Impact of Adding Sodium Chloride to Change of Turbidity and Iron Concentration on Treatment Waste Water Using Electrocoagulation Process

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Abstract. The treatment waste water of electrical industry was investigated through electrocoagulation process. The study was conducted by flowing of 4.5 liters of waste water into the three cells of electrocoagulation process tank. Each cell is filled 1.5 liters of waste water without adding of sodium chloride (NaCl). The electrocoagulation process is carried out at a voltage of 12 V and interval time for observation of electric current, turbidity and iron concentration in the water is done every 10 minutes. Subsequently, the same procedure was performed and added the sodium chloride with variation of weight of 0.5, 1.0 and 1.5 gram. To determine change value of electrical current, turbidity, metals pollutant was done using Ampere meter, turbidity meter and AAS respectively. The best conditions are recommended for use 0.5 gram of sodium chloride and 110 minutes for processing time. Under these conditions the voltage of 12 V and the current is 1.13 A. In this condition the turbidity can be removal from 44.10 to 2.35 NTU or 94.33 % and iron concentration from 1.21 to 0.29 mg/L or equal to 76.03 %. In conclusion adding of sodium chloride in simultaneous process of electrocoagulation and sterilization can cause increase of the electric current and accelerate the removal of pollutants in the wastewater.

1. Introduction
Industrial wastewater generally contains organic pollutants and heavy metals and has the potential to be reused into clean or drinking water. Wastewater that will be reused as drinking water must be treated so that the water parameters are in accordance with the regulation of Indonesian Ministry of Health No. 492 / Menkes / Per / IV / 2010. The water parameters in drinking water based on the Minister of Health regulation No. 492 / Menkes / Per / IV / 2010 are 0.3 mg/L for iron (Fe), 0.01 mg/L for arsenic (As), 2 mg/L for copper (Cu), 0.05 mg/L for chromium (Cr), 0.003 mg/L for cadmium (Cd), 0.01 mg/L for lead (Pb), 0.07 mg/L for nickel (Ni), 0.02 mg/L for aluminum (Al), 0.4 mg/L for manganese (Mn), 3.0 mg/L for zinc (Zn), 0.001 mg/L for mercury (Hg), 0.7 mg/L for barium (Ba), 200 mg/L for sodium (Na), 5 NTU for turbidity, 10 mg/L for organic compounds, 5 mg/L untuk chlorine (Cl2), 0 per 100 mL for Coliform bacteria and 0 per 100 mL for Escherichia Coli (E Coli) bacteria and pH 6.5 - 8.5.

Many methods can be used to treat wastewater into drinking water. One of it is electrocoagulation process. In order to carry out of electrocoagulation process is required an anode which can produce a coagulant compound. In generally the anode made from aluminum or iron. Coagulant compounds are useful for adsorbing organic and inorganic pollutants in wastewater [1]-[15]. Pollutants in wastewater...
usually consist of a mixture of organic and inorganic compounds that can form weak electrolyte solutions. In generally the weak electrolytes are very difficult to conduct electricity. Because the resistance of solution is very high, so that the electrical conductivity becomes very low[1],[3],[8],[10]. Thus the process of formation of coagulant compounds in wastewater becomes very slow. Because the process of formation of coagulant compounds depends on the changes of electrical conductivity in wastewater. If the electrical conductivity in the wastewater is higher, then the electrical current also increase, so the process of forming coagulant compounds becomes faster. To increase the electrical conductivity in wastewater can be added sodium chloride (NaCl) or Na₂SO₄[1],[3],[8],[10] into wastewater, so there is an increase conductivity of electrolyte in wastewater [1],[3]. The equation of the reaction occurring in the electrocoagulation process using anode of aluminum material can be expressed as follows [1]-[19]:

reaction at the anode (oxidation):  
$$2Al \rightarrow 2Al^{3+} + 6\text{e}^- \quad (1)$$

reaction at the cathode (reduction):  
$$6\text{H}_2\text{O}+6\text{e}^- \rightarrow 6\text{OH}^- + 3\text{H}_2 \quad (2)$$

Overall reaction:  
$$2\text{Al} + 6\text{H}_2\text{O} \rightarrow 2\text{Al(OH)}_3 + 3\text{H}_2 \quad (3)$$

At equation (3) it shown that Al(OH)₃ is formed which acts as coagulation agent, thereby facilitating pollutants in trapped water and forming floc which easily deposited clumps[2]-[19]. The working principle of electrocoagulation process shown in Figure 1[2],[3],[5],[6]-[8].

![Figure 1. The working principle of electrocoagulation process](image)

The equation for the mass of metal ions Al₃⁺ produced in the electrocoagulation continuous process can be expressed as follows:

$$m = (S)(A)(ar)(I)(Q)(96.500)(n) \quad (4)$$

where $S$ is height of vessel (cm), $A$ is cross sectional area of the vessel (cm²), $ar$ is (relative atomic mass), $I$ is flow of wastewater (cm/sec), and $n$ (change of oxide number of Al) in this case $n = 3$ dan $ar = 27$. Based on equation (4) can be explained, if the electric current is increased, so that the coagulant compound of Al (OH)₃ which is formed is also increase. Coagulant compounds of Al (OH)₃ are useful as pollutant absorbent compounds to form floc which is easily deposited on the bottom of the process tank [6]-[15].

The study of electrocoagulation processes with aluminum as electrodes was carried out in the wastewater that containing lead pollutants (Pb) 100 ppm and total suspended solid (TSS) of 200 ppm. In this process there is a sludge containing Pb together with Al(OH)₃ and discharged through the bottom of the process vessel, while clear water is removed through the top of the process vessel [11].

Another experiment was carried out in a continuous flow with a discharge of 1.5 l / min, electric currents vary from 1 to 5 ampere and variation of operating time from 60 to 120 minute. The Pb analysis in the final filtrate is measured by using an AAS device (Atomic Absorption Spectrophometer), and TTS analysis using gravimeter method. From the experiment obtained the
electrocoagulation efficiency value of contaminant Pb equal to 99.16% and TSS equal to 80.24% on the current of 5 ampere and operating time of 120 minute [11]-[15].

In the effluent treatment of animal slaughterhouse by electrocoagulation process has been done in batch by placing wastewater in the electrolysis cell. The process is run at certain time and low concentration of total suspended solid (TTS), total dissolved solid (TDS), pH and turbidity. From the research results obtained that TSS and TDS were reduced from wastewater. This indicates that water after processing has an improved of quality [4]-[6], [13]-[19].

In the study of electroagulation process using four aluminum (Al) and iron (Fe) electrodes, the process required shorter operation time to achieve maximum TTS and TDS removal efficiency than using only two electrodes. The use of four electrodes requires a 70 minute operation time with TSS and TDS removal capability of 99%, while on the use of two electrodes it takes 90 minutes operation time with maximum TSS and TDS removal capability of only 98% [3]-[6].

While the study conducted on the electrocoagulation process with the addition of sodium chloride (NaCl) of 740 mg/L can reduce the chemical oxygen demand (COD) to 98% and total suspended solid (TSS) to 93%. During the electrocoagulation process will form a byproduct of hypochlorite compound that is oxidizing and able to oxidize organic pollutants and kill bacteria in water. The mechanism of formation of hypochlorite compounds can be explained by the following reaction equation [8], [17]-[19]:

\[
\begin{align*}
NaCl & \rightarrow Na^+ + Cl^- \\
2Cl^- & \rightarrow Cl_2 + 2e^- \\
Cl_2 + H_2O & \rightarrow HOCl + Cl^- + H^+ \\
HOCl & \rightarrow OCl^- + H^+
\end{align*}
\]

\((5)\) \((6)\) \((7)\) \((8)\)

2. Methodology

2.1. Materials

The materials are needed ie: aluminum 1100 as electrode, sodium chlorida and wastewater. The composition of aluminum is shown in Table 1 and visual shape of geometries shown in Figure 2. The size of electrode (anode and cathode) is 19 cm long and 19 cm wide. Sodium chlorida was bought from market in Depok, East Java. The composition of sodium chlorida shown in Table 2 and sample shown in Figure 3.

| Table 1. The composition of aluminum 1100 |
|-----------------------------------------|
| Element     | content | Composition (%) |
| Cu (Copper) | 0.05 - 0.20 |
| Al (Aluminium) | 99 - 99.95 |
| Si (Silicon) | 0.95 |
| Fe (Iron) | 0.95 |
| Zn (Zinc) | 0.1 |
| another elements | 0.15 |

| Table 2. The composition of sodium chlorida |
|--------------------------------------------|
| Compound | content | Composition (%) |
| NaCl        | 94.7    |
| H_2O       | 7.0     |
| another compound | 0.1609 |

Figure 2. Aluminum electrode

Figure 3. Sample sodium chlorida

Wastewater was taken from sewerage channels in area industry electric, East Jakarta. The composition of wastewater shown in Table 3 and sample shown in Figure 4. Measuring of metals content in the
water using AAS (Atomic Absorption Spectrophotometer) - Shimadzu AA-6300 and measuring of turbidity using turbidity meter.

| Parameter     | Quantity  |
|---------------|-----------|
| Copper (Cu)   | 3.52 mg/L |
| Aluminum (Al) | 0.68 mg/L |
| Sodium (Na)   | 16.34 mg/L|
| Iron (Fe)     | 1.21 mg/L |
| pH            | 7.64      |
| Turbidity     | 44.10 NTU |
| Fat           | 27 mg/L   |

**Figure 4. Sample wastewater**

2.2. Research tool model

The models equipment using for research shown in Figure 5. The process tool model consists of a DC source, a volt meter, a feeding vessel, an electrocoagulation process tank, a dirt settling vessel and a clean water reservoir. DC source has a voltage capability between 0 to 30 volts and an electric current between 0 to 10 amperes. The shape of process tank is square with composed in three cells. Each cell have size 5 cm wide, 20 cm long and 25 cm high was equipped with anode and cathode made from aluminum with each size is 19 cm wide and 19 cm long. Distance between anode and cathode is 6.5 cm.

**Figure 5. The equipment for research**

2.3. Implementation of research

The research was conducted by flowing of 4.5 liters of wastewater into the three cells of electrocoagulation process tank. Each cell is filled 1.5 liters of wastewater without adding of sodium chloride (NaCl). The electrocoagulation process is carried out at a voltage of 12 V and interval time for observation of electric current, turbidity and iron concentration in the water is done every 10 minutes. Subsequently, the same procedure was performed and added the sodium chloride with variation of weight of 0.5, 1.0 and 1.5 gram. To determine change value of turbidity was done using turbidity meter and concentration of iron using AAS (Atomic Absorption Spectrophotometer).
3. Result and Discussion

Figure 6 is shown the wastewater after through processing by electrocoagulation. Based on Figure 6 can be seen that the pollutants in wastewater formed sludge and deposited on the bottom [1]-[19]. The water after filtered is shown in Figure 7.

![Figure 6. Sludge of pollutants](image1)

![Figure 7. Water after filtered](image2)

3.1. Impact adding sodium chloride on electric current

Impact adding sodium chloride in the electrocoagulation to change of electric current is shown on Figure 8. The measurement results of average electric current without the addition of sodium chloride is 0.23 ampere. From Figure 8 can be seen that the addition of a sodium chloride (NaCl) can increase the electrical current. On the addition sodium chloride of 0.5 gram can be increased the average electric current from 0.23 A to 1.13 A or 3.9 times greater than the initial value. While the addition of 1.0 gram of sodium chloride can be increased the average electric current from 0.23 A to 4.24 A or 17.4 times greater than the initial value and on the addition of 1.5 gram sodium chloride can be increased the average electric current from 0.23 A to 9.34 A or 39.6 times greater than the initial value. It can be explained that the addition of sodium chloride into the wastewater causes a decrease of resistance in solution or there has been a change properties from weak to strong electrolyte that was impact on decreasing the electrical resistance in the solution (R) [1],[3]-[5],[8]-[10].

![Figure 8. The change of electric current](image3)

3.2. Impact adding sodium chloride on turbidity

The result of the measurement of the impact of adding sodium chloride to the change of turbidity in water is shown in Table 4. Based on Table 4, can be seen that electrocoagulation process was run without adding sodium chloride until 140 minutes can reduce turbidity from 44.10 to 4.28 NTU or 90.29 %. Subsequently, at the same time for the addition of 0.5,1.0 and 1.5 gram sodium chloride each able to decrease the turbidity from 44.10 to 0.95 NTU or 97.85 %, from 44.10 to 0.15 NTU or 99.66 % and from 44.10 to 0.01 NTU or 99.98 % respectively.

| Time, minute | NaCl, 0.0 g | NaCl, 0.5 g | NaCl, 1.0 g | NaCl, 1.50 g |
|-------------|-------------|-------------|-------------|--------------|
| 0           | 44.10       | 44.10       | 44.10       | 44.10        |
| 10          | 44.00       | 40.85       | 39.29       | 38.04        |
| 20          | 43.98       | 37.15       | 35.12       | 33.48        |
The addition of sodium chloride has caused a decrease turbidity in the water. It can be explained that adding of sodium chloride in electrocoagulation process, the Al\(^{3+}\) and OH\(^{-}\) ions are more formed which are compounds of Al (OH)\(_3\). In this case the compound Al (OH)\(_3\) is an easy coagulant material to adsorb pollutants in the water to form a floc, so easily deposited on the bottom of process tank. The best time for process with adding of sodium chloride 0.5 gram to achieve turbidity of 5 NTU or less then it is 100 minute. In this condition the value of turbidity is reduced from 44.10 to 2.35 NTU or 94.33 %. The best time for process with adding of sodium chloride 1.0 gram to achieve turbidity of 5 NTU or less then it is 100 minute. In this condition the value of turbidity is reduced from 44.10 to 3.12 NTU or 47.57 %. The best time for process with adding of sodium chloride 1.5 gram to achieve turbidity of 5 NTU or less then it is 90 minute. In this condition the value of turbidity is reduced from 44.10 to 4.57 NTU or 89.64 % [4]-[6].

3.3. Impact of adding sodium chloride on iron concentration

The result of the measurement of the impact of adding sodium chloride to change of iron concentration in water is shown in Table 5.

| Time, minute | NaCl, 0.0 g | NaCl, 0.5 g | NaCl, 1.0 g | NaCl, 1.50 g |
|-------------|-------------|-------------|-------------|-------------|
| 0           | 1.21        | 1.21        | 1.21        | 1.21        |
| 10          | 1.20        | 1.19        | 1.10        | 0.98        |
| 20          | 1.17        | 1.10        | 0.90        | 0.88        |
| 30          | 1.12        | 0.93        | 0.81        | 0.72        |
| 40          | 1.00        | 0.89        | 0.68        | 0.60        |
| 50          | 0.97        | 0.83        | 0.58        | 0.51        |
| 60          | 0.93        | 0.74        | 0.50        | 0.40        |
| 70          | 0.90        | 0.65        | 0.44        | 0.31        |
| 80          | 0.87        | 0.54        | 0.32        | 0.25        |
| 90          | 0.85        | 0.52        | 0.27        | 0.12        |
| 100         | 0.81        | 0.45        | 0.15        | 0.08        |
| 120         | 0.78        | 0.29        | 0.11        | 0.01        |
| 140         | 0.71        | 0.11        | 0.03        | nd          |

Note: nd: not detected

Based on Table 5, shown that electrocoagulation process is run with longer time, the concentration of iron (Fe) in water has a tendency to decrease. It can be explained at the longer time the electrocoagulation process is run, the more Al\(^{3+}\) and OH\(^{-}\) ions are formed which are compounds of Al (OH)\(_3\). In this case the compound Al (OH)\(_3\) is an easy coagulant material to adsorb iron pollutants in the water to form a floc, so easily deposited on the bottom of process tank. Therefore the concentration of iron (Fe) in the water will decrease. Electrocoagulation process was run without
adding sodium chloride for 80 minutes can reduce iron concentration (Fe) from 1.21 mg/L to 0.87 mg/L or 28.10%. Subsequently, at the same time for the addition of 0.5, 1.0 and 1.5 gram sodium chloride each able to decrease the iron concentration from 1.21 mg/L to 0.54 mg/L or 55.37%, from 1.21 mg/L to 0.32 mg/L or 73.55% and from 1.21 mg/L to 0.25 mg/L or 79.34% respectively. The best time for process with adding of sodium chloride 0.5 gram to achieve iron concentration of 0.3 mg/L or less then it is 110 minute. In this condition the value of iron concentration is reduced from 1.21 to 0.29 mg/L (less then 0.3 mg/L) or 76.03 %. The best time for process with adding of sodium chloride 1.0 gram to achieve iron concentration of 0.3 mg/L or less then it is 90 minute. In this condition the value of iron concentration is reduced from 1.21 to 0.25 mg/L (less then 0.3 mg/L) or 77.69%. The best time for process with adding of sodium chloride 1.5 gram to achieve iron concentration of 0.3 mg/L or less then it is 80 minute. In this condition the value of iron concentration is reduced from 1.21 to 0.25 mg/L (less then 0.3 mg/L) or 79.34 % [11]-[15].

In conclusion, based on Table 4 and 5 is chosen the best time of 110 minute with adding sodium chloride of 0.5 gram in the simultaneous process of electrocoagulation and sterilization. In this condition showed that value of turbidity is 2.35 NTU (less then 5 NTU) or efficiency is 94.33 % and iron concentration is 0.29 mg/L or efficiency is 76.03 %. The best conditions is chosen with consideration on the efficiency of time and the lowest operating costs.

4. Conclusion
Adding of sodium chloride in simultaneous process of electrocoagulation and sterilization can cause increase of the electric current and accelerate the removal of pollutants in the wastewater. The best time is 110 minute with adding sodium chloride of 0.5 gram. In this condition showed that value of turbidity can reduced from 44.10 to 2.35 NTU or 94.33 % and iron concentration can reduced from 1.21 to 0.29 mg/L or 76.03 %.

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