Electrodecolorization of remazol violet with graphite electrodes: Application Of Statistical Designs And Regression Analysis

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Abstract. The electrodecolorization process of the remazol violet (RV) dye using graphite as an electrode has been done well. The RV is one of the synthetic dyes that are often used in the textile, paper, and other coloring industries. The parameters used in this study were RV concentration (20 mg/L-100 mg/L), pH (2-10), electrodecolorization time (2 minutes-20 minutes), volume H2O2 (0 mL-12 mL) and voltage (2 V-12 V). Based on experiments of 20 data that have been investigated then made the design of statistical model. The application of statistical design and regression analysis in this research is tested the feasibility, then tested by building data based on experimental data as amount 87319 data. This design is supported by ANOVA test, RMSE value, and ADD as the strengthening of the resulting model. Based on this study, the optimum conditions for pH parameters, electrodecolorization process time, H2O2 volume, RV concentration and voltage are 4;10 minutes;10 mL;20 mg/L; and 2V with a percentage of decolorization of 83.50%. The p-value results of the ANOVA test, the RMSE value, and ADD sequentially from this study are 0.002; 0,000; 0.201 so that the resulting model can be recommended for the application in dye waste management.

1. Introduction
The problem of waste, especially liquid waste is a very complex problem at this time. Given the increasing number of residents who are linear with the amount of industrial capacity it will cause a new problem that is the increased volume of waste generated. One of them is the use of synthetic dyes added to some production activities. The use of dyestuffs can not be adsorbed on the materials used, but part of it is wasted into the environment and causing pollution. Dye is an indispensable material for improving product quality, both in terms of quality and performance of products produced. Textile, paper, paint, medicine and stationery industries can not be separated from the coloring process. Commonly used dyestuffs are synthetic type dyes where they are not easy to break down in a simple way and have a relatively cheaper purchase price than the dyes available in nature. This will cause an environmental health imbalance, so that the treatment is needed that can improve the quality of the waste produced so that if it is released in the environment does not cause new problems. One of the most commonly used dyestuffs is remazol violet (RV) in which RV has 3 sulphonate functional groups, 1 azo group (R-N = N-R ‘) and has several other organic active groups [1]. This structure as shown in Figure 1, causes RV is a very stable and complex dye.

![Figure 1. Structure of Remazol Violet](image)
Techniques to treat the decomposition of the RV dyes include biological [2], adsorption[3], membrane [4], coagulation-flocculation [5], and advance oxidation process (AOPs) [7][8]. In this study a combination of electrolysis and AOP techniques is used by utilizing the electrical voltage combined with the use of hydrogen peroxide. The electrolysis method is reported able to increase the dye degradation performance maximally. The selection of materials as electrodes is something that must be considered in order to produce maximum degradation efficiency but still must consider in terms of its economy. The use of graphite electrodes gives higher performance and has lower economic efficiency compared with other electrodes[9]. Graphite electrode can perform oxidation process and reduction of RV dye optimally. Combination with hydrogen peroxide can increase the performance of the process. Improving the performance of RV oxidation and reduction processes in order to produce the optimum degradation percentage used statistical design and regression analysis. This design is based on experimental data modeled with empirical equations so that it will produce a formula that can give optimum performance. The equation model to be constructed is shown in equation 1.

\[
\eta = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5
\]  

(1)

The validity of the resulting model was tested using ANOVA test, root mean square error (RMSE), coefficient of determination (R²), and absolute average deviation (AAD). Research on modeling for the process for handling liquid waste containing synthetic dyes was carried out by several researchers. The modeling that has been done is modeling using statistical design [11] [12] [13], artificial neural network [14] [15] and surface method area [16] [17] [18]. Statistical analysis of the decolorization process of azo compounds based on their function groups has been investigated by Mathukumar et al. [19]. This research explains that acid dyes processing with naphtalene rings in its structure get faster decolorization than the dyes with the combination of benzene and naphtalene rings. The several dyes which studied, dyestuffs that have functional sulfonate groups provide an ability that is easier to decolorize. The increasing of azo groups, it takes longer for the decolorization process. Modeling of the decolorization process of acid orange 7, acid black and acid yellow ozonated using Multiple linear regression (MLR) has been well done by Fatimah et.al [11] and using response surface (RSM) has been well done by Katsiri et.al [17].

Modeling the decolorization process of acid black and acid yellow by ozonation using Levenverg-Marquard neural network (LM-NN) modeling has been well done by Fatimah et al. [20]. The results of this study showed that the percentage of decolorization experimentally for acid black and acid yellow was 93% and 98% respectively. The percentage of decolorization was predictably obtained by decolorization percentage for acid black and acid yellow respectively was 95.25% and 99.99%. The study by Ravikumar et.al [21] on the statistical design of response surface from the neonlan blue 2G (acid blue 158) dye adsorption process and basic methylene blue (basic blue 9) has been successfully predicted. Based on these studies, the percentage of decolorization by experimentally and prediction were 99.9% and 99.10% respectively.

A statistical experiment design approach for advanced oxidation of azo by photofenton treatment also did by Ay et.al [22]. Statistical design of direct red 28 dye oxidation process (DR 28) using Fenton photo using concentration independent variables of DR 28, H₂O₂, and Fe (II) concentration. The dependent variables are color removal and total organic carbon (TOC) removal as well as response functions. Color removal increased with increasing of H₂O₂ and Fe (II) concentration up to certain levels. At high concentrations of H₂O₂ and Fe (II) concentrations will affect the amount of color removal and TOC removal due to the presence of hydroxyl radicals as oxidizing agents. The optimal condition of this decolorization process occurs for 5 minutes with TOC mineralization process of nearly 16 minutes. The results of the decolorization percentage experimentally produced a value of 99.72% while the prediction resulted in a decolorization percentage of 100% with the composition of increasing the H₂O₂ concentration parameter. This modeling is necessary in order to be more effective and efficient in conducting RV electrodecolorization process. Modeling about RV electrodecolorization is still very minimal so it is important to have this research. The variables affecting the electrodecolorization process can be adjusted so as to suppress or maximize the existence of other variables. This is of course to provide good oxidation and reduction performance.

2. Material And Method
2.1 Material
The materials used in this study are from Merck. They are consist of H₂O₂, NaOH, H₂SO₄, Na₂SO₄, RV dyes from Solo Central Java. The statistical design analyzed by use the MATLAB R2014A and SPSS v.23 software.
2.2 Method
The stages which will be done in this study include the following stage:

2.2.1 Preparation of experimental procedure. The preparation of a standard RV solution is prepared by dissolving as much as 0.1 grams of RV powder dissolved in a 20 mL distilled water solution. The parent solution of H2O2 10,000 mg / L was made by diluting 15.02 mL H2O2 30% (specific gravity 1.11 g / mL) to 0.5 L. Determination of the optimum voltage was carried out by as much as 40 mL of RV series 25 mg / L solution included into a glass beaker, then added 0.71 grams of Na2SO4 and added 0.1 N H2SO4 until the pH shows 3, then the absorbance is measured. This is done to obtain absorbance value before electrolysis. The DC current source is regulated by starting the smallest voltage of 2 V to 12 V then electrolysis with a constant time of 5 min. After completion of the electrolysis the solution is filtered and its absorbance is measured. Voltages showing the maximum percent of decolorization were used in this study. The optimum time determination is performed with the solution conditions equal to the determination of the optimum voltage by varying the electrolysis time at the optimum voltage. The time is 2 minutes to 20 minutes at interval 2. The time that gives the maximum percentage of decolorization is used in this study. The determination of the optimum pH is carried out under solution conditions equal to the determination of the optimum voltage by varying the pH of the solution. The pH is 2 to 10 with interval 2. The pH conditions that produce the maximum decolorization percentage are used in this study. Electrodecolorization RV with optimum conditions. Spiral iron with a diameter of 0.5 cm is inserted into the electrolysis cell as anode and graphite carbon rod as cathode. In the glass cup, 40 mL of RV dye solution 25 mg / L was added to 0.71 gram Na2SO4 and added with 0.1 N H2SO4 until the pH showed optimum absorbance was measured. The solution is transferred into the electrolysis cell then connected to the outer electric potential at optimum time and the optimum voltage. After completion of electrolysis the electrolyzed solution was filtered and its absorbance was measured.

2.2.2 Experimental of optimization design. In this study the independent variables included pH, electrodecolorization time, H2O2 volume, initial RV concentration, and voltage. The dependent variable used in this research is the RV decolorization percentage efficiency. The experimental test treatment was carried out as many as 3 replicas and from each replica a total sample of 20 data were produced. The list of consecutive experimental symbols and sample design conditions is shown in Table 1 and Table 2. The data already obtained are then modeled for the regression equations. The model that has been obtained is tested for significance through ANOVA, RMSE, and AAD tests by SPSS. From the model obtained, the prediction data is built randomly using variables in accordance with the variables used and obtained as many as 87319 data. The data obtained is searched for optimum condition based on the prediction with the model that has been obtained. Both stage is used MATLAB software to obtained the data and predicted the optimum condition.

| Table 1. Consecutive of Experimental |
|-------------------------------------|
| Symbol    | Explanation               |
| X1        | pH                       |
| X2        | time (min)               |
| X3        | volume H2O2 (mL)         |
| X4        | dyes concentration (mg/L) |
| X5        | voltage (V)              |
| ηExp      | percentage decolorization experiment |
| ηPred     | percentage decolorization prediction |
| α0        | Constanta or determination coefficients |
| α1        | coefficients regression for pH |
| α2        | coefficients regression for time |
| α3        | coefficients regression for volume H2O2 |
| α4        | coefficients regression for dyes concentration |
| α5        | coefficients regression for voltase |
| ANOVA     | Analysis of Variance     |
| RMSE      | Root Mean Squared Error  |
| AAD       | Absolute Average Deviation |
Table 2. Sample Design of RV Electrodecolorization Matrix

| Run | X1 | X2 | X3 | X4 | X5 | nExp | nPred |
|-----|----|----|----|----|----|------|-------|
| 1   | 6  | 5  | 4  | 20 | 5  | 70   | 71,28640 |
| 2   | 2  | 8  | 6  | 45 | 5  | 60   | 67,70218 |
| 3   | 4  | 5  | 2  | 25 | 7  | 65   | 64,19629 |
| 4   | 6  | 12 | 6  | 20 | 5  | 79   | 77,01706 |
| 5   | 8  | 6  | 6  | 20 | 4  | 60   | 60,52727 |
| 6   | 6  | 10 | 0  | 40 | 5  | 60   | 82,40251 |
| 7   | 10 | 2  | 6  | 20 | 3  | 78   | 78,32508 |
| 8   | 6  | 5  | 8  | 20 | 5  | 77   | 62,79846 |
| 9   | 10 | 8  | 6  | 20 | 4  | 76   | 71,97680 |
| 10  | 6  | 5  | 30 | 7  | 60 | 73,68072 |
| 11  | 6  | 15 | 8  | 20 | 5  | 50   | 61,34546 |
| 12  | 4  | 3  | 6  | 25 | 5  | 60   | 74,75896 |
| 13  | 6  | 8  | 0  | 35 | 6  | 60   | 59,90856 |
| 14  | 8  | 5  | 2  | 20 | 5  | 80   | 71,14982 |
| 15  | 6  | 6  | 6  | 20 | 4  | 70   | 74,21769 |
| 16  | 2  | 3  | 0  | 60 | 5  | 60   | 69,60572 |
| 17  | 6  | 5  | 4  | 25 | 5  | 50   | 70,82954 |
| 18  | 6  | 5  | 6  | 20 | 6  | 70   | 72,67534 |
| 19  | 6  | 5  | 4  | 60 | 6  | 50   | 54,67820 |
| 20  | 2  | 4  | 6  | 45 | 4  | 70   | 74,24680 |

2.3 Evaluation parameters

The modeling resulted from this research will be determined some parameters which will be used to evaluate model feasibility. The evaluation parameters used are:

2.3.1 ANOVA Test. ANOVA test is carried out to determine the feasibility of a proposed model. The provision of this test is if the p-value or probability number is <0.05.

2.3.2 Root mean squared error (RMSE). This test is done to find out how big the difference between the data modeled with the experimental data. The formula is shown in equation (2). The predicted model formula is said to be good if the value of the RMSE is less than 0.1 [10].

\[
RMSE = \left( \frac{1}{n} \sum_{i=1}^{n} (\eta_{\text{predict}} - \eta_{\text{exp}})^2 \right)^{1/2}
\]

2.3.3 Coefficient of determination (R²). This test is to measure the spread of data in the research and is generated from the Total Sum of Squared (TSS) value. If the R² value is equal to 0, so there is not contribution of influence given to the dependent variable by the independent variable, or the variation of the independent variables used in the model does not explain the slightest variation in the dependent variable. Conversely if the R² values equals 1, so the percentage of contribution given by the independent variable to the dependent variable is perfect, or the variation of the independent variable used in the model explains 100% variation of the dependent variable. Formula for determining R² values shown by equation (3)

\[
R^2 = \frac{\left( \sum_{i=1}^{n} (\eta_{\text{predict}} - \eta_{\text{exp}})^2 \right)}{\left( \sum_{i=1}^{n} (\eta_{\text{exp}} - \eta_{\text{exp}})^2 \right)}
\]

2.3.4 Absolute average deviation (AAD). This test measures the deviation between the data generated and the predicted data, but is the absolute value [10]. The formula for determining the value of AAD is shown in equation (4). Based on research by Sinha [10] that the smaller the AAD value or the value close to 0, the model presented is feasible as a predictive model.

\[
AAD = \left( \frac{1}{n} \sum_{i=1}^{n} \left( \frac{\eta_{\text{predict}} - \eta_{\text{exp}}}{\eta_{\text{exp}}} \right) \right) \times 100
\]
3.  Result And Discussion

3.1 Electrodecolorization Process

The electrodecolorization process is a process based on the oxidation reaction and reduction. In this case the RV dye oxidation process is carried out experimentally in the laboratory. Combination techniques with the addition of hydrogen peroxide can help the process of oxidation and reduction reactions. In this electrodecolorization process, the graphite as a cathode, while the iron spiral acts as an anode. The use of graphite can adsorb dyes from organic compounds. The research procedure involves electrodes, electrolyte solutions and external potential. The initial study of this study was to conduct an electrodecolorization process with graphite as an electrode. The initial treatment is to determine the variables and their quantities in accordance with Table 1. In this treatment will occur the electron transfer process due to the voltage so that at the pH conditions and concentration of certain solutions will get the percentage value of RV degradation. Iron (Fe) is used as an anode for the reason to produce iron hydroxide floc which is not soluble in water. Iron hydroxide flocs act as floculants-coagulants that bind to the RV dye which is expected to be easily separated after the end of electrolys. Binding is based on the presence of a positive partial charge on iron hydroxide and a negative charge on the RV compound.

Hydrogen peroxide compounds have the ability to perform a high oxidation process that will help the process of formation of hydroxyl radicals. This hydroxyl radical has a role to break the structure of RV compounds into simpler compounds. At low pH in a solution it will decrease the intensity of the color. Oxidation of compounds from colored solutions to colorless is very effective. Many factors can influence the RV dye electrodecolorization, one of which is pH. The formation of the iron floc, the electrolysis process, and the influence of H$_2$O$_2$ are largely determined by the pH of the solution. The production of Fe$^{3+}$ ions in an acidic condition during electrolysis is more than in an alkaline condition. The Fe$^{2+}$ ions are the oxidation of Fe$^{3+}$ ions due to the strong oxidizing agent H$_2$O$_2$. Fe$^{3+}$ ions are more stable than Fe$^{2+}$ ions. The reaction is indicated by the Reaction 5 to Reaction 7.

\[
\begin{align*}
\text{Fe} + 2\text{H}^+ & \rightarrow \text{Fe}^{2+} + \text{H}_2 & (5) \\
\text{Fe}^{3+} + 2\text{OH}^- & \rightarrow \text{Fe(OH)}_2 & (6) \\
2\text{Fe(OH)}_2 + \text{H}_2\text{O}_2 & \rightarrow 2\text{Fe(OH)}_3 & (7)
\end{align*}
\]

In Fe$^{3+}$ ion there is an electrostatic attraction with the OH$^-$ anion from RV dye. At low pH this interaction will increase, whereas at high pH the surface of Fe$^{3+}$ decreases the load causing repulsion. The high percentage of decolorization at this acid pH condition can occur because in an acid condition there will be neutralization of negative charges of hydroxide ions by hydrogen ions so as to help bind RV dye molecules. Iron in an acidic condition is more easily oxidized than in an alkaline condition so that at the same time more hydroxide is produced. In the acidic condition, hydrogen ions are more easily absorbed by the gelatinous deposits of iron hydroxide resulting in iron hydroxide getting positively charged. Iron hydroxide will be increasingly negatively charged so that it will result in RV particles which easily precipitated. The pH conditions during electrodecolorization process, RV molecules will undergo ionization process according to their acidity [21].

Hydrogen peroxide will be able to oxidize or reduce a solution with a very rapid reaction rate especially in acid solution. The Fe$^{3+}$ ion can be a catalyst for H$_2$O$_2$ to produce OH radicals which can be used to remove RV dyes, where OH radicals will reduce RV dyes to CO$_2$ after going through a series of intermediate states. During this time Fe$^{3+}$ catalyst was obtained by adding Fe$^{2+}$ salts, but by seeing that the first result of iron electrolysis was Fe$^{2+}$, in this study it was assumed that before the process of RV dyestuff precipitation by Fe(OH)$_3$ first occurred some RV dyestuff reduction by OH radicals obtained from H$_2$O$_2$ catalyzed by Fe$^{2+}$. The reaction is shown in Reactions 8 and Reaction 9.

\[
\begin{align*}
\text{Fe(s)} + \text{H}_2\text{O}_2 & \rightarrow \text{Fe}^{2+}(\text{aq}) & (8) \\
\text{Fe}^{2+}(\text{aq}) + \text{H}_2\text{O}_2 & \rightarrow \text{Fe}^{3+}(\text{aq}) + \text{OH}^- + \bullet\text{OH} & (9)
\end{align*}
\]

This assumption shows that the decolorization process of RV dyes is not only by electrocoagulation or electrophylulation alone, but by reducing RV dyes into harmless particles. The RV colorant in order to bind with FeO(OH) must release the hydroxyl group to suit the concept of acid base equilibrium. The decolorization process of RV dyes is due to two reasons, namely due to the process of RV precipitation in gelatinous iron hydroxide deposits and the formation of RV dye complexes with iron hydroxide. Iron hydroxide in the water will be suspended to form colloid in the form of large and stable particles, eventually the particles will precipitate as a gelatinous precipitate. The process of formation of the gelatinous precipitate, iron hydroxide will co-precipitate the RV dye.
The coprecipitation of the RV dye by the iron hydroxide precipitate may occur because of the interaction between the iron hydroxide and the RV dye of Van der Walls style. In addition to the effect of Van der Walls forces caused by the difference in charge between iron hydroxide and RV dye, the process of decolourizing RV dyes is also caused of the formation of iron complexes with RV dyes that have a large molecular weight so that the complex is easily settled. The bond between the dye and the iron is a coordinate covalent bond, assuming the iron acts as a central atom and a dye as a ligand. The mechanism of its formation is as shown in Reaction 10.

\[
L-H + (HO)OFe \rightarrow L-OFe + H2O \tag{10}
\]

The reaction where L is an RV dye, shows that the iron hydroxide binds the oxygen ions to the position of the carboxylic atoms and not to the amide position. This is due to the acidity of carboxylic ions greater than the amide ionic amide properties. The acidity causes the negative charge of the oxygen ions in the carboxylic group to be greater than the chloride ion charge clouds in the amide so that the oxygen ions in the carboxylic ions are more susceptible to the positive iron hydroxide ions, although there is the possibility of iron hydroxide binding to nitrogen. This is because nitrogen has a pair of free electrons that can be donated to form bonds with Fe (III). According to the Pearson acid-base theory, Fe5+ which is a hard acid would be more likely to bind to oxygen which is a hard base compared to nitrogen which is a soft base. Consequently the interaction between Fe (III) with oxygen from the RV dye is more likely to occur. In addition to the amide group, the steric blockage is greater than that of the hydroxyl group, so that Fe5+ ions will be more readily attached to the carboxyl group.

### 3.2 Statistical Design Analysis

The events in each condition of this variable will bring the consequences that the electrodecolorization process can be performed optimally. This condition is expected to be better than the previous experimental conditions. Therefore in this study modeling was carried out using a regression model. In the optimization process of RV electrodecolorization with this graphite produces equations or modeling according to the mathematical equation (11).

\[
\eta = 64,134 + 1,129X_1 - 0,635X_2 + 1,760X_3 - 0,27X_4 - 0,588X_5 \tag{11}
\]

The independent variables in this experiment based on ANOVA test in Table 4 have a very important role because it affects the performance of the electrodecolorization process and the performance of the decolorization percentage. Equation (5) interprets that the electrodecolorization process of RV with graphite and iron as electrodes can be modeled using software. Based on the proposed model it has a significance value of 0.002 so that this model is good for prediction on the experiment. The resulting equation or model means that the decolorization percentage value is 0 when the value of the coefficient for the variable pH, electrolysis time, H2O2 volume, RV dye concentration, and voltage are 1.129; -0.635; 1.760; -0.27; -0.5. Equation (5) show that for the time variable of electrolysis, the RV and voltage concentrations have negative values when compared with other variables. Experimental and modeling decolorization percentage results are shown in Table 3. Based on the experimental results it was obtained that for the optimal decolorization percentage that is equal to 80.10% then the conditions that occur are at a pH of 4 electrodecolorization time for 8 minutes, the addition of H2O2 is 6 mL, RV concentration is 20 mg / L, and voltage is 4 V. If based on prediction, the decolorization percentage of 83.50% is obtained with variable conditions free of pH, electrodecolorization time, addition of H2O2 volume, RV concentration, and the voltage in sequence is 4; 10; 10; 20; and 2. These results indicate that the relationship between variables is very varied. In the independent variable does not occur very high or low correlation so that it does not happen the multicollinearity. Observed data shows normal distributed data so that the data between the experimental results and the modeling results do not show very much difference.

Based on Table 3 that there is a difference between experimentaly and prediction decolorization percentage, which is 3.40% which is accompanied by an increase in electrolysis time and the volume of H2O2 used. This is
of course according to the circumstances that when the electrolysis time and the volume of H₂O₂ increases but does not change the pH, the percentage decolorization value will increase. This is because when the electrodecolorization time increases which is accompanied by the addition of H₂O₂ volume it will increase the production of hydroxyl radicals that will attack the RV molecule so that it will be heavier. As more and more RV molecules will require a lot of hydroxyl radicals to aid the oxidation process, although it has increased the volume of H₂O₂ and prolonged the electrodecolorization time but the voltages remain. However, the amount of free radicals available will also have an equilibrium state with hydrogen peroxide. In this state, OH radicals react massively with hydrogen peroxide and produce hydroperoxide radicals (HO²●). This hydroperoxide radical has a lower reactivity than the HO● radical. This is what causes a decrease in the percentage of decolorization. The reaction shown in the Reaction 12 until Reaction 16.

\[
\begin{align*}
H_2O_2 &\rightarrow 2OH● & (12) \\
H_2O_2 + OH● &\rightarrow HO_2● + H_2O & (13) \\
H_2O_2 + OH● &\rightarrow O_2● + H^+ + H_2O & (14) \\
OH● + OH● &\rightarrow H_2O_2 & (15) \\
OH● + HO_2● &\rightarrow H_2O + O_2 & (16)
\end{align*}
\]

**Table 3. Optimum Values of The Process Parameters For Maximum Percentage Decolorization**

| Parameters | Optimum Value |
|------------|---------------|
| η (Percentage decolorisation, %) | 80,10 83,54 |
| X1 (pH) | 4 4 |
| X2 (Electrodecolorization Time, min) | 8 10 |
| X3 (Volume H₂O₂, mL) | 6 10 |
| X4 (Dyes concentration, mg/L) | 20 20 |
| X5 (Voltase, V) | 4 2 |

Based on Table 4, show the correlation test between each variables in the electrodecolorization process. The correlation value between the variable of decolorization percentage with the pH, electrodecolorization time, H₂O₂ volume and RV dye concentration respectively are 0.594; 0.222; 0.103; and 0.222.

**Table 4. Statistical Result**

| Statistical Analysis Based On Data Experiment | Independent Variables |
|---------------------------------------------|------------------------|
| X1 | X2 | X3 | X4 | X5 |
| Pearson Correlation | 0.594 | 0.322 | 0.103 | 0.222 | -0.451 |
| p-value | 0.000 | 0.115 | 0.291 | 0.109 | 0.005 |
| Muticollinearity VIF | 1.000 | 1.003 | 1.027 | 1.109 | 1.136 |
| Standar deviation | 9.61 | 0.868 |
| R² square | |
| SSE (standar error of estimate) | 6.5 |
| Durbin Watson | 1.64 |
| Sig. For ANOVA | 0.002 |
| RMSE | 0.000 |
| AAD | 0.201 |

This relationship is a unidirectional relationship. Unlike voltage variables that have negative or opposite correlation values that are inverse relationships. The voltage is an important parameter for controlling the reactant rate, the generation of metalions and formation of hydroxyl radical. This parameter directly affects anodic dissolution of ion electrode [23]. The greater the voltage value, the greater the percentage of decolorization due to the abundant hydroxyl production so that the RV reduction and oxidation process gets bigger. This may be due to the competitive reactions in the cell. The oxygen production on anode and the hydrogen production on cathode occur at high voltage. This reaction inhibits the main electrolysis reaction [24]. At the moment the voltages do not increase while the RV concentration increases then this will reduce the percentage of decolorization. In Table 4 shows that if the voltage is not increased, while the RV concentration and electrodecolorization time are added, the percentage of decolorization will decrease. This is due to large
amount of hydrogen peroxide production which causes H₂O₂ decomposition to oxygen and water. The OH• radical combination decreases the hydroxyl radical concentration. The increased concentration of hydrogen peroxide, it will be possible to decrease the percentage of RV degradation. This is because when the concentration of hydrogen peroxide increases, the amount of hydroxyl radicals that will attack RV compound molecules is also increasing.

4. Conclusions
Treatment the liquid waste is needed nowadays to overcome human problems so that environmental balance continues. In this study, the results of the study were clearly and in detail about the handling of RV dye waste by electrodecolorization method combined with the addition of hydrogen peroxide using graphite electrodes. Based on this study, the optimum conditions for pH parameters, electrodecolorization time, H₂O₂ volume, RV concentration and voltage in sequence are 4; 10 minutes; 10 mL; 20 mg / L; and 2 V with a percentage of decolorization of 83.50%. The p-value results from the ANOVA test, the root mean squared error (RMSE), and absolute average deviation (ADD) values respectively from this modeling study are 0.002; 0.000; 0.201 so that the resulting model can be recommended for application of RV dye handling. the dimerization process of hydrogen peroxide at high concentrations.

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