Effect of Changes Turbidity on Oxygen Solubility in Fish Pond Water Electrocoagulation Process

Sutanto Sutanto*, Toto Supriyanto1, Danang Widjajanto1

1Department of Electrical Engineering, Politeknik Negeri Jakarta, Indonesia

*Email: stanto09@gmail.com

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ABSTRACT
The water used for fish farming by the Mina Lestari is very dirty, because many soil particles are dissolved in water. The water with high dirty in generally has very high turbidity. So that oxygen is difficult to dissolve in water and is not sufficient for fish life. So many fish die, due to insufficient oxygen for breathing. To reduce water turbidity is treated by electrocoagulation process combined with the aeration process. The aim of the research was to study the effect of changes in turbidity on dissolved oxygen in water. The study began by measuring the turbidity using a turbidimeter and dissolved oxygen using a DO meter. Furthermore, pour 10 liters of water into the electrocoagulation process tank. The electrocoagulation was carried out at 12 volt or 0,3 ampere for 10 minutes. The process was stopped, then the water flowed into the settling tank and left for 30 minutes to precipitate of the dirt. The water flowed into a holding tank and followed aeration process by flowing air at a rate of 500 cc per minute for 30 minutes. Then followed measuring turbidity by turbidimeter and dissolved oxygen by DO meter. Subsequent studies were carried out using the same procedure with an interval of 10 minutes processing time for electrocoagulation process. The results showed that an increase in processing time can reduce water turbidity from 68 NTU to 45 NTU or 33.82% and increase dissolved oxygen from 2.8 mg/L to 5.3 mg/L or 89.29% at 50 minutes processing.

Keywords:
Turbidity
Electrocoagulation
Aeration
Dissolved Oxygen

INTRODUCTION
The Mina Lestari fish farmer group in the Duren Mekar area, Depok, has started a consumption fish farming business since 2017. The number of members until 2023 is 22 people with 18 ponds. Types of fish cultivated include catfish, tilapia, pomfret, goldfish, patchouli, carp and tilapia.

The problem for fish farmers until now is that every day there are fish that die. One reason is the very high turbidity of the water. Based on the results of field measurements, the average daily turbidity is 68 NTU. Even though the maximum permissible water turbidity requirement for fish farming is 50 NTU and a minimum dissolved oxygen of 5.0 mg/L [1]. Thus, it can be estimated that one of the causes of fish death is insufficient oxygen content, caused by very high water turbidity.

In this study the aim was to reduce the turbidity of pond water by means of an electrocoagulation process combined with an aeration process to increase the solubility of oxygen in the water.

Based on the results of research on the effect of changes in turbidity on the solubility of oxygen in water, it shows that the more turbid the water, then the oxygen dissolved in the water is getting smaller. In this case the change in turbidity can also be shown as a change in the BOD (Biological Oxygen Demand) value. [2]. The results showed that at BOD of 8.1 mg/L the ability to dissolve oxygen (DO) in water was 5.73 mg/L, whereas when the BOD increased to 8.32 mg/L the solubility of oxygen decreased to 5.2 mg/L or equivalent of 9.25% [3].

Water with high salinity is water that contains ions dissolved in water, such as chloride, carbonate, bicarbonate, sulfate, sodium, calcium, and magnesium. Water with a high salinity dissolves oxygen more
easily in water than with a lower salinity. The results showed that water with salinity of 24.7 ppt was able to dissolve oxygen by 7.84 ppm, while at a salinity of 31.3 ppt it was able to increase the solubility of oxygen by 7.87 ppm or an increase of 0.38% [4].

The increase in the solubility of oxygen in water is caused by differences in ion concentrations, thus causing water circulation which results in an increase oxygen dissolved in water. It appears that the increase in dissolved oxygen is less significant [5].

Other studies have shown that increasing turbidity or impurities will result in a decrease in dissolved oxygen in water. The results of research on the distribution of dissolved oxygen due to the influence of phosphate levels in the waters of the Lembeh Strait, showed that at a phosphate level of 0.011 mg/L it could dissolve 5.85 ppm oxygen, while at a level of 0.015 mg/L it could dissolve 5.59 ppm oxygen. This means that when there is a decrease in impurities by 26.67%, the dissolved oxygen increases by 4.65% [6].

The mass transfer rate of gas passing on the surface can be expressed in equation [7]:

$$N_A = k_t (C_S - C)$$ (1)

with:

- $N_A$: mass transfer rate, mg/(hour·L)
- $k_t$: total transfer coefficient, h$^{-1}$
- $C_S$: concentration of saturated gas, mg/L
- $C$: concentration of gas in liquid, mg/L

From Equation (1) it can be seen that the rate of gas transfer in water is directly proportional to the total transfer coefficient or inhibiting factor.

One of the inhibiting factors for the rate of solubility of oxygen in water is the level of cleanliness of the water or the impurity layer on the surface of the water. Water with a high content of impurities or a high level of turbidity can result in a decrease in the total transfer coefficient. Thus, there will be a decrease in the rate of dissolution of gas into the water [8].

The concentration of dissolved oxygen in water can be corrected by inflating air into the water using a micro bubble. The results showed that air bubbled into the water with a smaller flow rate, lower pressure and longer flow time can increase the oxygen dissolved in the water. In the process of inflating air into water with a flow time of 50 minutes, a pressure of 3 Psi and flow rate of 0.000007 m$^3$/s, it shows that the dissolved oxygen in water is 8.2 mg/L. If the air pressure is increased to 10 Psi while the process time and airflow rate are made the same, the oxygen that can dissolve in the water drops to 4.2 mg/L [9].

The results of research on the electrocoagulation process in waste water conducted by Meneses et al., showed that to remove turbidity of 99.75% from 1130 NTU, an electric voltage of 10 volts, pH 7.5 and processing time of 60 minutes were required. Under the same conditions the process is also able to eliminate the demand for chemical oxygen or Chemical Oxygen Demand (COD) and biochemical oxygen demand or Biological Oxygen Demand (BOD) reaching respectively 33.2% and 39.36% [10].

Abbas et al. conducted research on the electrocoagulation process in waste water containing oil. The results of the four experiments were carried out at constant operational conditions, namely: pH = 6.98, current density $I = 0.01266$ A/cm$^2$, electrolysis time (2–12 minutes), and varied distances (0.5, 1, 2, and 3 cm) between electrodes, indicating that the turbidity decreased slightly when the distance was increased from 0.5 to 1 cm (from 7.9 to 7.79 NTU), but the turbidity increased to 9 NTU when the spacing between electrodes was 2 and 3 cm. Thus, the optimal distance is indicated to be about 1 cm. It can be explained that decreasing the space between the electrodes in low resistance through the solution can increase the rate of dissolution of aluminum and release of Al$^{3+}$. By increasing the dissolution rate of Al$^{3+}$ which can form coagulant compounds Al(OH)$_3$ can cause more turbidity removal from the solution. However, reducing the distance between the electrodes can improve the flotation process by limiting the resulting bubbles in a narrow space. Thus, it can increase the efficiency of water turbidity removal [11].

Three factors have been studied, namely: processing time, voltage and electrode size which are related to the effect of reducing chemical oxygen demand (COD) and turbidity in the waste water electrocoagulation process. The results of the statistical study showed that these three factors had a significant effect on the reduction of COD and turbidity. This means that the ability to reduce COD and turbidity from the electrocoagulation process in waste water treatment can be adjusted by changing the processing time, the amount of voltage and the dimensions of the electrodes [12].
Optimization of the electrocoagulation process using the Response Surface Methodology (RSM) through the Behnken-Box Design (BBD) has been carried out by Igwegbe et al., to treat wastewater from aquaculture ponds using iron-aluminum (Fe-Al) electrodes. From the research results it was found that the optimum conditions were found with a filling time of 11.970 minutes, a settling time of 29.994 minutes and a current density of 2.389 A. In these conditions the process was able to remove turbidity reaching 91.84% at a temperature of 30 °C and an initial pH of 8 for a volume of 500 mL of waste water [13].

Various electrocoagulation methods for waste water treatment have been carried out. Nevertheless, no comparison was made for the removal efficiency of sono-alternate current (SAC), alternative current (AC), sono-direct current (SDC), and direct current (DC) electrocoagulation processes. The efficiency of the electrocoagulation method was compared for removing color and turbidity. Batch reactor DC/AC electrocoagulation cells were used to determine the removal efficiency. During the comparison process, response surface methodology (RSM) was used to analyze and optimize the data retrieved from the laboratory. In addition, ANOVA is also used to analyze the interaction effect of different parameters. The results showed that the removal of color and turbidity of domestic waste water was 97.53% and 95.28%, respectively, using direct current electrocoagulation (DCE). For alternative current electrocoagulation (ACE), the removal of color and turbidity were 98.35% and 96.12%, respectively. Discoloration and turbidity for sono-DCE (SDCE) were obtained 98.55% and 98.27%, respectively and for sono ACE (SACE), decolorization and turbidity were 99.95% and 99.76%, respectively, on initial conditions of the experiment with a chemical oxygen requirement (COD) of 960 g/L, pH 6.8, current density of 0.4 A/dm², 1 cm distance between electrodes made of Al-Al. The SAC method electrocoagulation process is the best and promising technique compared to all other electrocoagulation methods [14].

The implementation of electrocoagulation process research combined with ultrasonic energy (Sono-Electrocoagulation) has been carried out to reprocess oily car wash waste water. The variables studied were stress and time for removal of COD, turbidity, conductivity, and total dissolved solids (TDS). The electrocoagulation process was carried out at an initial pH of 7 and an electrode distance of 2 cm. The best research results from removing COD, turbidity, TDS, and reducing electrical conductivity are when the voltage is 30 V and the processing time is 90 minutes [15].

The equation for the reaction that occurs in the electrocoagulation process with aluminum electrodes is as follows (Kowalski et al., 2019)[16]:

reaction at the anode (oxidation):
\[ 2 \text{Al} \rightarrow 2 \text{Al}^{3+} + 6 \text{e}^- \]  \hspace{1cm} (2)

reaction at the cathode (reduction):
\[ 6\text{H}_2\text{O} + 6\text{e}^- \rightarrow 6\text{OH}^- + 3\text{H}_2 \]  \hspace{1cm} (3)

total reaction
\[ 2 \text{Al} + 6\text{H}_2\text{O} \rightarrow 2 \text{Al(OH)}_3 + 3\text{H}_2 \]  \hspace{1cm} (4)

From Equation (4) it appears that the coagulant Al(OH)_3 is formed which is a compound that easily forms lumps or flocs, making it easier for pollutants in water to be trapped and precipitated. One of the advantages of using the electrocoagulation process is that there is no need for a filter to filter bacteria or other pollutants, because the bacteria will be carried away by the Al(OH)_3 coagulant.

METHODS

The procedure of the research was carried out in the following order: preparing raw materials, preparing equipment, preparing the place, designing research tools, conducting research, analyzing and concluding results.

The materials needed include: fish pond water, electrical cables, pralon pipes and aluminum plates. While the equipment needed includes: avometer, electrocoagulation process tank, settling tank, process water storage tank, compressor, DC source, DO meter (dissolved oxygen meter), and turbidimeters. The place of research is in the Telecommunications Laboratory and the Electrical Laboratory.

Figure 1 shows a digital turbidimeter and Figure 2 is digital DO (dissolved Oxygen) meter device.

**Turbidity measurement**

**a. Perform tool calibration**

Clean the standard bottle to be used for calibration. Insert the standard bottle into the sample holder. Pressing the command
CAL. Turbidimeter will show the value according to the standard turbidimeter solution. Repeat turbidimeter calibration for other standard turbidity values (used include: 0 NTUs, 0.02 NTUs, 200 NTUs, 500 NTUs, 1000 NTUs).

b. Measurement of turbidity
Connect the turbidimeter to an electric current source and let it stand for approximately 15 minutes. Place the bottle containing the sample at the sample measurement site on the turbidimeter. Read the turbidity value on the screen. Repeat the turbidity measurement at least 3 times. The value of turbidity is taken by the average result of the three experimental results.

Figure 1. Turbidimeter

Dissolved Oxygen measurement

a. Perform tool calibration
Calibration is carried out by comparing the measurement results with the measurement results using the Winkler titration method for the same sample water.

b. Measurement of Dissolved Oxygen
To measure dissolved oxygen in water, it is done by taking a water sample between 10 to 20 cc and putting it into the Erlenmeyer. Next, insert the digital DO meter into the Erlenmeyer which has been filled with water. Turn on the DO meter in a few minutes until the tool reading is at a stable number. When reading the numbers has been completed, the DO meter is turned off. Measurement of dissolved oxygen content was repeated a minimum of three times for each experiment. The value of dissolved oxygen was taken from the average result of the three experimental results.

Figure 2. DO (dissolved Oxygen) meter
The set of equipment used for research can be seen in Figure 3.

Figure 3. The equipment for research
In this study, the process of water flow was carried out in batches and the flow pattern occurs by gravity. The study began by measuring the turbidity of fish pond water using a turbidimeter and dissolved oxygen in the water using a DO (dissolved oxygen) meter.

In the first experiment, 40 liters of fish pond water samples were taken from one edge of the fish pond. Then put the water sample into the storage tank. In the second experiment, 40 liters of fish pond water samples were taken from the other side of the fish pond. Then put the water sample into the storage tank. In the third experiment, 40 liters of fish pond water samples were taken from the center of the fish pond. Then put the water sample into the storage tank.

For each experiment, drain 10 liters of fish pond water from storage tank with a size of 40 x 40 x 40 cm into the electrocoagulation process tank with the chamber divided into three cells. In each cell with a size of 5 x 25 x 25 cm was installed an anode and cathode are made from aluminum with a size of 1 mm x 20 x 20 cm. The electrocoagulation process is carried out at 12 volt in electric voltage or 0.3
ampere in electric current and every 10 minutes the process was stopped, and then the water was flowed into the settling tank with a size of 15 x 15 x 15 cm. The residence time of water in the settling tank was 30 minutes to precipitate impurities by gravity. The water that has been separated from the sediment is flowed into the holding tank with a size of 15 x 15 x 15 cm and followed by aeration process. The air for the aeration process was passed through a perforated pipe with a diameter of 2 mm as many as 100 pieces. The rate flow of air was 500 cc per minute for 30 minutes. The aeration process was stopped and turbidity and dissolved oxygen in the water were measured. Take a sample water of 10 to 20 cc from the holding tank and put it in the sample bottle. Measure turbidity with a turbidimeter and dissolved oxygen with a DO meter in a sample placed in the bottle. Turbidity and dissolved oxygen measurements were carried out in three times. The value of turbidity and dissolved oxygen is taken from the average of the three measurement results.

Subsequent studies were carried out using the same procedure, but the electrocoagulation process was carried out with a difference process time of 10 minutes.

RESULT AND DISCUSSION
The results of water quality measurements taken directly from pond water are shown in Table 1.

Table 1. The quality of fish pond water

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Measurement Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>2.9 mg/L</td>
</tr>
<tr>
<td>Manganese</td>
<td>2.2 mg/L</td>
</tr>
<tr>
<td>pH</td>
<td>6.1</td>
</tr>
<tr>
<td>Turbidity</td>
<td>68 NTU</td>
</tr>
<tr>
<td>Organic Com</td>
<td>25 mg/L</td>
</tr>
<tr>
<td>Sodium</td>
<td>232 mg/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>27 mg/L</td>
</tr>
<tr>
<td>Dissolved O2</td>
<td>2.8 mg/L</td>
</tr>
</tbody>
</table>

From Table 1, it can be explained that the turbidity of the fish pond water reaches 68 NTU. This shows that the quality of fish pond water is not suitable for fish farming. Because the maximum allowable requirement for fish farming is 50 NTU [1]. This means that the fish pond water must be treated until the maximum turbidity is met at 50 NTU. In this case the processing is carried out using the electrocoagulation method combined with the aeration process. The aeration process is carried out to help accelerate the process of dissolving oxygen in the resulting water.

The results of the research on the effect of changes in turbidity on dissolved oxygen from the results of the electrocoagulation and aeration processes can be seen in Table 2.

Table 2. The results of measurement of the turbidity and dissolved oxygen

<table>
<thead>
<tr>
<th>Time (Minutes)</th>
<th>Turbidity (NTU)</th>
<th>Dissolved Oxygen (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>68</td>
<td>2.8</td>
</tr>
<tr>
<td>10</td>
<td>66</td>
<td>3.1</td>
</tr>
<tr>
<td>20</td>
<td>63</td>
<td>3.6</td>
</tr>
<tr>
<td>30</td>
<td>59</td>
<td>4.1</td>
</tr>
<tr>
<td>40</td>
<td>54</td>
<td>4.7</td>
</tr>
<tr>
<td>50</td>
<td>45</td>
<td>5.3</td>
</tr>
<tr>
<td>60</td>
<td>41</td>
<td>5.7</td>
</tr>
<tr>
<td>70</td>
<td>36</td>
<td>6.1</td>
</tr>
</tbody>
</table>

Based on Table 2, it can be explained, if the electrocoagulation process takes longer, the turbidity will be decreased. Meanwhile, the solubility of oxygen in water was increased.

The decrease in turbidity as a result of the increasing number of pollutants absorbed by the Al (OH)₃ coagulant forms clumps or flocs which are increasing in number and easily deposited on the bottom of the process tank [16]. Thus the fish pond water was processed by electrocoagulation becomes clearer [15].

From Table 2, it appears that reducing the turbidity of water can increase the solubility of oxygen in water [3]. Water with low turbidity can help accelerate the solubility of oxygen in water [6]. Because water that has a high level of clarity will have a higher total transfer coefficient than water that is dirtier. Thus, the rate of mass transfer (diffusion) of oxygen into the water increases [8], so that the solubility of oxygen into the water increases more and more [7]. The requirement for water turbidity for fish farming is 50 NTU and a minimum dissolved oxygen of 5.0 mg/L [1]. Based on Table 2, it can be found that the conditions meet the requirements to produce water for fish farming. These conditions can be found in the electrocoagulation process with a processing time of 50 minutes combined with an aeration process for 30 minutes at an air discharge of 500 cc per minute. Under these conditions the turbidity of the
water is 45 NTU and dissolved oxygen is 5.3 mg/L. In this case, there was a decreased in turbidity from 68 NTU to 45 NTU or the equivalent of 33.82% and an increased in dissolved oxygen from 2.8 mg/L to 5.3 mg/L or the equivalent of 89.29%.

Fish pond water that has been processed by electrocoagulation at voltage of 12 volts or the current at 0.3 ampere for minimum process time at 50 minutes and combined with aeration process for 30 minutes has a turbidity of 45 NTU and dissolved oxygen of 5.3 mg/L. Based on water quality standards for fish farming, the treated water is quite suitable for fish farming. Because the turbidity is less than 50 NTU and the dissolved oxygen is more than 5 mg/L.

If the relationship between the effect of turbidity on the solubility of oxygen in water is made into a curve, then this relationship can be seen in Figure 4.

![Figure 4. Curve turbidity vs DO](image)

From Figure 4, it can be explained that the solubility of oxygen in the water tends to decrease when there is an increase in turbidity, because it appears from the negative value of the coefficient. Based on Figure 4, it can also be analyzed that the turbidity and the solubility of oxygen in the water have a very close relationship, because the determination value (R²) is 0.9814. This means, when there is more increasing in turbidity, the oxygen that can dissolve into the water is decreasing.

**Application of equipment for fish farming**

The water treatment equipment that has been made can be used to help consumption fish farmers whose water has turbidity exceeding safe limits. For applications in the field, the tool must be scale up to a larger size and the process is conducted in continuously.

Another function of this equipment is to increase the pH of the water. Usually, the water becomes acidic when it rains and can cause death to fish. By processing using this tool, acidic water can be reduced its acidity level.

**CONCLUSION**

The electrocoagulation process combined with the aeration process can be reduced turbidity and increased dissolve oxygen in pond water. The best conditions were obtained in the electrocoagulation process which was conducted at 12 volts at process time of 50 minutes with combined an aeration process for 30 minutes with an air discharge of 500 cc per minute. Under these conditions turbidity can be reduced from 68 NTU to 45 NTU or equivalent to 33.82% and dissolved oxygen can be increased from 2.8 mg/L to 5.3 mg/L or equivalent to 89.29%

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