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Application of Response Surface Methodology (RSM) for wastewater of hospital by using electrocoagulation

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Abstract. Hospital wastewater is a source of potential environmental contamination. Therefore, the waste water needs to be treated before it is discharged into the landfill. Various research methods have been used to treat hospital wastewater. However, some methods that have been implemented have not achieved the effluent standards for hospitals that have been set by the government. The experiment was conducted by an electrochemical method is electrolysis using aluminum electrodes with independent variable is the voltage, contact time and concentration of electrolytes. The response optimization using response surface with optimum conditions obtained by the contact time of 34.26 min, voltage 12 V, concentration electrolyte 0.38 M can decrease of COD 65.039%. The model recommended by the response surface for the three variables, namely quadratic response.

1. Introduction

Hospital is a public place that provides health services for all levels of society as well as a center for health and research education. A wide range of activities can take place in a hospital, from non-medical activities to medical activities that generate solid, liquid and gas waste. Each of these wastes will impact the soil, water and air [6]. Hospital wastewater contains high concentrations of organic compounds, as well as other chemical compounds and pathogenic microorganisms that can cause disease to the surrounding communities. the activities of the hospital will produce pathogenic microorganisms such as viruses, bacteria, including Escherichia coli, Campylobacter and Shigella, and protozoa, including G. lamblia and Cryptosporidia, and heavy metals such as arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), copper (Cu), Zinc (Zn), which are very harmful to human health that is still present in water and discharges from laboratories, pharmacies, radioactive elements and other chemicals that cannot be eliminated by simple waste treatment. Some technology has been applied in treating hospital wastewater inside it fluidized bed biofilm reactor, Contact Aeration Process, Rotating Biological Contactor, Biofilter Up Flow and Activated Sludge [7]. The use of chemicals in sewage processing produces a lot of sludge, while the microbiological processing system requires a large area of land and requires a relatively long processing time, therefore the conventional processing as described has been much forgotten. another alternative that can be tried to cover the shortage of technology that has ever been electrocoagulation. electrocoagulation is a technology that is currently developing effectively applied for treating wastewater [5] Electrocoagulation for water treatment where the anode occurs the release of active coagulant in the form of metal ions (usually aluminium or

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iron) into the solution, while the cathode electrolysis reaction in the form of release of hydrogen [3]. in this research, electrode used in the form of aluminum. the reaction that occurs on is as follows :

Anode : $Al^{3+} + 3H_2O \longrightarrow Al(OH)_3 + 3H^- + 3e^-$

Cathode : $2H_2O + 2e^- \longrightarrow 2OH^- + H_2$

2. Materials and method

This research used the sample of hospital wastewater from the initial storage at the Tgk Chik Ditiro Sigli Wastewater Treatment Plant. All types of liquid waste generated from all parts of the RS are collected in the tub. The initial COD content of the hospital wastewater generated is still above the standard quality standard of 107.157mg /l.

2.1 Materials and research procedure

Electrodes are prepared as much as 2 sets (300 x 150 x 2) mm, then cleaned by sandpaper with sandpaper. After that the tool is assembled for container batch system, then put into it the hospital liquid waste as much as 1,3 L to be analyzed with electric voltage which is set at rectifier as specified variable (6 V). Snippets are captured at each time interval t15; 30, and 45 minutes for COD testing. After the electrodes are sanded back at different voltages of 9 and 12 V with the same time interval.

2.2 Experimental design

Design Expert Software is a collection of statistical and mathematical techniques useful for experimental design, model fit and determines optimum operating conditions for predetermined responses. In Design Expert Software there are several methods that can be used for response optimization, but in this research the method used is Box Bhenken to optimize and see the effect of variable contact time, voltage and electrolyte to decrease COD. on the electrocoagulation of hospital waste water treatment. Based on Design Expert Software using Box Bhenken method resulted in a trial design of 17 run experiments with the repetition at the center point (center point) as much as 5 runs. Repetition is useful for calculating pure errors from sum of squares. As shown in Table 1, the factors were designed as A, B, and C. All factors were prescribed into three levels, namely +1, 0, -1 for high, intermediate and low value, respectively.

Table 1. Input variable and code factor of response surface method of Box-Behnken design

Code Factor	Variable	-1	0	1
For electrocoagulation and electro-Fenton				
A	Time (minute)	15	30	45
B	Voltage (V)	6	9	12
C	Electrolyte concentration (ppm)	0	0.5	1

Some of the factorials of bhenken box designs are calculated in ANOVA. ANOVA also results in the interaction between process variables and response variables. Where the components will be used in calculating the F-Ratio in determining the effectiveness of a model [2]. The tables available on ANOVA are usually used for the test performance of a model.

3. Result and discussion

3.1. Summary of statistical models for decrease in COD

The Statistical Model Summary provides suggestions for choosing the right model and in accordance with the experimental data. Table 2 shows the statistical model for percentage reduction of COD resulting from the Box-Behnken design.

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Table 2. Summary of statistical models for decrease in COD

Response	Source	Std. Dev	R-Square	Adj-R^2	Pre-R^2	PRESS
% Decrease COD	Linear	7,04	0,8488	0,8139	0,7587	1027,83
	2FI	7,81	0,8570	0,7711	0,5774	1799,70
	Quadratic	1,82	0,9945	0,9875	0,9396	257,44 (Suggested)

From Table 2 it can be seen that the suggested model is quadratic. The quadratic model shows R^2 value closer to 1, ie 0.9945 and Adj-R^2 is 0.9875. The statistical summary model focuses on the value of R^2 obtained to see the suitability of the model. stating that the value of R^2 close to 1 indicates a high degree of correlation between observation and prediction value [10]. The value of R^2 obtained from a good model is above 0.8 and close to 1, because at that value the reaction can be well explained. R^2 is a value that explains the ratio of a ratio of variation to total variation and is a measure of the degree of suitability of the model. Similarly, the value of Adj-R^2 shown model, which is equal to 0.9875. the higher the value of Adj-R^2, indicating a more significant model. This value states that 98.75% of contact time, electrolyte and voltage variables affect the uniform response. While 0.25% influenced by other factors that are not included into the variable to be studied. Box-Behnken design also provides an actual mathematical model to predict the value of % COD decrease in wastewater processing by electrocoagulation as follows :

$$Y = -80.71725 + 3.9863833\ X_1 + 7.8601667\ X_2 + 41.9245\ X_3 - 0.045141\ (X_1)^2 - 0.274917\ (X_2)^2 - 17.887\ (X_3)^2 + 0.0082222\ X_1.X_2 - 0.033667\ X_1.X_3 - 1.94\ X_2.X_3 \quad (1)$$

The above equations are based on actual factors of each variable ie X1 for contact time, X2 for voltage and X3 for electrolyte. contact time (X1), voltage (X2) and electrolyte (X3), all of which have positive influence means the addition of the three independent variables will increase the percentage decrease of COD. From Equation 1 the predicted result of % decrease of COD of hospital effluent treated by electrocoagulation. Comparison of data of research result with result data from calculation using equation 1 can be seen in Table 3. The highest percentage of COD decrease obtained from the research result was 69.51% with 45 minutes contact time, 12 V voltage and 0.5 M electrolyte. While the percentage value of COD decrease obtained from model prediction was 70.53% at the time contact 45 minutes, 12 V voltage and 0.5 M electrolyte. The lowest percentage of COD decrease obtained from the results of the research was 18.36% with contact time 15 minutes, voltage 6 V and electrolyte concentration of 0.5 M. While the percentage value of COD decrease obtained from the model prediction is 17.34% at contact time 15 minutes, 6 V voltage and 0.5 M electrolyte.

Table 3. Experiment result data and model prediction results on% COD decrease

Run	Value of Variabel X			COD Decrease (%)	
	X_1 (Contact time)	X_2 (Voltage)	X_3 (Electrolyte)	Experiment	Prediction
1	45	12	0,5	69,51	70,53
2	45	6	0,5	58,21	56,66
3	15	9	1	24,41	24,58
4	30	6	1	47,53	48,38
5	15	12	0,5	28,18	29,73
6	30	9	0,5	57,70	56,20
7	30	12	0	56,79	55,94
8	45	9	1	63,42	64,12
9	15	6	0,5	18,36	17,34
10	30	9	0,5	54,23	56,20
11	30	9	0,5	56,55	56,20
12	45	9	0	59,23	5906
13	30	9	0,5	55,32	56,20
14	30	9	0,5	57,18	56,20
15	30	6	0	35,27	36,99
16	15	9	0	19,21	18,50
17	30	12	1	57,41	55,69

For the condition at the center point (center point) done as much as 5 runs, namely at the time of contact 30 minutes, voltage 9 V and electrolyte 0.5 M. The percentage value of COD decrease obtained from the research results are 57.7, 54.23, 56, 55, 55,32 and 57,58% while from model prediction result is 56.2% for the 5 runs. The relationship between the experimental results and the predicted results of hospital effluent treatment on the COD% decrease, illustrated in Figure 1.

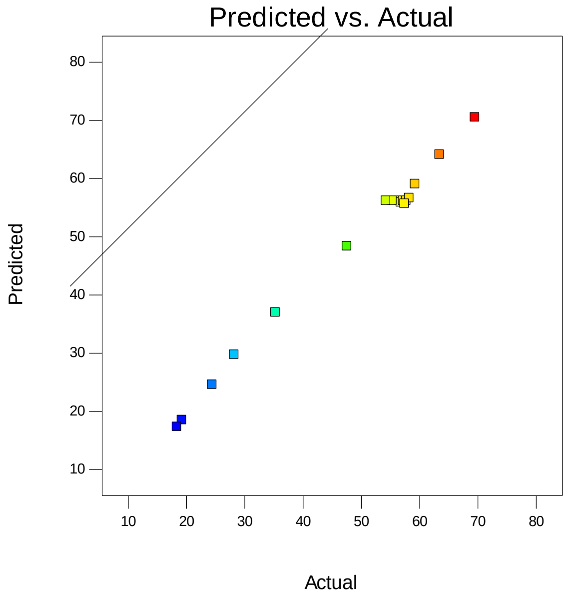

Figure 1. Relationship between research value and prediction value% decrease in COD on hospital wastewater treatment.

3.2 Analysis of variance (ANOVA) for decrease in COD

Some of the factorials of box bhenken designs are calculated in ANOVA. ANOVA also results in the interaction between process variables and response variables. Where the components will be used in calculating the F-Ratio in determining the effectiveness of a model [2]. The tables available on ANOVA are usually used for the test performance of a model.

Table 4. ANOVA results electrocoagulation of hospital effluent treatment to% COD decrease

Source	Sum of Square	df	Mean Square	F value	P-value Prob>F	Characteristics
Model	4235,81	9	470,65	141,41	<0,0001	Significant
A- Contact Time	3208,41	1	3208,41	963,97	<0,0001	Significant
B - voltage	344,79	1	344,79	103,59	<0,0001	Significant
C- electrolyte	61,99	1	61,99	18,63	0,0035	Significant
A^2	434,36	1	434,36	130,50	<0,0001	Significant
B^2	25,78	1	25,78	7,74	0,0272	Significant
C^2	84,20	1	84,20	25,30	0,0015	Not Significant
AB	0,55	1	0,55	0,16	0,6971	Not Significant
AC	0,26	1	0,26	0,077	0,7899	Not Significant
BC	33,87	1	33,87	10,18	0,0153	Significant

The first thing to do for output analysis, is to detect the suitability of the model. Based on the above table, it can be said statistically significant model. Significant models can be applied to Waste treatment to obtain optimum treatment for COD reduction. This statement can be proven by looking at the value of P-value model (<0.0001) and F-value model (141,41). P value below 0.05 indicates that the model is significant. The calculated p value indicates a significant test for each variable and a good interaction for each of these variables. If the p value is greater than 0.05, then the model is not significant. Significant models can be applied to Waste treatment to obtain optimum treatment for COD reduction.

3.3 Response surface analysis against percentage decrease of COD by electrocoagulation.

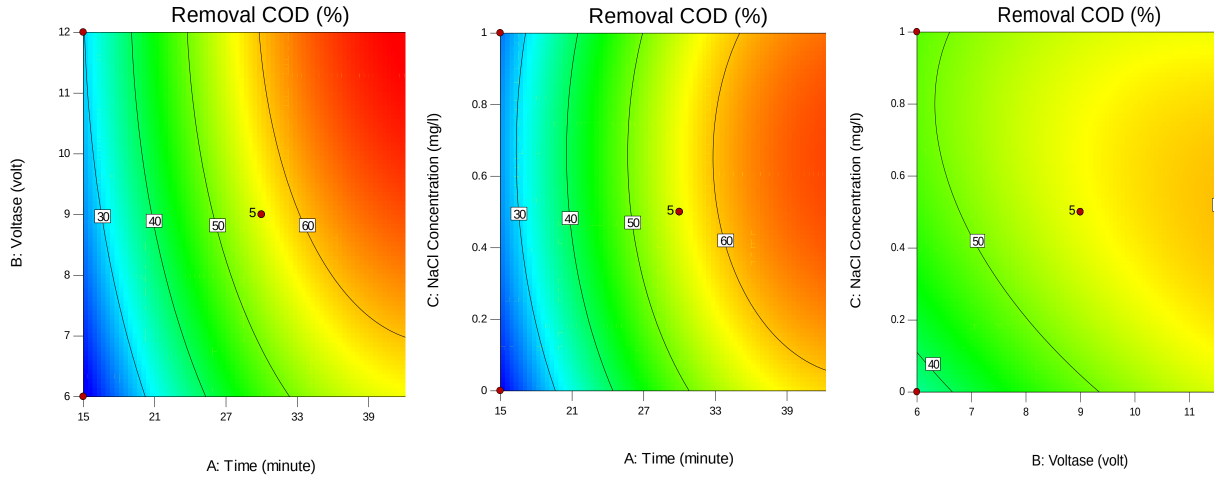

Figure 2. Two-dimensional contour plots express the effect of time, voltage and electrolyte concentration on electrocoagulation.

From the Figure presented, it appears that the three independent variables (contact time, voltage and electrolyte) significantly influence the% COD decrease. COD (Chemical Oxygen Demand) is the amount of oxygen needed to oxidize all organic matter chemically by using a strong oxidizer. In this research the voltage varied is 6 V, 9 V and 12 V. Contact time 15 min, 30 min and 45 min and electrolyte concentration ie without electrolyte 0 M, 0,5 M and 1 M. In electrochemical process with the addition of current into the process will result in oxidation reactions at the anode. Anode made of aluminum will experience an oxidation reaction forming Al3 + which will react with OH- form Al (OH) 3. Al (OH) 3. This in itself, serves as a coagulant that can bind both dissolved and suspended contaminants in solution. The higher the voltage given the coagulant to be formed will be more as well. The optimum voltage for the electrocoagulation process is 12 V [8]. In addition to being affected by the voltage, the decrease of COD in electrocoagulation is also affected by the electrolyte and the contact time. Electrolytes in the electrocoagulation process serves as a catalyst [1]. The addition of electrolytes to the electrochemical process will result in the following reactions:

$$2Cl^- \longrightarrow Cl_2 + 2e^-$$

$$Cl_2 + H_2O \longrightarrow HOCl + Cl^- + H^+$$

$$HOCl \longrightarrow OCl^- + H^+$$

The addition of electrolytes in the electrocoagulation process will decrease COD levels by up to 89% [9]. Another variable that affects COD decrease is contact time. long contact time results in longer contact between coagulants and contaminants in the waste, thereby decreasing larger COD. Electrocoagulation is generally an adsorption particle flocculation in which the coagulant at positive charged electrocoagulation will absorb negative ions in wastes such as nitrates, phosphates, nitrites and other organic compounds and form flocs that help the process of decreasing COD. This is consistent with [9] which states that the longer electrolysis time using Al electrode will increase the formation of metal hydroxide clumps that can neutralize the floc present on the surface.

4. Conclusions

This research investigates electrocoagulation performances in hospital wastewater treatment. The efficiency of COD removal is the main response of this research. The research uses response surface method (RSM) with Box-Behnken Design to get the experimental data interaction.. ANOVA provides the R2 values to verify that the processes are quadratic models. The largest percentage of COD decline was 69.51% and the lowest was 18.36% with R^2 value 0.9945.

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