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Combination of Electrocogulation and Aeration Processes by Addition NaCl for Leachate Treatment

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***Abstract*— Leachate is water which is formed in a pile of garbage that dissolves a lot of existing compounds so that it has a very high pollutant content, especially organics substances. Leachate has the potential to cause water pollution, both surface water, ground water and underground water, so it needs to be managed properly. Leachate processing uses a combination of electrocoagulation and aeration methods. The objective of this study is to determine leachate characteristics before and after the processes, the optimum treatment conditions, and the effectiveness of the treatment processes in reducing pollutant content. Electrocoagulation is able to reduce the characteristics of the waste pollutant content in terms of increasing pH and decreasing total disolved solid (TDS), total suspended solid (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD5), and waste turbidity. This condition occurs due to the process of coagulation of pollutants by applying electric current to electrochemical reactions. The working principle of electrocoagulation is the dissolution of anode metal (M+), which reacts with hydroxyl ions (OH-) to form coagulants. The experiment was conducted in batch, where the leachate is put into an electrochemical cell containing 2 aluminum electrodes with dimensions of 10 cm x 10 cm. The parameters varied are the aeration process and variations in the addition of NaCl. The optimum conditions are achieved in the electrocoagulation process with aeration and the addition of 2 g/L NaCl. The most significant processing effectiveness of the process is TDS 34.06%, TSS 81.46%, COD 54.26%, BOD5 53.76%, and turbidity 92.92% respectively.**

***Keywords*— leachate; aeration; electrocoagulation; grbage; treatment.**

I. INTRODUCTION

Leachate is the liquid formed by decomposing a pile of garbage that dissolves into compounds with a very high pollutant content, especially organic substances. The liquid fills cavities in the garbage. If the capacity exceeds the wastewater pressure capacity, then the liquid comes out and extracts the organic and inorganic materials resulting from the physical, chemical, and biological processes that occur in the waste. Leachate has the potential to cause water pollution, both surface water, groundwater, and underground water; therefore, proper treatment is necessary to prevent the harmful effect of leachate [1]-[4].

Leachate contains organic compounds (hydrocarbons, humic acids, sulfates, tanates, and gallates) and inorganic (sodium, potassium, calcium, magnesium, chlorine, sulfate, phosphate, phenol, nitrogen and heavy metal compounds) which is highly polluting the soil environment. Concentrations of these components in leachate can reach 1000 to 5000 times higher than concentrations in groundwater [5]-[8].

Appropriate counter measures must be taken to avoid environmental pollution caused by the leachate. The methods to prevent leachate recirculate back into landfills are biological, chemical, and membrane treatments [9], [10]. Leachate treatment by circulating back into the landfill

requires a large amount of energy and is less effective during the rainy season. Biological leachate treatment is considered less effective in reducing metal content in leachate, whereas chemical and membranes treatment are also considered to be less effective because they require many chemicals and are relatively expensive. The cheap and electromechanically effective method is the electrocoagulation process [11]-[15].

Electrocoagulation is a cheap and effective method of processing industrial waste [16], [17]. Electrocoagulation is an electrochemical method for water and wastewater treatment where an anode occurs in the release of active coagulant in the form of metal ions (usually Al or Fe) into solution. At the cathode, the electrolysis reaction occurs in the form of the release of hydrogen gas [18]-[20]. To increase the effectiveness of decreasing metal ions and other substances contained in the waste, the researchers made variations in the addition of sodium chloride (NaCl) and the aeration process in the processing of the leachate [21], [22].

Aeration technique is one of the wastewater treatment conducted by adding oxygen to liquid waste. Oxygen addition is to capture the pollutant in the waste; therefore, pollutant concentration is reduced or even eliminated. Substances captured can be gases, liquids, ions, colloids, or other mixed materials; therefore, the combination of electrocoagulation and aeration methods can be used to treat leachate properly [23]-[26].

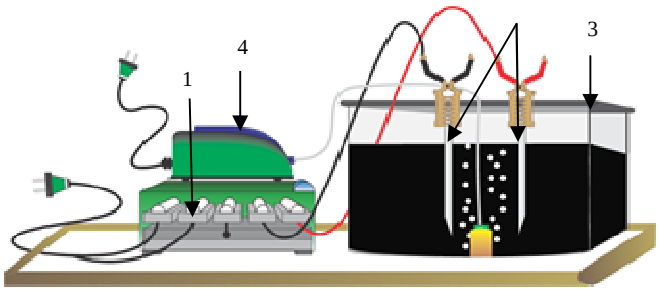
Leachate waste management is intented to minimize the volume, concentration and toxicity of pollutant waste contained in the waste leachate. Liquid waste must be treated until it fulfilled the requirements for disposal. Some researchers hypothesize that this combination of electrocoagulation and aeration methods can be used to treat leachate wastewater properly [27].

The purpose of this study is to analyze leachate wastewater based on the characteristics of the leachate before and after treatment with parameters pH, TDS, TSS, COD, BOD5, and turbidity and determine the optimum process conditions (NaCl concentration and aeration process) on the quality of treated leachate.

II. Material and Methode

Leachate sample in the pond of a landfill in Garbage Landfill, Sukawinatan, Palembang City, South Sumatra, Indonesia, were examined for the physical and chemical characteristic. The physical parameters tested were the pH, total suspended solid (TSS), total dissolved solid (TDS) and turbidity. Chemical test involves determination of biological oxygen demand (BOD) and chemical oxygen demand (COD). After the initial characteristics of the raw leachate were obtained, electrocoagulation was conducted to treat the raw leachate samples in order to remove the pollutants.

Figure 1 shows the instrumentation using this study consists of electrolysis displaying a direct current power supply (DC), a cathode and anode, and the electrolyte solution (NaCl). During the process, the voltage used is 12V and the contact time is two hours with the addition of NaCl at intervals of 0.5 gr/L to 2 g/L. This analysis is used in leachate materials and the results of waste leachate treatment using a combination of electrocoagulation and aeration methods. In this research, aluminum electrodes were used as the cathode and anode with dimension 10 cm long, 10 cm wide and 0.1 cm thick.



Note:
1. Regulator / Power Supply
2. Electrode
3. Reactor
4. Aerator

Fig. 1 Electrocoagulation and aeration experimental setup

This research was run in batch modes. Each pair of the similar plates were placed 3 cm. However, this research used small electric current by a direct power supply to the circuit (12V).

III. Results And Discussion

A. Leachate Characterization

Preliminary analysis of raw leachate from the Sukawinatan landfill waste collection pond, Palembang City, South Sumatra, can be seen in Table 1.

TABLE I
Initial Characterization Of Leachate Waste

No	Parameter	Unit	Results	Quality Standard*
1	pH	-	7.73	6.0-9.0
2	TDS (**)	mg/L	8963	2000
3	TSS	mg/L	151	100
4	COD	mg/L	129	300
5	BOD_5	mg/L	42.6	150
6	Turbidity	NTU	40.1	-

* Minister of the Environment Regulation No.68 Year 2016 and (**) No. 5 of 2014

From the analysis of Sukawinatan landfill waste disposal characteristics in Table 1, it can be seen that there are several parameters in the waste that have met the quality standards where the waste may be discharged into the environment, including parameters pH, BOD5, and COD from the waste. While the parameters of TDS and TSS do not meet the quality standard. Therefore, it is still necessary to process this waste.

The leachate pH value taken from the Sukawinatan landfill waste has reached the quality standard that is allowed to be disposed of in the environment. The high pH value in this leachate is caused by the NH_3 content in the waste, and the low CO_2 content, the presence of hydroxide salts dissolved in the waste also affects increasing the pH value. The waste ph is in the range of pH 7.5-8 that shows the waste still contains acidification. This acidification is caused by the organic decay in the waste substances; therefore, pH value tends to be neutral. The proposed treatment process increases the pH value in the liquid by reducing acidification agents (such as CO_2 and H_2S) using

aeration process and also due to the formation of alkali hydroxide compounds from the electrocoagulation reaction.

TDS, TSS, and turbidity (turbidity) are parameters that significantly affect the quality of waste. In Table 1, TDS and TSS from leachate are higher than the established quality standards. The high TDS indicates that the waste contains a lot of dissolved solids, which is indicated by its ability to conduct electricity, while too high TSS indicates that the waste has many suspended solids and can directly cause turbidity in water. TSS and turbidity tend to be linear because TSS and turbidity both indicate the number of impurities that causes turbidity of wastewater. This parameter has a high impact on the waste ecosystem indirectly, namely the decrease in DO (Dissolved Oxygen) levels of the waste that affects the life of aquatic organisms and soil fertility and directly the impurity enter the respiratory system and organism's metabolism. This condition can endanger the survival of aquatic organisms.

BOD5 and COD characterize large contamination of pollutants in water. From Table 1, it can be seen that the BOD5 and COD values are below the quality standards set for waste disposal into the environment, which is higher compared to clear water. This treatment is also intended to reduce the content of BOD5 and COD to get more transparent water. COD value in wastewater shows the amount of material in wastewater, both organic and non-organic, which can be oxidized (excluding ammonia oxidation). The BOD5 value in wastewater only shows the amount of material in wastewater that can be biodoxically oxidized (biodegradable materials), including ammonia oxidation. COD is always higher than the BOD value, and the COD/BOD ratio is usually determined to determine the ability of the waste to be biologically degraded.

B. Characterization of leachate after processing

The result analysis of leachate, which has been processed using the electrocoagulation process with aluminum electrodes based on the influence of NaCl concentration and the presence or absence of aeration, can be seen in Table 2 and 3.

After leachate treatment, shown in Table 2 and Table 3, the number of pollutants contained in leachate decreases, indicated by an increase in pH and a decrease in the value of TDS, TSS, COD. BOD5 and turbidity. This contaminant content reduction occurs due to the electric coagulation process that binds the contaminant content to be the floating and the sediment to separate the waste solution. This process separates the pollutant inside the waste, and processed waste has better parameters than before.

TABLE II
LEACHATE ANALYSIS RESULTS USING ELECTROCOAGULATION PROCESS WITH A COMBINATION OF AERATION PROCESSES

NaCl addition (g/L)	**Parameters**					
	pH	**TDS mg/L**	**TSS mg/L**	**COD mg/L**	**BOD5 mg/L**	**Turbidity NTU**
0	8.02	8180	135	77	25.6	32.5
0.5	8.09	8070	103	75	25	18.5
1.0	8.12	7600	96	72	22.7	14.9
1.5	8.14	6690	53	68	22.3	10.4
2.0	8.21	5910	28	59	19.7	2.84

TABLE III
LEACHATE ANALYSIS RESULTS USING ELECTROCOAGULATION PROCESS WITHOUT COMBINATION OF AERATION PROCESSES

NaCl addition (g/L)	**Parameters**					
	pH	**TDS mg/L**	**TSS mg/L**	**COD mg/L**	**BOD5 mg/L**	**Turbidity NTU**
0	8.02	8180	135	77	25.6	32.5
0.5	8.09	8070	103	75	25.0	18.5
1.0	8.12	7600	96	72	22.7	14.9
1.5	8.14	6690	53	68	22.3	10.4
2.0	8.21	5910	28	59	19.7	2.84

Aeration also provides the effect of decreasing contaminants in waste, which can be proven by comparing Table 2 and Table 3. Table 2 uses a new aeration process while Table 3, without the aeration process. Aeration helps to reduce the pollutant found in waste. Aeration can increase dissolved oxygen in water, reduce the gaseous elements present in waste (CO_2, H_2S), and at the same time, as an oxidizing agent that causes easily oxidized substances to get enough oxygen supply so that oxidation reactions can occur and oxidized substances separate from solution.

The best characteristics of leachate occur in the variation of the aeration process and the addition of 2 g/L, consists of pH 8.21, TDS 5910 mg/L, TSS 28 mg/L, COD 59 mg/L, BOD5 19.7 mg/L, turbidity 2.84 NTU. This indicates that the quality of leachate after being processed by the electrocoagulation method is below the environmental quality standard, as stated in the Regulation of the Minister of Environment No.68 Year 2016. TDS value is not below the quality standard value, due to the Minister of Environment Regulation Life No. 5 of 2014 states that the TDS quality standards are intended for class I water (raw water for drinking water).

C. Effects of aeration process and NaCl addition to leachate after electrocoagulation preocessing

1) Effect of aeration processes and NaCl additional to pH

Hydrogen is a physical property that characterizes the acidity of a substance in the range of values from 0-14. The standard pH quality value for waste that may be discharged into the environment is between pH 6.0-9.0, which means that the initial leachate has been considered safe to be discharged into the environment. Leachate contains ammonia obtained from the decay of organic substances contained in the waste and causes it to become an alkaline solution.

After the electrocoagulation process is carried out, some alkali hydroxide content is formed as a result of the alkalization process of aluminum metal and other alkaline earth metals present in water. This process is oxidized to form metal ions in the anode and bind with hydroxide (OH) ions resulting from water reduction (H_2O), which occurs at the cathode. The oxidation forms alkaline hydroxide compounds that are base and cause an increase in pH value.

Alkaline hydroxide is a base substance; therefore, the pH of the solution increase, as shown in Figure 2. The increasing salt concentration causes an improvement in the electrical conductivity of the solution. The more NaCl added results in an increase in electrical conductivity or a decrease

in the resistance of the type of solution. If the resistivity of the type of solution decreases, the resistance of the solution is also reduced. This condition indicates that the electric current flowing becomes more significant and more impact on the more alkali hydroxide formed. Therefore, higher levels of NaCl causes an increase in pH.

Figure 2 shows that the aeration process increases the pH value of waste due to carbon dioxide (CO_2) content in leachate, which is an acidic substance. Air flowed through the solution draw CO_2 dissolved weakly in the water; therefore, CO_2 diffuses into the air beforehand. This event reduces the concentration of CO_2 in water and makes the solution loses the acidic carrier substance. Aeration can reduce the H_2S compound, which is a strong acid by oxidizing it to produce water and free sulfur. The oxidation causes an increase in pH value when the electrocoagulation process is combined with the aeration process. From Figure 2, the optimum condition of the process is obtained in the electrocoagulation process with the highest combination of aeration and NaCl addition processes.

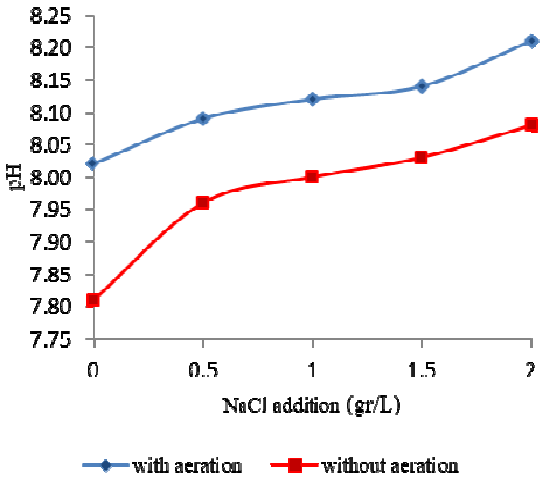


Fig. 2 Effect of aeration processes and NaCl concentration on pH

2) Effect of aeration processes and NaCl addition to TDS

TDS is the solid weight in the form of organic and non-organic substances that are dissolved in the solvent and filtered in a 0.2 μm sieve from the sample that has been clarified after heating the sample at a temperature of 105°C to have a fixed weight. The solid is not a suspended solid but is dissolved in solution.

The electrocoagulation process decreases waste TDS value due to the coagulation of some contents and separated from the waste. The decrement in TDS occurs when double layer compression occurs around the species due to interactions with ions formed from oxidation in the electrodes. The ion causes a decrease in repulsion between particles in water to make the coagulation process occurs.

The addition of NaCl causes better interaction between ions due the increment of electrical conductivity in the solution increases; therefore, more substances coagulated in solution.

Aeration has little ability to reduce the TDS value of the solution because aeration is less efficient in removing soluble substances. Figure 3 shows that aeration can reduce the TDS value because this process can oxidize iron and manganese in leachate and form insoluble compounds that can be separated. The alkaline solution also accelerates the manganese oxidation process that dissolved solids in water decrease.

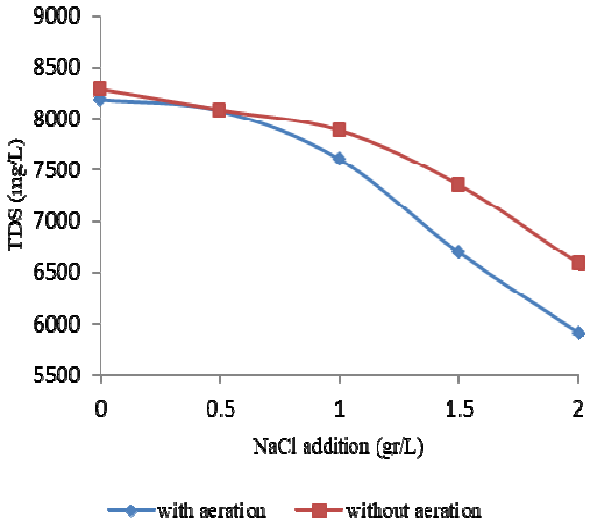


Fig. 3 Effect of aeration processes and NaCl concentration on TDS

3) Effect of aeration processes and NaCl addition to TSS

Total Suspended Solids (TSS) are suspended materials (> 1-micrometer diameter) that are held in a millipore filter with a pore diameter of 0.45 micrometers. Suspended solids are solids with a larger diameter than dissolved and colloidal solids, and suspended solids tend to be visible and increases turbidity in water. From Figure 4, it can be seen that the TSS value gradually decreases after electrocoagulation and aeration. The process of reducing TSS in electrocoagulation occurs when solid material from a suspended solid undergoes an adsorption process into the coagulant ($Al(OH)_3$). The results of this adsorption separate the suspended content from the waste to decrease TSS value. When NaCl is added to the sample, the TSS reduction is accelerated. The reduction is proportional to NaCl addition due to an increase in electrical conductivity result in the production of $Al(OH)_3$, which occurs in the electrode increases. $Al(OH)_3$ is a coagulant compound that can quickly precipitate suspended solids, the more the amount of $Al(OH)_3$, the better the coagulation process takes place.

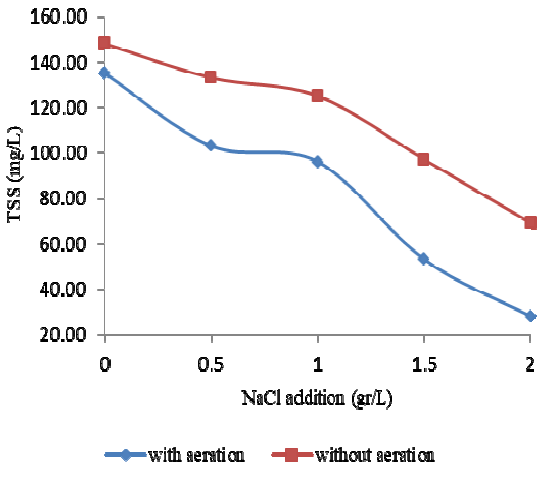


Fig. 4 Effect of aeration processes and NaCl concentration on TSS

Aeration is also an influential factor in reducing TSS levels in this process. Aeration is a physical method that is carried out by injecting air into the waterbody. Air bubbles obtained from the aeration process directly function as a dispersing media of coagulant ($Al(OH_3)$) formed the suspended substances that are easier to contact and bond with the coagulant, in addition to that the aeration process also functions as a transport media in the form of a suspension substance in the form of float that contaminants can separate more easily. The optimum conditions are obtained with increasing salt concentration and the aeration process in water.

4) Effect of aeration processes and NaCl addition to COD

COD is the amount of oxygen needed to oxidize organic and inorganic compounds in the waste. High levels of COD indirectly indicates the number of contaminant compounds in water that can be chemically oxidized. COD indicates the overall chemicals in waste that can be oxidized, while BOD5 only indicates the number of substances that are easily oxidized by bioorganisms biologically in the waste.

Figure 5 shows that the addition of NaCl increases the solution conductivity and increase in alum ($Al(OH)_3$) production. This process decreases the waste content in the sample. Aeration prepares a relatively large supply of oxygen for the oxidation process of iron and manganese, and form a sediment at the bottom of the liquid surface. Data in Figure 5 shows that the aeration process and the amount of NaCl dissolved in the waste reduces the COD value. Processes that include aeration can reduce COD content by about 5% better than those without aeration.

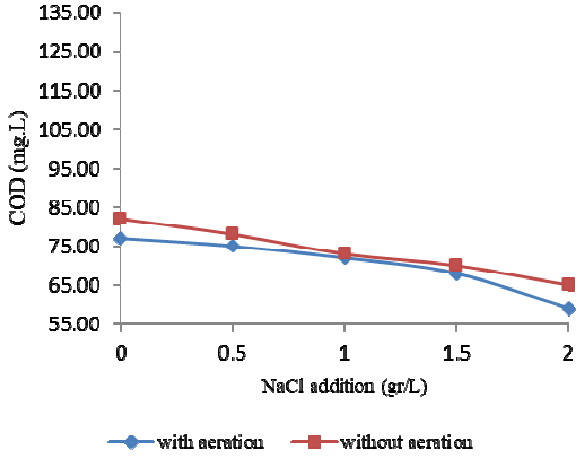


Fig. 5 Effect of aeration processes and NaCl concentration on COD

5) Effect of aeration processes and NaCl addition to BOD5

BOD5 is the amount of oxygen needed by bacteria during the breakdown of organic compounds under aerobic conditions for 5 days. The measurement process is in 5 days to ensure the number of organic compounds described had reached 70%. The BOD5 value indicates the number of substances in waste that is easily degraded biologically. A high BOD5 value plays an essential role in supporting the growth of algae and aquatic organisms. Bacterial population affects the level of water pollution.

The electrocoagulation process produces an adsorber that binds most of the water contaminants in water, including organic substances. Organic substances are separated from the solution that the total oxygen used to oxidize organic content in waste is also reduced. In the previous parameters, NaCl increases the conductivity of the solution and the amount of coagulant formed while aeration can increase the homogeneity of the solution with the coagulant formed and provide additional oxygen to the body of water, which causes oxygen to oxidize some of the organic substances contained in the leachate and organic waste content in the sample decreases.

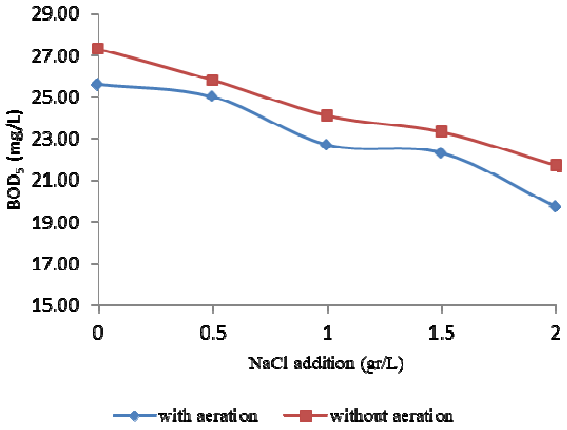


Fig. 6 Effect of aeration processes and NaCl concentration on BOD5

Figure 6 shows that the aeration process and the higher addition of NaCl added to the sample causes a decrease in BOD5. From Figure 6, it can be concluded that the increase of salt addition increases solution electrolysis, and the combination with the aeration process provides optimum conditions in the process of leachate treatment by electrocoagulation.

6) Effect of aeration processes and NaCl addition to turbidity

Turbidity is the amount of light that can be refracted by a sample when passed light. The refraction of light occurs due to the occurrence of substances that are able to refract the light. In contrast to TSS, turbidity values are not only affected by suspended solids but also affected by the number of colloids contained in the sample. It should be noted that color intensity is not a parameter in measuring turbidity.

The effect of adding NaCl and the aeration process also causes a decrease in turbidity values to take place better, as shown in Figure 6. NaCl added to the solution can cause a potential increase in the turbidity value of the solution, but the effect is not proportional to increasing $Al(OH)_3$ coagulants. The slight addition of NaCl is not proportional to the reduced levels of pollutants in the waste due to coagulation by coagulants, that is what causes the NaCl effect in the electrocoagulation process to bring a positive correlation to impairment turbidity of waste. Aeration can expand the contact between the solution and the coagulant, which causes more flocculants to form and settle to the bottom of the water. The float formation is faster due to the aeration process.

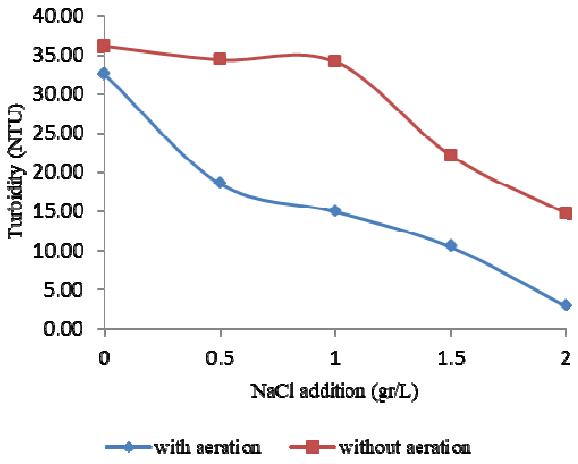


Fig. 7 Effect of aeration processes and NaCl addition to turbidity

D. The effectiveness of the electrocoagulation method in processing leachate

Effectiveness is a comparative value that shows the ratio between changes in the initial and after the experiment leachate. Processing for each electrocoagulation leachate treatment parameter is not the same since each parameter has its response in receiving the electrocoagulation treatment process. Changes in TDS values have the least effective among other parameter changes, while turbidity has the most significant processing effectiveness compared to other parameters

Figures 8 and 9 show that the addition of NaCl and the aeration process have a positive effect in increasing the value of the effectiveness of leachate treatment. Both of these variations have a considerable influence on increasing the value of the effectiveness of the process. From Figures 8 and 9, it can be concluded that the most effective electrocoagulation process is a combination of aeration processes and NaCl additions to the leachate sample.

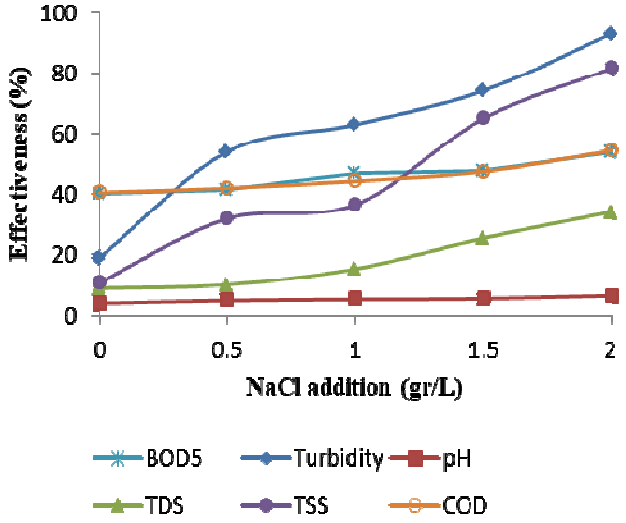


Fig. 8 Electrocoagulation effectiveness of NaCl addition with combination of aeration processes

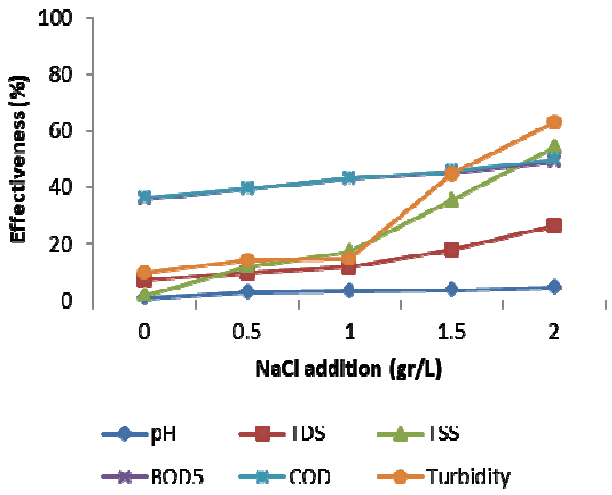


Fig. 9 Electrocoagulation effectiveness of NaCl addition without combination aeration processes

IV. Conclusion

The most effective of the electrocoagulation process with the aeration process occurred in the addition of sodium chloride 2 g/L, which consists of the TDS value of 34.06%, TSS 81.46%, COD 54.26%, BOD5 53.76%, and turbidity 92.92%. While the highest effectivity of the electrocoagulation process without the aeration process occurs in the addition of 2 g/L sodium chloride, consists of the TDS value of 26.59%, TSS 54.3%, COD 49.61%, BOD5 49.06%, and turbidity 63.34 %. The result proves that the aeration variations process and the addition of sodium chloride increase the value of the effectiveness of the process. The optimum condition of the electrocoagulation process using aluminum electrodes is in a process that is combined with the aeration process and occurs at the highest addition of salt, which is 2 g/L. This indicates that the aeration process and the addition of NaCl reduce the level of pollutants in the waste.

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