	25	80	21.83	29.641	0.003788	174
17	26	78	20.83	30.401	0.002944	141
18	28	76	17.79	31.201	0.002101	118
19	30	75	15.56	31.617	0.001679	108
20	32	74	14.60	32.045	0.001257	86
21	34	73	11.84	32.484	0.000836	71
22	35	72	11.11	32.935	0.000414	37
23	36	71	11.11	33.399	0	0
24	38	71	11.11	33.399	0	0

$$A = 3.017\ \mathrm{m}^2$$

Assuming that at $Q_0 = 0.5\ \mathrm{m}^3\ \mathrm{min}^{-1}$, the treated effluent was taken in sedimentation chamber.

$$\frac{\pi D^2}{4} = 3.017\ \mathrm{m}^2$$

$$D = 3.84\ \mathrm{m}$$

Since height to diameter ratio of cylinder was 3.26, the height of settling chamber would be equal to 12.39 m.

Filtration studies. Filtration is a separation process used to separate the liquid and solid from a slurry. Many industries use this because the supernatant (liquid) after filtration contains less dissolved solid as compared to settling, and the solid obtained has dense mass so dewatering costs are lower for the further disposal of the sludge. To evaluate filtration parameters, experiments were performed over Whatman filter paper (No. 42) supported on a Buchner funnel, under constant pressure (atmospheric). The values of the filtration characteristics are given in Table V. The volume of filtrate obtained at different times was noted and it was used to find filter media resistance and cake resistance using the filtration Eq. (11):[30]

$$\frac{\mathrm{d}t}{\mathrm{d}V} = \frac{\mu}{A\Delta P}\left(\frac{\alpha C V}{A} + R_\mathrm{m}\right) \tag{11}$$

where V is the volume of filtrate collected in time t, C is the concentration of slurry, μ is the viscosity of filtrate, ΔP is pressure drop across filter media. The value of R_m and α were evaluated for filtration of slurry obtained by ECT of SIE using an MS electrode.

Table V. Filtration characteristics of EC treated slurry using MS electrode

pH	c / kg m^{-3}	μ / mPa s	ΔP / MPa	α / Tm kg^{-1}	R_m / Tm^{-1}
7	2.391	1	0.1	91.6	3.37

The dt/dV is the ratio of time required to volume of filtrate (clear liquid) collected. A plot between dt/dV *vs.* V is shown in Fig. 4, which is a straight line. The values of α was evaluated from the slope of graph and R_m from intersect, which are 91.6 Tm kg^{-1} and 3.37 Tm^{-1}, respectively. Filter media resistance is important only at earlier stage of filtration and the cake resistance plays major role in filtration. Sahu *et al.*[31] evaluated $\alpha = 19–78$ Tm kg^{-1} for filtration of slurry obtained by EC of sugar industry effluent using an aluminum electrode. Similarly, Barnes *et al.*[32] reported $\alpha = 40–120$ Tm kg^{-1} for filtration of activated sludge and $\alpha = 0.3–1.0$ Tm kg^{-1} for a digested sludge. In present case, the value of α was in the range of those for activated sludge. These data show filtration of slurry obtained after EC of SIE had properties similar to those of activated sludge and the filtration process could be used for separation of solid and liquid contained in the EC of treated SIE. In the EC process, the metals released into the solution participated in the coagulation process, thus the chances of the of the presence of metals in the solution are very low. The iron content in the treated water was not determined. However, no iron was evidenced when the pulp and paper industry effluent was treated by the EC process using an iron electrode.[33]

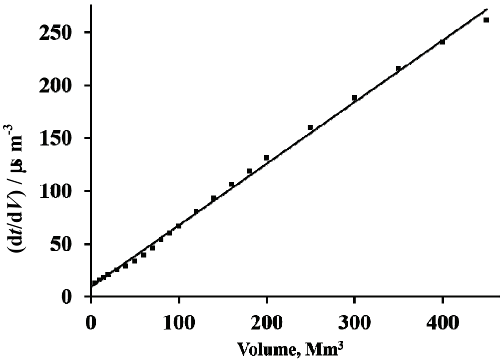

Fig. 4. Filtration characteristic of electrocoagulation using an MS electrode.

In the separation studies of sludge, supernatant formation was found to be 75 % in 60 min of settling, which is very good. It is the most economical separation process and thus, settling should be chosen in place of filtration. The effluent has moderate *COD* value (organics), thus the solid residue also has a smaller amount of organics and greater amounts of inorganics. The possible disposal method is incineration of the sludge and blends the ash with refractory manufacturing substances.

CONCLUSIONS

The studies show that the surface response methodology (RSM) is a suitable method to optimize the EC process for *COD* removal. The optimum conditions were found to be pH 6.66, j = 104.5 A m^{-2}, and t_R = 100 min with a *COD* removal of 75.98 %. The settling studies to separate solid and liquid from treated SIE shows good settling property of the treated effluent. The treated effluent was also chosen for filtration, for which filter medium resistance α = 91.6 Tm kg^{-1} were obtained, which is near to that obtained for the separation of activated sludge. Overall, EC process using MS could be applied successfully to treat SIE.

SUPPLEMENTARY MATERIAL

Additional data are available electronically at the pages of journal website: https:////www.shd-pub.org.rs/index.php/JSCS/index, or from the corresponding author on request.

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ИЗВОД

ТРЕТМАН ОТПАДНИХ ВОДА ИЗ ИНДУСТРИЈЕ ШЕЋЕРА КОРИШЋЕЊЕМ ПРОЦЕСА ЕЛЕКТРОКОАГУЛАЦИЈЕ: ОПТИМИЗАЦИЈА ПРОЦЕСА КОРИШЋЕЊЕМ МЕТОДОЛОГИЈЕ ПОВРШИНСКОГ ОДЗИВА

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Отпадне воде из ибдустрије шећера садрже велике количине органских и неорганских полутаната. Испуштање нетретираних или делимично третираних отпадних вода има негативан утицај на околину и живот људи, биљака и животиња. У овом истраживању покушали смо да третирамо отпадне воде из индустрије шећера процесом коагулације уз коришћење меког челика као електродног материјала. За ову сврху, одабрана су три процесна параметра за оптимизацију коришћењем методологије површинског одзива (RSM), и то: pH (5–9), густина струје (j = 34,7–104,5 A m^{-2}) и време трајања третмана (t_R = 20–100 min). Добијено је да су оптимални услови за pH 6,66, j = 104,5 A m^{-2} и t_R = 100 min. Максимално умањење хемијске потрошње кисеоника од 75,98 % је постигнуто при овим оптималним условима. Предикција модела заснованог на RSM је показала R^2 = 0,9515. После третмана отпадних вода, муљ у третираној води је ефикасно одвојен филтрацијом и таложењем.

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