The effectiveness of anode variations for electrocoagulation and its application for laundry wastewater treatment

Suhartana
Department of Chemistry, Diponegoro University Jl. Prof. H. Soedharto, SH, Tembalang, Semarang, Indonesia

Corresponding author: suhartana@lecturer.undip.ac.id

Abstract. Since Diponegoro University moved its campus to the Tembalang area, it has been full of issues of decreasing groundwater quality and aesthetic decline caused by laundry wastewater and washing and toilet wastewater which has growing rapidly along with the growth of boarding houses in the Tembalang area. This will have an impact on the health quality of the people who live in the Tembalang area. This study aims to reduce the content of dissolved organic matter in laundry wastewater and bath wash also bath, wash and toilet wastewater. The method chosen was the electrocoagulation method, using 2 different electrodes. The electrodes chosen are aluminum metal and ferrous metal (as anode) and carbon (as cathode). With the electrocoagulation method using aluminum electrodes (as anode) and carbon (as cathode) the amount of organic material that could be removed was 60.1%. Meanwhile, with ferrous metal (as anode) and carbon (as cathode) the amount of organic material that can be removed is smaller, namely 52.2%. The addition of 100 ppm NaCl solution and 100 ppm Na₂SO₄ solution was able to increase the efficiency of organic matter removal by 1.8-2.5%.

1. Introduction
Wastewater from the laundry process usually contains surfactants, and by the community the wastewater is discharged directly into rivers or sewers. Laundry wastewater that is not treated and disposed of directly by the community has the potential to be a major source of pollution for rivers in big cities in almost all countries. Water treatment methods that are often and most widely used for laundry wastewater treatment are coagulation, flotation, adsorption and chemical oxidation or a combination of both. Due to the increasing number of washing machines, the resulting laundry wastewater will also increase. Therefore, the development of laundry wastewater treatment methods is interesting and necessary. Recently, electrochemical methods are quite popular in treating wastewater because of their safe and environmentally friendly nature [1, 2]. Several decades of electrochemical techniques have been quite effective in treating wastewater containing several organic and inorganic compounds, including phenols, dyes, metal ions, cyanides, surfactants etc., as investigated by several authors [1-5]. The indirect electrochemical oxidation of linear alkyl sulfonates (LAS) and alkylbenzene sulfonates (ABS) can be completely eliminated (almost completely lost), in particular [3, 4] by indirect electrochemical oxidation in conjunction with chemical coagulation. BDD and graphite electrodes were used to degrade two surfactants in aqueous solution [4, 5].

Detergent from washing wastewater can cause water pollution. Detergent compounds do not decompose or degrade in aquatic systems. This detergent is very dangerous and poisonous. Accumulation of some detergents in wastewater is a serious environmental problem [6]. Detergent is a
material containing soap or other surfactants intended for the water-based dishwashing or washing process. Detergent can be used in any form (paste, bar, liquid, powder, cake, mold, etc.), widely for household, household and industrial cleaning products. Surfactants are organic substances, used in detergents, which are intentionally added for cleaning, rinsing and/or softening fabrics because of their surface active properties [7]. Surfactants consist of one or more hydrophilic and hydrophobic groups with such properties and sizes that they can form micelles. Surfactants include chemicals with high environmental relevance due to their large volume of production. If the surfactants are discharged directly into the environment as wastewater, either after being treated in a wastewater treatment plant or directly disposed of [7]. Surfactants are widely used for household and industrial use, particularly as detergents in cleaning applications. Surfactant deconcentrating involves processes such as chemical and electrochemical [7-9]. Among electrochemical technologies, electrocoagulation and electro flotation may be effective substitutes for conventional coagulation and automation in wastewater treatment processes [10]. Electrocoagulation and electoflocculation have been reported to successfully treat wastewater of various types, which contain oil [11], fluoride [12], arsenic [13], dyes [14-19], suspended particles [20], surfactants [21], chromium ion [21], phosphate [22-24] and so on.

Electrocoagulation is an electrochemical technology for treating polluted water where the anode can dissolve due to the difference in potential/voltage applied to the electrocoagulation system, resulting in active coagulant/sediment, as an active adsorbent in situ (such as hydro iron oxide, aluminum hydroxide). Good reviews of electrocoagulation are provided by [25-27]. In electrocoagulation cells, the electrochemical reaction with the Al metal as the resulting Al³⁺ cation electrode is immediately hydrolyzed to produce the appropriate hydroxide and/or polyhydroxide in enough pH. Aluminum hydroxide and polyhydroxide from electrochemical solutions are reported to have a stronger affinity for trapping pollutants in wastewater, causing more coagulation than conventional Al coagulants [27]. The reaction is as follows:

The oxidation reactions taking place at the anode are as follows:

\[
Al \rightarrow Al^{3+} + 3e^- \\
Fe \rightarrow Fe^{3+} + 3e^-
\]

The reduction reaction taking place at the anode is as follows:

\[
3H_2O + 3e^- \rightarrow 3/2 H_2 + 3OH^- 
\]

Dissolving the aluminum anode yields Al³⁺ and Al(OH)²⁺ at low pH, which at the appropriate pH are initially converted to Al(OH)₃. However, depending on the pH of the aqueous medium, other ionic species such as Al(OH)²⁺, Al₂(OH)₄⁺ and Al(OH)₃⁺ can also be present in the EC system [26].

\[
Al^{3+} + H_2O \rightarrow Al(OH)^{2+} + H^+ \\
Al(OH)^{2+} + H_2O \rightarrow Al(OH)_2^{2+} + H^+ \\
Al(OH)_2^{2+} + H_2O \rightarrow Al(OH)_3^{3+} + H^+ 
\]

The formation of hydroxide deposits in the sample affects Al dissolution and electron transfer and limits the formation of Al³⁺ in solution. As a result, electrocoagulation systems are usually designed to operate in high voltage conditions, (typically higher than 10 V). Therefore, the energy consumption is high, and the electrodes are likely to be damaged when using high voltages for long-term operation. To overcome this, some researchers need voice assistance at frequency (20-400 Hz) to improve/increase the percentage of detergent removal in washing water using carbon and steel as electrodes [28].

This study aims to treat detergent wastewater using the electrocoagulation method. It is often encountered that the degradation of organic pollutants in wastewater requires special electrodes [2]. Electrocoagulation experiments on detergents were carried out with aluminum and ferrous metals as anodes, and carbon as anodes. Electrocoagulation involves forming a coagulant in situ by electrically dissolving aluminum or iron ions from an aluminum or iron electrode. Metal ion formation occurs at the anode, hydrogen gas is released from the cathode. Hydrogen gas will also help to remove flocculated
particles from the water. This process is often called the electrocoagulation or electroflocculation process [29]. With the electrocoagulation method using aluminum electrodes (as anode) and carbon (as a cathode), the amount of organic material that can be removed is 60.1%. Meanwhile, with ferrous metal (as anode) and carbon (as cathode), the amount of organic material that can be removed is smaller, namely 52.2%. The addition of 100 ppm NaCl solution was able to increase the efficiency of organic matter removal by 1.8-2.5%.

2. Research method

2.1. Equipment and materials
The equipment used is an Electrocoagulation waste treatment reactor, adapters, aluminum and iron metals (anodes) and carbon (cathode). Also equipped with a rectifier as a regulator of current and voltage. Titration equipment such as a set of titration devices (erlenmeyer, burette and stative), glassware (20 mL volume pipette, 100 mL measuring flask and dropper pipette).

The materials used were air household laundry waste from boarding houses in Tembalang and from Bukit Kencana Jaya Tembalang Semarang, Na$_2$SO$_4$, NaOH, H$_2$SO$_4$, K$_2$Cr$_2$O$_7$, HgSO$_4$, Ag$_2$SO$_4$, ferro ammonium sulfate, ferroin indicator, Whatman 40 paper and distilled water.

2.2. Sampling procedure
Samples were collected from household laundry wastewater from the boarding house in Tembalang and from the Bukit Kencana Jaya Tembalang housing complex, Semarang. The resulting waste is disposed of into sewers/drains or into rivers without any treatment. Detergent wastewater sampling is carried out according to standard methods for inspection of wastewater.

2.3. Electrode preparation
The metal electrodes used are made of aluminum and iron, with a width of 20 mM, 150 mM long and 1.5 mM thick (as anode) and carbon electrode (as a cathode) with a width of 20 mM, 150 mM long and 1.5 mM thick,

2.4. Instrument design
The electrolysis reactor consisted of an adaptor, Aluminium (Al) and Iron (Fe) (as anode) placed parallel to the carbon plate (cathode), with varying distances of 1, 2, 3, 4, 5, 6 and 7 cm. The setup was then mounted on a 1000 mL glass container and connected to a DC current source.

The experimental image is presented in Figure 1 as follows. A set of electrocoagulation reactors, consisting of aluminum metal, ferrous metal (as anode) and carbon (as a cathode).

![Figure 1. Schematic diagram of electrocoagulation experimental equipment [26]](image-url)
2.5. Effects of voltage, electrode distance, pH, and time on decreasing COD value.
The sample, 1000 ppm of household laundry wastewater from the boarding house in Tembalang and
from the Bukit Kencana Jaya Tembalang housing complex, Semarang, was put into the reactor. HCl and
NaOH were added into the solution to regulate acidic and alkaline atmospheres of the solution. In this
study the pH of the solution, voltage, electrode distance and electrolysis time were varied.

Aluminium (Al) and carbon electrodes were immersed into the reactor with a distance of 1 cm. The
solution was electrolyzed at a time variation of 0 to 100 minutes with an interval of 10 minutes at a
voltage of 10 V and a current density of 12.5 mA/cm². COD values are determined before and after
electrolysis. The same procedure was performed for voltage variations of 2, 4, 6, 8, 10 and 12 Volt,
electrode distance of 1; 2; 3; 4; 5; 6 and 7 cm. The same procedure was also carried out for Iron (as
anode) and carbon electrodes.

2.6. COD analysis (APHA, 1995)
COD determination was carried out using the iodometric titration method. As much as 5 mL distilled
water as blank solution and 5 mL of sample were put into Erlenmeyer 250 mL. They were added with
2.5 mL K₂Cr₂O₇-HgSO₄ and 5 mL H₂SO₄-Ag₂SO₄. The solutions were covered and heated for 2 hours
in an oven at 150°C. They were then cooled, and the lids were rinsed with 2 mL of distilled water. 1 mL
of concentrated H₂SO₄ and 3 drops of ferroin indicator were added. Titration was done with ferrous
ammonium sulfate standard solution of 0.025 N until the equivalence point (colored red brown) was
reached. Determination of COD levels is calculated by the following formula:

\[ \text{COD Concentration (ppm)} = (A - B) \times N \times 8000 \text{ mL sample} \]

Descriptions:
A: Volume (mL) of titrant for blank solution
B: Volume (mL) of titrant for sample solution
N: Solution normality of Fe(NH₄)₂SO₄

3. Result and discussion
The electrocoagulation method is carried out using two different anodes, namely aluminum metal and
ferrous metal. Theoretically all these metals are capable of functioning as anodes. But in fact, even
though aluminum and ferrous metals can work optimally for the electrocoagulation process and give a
different percentage of organic matter removal results. In fact, ferrous metal gives a smaller percentage
of organic matter removal than aluminum metal which is used as an electrode in electrocoagulation. The
effectiveness of the two methods (electrocoagulation) was seen from the reduction in Chemical Oxygen
Demand (COD) from the laundry wastewater between before and after undergoing treatment. The
samples chosen in this study were laundry wastewater from the Tembalang Campus Area Washing
Semarang and laundry wastewater from the Bukit Kencana Jaya Housing Area Washing Semarang. The
analysis was carried out by physical analysis and chemical analysis. In summary, the results of the
physical analysis and chemical analysis of leachate from the two samples (Tembalang Campus Area
Semarang and the Bukit Kencana Jaya Semarang Housing Area) can be explained as follows.

3.1. Results of analysis of laundry wastewater in Tembalang campus area Semarang and Bukit Kencana
Jaya housing area Semarang
Measurement of the quality of laundry wastewater at Tembalang Dormitory area and the Bukit Kencana
Jaya Semarang residential area were carried out by physical and chemical measurements. Physical
measurements include odor, color, taste, temperature, dissolved residue and suspended residue.
Chemical measurements include pH, COD, BOD, NO₃ as N and NO₂ as N [25]. The results of the
analysis of Laundry Wastewater in the Tembalang Semarang Campus Area were compared with the
requirements permitted by the Government of the Republic of Indonesia, namely the Regulation of the Minister of Health (PerMenKes) RI No: 416/MENKES/PER/IX/1990 and PP No: 82 of 2001, especially on quality water IV. The results obtained are as follows:

**Table 1.** The results of the analysis of the average laundry wastewater from the Tembalang campus of Semarang after the electrocoagulation process using aluminum and iron (as anode) and carbon (as a cathode) at a voltage of 10 volts.

| Parameter         | Before electrocoagulation process | After electrocoagulation | PerMenKes No: 416/1990 | PP No: 82 year 2001 |
|-------------------|-----------------------------------|--------------------------|------------------------|---------------------|
| Odor              | A little smelly                   | No odor                  | No odor                | No odor             |
| Color             | 3.1 scale TCU                     | No color                 | 15 scale TCU           | No color            |
| Taste             | -                                 | -                        | No taste               | No taste            |
| Turbidity         | 1.1 scale NTU                     | 0.1 scale NTU            | 5 scale NTU            | -                   |
| Temperature       | 29.8°C                            | 29°C                     | Room T ± 3°C           | Deviation 3°C from room T |
| Dissolved residue | 690 mg/L                          | 108.8-74.2 mg/L          | 2000 mg/L              | 2000 mg/L           |
| Suspended Residue | 82.1 mg/L                         | 9.2 mg/L                 | 400 mg/L               | 400 mg/L            |
| pH                | 6.1                               | 6.9                      | 5.9                    | 5.9                 |
| COD               | 48 mg/L                           | 8.62 mg/L                | 100 mg/L               | 100 mg/L            |
| BOD               | 2.2 mg/L                          | 0.21 mg/L                | 12 mg/L                | 12 mg/L             |
| NO3 as N          | 3.1 mg/L                          | 0.31 mg/L                | 10 mg/L                | 20 mg/L             |
| NO2 as N          | -                                 | -                        | 1 mg/ L                | -                   |

The results of the analysis of Laundry Wastewater for the Bukit Kencana Tembalang Semarang residential area were compared with the requirements permitted by the Government of the Republic of Indonesia, namely the Regulation of the Minister of Health (PerMenKes) RI No: 416/MENKES/PER/IX/1990 and PP No: 82 of 2001 especially on water quality IV. The results obtained in table 2.

If you pay attention to the results of the analysis of the quality of laundry wastewater from the Tembalang campus area in Semarang and Laundry Wastewater in the Bukit Kencana Tembalang Housing Area, Semarang after the electrocoagulation process using aluminum and iron (as anode) and carbon (as a cathode) at a voltage of 10 volts, it is experiencing a decrease. varies. The results of the analysis of the quality of laundry wastewater from the Tembalang campus area in Semarang are slightly worse when compared to Laundry Wastewater for the Bukit Kencana Tembalang Housing Area, Semarang because the population density in the Tembalang area is denser than in the Bukit Kencana Jaya Housing, so that the laundry waste water obtained is also less not good. From the electrolysis variable data obtained (voltage, time, electrode distance and pH), it can be concluded that electrolysis without the help of electrolyte solutions is still small (below 60%). Therefore, to increase the yield of electrolysis is done by adding a strong electrolyte solution (NaCl 100 ppm and NaCl 200 ppm), as well as with a strong electrolyte (Na2SO4 100 ppm and Na2SO4 200 ppm). The electrocoagulation process was able to reduce the Chemical Oxygen Demand (COD) price by 68.6%, by using aluminum as anode, while using iron was only able to reduce it by 61.1%. The addition of inorganic salts (100 ppm NaCl and 100 ppm Na2SO4) was able to increase the yield of organic matter removal between 2.1-5.1%. This
may be due to the difference in oxidation potential between iron and aluminum. The oxidation potential and oxidation reaction of the two anode metals are as follows:

\[
\text{Fe/Fe}^{2+} : \text{Fe}^{2+} + 2 \text{e} \rightarrow \text{Fe}. \ E_{\text{red st}} = -0.44 \text{ Volt} \\
\text{Fe/Fe}^{3+} : \text{Fe}^{3+} + 3 \text{e} \rightarrow \text{Fe}. \ E_{\text{red st}} = -0.46 \text{ Volt} \\
\text{Al/Al}^{3+} : \text{Al}^{3+} + 3 \text{e} \rightarrow \text{Al}. \ E_{\text{red st}} = -1.16 \text{ Volt}
\]

Table 2. The results of the average analysis of Laundry Wastewater in the Bukit Kencana Tembalang Housing Area, Semarang, after the electrocoagulation process using aluminum and iron (as anode) and carbon (as cathode) at a voltage of 10 volts.

| Parameter          | Before electrocoagulation Process | After electrocoagulation process | PerMenKes No: 416/1990 | PP No: 82 year 2001 |
|--------------------|-----------------------------------|----------------------------------|-------------------------|---------------------|
| Odor               | A little smelly                   | No odor                          | No odor                 | No odor             |
| Color              | 3 scale TCU                       | No color                         | 15 scale TCU            | No color            |
| Taste              | -                                 | -                                | No taste                | No taste            |
| Turbidity          | 1.1 scale NTU                     | 0.1 scale NTU                    | 5 scale NTU             | -                   |
| Temperature        | 29.8°C                            | 29°C                             | Room T ± 3oC            | Deviation 3°C from room T |
| Dissolved Residue  | 670 mg/ L                         | 102.6-71.2 mg/L                  | 2000 mg/ L              | 2000 mg/ L          |
| Suspended Residue  | 78.1 mg/ L                        | 8.7 mg/ L                        | 400 mg/ L               | 400 mg/ L           |
| pH                 | 6.1                               | 6.9                              | 5-9                     | 5-9                 |
| COD                | 42 mg/ L                          | 8.02 mg/ L                       | 100 mg/ L               | 100 mg/ L           |
| BOD                | 2.2 mg/ L                         | 0.21 mg/ L                       | 12 mg/ L                | 12 mg/ L            |
| NO3 as N           | 3.1 mg/ L                         | 0.31 mg/ L                       | 10 mg/ L                | 20 mg/ L            |
| NO2 as N           | -                                 | -                                | 1 mg/ L                 | -                   |

As a test of the effectiveness of the performance of the two electrodes, samples of laundry wastewater from the Tembalang campus area in Semarang were used and the Laundry Wastewater for the Bukit Kencana Tembalang Semarang housing area was electro coagulated in various alkaline conditions (pH = 8), in which the sample was dissolved in distilled water without electrolytes (presented on a graph in the notation Fe and Al). In the electrocoagulation method aluminum metal (as anode) always has a better efficiency than ferrous metal, because the oxidation potential of Al/Al³⁺ is higher than that of Fe/Fe²⁺, so that the process of forming Al(OH)₃ deposits is more effective than the process of forming a precipitate Fe(OH)₃. Whereas in the electro method Fenton aluminum metal (as anode) always has a better efficiency than ferrous metal, because the oxidation potential of Al/Al³⁺ is higher than Fe/Fe²⁺, so the redox process on aluminum anodes tends to be more effective than iron anodes.

3.2. Optimization of electrolysis method

In this research, a study on the optimization of the electrocoagulation process from a household laundry wastewater from a boarding house in Tembalang and from the Bukit Kencana Jaya Tembalang housing complex has been carried out. Electrocoagulation by varying the type of electrode, electrode distance, voltage, adjusting the degree of acidity (pH) and contact time to the percentage of electrocoagulation. The indicator of the success of the electrolysis process is measured by looking at the decrease in COD values between before and after experiencing the electrocoagulation process, this is in accordance with the method that has been done and reported by [12, 16, 17] or by measuring COD and BOD [16, 17].
3.2.1. **Voltage optimization and electrocoagulation time optimization.** In this electrolysis research, voltage variations have been carried out for various anodes. For ferrous metals (as anode) the voltage is given from 6; 8; 10; 12 and 14 volts. The results obtained are quite optimal at 10 volts. For aluminum metal (as anode) the voltage is given from 6; 8; 10; 12 and 14 volts. The results obtained are quite optimal at 10 volts. The results of the optimal voltage from each anode are then used to find the optimization of other variables that affect the percentage of electrolysis yield. It's just that the results of the percentage of removal of organic matter from household laundry wastewater from the boarding house in Tembalang and from the Bukit Kencana Jaya Tembalang Semarang housing that were obtained after experiencing the electrocoagulation process are different, as seen in Figure 2 and Figure 3.

![Graph](image1.png)

**Figure 2.** Percentage results of organic matter removal after electrocoagulation using ferrous metal (as anode) and carbon (as cathode) at a voltage of 10 volts.

![Graph](image2.png)

**Figure 3.** The results of the percentage of organic matter removal after the electrocoagulation process using aluminum metal (as anode) and carbon (as a cathode) at a voltage of 10 volts.
3.2.2. Optimization of electrocoagulation time. After obtaining the optimal voltage, then determine the optimal electrocoagulation time. The selected time variations are from 10, 20, 30, 40, 50, 60, 70 and 80 minutes. It turns out that the optimal time obtained for metformin electrolysis is 50 minutes. However, the result of removal of organic matter in household laundry wastewater from the boarding house in Tembalang and from the Bukit Kencana Jaya Tembalang housing complex, Semarang provides a percentage of removal for organic matter from different laundry wastewater (from the boarding house in Tembalang and from the Bukit Kencana housing complex, Jaya), as shown in Figure 4.

![Figure 4](image)

**Figure 4.** The result of the percentage removal of organic matter against time, after the electrocoagulation process using aluminum and ferrous metals (as anode) and carbon (as a cathode) at a voltage of 10 volts.

3.2.3. Optimization of electrode distance. After obtaining the optimal voltage and optimal time is obtained then determined to determine the optimal electrode distance in the electrocoagulation process for the removal of organic material in household laundry wastewater from the boarding house area in Tembalang and from the Bukit Kencana Jaya Tembalang housing complex, Semarang. The electrode distance varied as following, starting from: 1; 2; 3; 4; 5; 6 and 7 cM. The results are presented in Figure 5.

![Figure 5](image)

**Figure 5.** The result of the percentage of organic matter removal to the Electrode Distance after the electrocoagulation process using aluminum and ferrous metals (as anode) and carbon (as a cathode) at a voltage of 10 volts.
3.2.4. Optimization of pH. After obtaining the optimal voltage, optimal time, the optimal distance is obtained and then determined to determine the optimal pH conditions in the electrocoagulation process for removal of organic matter in household laundry wastewater from boarding houses in Tembalang and from the Bukit Kencana Jaya Tembalang housing complex, Semarang. The varied pH are as follows, starting from: 1; 2; 3; 4; 5; 6; 7; 8; 9; 10 and 11. The results are presented in Figure 6.

![Figure 6](image_url)

**Figure 6.** The result of the percentage of organic matter removal to pH after the electrocoagulation process using aluminum and ferrous metals (as anode) and carbon (as cathode) at a voltage of 10 volts.

3.2.5. Optimization of electrolyte addition. From the data obtained from electrolysis variables (voltage, time, electrode distance and pH), it can be concluded that electrolysis without the help of electrolyte solutions is still small (below 51% for Fe anode and below 62% for Al anode). Therefore, to increase the yield of electrolysis is done by adding a strong electrolyte solution (NaCl 100 ppm), and with a strong electrolyte (Na2SO4 100 ppm) carried out at pH = 8, obtained a significant increase in electrolysis results. With the electrocoagulation method, when aluminum metal (as anode) was used, the amount of organic material that could be removed was 64.8%, while with ferrous metal (as anode) the amount of organic material that could be removed was smaller at 53.2%. The addition of inorganic salts (100 ppm NaCl and 100 ppm Na2SO4) was able to increase the yield of organic matter removal between 2.1-5.1%.

The presence of an electrolyte solution is thought to be able to help the mobility of electric current during the electrolysis process, so that the anode oxidation process can run well. The oxidation reaction of ferrous metal and aluminum metal (as anode) is as shown in Figure 7 as follows:

![Figure 7](image_url)

**Figure 7.** Effect of strong electrolyte solutions (NaCl and Na2SO4) on the percentage of removal of organic matter on the Electrode Distance after the electrocoagulation process using aluminum and ferrous metals (as anode) and carbon (as a cathode) at a voltage of 10 volts.
With the electrocoagulation method, when aluminum metal (as anode) was used, the amount of organic material that could be removed was 64.8%, while with ferrous metal (as anode) the amount of organic material that could be removed was smaller at 53.2%. This may be due to the difference in oxidation potential between iron and aluminum.

As a test of the effectiveness of the performance of the two electrodes, samples of household laundry wastewater from the boarding house in Tembalang and from the Bukit Kencana Jaya Tembalang Semarang housing were used electrocoagulation under various alkaline conditions (pH = 8), in which the sample was dissolved in distilled water without electrolytes (represented in graphs in Fe and Al notation). Meanwhile, the addition of strong electrolytes (NaCl and Na$_2$SO$_4$) (presented in the graph in the notation Fe + NaCl (100 ppm) and Fe + Na$_2$SO$_4$ (100 ppm), as well as the addition of strong electrolytes (NaCl and Na$_2$SO$_4$) are presented in Figure 7 above.

The addition of electrolyte solutions can affect the yield of electrolysis. The addition of sodium chloride (100 ppm) and sodium sulfate (100 ppm) salt can increase the electrolysis yield. This is presumably because the ion activity in the solution will increase if there is an addition of electrolyte solution, so that the mobility of the formation of ferric hydroxide and aluminum hydroxide flocks is easier to occur.

The advantages of electrocoagulation include high particulate removal efficiency, relatively easy maintenance facilities, relatively low cost and relatively good yields. The electrocoagulation chemical reaction mechanism that occurs at the anode in the process is given as follows (Songsak, 2006).

**Figure 8.** Mechanism of electrocoagulation chemical reaction [29]

Figure 8 shows the electrocoagulation reaction mechanism of organic compounds using an Al anode. The Al$^{3+}$ or Fe$^{2+}$ ion is a very efficient coagulant for particulate floculation. The hydrolyzed aluminum ion can form a large network of Al-O-Al-OH which can absorb pollutants chemically. Aluminum is usually used for water treatment and iron for wastewater treatment. Likewise, hydrolyzed Fe anode can form a large network of Fe-O-Fe-OH which can also absorb pollutants chemically such as Al anode [1, 5, 29].

**4. Conclusion**

The content of dissolved organic matter in laundry waste water from the Tembalang dormitory area is 48 ppm, and the dissolved organic matter content in laundry waste water from the Bukit Kencana Jaya Housing area is 42 ppm, still far below the limit of the Regulation of the Minister of Health of the Republic of Indonesia in PerMenKes No. : 416/1990 (100 ppm). The electrocoagulation method uses aluminum metal (as anode), the amount of organic material that can be removed is 60.1%, while using ferrous metal (as anode) the amount of organic material that can be removed is smaller, namely 52.2%. The addition of inorganic salts (100 ppm NaCl and 100 ppm Na$_2$SO$_4$) can increase the yield of organic matter removal between 2.1-5.1%.
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