Electrocoagulation and electro fenton and their applications in the processing of lindi water from landfill waste in campus area of Diponegoro University

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Abstract. Piles of garbage could an impact on reducing aesthetics, lowering the quality of groundwater and the health of the people who live around the landfill (TPA). The focus of research aims to reduce the content of organic pollutants dissolved in leachate at the Diponegoro University landfill (TPA). There are 2 methods chosen, namely the electrocoagulation method and the Fenton electro method. The electrodes used in these 2 methods are the same, namely aluminum and ferrous metals (as anode) and carbon (as cathodes). Our observations in the laboratory show that the dissolved organic matter in leachate at Diponegoro University's final disposal site (TPA) (COD parameter) was 6.2 ppm, still far below the leachate content of TPA Jati barang 9.1 -16.2 ppm. The limit of the Government of the Republic of Indonesia in PP 82, 2001 (10 ppm). With the electrocoagulation method, when aluminum metal (as anode) was used, the amount of organic material that could be removed was 77.6%, while with ferrous metal (as anode) the amount of organic material that could be removed was smaller, namely 69.8%. Whereas with the Fenton electro method, when using aluminum metal (as anode), the amount of organic material that could be removed was 89.9%, while with ferrous metal (as anode) the amount of organic material that could be removed was smaller, namely 71.6%. 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%.

1. Introduction
The trend of significant population growth, resulting in population growth. The existence of urbanization and industrialization used to achieve the quality and welfare of human life has resulted in high waste production (solid, liquid and gas). As a result of the massive migration of villagers to urban areas, besides being able to increase the country's per capita income, it could potentially increase waste (solid and liquid) by up to 90% in almost the last decade including Indonesia and Malaysia [1]. With the rapid increase in landfills in landfills, the land used for disposal has also increased. However, in landfills, leachate is generally a problem as a source of wastewater, because it can cause serious pollution to the ecosystem and this results as a factor in decreasing the quality of human life comfort. Leachate discharge can directly seep into groundwater or mix with surface water so as to contaminate soil, groundwater and surface water [2].

Often times, landfills are then covered with earth. In fact, landfilling is one of the most common ways to manage municipal waste. However, this technique can be associated with several environmental problems if the landfill is not properly monitored. For example, percolation of rainwater into landfills leads to the production of materials contaminated by organic, inorganic, and...
microbial materials called leachate, which have potential threats to both groundwater and surface water [3]. Almost every major city in Indonesia has provided a final waste processing site (TPA). However, most of these landfills only focus on waste processing. In fact, the landfill also causes leachate flow which can pollute the environment [4].

Leachate (leachate) produced from domestic waste generally has the characteristics of high organic matter content. So far, the handling of leachate from domestic waste is collected and processed in the processing system. This is usually done in landfills where there are leachate collection facilities and leachate treatment plants, but the reality on the ground shows that systems with these facilities are very rare, both in big cities and regions. Thus, most of the leachate treatment found in landfills is only collected and immediately disposed of into the environment, including some of it is infiltrated into the soil so that it can pollute the soil [5].

The leachate characteristics of landfill can be determined by several parameters: mode of operation (level of compaction, level of effluent, etc.). The character of waste pollution in TPA is influenced by several variables, for example the age of waste disposal, local climate, geological site and others. However, the character of waste is very much determined by age factor of the waste. Therefore, wastewater from landfill can be classified into 3 categories, namely: “mature”, characteristic of having a high concentration of organic pollutant decomposition product [6]. As a comparison, leachate of mature landfills can have more decomposed organic compounds than immature landfills. The mature land is usually more than ten years old [7].

The final waste disposal site at Diponegoro University is a center for collecting garbage from all Vocational Schools and Faculties, or BP and UPT in Diponegoro University. The existence of garbage collected in the landfill is immediately processed. The decomposed waste (organic, such as leaves, rotten fruits, etc.) is cut into small pieces, then fermented to obtain compost. Non-biodegradable waste such as paper, plastic, and others are separated and packed immediately because there are collectors who buy them. Because the waste processing system in Diponegoro University's landfill is quite good, the leachate obtained from TPA of Diponegoro University after analyzed showed good results. The average results of the analysis obtained during the study in January-March 2020 are as follows: color analysis 4.2 on the TCU scale; turbidity analysis 1.8 NTU scale; temperature 29.3°C; dissolved residue analysis 710 mg / L; analysis of suspended residues 96.2 mg / L; pH = 6.1; analysis COD = 6.2 mg / L; analysis of BOD = 2.1 mg / L and analysis of NO3 as N = 3.3 mg / L, still below the value stipulated by the Minister of Environmental and Forestry of the Republic of Indonesia.

In this research, the electrocoagulation method and the electrocoagulation method were chosen to treat leachate at the Diponegoro University landfill because they are quite easy to do and have a high enough efficiency. The principle of electrocoagulation (EC) is the occurrence of oxidation and reduction reactions in which the destabilization of contaminants (dissolved emulsified, or suspended) due to the application of an electric current to a sample solution. The EC equipment consists of an electrolytic cell and metal (Al and Fe) as anodes which are connected to an external power supply. A conductive metal plate is known as the 'reinforcing electrode' is made up of the same or very different material as the anode or cathode. In the EC process, anodic dissolution produces a coagulant which together with hydroxyl ions and hydrogen gas at the cathode. This coagulant causes the formation of hydroxide flocks on metal (Al or Fe) and /or poly hydroxide types. Hydrogen gas generated at the cathode carries light deposit on the surface of the water [8]. The conductivity (strongly influenced by chemical properties of the water medium) largely determines the EC mechanism [9]. Other factors such as pH, current density and electrode material also greatly influence EC and can act synergistically in removing pollutants from wastewater [10]. The ion generation mechanism by EC can be explained by the example of aluminum, which is used as anode and cathode in this study. The reactions that occur in the EC process using aluminum and iron anodes can be summarized as follows:

At the anode the reactions occur is the oxidation of the metals to its cations as follows:
whereas at the anode what occurs is a reduction reaction as follows:

\[ 3\text{H}_2\text{O} + 3\text{e}^- \rightarrow 3/2 \text{H}_2 + 3\text{OH}^- \]  

(3)

However, if given a high enough potential at the anode, it will cause a secondary reaction, namely the formation of oxygen as shown below [11]:

\[ 2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^- \]  

(4)

The presence of Cl- ions in wastewater can affect the oxidation reaction of organic compounds and often cause secondary reactions at the anode [12] as below:

\[ 2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^- \]  

(5)

Aluminum as positive ions (Al\(^{3+}\)) produced by anode dissolution (Equation (1)) immediately undergo a spontaneous hydrolysis reaction which produces various monomer species (Equations (6) - (8)) at high pH ranges / in alkaline conditions [13]. In acidic conditions the aluminum dissolves to produce Al\(^{3+}\) and Al(OH)\(^{2+}\), but later at the appropriate pH it can converted to Al(OH)_3. However, the concentration of hydroxide ions the sample solution will present other ionic species such as Al(OH)\(^{3+}\), Al\(_2\)(OH)\(_3\)\(^{5+}\), and Al(OH)\(_4^-\) in the EC system [14].

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

(6)

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

(7)

\[ \text{Al(OH)}_2^+ + \text{H}_2\text{O} \rightarrow \text{Al(OH)}_3^+ + \text{H}^+ \]  

(8)

For ferrous metals as anodes, the same applies. Starting with dissolving the iron anode at low pH yields Fe\(^{3+}\) and at low pH, which at the are initially converted to Fe(OH)\(^{2+}\) and Fe(OH)_3[14].

\[ \text{Fe}^{2+} + \text{H}_2\text{O} \rightarrow \text{Fe(OH)}^{2+} + \text{H}^+ \]  

(9)

\[ \text{Fe(OH)}^{2+} + \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_2^+ + \text{H}^+ \]  

(10)

\[ \text{Fe(OH)}_2^+ + \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3^+ + \text{H}^+ \]  

(11)

Whereas Fenton electrolysis is electrolysis using the help of Fenton’s reagent (introduced by Fenton, in 1894), a mixture of H\(_2\)O\(_2\) and iron salts, has been shown to be an effective and simple oxidant for various types of organic contaminants [15]. In this system, a hydroxyl radical (OH) is generated by reducing H\(_2\)O\(_2\) with iron ions (reaction 12).

\[ \text{H}_2\text{O}_2 + \text{Fe}^{2+} \rightarrow \bullet \text{OH} + \text{OH}^- + \text{Fe}^{3+} \]  

(12)

Aromatic compounds such as aromatic amines, nitrophenols, and chlorobenzene when removed by Fenton method proved to be very effective [16]; [17]; [18] The downside of Fenton's reagent is that the overall oxidation process slows down after the conversion of Fe\(^{2+}\) to Fe\(^{3+}\) (reaction 12), because the reduction in Fe\(^{2+}\) to Fe\(^{3+}\) by hydrogen per oxide (reaction 2) is much slower than reaction (1). Is of Fenton’s reagent in the removal of organic compounds constrained by slurry systems which produce large amounts of Fe(OH)_3, sludge, thus requiring further separation and disposal [19].

\[ \text{H}_2\text{O}_2 + \text{Fe}^{2+} \rightarrow \bullet \text{OH} + \text{OH}^- + \text{Fe}^{3+} \]  

(13)

In the last few decades, the electro-Fenton method has received considerable attention [20]; [21]; and can be divided into three types. The first type uses electrogenerated Fe\(^{2+}\) and H\(_2\)O\(_2\) [22]. The second type uses electrogenerated H\(_2\)O\(_2\) and Fe\(^{2+}\) produced by oxidation of iron, sacrificial anodes [23]; [24]. The final type (Fered-Fenton process) uses electrogenerated H\(_2\)O\(_2\)and Fe\(^{2+}\) produced via reduction of iron sulfate or iron hydroxide slurry [25]. Huang et al., (1999) [24] have verified that this system can effectively treat petrochemical wastewater after 5 uses.

In this study, the removal of organic matter in leachate at the final landfill in the Diponegoro
University area with the electrocoagulation method and the Fenton electro method obtained quite good results, and there were differences in the rendition of the process using aluminum metal as anode and ferrous metal as anode. With the electrocoagulation method when using aluminum metal (as anode) the amount of organic material that can be removed is 77.6%, while with ferrous metal (as anode) the amount of organic material that can be removed is smaller, namely 69.8%. Whereas with the Fenton electro method, when using aluminum metal (as anode), the amount of organic material that could be removed was 89.9%, while with ferrous metal (as anode) the amount of organic material that could be removed was smaller, namely 71.6%. 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%.

2. Research methods

2.1. Tools and materials

This research was carried out in a batch reactor consisting of a 1000 mL beaker and equipped with carbon (as a cathode) and aluminum and ferrous metals (as anodes). The electrodes used are made of aluminum and are installed parallel to the dimensions of 0.2 cM X 6 cM X 15 cM. The total effective electrode area is 2 \((15x6 + 15x0.2 + 6x0.2) = 188.4 \text{ cm}^2\) and the distance between the electrodes is varied from 1; 2; 3; 4; 5; and 6 cm. The leachate sample (approximately 900 – 1000 mL volume) is placed in a beaker. The anode and cathode are connected to direct current with a DC power scale (2; 4; 6; 8; and 10 Volts). Magnetic stirrer was also used in this experiment (the mixing speed was set constant at 300 rpm) to obtain homogeneous mixing.

2.1.1. Tools. The tools used are a set of batch reactors that function as a place for Fenton's electrocoagulation and electro reactions, which include a 2 liter beaker capacity, rectifier, aluminum metal, ferrous metal (as anode) and carbon (as a cathode), voltmeter, DC current source and a set of glass tools such as a volume pipette (20 mL) and a set of titration tools.

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).

![Scheme of electrocoagulation equipment](image)

**Figure 1: Scheme of electrocoagulation equipment [26]**

2.1.2. Material. Leachate samples from the Diponegoro University landfill, Fenton's reagent (mixture of hydrogen peroxide \((\text{H}_2\text{O}_2)\) and iron sulfate salt \((\text{FeSO}_4 \cdot 7 \text{H}_2\text{O})\)), Sodium Hydroxide \((\text{NaOH})\), Hydrochloric acid \((\text{HCl})\), Ferro ammonium Sulfate \((\text{Fe(NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O})\), Sodium chloride \((\text{NaCl})\), Sodium Sulfate \((\text{Na}_2\text{SO}_4)\), Ag_2SO_4, HgSO_4, Feroin indicator, aluminum metal and ferrous metal (as anode) and carbon (as cathode).
2.2. Design of experimental equipment
In this experiment, the electrocoagulation method and the Fenton electro method were carried out using two different anodes, namely aluminum metal and ferrous metal. The tool used is a set of batch reactors that functions as a place for Fenton's electrocoagulation and electro reactions, which includes a 2 liter capacity beaker & rectifier. The sample was carried out a study on the optimization of the electrocoagulation process and the electrocoagulation process of Fenton from a waste water / leachate / seepage water from a landfill in the Diponegoro University campus area.

2.3. Designing optimization of dissolved organic material in leachate water
Optimization design for the removal of dissolved organic matter in leachate from the final waste disposal site at the Diponegoro University campus area by varying the type of electrode, electrode distance, voltage, adjusting the degree of acidity (pH) and contact time to the percentage of electrocoagulation and the percentage of electro Fenton.

2.4. COD analysis
To measure the presence of dissolved organic pollutants, COD measurement were used (APHA method, 1995). 5 mL of distilled water (as blank) and 5 mL sample are put into a 250 mL Erlenmeyer. Given 5 mL H$_2$SO$_4$ - Ag$_2$SO$_4$ and 2.5 mL K$_2$Cr$_2$O$_7$ - HgSO$_4$ then covered and heated in an oven at 150$^\circ$C for 2 hours. Once cool, the lid rinsed with 2 mL of distilled water, given 1 mL of concentrated H$_2$SO$_4$ 1 N and a drop of ferroin indicator (3 drops). Then measure in with a standard solution of Fe(NH$_4$)$_2$(SO$_4$)$_2$ to equivalence point. The formula for determining COD levels is a follow:

$$\text{COD value (ppm)} = (P - Q) \times N \times 8000 \text{ mL sample}$$

Description:
- P: Volume (mL) of the titrant for a blank
- Q: Volume (mL) of the titrant for the sample
- N: Normality of Ferrous ammonium sulfate solution

3. Results and discussion
The electrocoagulation (EC) and the Electro Fenton (EF) by used two different anodes, namely aluminum and ferrous metals. Theoretically all these metals are capable of functioning as anodes. But in reality, although aluminum and ferrous metals can work optimally for Fenton's electrocoagulation and electro processes, they give different percentage results for organic matter removal. In fact, ferrous metal gives a smaller percentage of removal of organic matter than aluminum metal which is used as an electrode in the EC and EF. The effectiveness of the two methods (electrocoagulation and electro Fenton) was seen from the result of decreasing Chemical Oxygen Demand (COD) from leachate between before and after treatment. The sample chosen in this study is for leachate from the landfill in the Diponegoro University campus area. The analysis was carried out by physical analysis and chemical analysis. The results of physical and chemical analysis of landfill leachate in the Diponegoro University campus area can be explained as follows.

3.1. Results of analysis of leachate water from landfills in the Diponegoro University campus area
Measurement of the quality of leachate from the landfill in the Diponegoro University campus area is 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, NO$_3$ as N and NO$_2$ as N [26]. The results obtained were compared with the requirements allowed with national standard Indonesian No: 416 / MENKES / PER / IX / 1990 and PP No: 82 of 2001, especially on water quality IV (The Government of the Republic of Indonesia, Minister of Health of the Republic of Indonesia). The results obtained are as follows:
Table 1. The percentage results of the quality of leachate water from the final waste disposal site in the Diponegoro University campus area after the Fenton Electrocoagulation and Electro Fenton process using carbon (as a cathode), aluminum and iron (as anode) at a voltage of 4 volts

| Parameter       | Before Process EC dan EF | Process EC dan EF | PerMenKes No: 416/1990 | PP No: 82 Tahun 2001 |
|-----------------|--------------------------|-------------------|------------------------|----------------------|
| Odor            | A little smelly          | No odor           | No odor                | No odor              |
| Color           | 4.2 scale TCU            | No color          | 15 scale TCU           | No color             |
| Taste           | -                        | -                 | No taste               | No taste             |
| Turbidity       | 1.8 scale NTU            | 0.3 scale NTU     | 5 scale NTU            | -                    |
| Temperature     | 29.3 °C                  | 29 °C             | Room T ± 3°C           | Deviation 3°C from room T |
| Dissolved residue | 710 ppm                | 210.41 - 71.72 ppm | 2000 ppm               | 2000 ppm             |
| Suspended Residue | 96.2 ppm              | 29.05 - 9.7 ppm   | 400 ppm                | 400 ppm              |
| pH              | 6.1                      | 6.9               | 5 - 9                  | 5 - 9                |
| COD             | 6.2 ppm                  | 1.2 - 0.62 ppm    | 100 ppm                | 100 ppm              |
| BOD             | 2.1 ppm                  | 0.63 - 0.21 ppm   | 12 ppm                 | 12 ppm               |
| NO₃ as N        | 3.3 ppm                  | 0.99 - 0.33 ppm   | 10 ppm                 | 20 ppm               |
| NO₂ as N        | -                        | -                 | 1 ppm                  | -                    |

If you pay attention to the results of the percentage of leachate quality from the Final Waste Disposal Site in the Diponegoro University campus area after the EC and the EF processes of Fenton using aluminum and iron (as anode) and carbon (as a cathode) at a voltage of 4 volts, the decrease varies. From the data obtained from the electrolysis variables (voltage, time, electrode distance and pH), it can be concluded that electrolysis without the help of electrolyte solutions is still small (below 70%). 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 a strong electrolyte (Na₂SO₄ 100 ppm and Na₂SO₄ 200 ppm) carried out at pH = 8, obtained a significant increase in electrolysis results. The biggest decline in the price of COD was in the Electro Fenton process using aluminum as anode (89.9%), using iron (71.6%). While the electrocoagulation process was only able to reduce the COD price by 77.6%, using aluminum as anode, while using iron was only able to reduce it by 69.8%. 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%.

With the EC method, when aluminum metal (as anode) was used, the amount of organic material that could be removed was 77.6%, while with ferrous metal (as anode) the amount of organic material that could be removed was smaller, namely 69.8%. 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:

\[
\begin{align*}
\text{Fe/Fe}^{2+} & \rightarrow \text{Fe}^{2+} + 2e^- \quad E_{\text{red st}} = -0.44 \text{ volt} \\
\text{Fe/Fe}^{3+} & \rightarrow \text{Fe}^{3+} + 3e^- \quad E_{\text{red st}} = -0.46 \text{ volt} \\
\text{Al/Al}^{3+} & \rightarrow \text{Al}^{3+} + 3e^- \quad E_{\text{red st}} = -1.16 \text{ volt}
\end{align*}
\]

As a test of the effectiveness of the performance of the two electrodes, a sample of wastewater from the TPA of Diponegoro University was used to test EC under various basal conditions (pH = 8). Whereas with the EF method when using aluminum metal (as anode) the amount of organic material that can be removed is greater than the electrocoagulation method, which is 89.9%, whereas with ferrous metal (as anode) the amount of organic material that can be removed is smaller, which is 71.6%. As a test of the effectiveness of the performance of Fenton's electro from the two electrodes, a sample of wastewater from the Diponegoro University TPA was used. Electro Fenton was carried out in an acidic atmosphere (pH = 3). In the EF method aluminum metal (as anode) always has better
efficiency than ferrous metal, because the oxidation potential of Al/Al$^{3+}$ is higher than that of Fe/Fe$^{2+}$, so the process of forming Al(OH)$_3$ deposits is more effective than the process of forming a precipitate, Fe(OH)$_3$. Whereas in the EF method aluminum metal (as anode) always has better efficiency than ferrous metal, because the oxidation potential of Al/Al$^{3+}$ is higher than Fe/Fe$^{2+}$, so that 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 EC process from a waste water / leachate / seepage water from a landfill in the Diponegoro University campus area has been carried out by varying the type of electrode, electrode distance, voltage, adjusting the degree of acidity (pH) and contact time to the percentage. electrocoagulation. The success indicator of the electrolysis process is measured by looking at the decrease in the COD value between before and after experiencing the EC process, this is in accordance with the method that has been done and reported by [27] or by measuring COD and BOD [28].

3.2.1. Voltage and time electrocoagulation and electro Fenton Optimization. In this electrolysis research, voltage variations have been carried out for various anodes. For ferrous metals (as anode) the voltage is given from 2; 4; 6; 8 and 10 volts. The results obtained are quite optimal at 4 volts. For aluminum metal (as anode) the voltage is given from 2; 4; 6; 8 and 10 volts. The results obtained are quite optimal at 4 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 removal of organic matter from leachate obtained after undergoing the EC process are different, as shown in Figure 2 and Figure 3.

![Figure 2](image-url)  
Figure 2. Percentage results for organic matter removal after EC process using carbon (as cathode) and ferrous metal (as anode) a voltage of 4 volts.
Figure 3. The results of the percentage of organic matter removal after the EC process using carbon (as a cathode) and aluminum metal (as anode) at a voltage of 4 volts.

While the results of the percentage of organic matter removal from leachate obtained after undergoing the Fenton electro process also experienced a difference, as seen in Figure 4 and Figure 5 as follows:

Figure 4. The result of the percentage of organic matter removal after the EF process using carbon (as a cathode) and ferrous metal (as anode) at a voltage of 4 volts.
Figure 5. The result of the percentage of organic matter removal after the EF process using carbon (as a cathode) and aluminum metal (as anode) at a voltage of 4 volts.

3.2.2. Electrocoagulation time optimization. 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 results of removal of organic matter in leachate from the Final Waste Disposal Site in the Diponegoro University campus area provide a percentage of organic matter removal from different leachate water, as presented in Figure 6 as follows:

Figure 6. 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 cathode) at a voltage of 4 volts.
3.2.3. Optimization of Electrode Distance. After obtaining the optimal voltage and optimal time, it is determined to determine the optimal electrode distance in the EC process for the removal of organic pollutant in leachate from the final waste disposal site in the Diponegoro University campus area. The electrode spacing which was varied was as follows, starting from: 1; 2; 3; 4; 5; 6 and 7 cm. The results are presented in Figure 7 as follows:

![Electrode Distance vs. COD Removal](image1)

**Figure 7.** The result of the percentage of organic matter removal to the Electrode Distance after the EC and EF processes using aluminum and ferrous metals (as anode) and carbon (as cathode) at a voltage of 4 volts.

3.2.4. pH Optimization. After obtaining the optimal voltage, optimal time, optimal distance is obtained and then determined to determine the optimal pH in the EC and in the EF process for removal of organic pollutant in leachate from the final waste disposal site in the Diponegoro University campus area. 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 8 as follows:

![pH vs. COD Removal](image2)

**Figure 8.** The result of the percentage of organic matter removal to pH after the EC and the EF process using aluminum and ferrous metals (as anode) and carbon (as cathode) at a voltage of 4 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 80%). 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 a strong electrolyte (Na$_2$SO$_4$ 100 ppm and Na$_2$SO$_4$ 200 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 77.6%, while with ferrous metal (as anode) the amount of organic material that could be removed was smaller, namely 69.8%. The addition of inorganic salts (100 ppm NaCl and 100 ppm Na$_2$SO$_4$) 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 EC and the EF process, so that the anode oxidation process can run well. The oxidation reaction of ferrous metal, aluminum metal and zinc metal (as anode) is as follows:

$$\text{Fe}^{2+} + \text{2H}_2\text{O} \rightarrow \text{Fe}^{3+} + \text{4H}^+ + \text{2OH}^-$$

$$\text{Al}^{3+} + \text{3H}_2\text{O} \rightarrow \text{Al}^{3+} + \text{3H}^+ + \text{3OH}^-$$

$$\text{Zn}^{2+} + \text{2H}_2\text{O} \rightarrow \text{Zn}^{2+} + \text{2H}^+ + \text{2OH}^-$$

The addition of electrolyte solutions can actually affect the yield of electrolysis. The addition of sodium chloride salt (100 ppm + 200 ppm) and sodium sulfate (100 ppm + 200 ppm) 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 will occur more easily.

![Figure 9. Effect of strong electrolyte solutions (NaCl and Na$_2$SO$_4$) on the result of the percentage of removal of organic pollutant on the Electrode Distance after the EC process using aluminum and ferrous metals (as anode) and carbon (as a cathode) at a voltage of 4 volts.](image-url)

With the EC method, when aluminum metal (as anode) was used, the amount of organic material that could be removed was 77.6%, while with ferrous metal (as anode) the amount of organic material that could be removed was smaller, namely 69.8%. 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, a sample of wastewater from the TPA of Diponegoro University was used EC under various acidic conditions (pH = 8), in which the sample was dissolved in distilled water without electrolytes (presented in graphs in Fe and Al notations). Meanwhile, the addition of strong electrolytes (NaCl and Na$_2$SO$_4$) (presented in the graph in the notation Fe + NaCl (100 ppm + 200 ppm) and Fe + Na$_2$SO$_4$ (100 ppm + 200 ppm) and the addition of strong electrolytes (NaCl and Na$_2$SO$_4$) (presented in the graph in notation Al + NaCl (100 ppm + 200 ppm) and Al + Na$_2$SO$_4$ (100 ppm + 200 ppm).

The addition of electrolyte solutions can actually affect the yield of electrolysis. The addition of sodium chloride salt (100 ppm + 200 ppm) and sodium sulfate (100 ppm + 200 ppm) 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 will occur more easily.
hydroxide flocks is easier to occur. Whereas with the Fenton electro method when using aluminum metal (as anode) the amount of organic material that can be removed is greater than the EC method, which is 89.9%, whereas with ferrous metal (as anode) the amount of organic material that can be removed is smaller, which is 71.6%. As a test of the effectiveness of the performance of EF from the two electrodes, a sample of wastewater from the Diponegoro University TPA was used. The EF was carried out in an acidic atmosphere (pH = 3). The results obtained by Fenton's electro method are presented graphically in Fe and Al notation. The oxidation reaction of aluminum metal, ferrous metal and zinc metal (as anode) is as shown in Figure 10 as follows:

Figure 10. Effect of strong electrolyte solutions (NaCl and Na$_2$SO$_4$) on the percentage of removal of organic pollutant on the Electrode Distance after EF process using carbon (as a cathode) and aluminum and ferrous metals (as anode) at a voltage of 4 Volts.

4. Conclusion
Dissolved organic pollutants in leachate in Diponegoro University's final disposal site (TPA) (COD parameter) is 6.2 ppm, still far below the threshold value of the national standard Indonesian No: 416 / MENKES / PER / IX / 1990 and PP No: 82 of 2001, especially on water quality IV (The Government of the Republic of Indonesia, Minister of Health of the Republic of Indonesia). 2. The electrocoagulation method uses aluminum metal (as anode), the amount of organic material that can be removed is 77.6%, while using ferrous metal (as anode) the amount of organic material that can be removed is smaller, namely 69.8%. 3. The Fenton electro method uses aluminum metal (as anode), the amount of organic material that can be removed is 89.9%, while using ferrous metal (as anode) the amount of organic material that can be removed is smaller, namely 71.6%. 4. 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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