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Research Article

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Electrochemical Degradation of DSW Using Fe- Fe and Al- Al Electrodes Taguchi and Anova Approach

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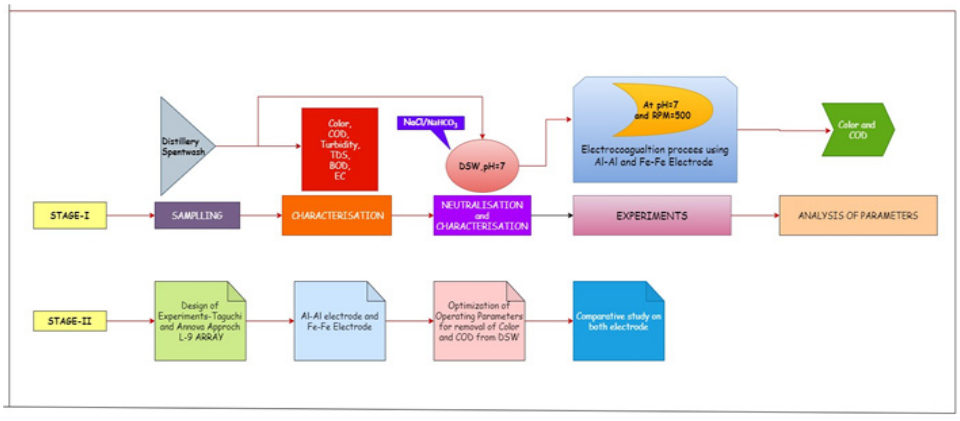
Abstract

Expulsion of toxins from distillery spent wash (DSW) was applied by utilizing a blend of matched aluminum and iron electrodes in a clump method of activity utilizing electrochemical procedure. The refinery spent wash was described diagnostically utilizing standard strategy for examination and the treatment results were dissected as far as COD and Colour. The examinations were directed to consider the impact of working boundaries, for example, voltage, separation between the electrodes and electrolysis time and were optimized by utilizing Taguchi and ANOVA technique. pH and stirring speed were kept constant as 7 and 500 rpm. The most extreme expulsion efficiencies of COD and Colour were monitored by considering total of 16 experiments each with three trials. The Taguchi method led to COD of 95% and color removal of 94%, optimized with Al-Al electrodes at the voltage of 25V, distance of electrodes 2 cm and the electrolysis time of 150 minutes. The most extreme COD and Colour removal efficiencies found to be 92% and 89% from Fe-Fe electrodes at the indistinguishable working conditions. In any case, the aluminum electrodes seen progressively appropriate for the deprivation of DSW when contrasted with iron electrodes.

Keywords: Aluminum, COD, Taguchi, Distillery spentwash, Iron, Anova.

Graphical Abstract



Introduction

In recent years, DSW, as prospective candidate for polluting water, which has more ratio of volatile and organic matter. DSW is acidic in nature and is characterized by higher recalcitrant pollutants as colour, trivial pH, maximum content of ash, higher COD,organic/inorganic chemicals and dissolved salts [1-3].carried out electrocoagulation for the distillery spent wash by utilizing Al and Fe electrodes in a cluster mode activity and discovered optimal estimations of different working boundaries [4]. The optimal current density was seen as 17.9 mA/cm^2 at a pH of 7.2 and 98% of COD evacuation effectiveness was seen with 3 hours of electrolysis. applied electrocoagulation mode for the colour and COD exclusion from a biodigester sewage having 9310 mg/L of COD for batch mode electrolytic effluent system SS-electrodes, initially observed the effect of electrode distance, current density, electrolysis time at last pH on reduction of COD[5].

They found the highest colour and COD removal of 98.4% and 61.6%. carried out electrocoagulation for DSW using electrodes of Fe and Al in batch mode operation. In ideal estimation of current density was seen as 71.8 mA/cm^2 at pH of 7.2. The most extreme COD expulsion effectiveness of 99% was acquired at an electrolysis time of 1 hr. utilized anodized graphite plates for the cure of refinery profluent (COD of 12000 mg/L; multiple weak 10 times) and examined the impact of current density, pH and halides (NaF, NaCl and NaBr) on supporting electrolytes for the treatment. They accomplished higher evacuation efficiencies (BOD 93.5%; COD 85.2%; colour 98%) in nearness of electrolyte NaCl [6-8]. examined the electrochemical oxidation of waste water (COD 42240-46440mg/L) for aluminum electrodes and measured the influence of current density, pH and electrolysis time on the removal of COD, 72.3% of its removal efficiency for 120 minutes, 0.03 A/cm^2 current density at a pH of 3. The wastewater later treatment still contained maximum COD and BOD required auxiliary cure afore releasing into normal water bodies [9].directed electrochemical deprivation explores different avenues regarding ruthenium oxide covered titanium work going about as anode and tempered steel as cathode to DSW (COD10000-11000 mg/L) and examined the impacts of current density, dilution, electrolysis time and pH on the debasement rate. They institute that expanding the underlying pH and weakening diminished the decolourization productivity.

In this investigation is to assess the viability of electrocoagulation treatment of DSW utilizing the mix of Al-Al and Fe-Fe as electrodes in a potentiostatic mode and to, further, advance the boundaries, for example, voltage, separation between the anode-cathode and time span by utilizing Taguchi and ANOVA approach.

Materials and Methods

Materials

In this assessment, the DSW accumulated from a distillery in Davangere, Karnataka and it was depicted for various limits and the effects are depicted in Table-1. The Fe and Al plates were purchased from neighborhood synthetic substances organization. pH was estimated by utilizing pH meter, turbidity by Nephelon turbidity meter (HACH, USA), electrical conductivity by utilizing conductivity meter (HACH, USA), Colour by utilizing UV-Vis spectrophotometer (Model DR2007, HACH, USA), Total Dissolved solids (TDS) by utilizing TDS analyzer (Electrometric TDS Eco analyzer, HACK, USA), COD by shut reflux titrimetric strategy in nearness of potassium dichromate and BOD by 5-day 20°C test according to APHA (2005). The processing plant spent wash was viewed as acidic with astoundingly most extreme BOD (59072 mg/L) and COD (134000mg/L) content.

Table 1: Initial Characterization of DSW

S.N.	Parameter	Unit	Value
1	pH	-	4.15
2	Turbidity	NTU	15880
3	EC	mS/cm	22.47
4	COD	mg/L	134000
5	BOD	mg/L	59072
6	Color	Pt-co	316000
7	TDS	ppm	12300

Methods

The representing chart of the exploratory system is appeared in Figure 1. The trials remained led in a 2000 mL round bottomed measuring glass in cluster genre activity. The Al and Fe combined terminals of measurements of 15 cm × 5 cm × 0.3 cm were utilized as anode and cathode. The cathodes were dunked into arrangement with the zone of around 10 x 5 cm^2 and the examinations were led utilizing joined Fe-Fe and Al-Al anodes. The dressed and dehydrated anodes are associated with terminals of DC power supply. The electrocoagulation was done under potentiostatic environments 32V/2A where the consistent voltage was drawn from a DC power supply (Model LD 3202, Aplab Regulated Dual DC Power Supply, India) with steady blending rate of 500rpm.

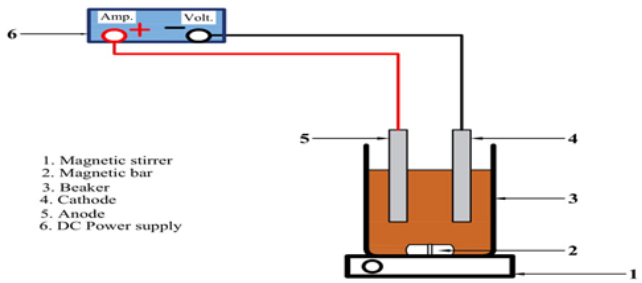


Figure 1: Experimental setup for electrocoagulation treatment of distillery spent wash

The pH of DSW remained recorded prior and later to electrolysis. The impact of voltage, separation between the terminals and electrolysis time was examined. Each examination was directed in clump mode for a positive length and the examples were attracted to decide the Colour and COD. Toward the finish of each trial, the examples were moved into another measuring glass and saved undisturbed for 30 minutes so as to permit the flocs, which framed during electrocoagulation to settle down. The trials were led in various voltages going from 10 V to 25 V; separations of cathodes going from 2 cm to 5 cm; and electrolysis time extending from 60 min to 150 min. A four-level-three-factor (L9) in Taguchi Orthogonal Array (OA) structure was utilized utilizing Minitab-18 mea-

surable programming to create trial runs by considering three free information factors viz. Voltage (V), Electrode separation (cm), and Electrolysis time (minute). The level of Colour and COD expulsion were evaluated as yield reaction. In light of writing and fundamental trials, the base and the most extreme range levels of the procedure boundaries were fixed [11]. pH and speed of blending were kept consistent as 7 and 500 rpm, separately, during the treatment investigates DSW for an aggregate of 16 tests.

Result and Discussion

The test esteems and Taguchi anticipated qualities are organized in Table 2 and Table 3. The trial model target was to satisfactorily portray the connection of variables affecting the procedure evacuation efficiencies in the rate ranges. Test and anticipated qualities on COD and Colour evacuation efficiencies for Fe-Fe and Al-Al anodes are appeared in Table 2 and Table 3. The inspected Colour and COD evacuation esteems change between 25-95% and 41-94% for Al-Al electrodes, 39-89 % and 41-92 % for Fe-Fe terminals individually, which are in acceptable concurrence with the anticipated qualities as indicated Tables 2 and 3.

Table 2: Experimental and predicted Values for Color and COD removal efficiencies with process parameters premeditated by Taguchi method for Al-Al electrodes

S.N.	Voltage (V)	Electrode distance (cm)	Electrolysis time (minute)	Color removal efficiency (%)			COD removal efficiency (%)		
				Experimental response	Predicted (Taguchi)	S/N ratio	Experimental response	Predicted (Taguchi)	S/N ratio
1	10	2	60	48	49	33.6	36	40	31.1
2	10	3	90	58	56	35.2	52	53	34.3
3	10	4	120	72	72	37.1	68	67	36.7
4	10	5	150	75	75	37.5	80	76	38.0
5	15	2	90	74	67	37.3	70	65	36.9
6	15	3	60	39	45	31.7	37	37	31.3
7	15	4	150	83	82	38.4	84	84	38.5
8	15	5	120	72	73	37.2	64	69	36.1
9	20	2	120	84	87	38.5	87	84	38.8
10	20	3	150	87	86	38.8	89	89	39.0
11	20	4	60	49	44	33.7	30	30	29.6
12	20	5	90	53	56	34.5	45	47	33.0
13	25	2	150	92	94	39.2	92	95	39.3
14	25	3	120	85	80	38.6	76	75	37.6
15	25	4	90	53	59	34.5	48	49	33.6
16	25	5	60	44	41	33.0	29	25	29.2

Table 3: Experimental and predicted results for Color and COD removal efficiencies with process parameters intended by Taguchi method for Fe-Fe electrodes

S.N.	Voltage (V)	Electrode distance (cm)	Electrolysis time (minute)	Color removal efficiency (%)			COD removal efficiency (%)		
				Experimental	Predicted (Taguchi)	S/N ratio	Experimental response	Predicted (Taguchi)	S/N ratio
1	10	2	60	51	52	34.2	31	35	30.0
2	10	3	90	68	65	36.6	70	67	36.9
3	10	4	120	72	75	37.2	73	75	37.3
4	10	5	150	77	77	37.8	77	74	37.7
5	15	2	90	75	72	37.5	68	69	36.6
6	15	3	60	42	48	32.5	42	40	32.6
7	15	4	150	85	83	38.6	81	81	38.1
8	15	5	120	74	73	37.3	74	74	37.3
9	20	2	120	85	89	38.6	86	80	38.7
10	20	3	150	88	90	38.9	84	85	38.5
11	20	4	60	55	48	34.7	38	38	31.5
12	20	5	90	61	62	35.7	61	65	35.7
13	25	2	150	92	92	39.3	88	89	38.9
14	25	3	120	86	81	38.7	84	87	38.4
15	25	4	90	58	63	35.2	76	73	37.6
16	25	5	60	41	41	32.3	41	39	32.3

The outcomes on investigation of difference are classified in Tables 4 and 5. Estimations of Prob > *F* under 0.0500 propose that the model terms are noteworthy whereas values more noteworthy to 0.1000 are approved as inconsequential to relapse model [12]. In the current exploration work, *F* estimations of 117.49 and 95.68 for COD reduction by Al-Al and Fe-Fe electrodes and those of 38.74 and 36.4 for Colour expulsion by Al-Al and Fe-Fe anode-cathode separately, show that the model was critical. The best attack of the model is likewise checked by R^2 esteem in both the cases. The qualities for this relapse coefficient were 98.48% and 95.57%, it infer that selected model is measurably significant and sensible pledge with the balanced R^2.

Table-4: ANOVA examination of the model for COD and Color removal efficiencies for Al-Al electrodes

Analysis of Variance										
	Color removal efficiency (%)					COD removal efficiency (%)				
Source	DF	Adj SS	Adj MS	F-Value	P-Value	DF	Adj SS	Adj MS	F-Value	P-Value
Voltage (V)	3	70.96	23.65	0.71	0.580	3	52.57	17.52	0.94	0.478
Electrode distance (cm)	3	367.85	122.62	3.69	0.082	3	645.98	215.33	11.54	0.007
Electrolysis time (minute)	3	3866.67	1288.89	38.74	0.000	3	6579.18	2193.06	117.49	0.000
Error	6	199.64	33.27			6	112.00	18.67		
Total	15	4505.13				15	7389.73			

Table-5: ANOVA examination of the model for Color and COD removal efficiencies for Fe-Fe electrodes

Analysis of Variance										
	Color removal efficiency (%)					COD removal efficiency (%)				
Source	DF	Adj SS	Adj MS	F-Value	P-Value	DF	Adj SS	Adj MS	F-Value	P-Value
Voltage (V)	3	51.63	17.21	0.54	0.672	3	173.5	57.85	3.42	0.094
Electrode distance (cm)	3	346.78	115.59	3.63	0.084	3	102.9	34.30	2.03	0.212
Electrolysis time (minute)	3	3473.83	1157.94	36.40	0.000	3	4859.2	1619.75	95.68	0.000
Error	6	190.87	31.81			6	101.6	16.93		
Total	15	4063.11				15	5237.3			

Moreover, "adequate precision" in terms of the signal to noise (*S/N*) ratio has been estimated to govern the validity of the model. In the present work, *S/N* ratio values of 39.2 and 39.3 for COD and Colour removal efficacies designate an acceptable signal for the use of Al-Al electrodes in electrocoagulation process. The foremost impacts plot appeared in Figure 2 show that this model will utilize to coordinate the plan space.

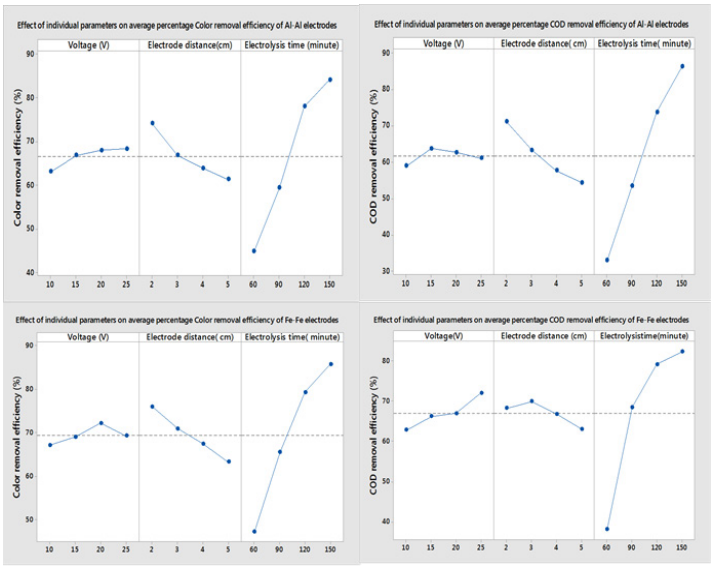


Figure 2: Foremost properties plots for S/N -ratios for COD -and colour exclusion efficiencies of electrodes (Fe-Fe and Al-Al)

Another check point for approving the trial information is the investigation of ordinary likelihood plots. The typical likelihood plot shows whether the residuals follow an ordinary circulation, wherein case the focuses will follow a straight line [13].The ordinary likelihood plots for present investigation are appeared in Figure. 3. The improvement of the key boundaries for shading and COD evacuation efficiencies viz. voltage, separation between the cathodes and electrolysis time by Taguchi technique ended up being 94% for Colour and 95% for COD by Al-Al electrodes, and 92% of Colour and 89% of COD by Fe-Fe anode-cathode. Since Al-Al anodes accomplished better than Fe-Fe terminals, the COD and Colour removal efficiencies of matched Al cathodes are summarized up in Table 6[14,15].

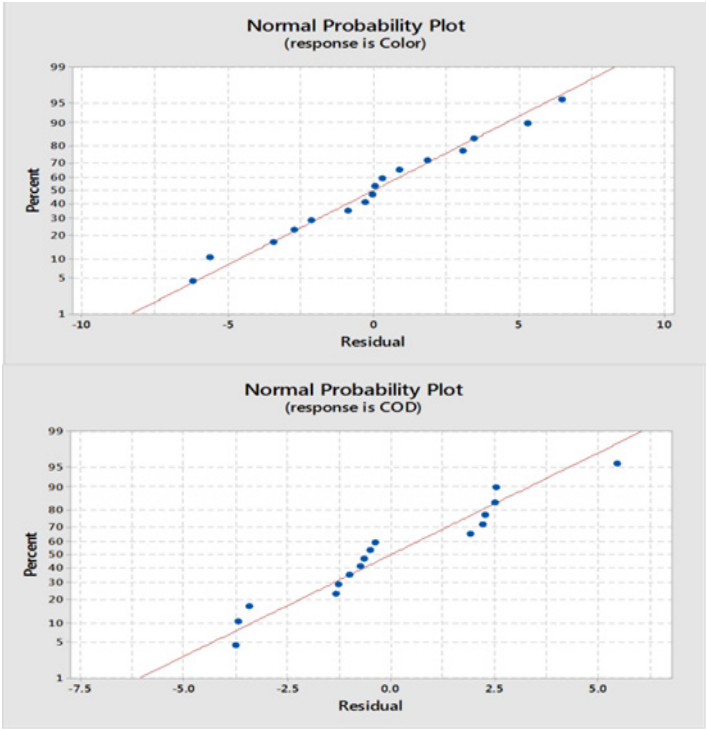


Figure 3: Normal probability plot for color and COD removal efficiencies

Table-6: Model summary of Color and COD removal efficiency for Al-Al electrodes

Color removal efficiency (%)				COD removal efficiency (%)			
S	R-sq	R-sq (adj)	R-sq (pred)	S	R-sq	R-sq (adj)	R-sq (pred)
5.76834	95.57%	88.92%	68.49%	4.32048	98.48%	96.21%	89.22%

Conclusion

In this research study, the optimization technique of Taguchi orthogonal array was selected for optimising the electrocoagulation process with three parameters viz. voltage, electrode distance and electrolysis time. The following conclusions can be drawn on the basis of findings:

I. Taguchi method offered four levels and three parameters of L9 array for analysing of experiments results.
II. At optimized conditions, electrocoagulation process of Al-Al and Fe-Fe electrodes would be able to achieve 94% and 92% decolorization efficiencies and 95% and 89% COD removal efficiencies, respectively.
III. Electrolysis time was the most contributing component by S/N proportion and ANOVA under Taguchi strategy with percent commitment of 39.2 and 39.3 for Colour and COD expulsion efficiencies, individually.
IV. The efficiency of Taguchi for its facility to predict the DSW colour and COD removal efficiencies was paralleled and observed superior in relations of R^2 values of 98.48%. 95.57% and 98.8% for color and COD removal efficiencies obtained in electrocoagulation process using Al-Al electrodes, respectively.

This work proves that the exercise of experimental results using for Taguchi method COD and decolourization of spent wash was potential.

Therefore, it very well may be presumed that Taguchi technique is a solid factual apparatus for test structure and the procedure streamlining for both Al-Al and Fe-Fe electrodes. The exploratory outcomes remained dissected and the enhanced for working boundaries with least quantities of trials and charts were gotten, which were anything but difficult to peruse and comprehend.

The ANOVA investigations of the similarly interrelating essential factors unmistakably indicated a solid association between the test and the anticipated outcomes. The streamlined test input and the yield information were taken care of as information for the Taguchi and ANOVA apparatus to anticipate the mistake. A feed forward back spread technique was utilized to anticipate the outcomes. The viability of Taguchi for its office to foresee the spent wash decolourization and COD expulsion effectiveness was thought about and was discovered improved in terms of anticipating, actuality suitable and assessment with a R^2 values of 95.7% and 93.6% in electrocoagulation process utilizing Al–Al anode-cathode, respectively. The examination study demonstrated that the activity of utilizing Taguchi technique for Colour and COD expulsion from spent wash was found to have potential for field application.

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References

1. Kaul SN, Nandy T, Trivedi RK (1993) Pollution control in distilleries. Environmental media, Karad, India (1993).
2. Shojaosadati SA, Khalilzadeh R, Jalilzadeh A, Sanaei HR (1999) Bioconservation of molasses stillage to protein as an economic reatment of this effluent. Resource Con Rec 27: 125-138.
3. Jimenez AM, Borja R, Martin A (2003) Aerobic/anaerobic biodegradation of beet molasses alcoholic fermentation waste water. Proc Biochem 38: 1275-1284
4. Khandegar V, Anil K Saroh (2014) Treatment of distillery spent wash by electrocoagulation. J clean energy tech 244-247.
5. Chandrakant Thakur, Vimal Chandra Srivastava, IndraDeo Mall (2009) Electrochemical treatment of a distillery wastewater: Parametric and residue disposal study. Chem Engg J 496-505.
6. Khandegar V, Saroha AK (2013) Electrocoagulation of Distillery Spentwash for Complete Organic Reduction. International journal of Chem Tech Research 5:712-718.
7. Manisankar P, Rani C, Viswanathan S (2004) Effect of halides in the electrochemical treatment of distillery effluent. Chemosphere 57: 961-966.
8. Krishna BM, Usha NM, Manoj KB, Lokesh KS (2010) Electrochemical pretreatment of distillery wastewater using aluminum electrode. J Appl Electrochem 40:663-667.
9. Prasad RK, Srivastava SN (2009) Electrochemical degradation of distillery spent wash using catalytic anode: factorial design of experiments. Chem Eng J 146: 22-29.
10. APHA (2005) (American Public Health Association). Standard Methods for the Examination of Water and Wastewater. 20th Ed., Washington DC.
11. Charles David M, Arivazhagan, Mohamed Ibrahim (2015) Spent wash decolourization using nano-Al2O3/kaolin photocatalyst:Taguchi and ANN approach. J Saudi Chem Soc 537-548.
12. Anam A, Abdul A, Abdul R (2014) A Comparison of Central Composite Design and Taguchi Method for Optimizing Fenton Process. The Scientific World Journal 1-17.
13. Nour Sh El Gendya, Salem S Abu Amrb, Radwa A El Salamonya, Hussein N Nassar (2015) Factorial design analysis for biosorption of Reactive Red-84 dye using fermentation spent waste biomass, biosorbent regeneration and desorbed dye photo-degradation using TiO2 nanoparticles. Desalination and Water Treatment 56: 3403-3413.

14. PSaravanan R, Karthikeyan S, Gupta VK, Sekaran G, Narayanan V, et al.(2013) Enhanced photocatalytic activity of ZnO/CuO nanocomposite for the degradation of textile dye on visible light illumination. Mat Sci Engg 91-98.

15. Madaeni SS, Koocheki S (2006) Application of Taguchi method in the optimization of waste water treatment using spiral-wound reverse osmosis element. Chem Engg J 37-44.