

Batch leachate treatment using stirred electrocoagulation reactor with variation of residence time and stirring rate

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Abstract. This study aims to reduce pollutant levels of the leachate by electrocoagulation method using a stirred electrocoagulation reactor as the electrochemical water treatment. The release of active coagulants as metallic ions took place in the anode, while in the cathode, the electrolysis reaction in the form of hydrogen gas discharge occurred. The source of wastewater is Waste Water Treatment Plant inlet III of Bantar Gebang, Bekasi. Some parameters were analyzed in this research, i.e., Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), NH_3 , NO_3^- , NO_2^- , N-total, and organic substances as well as the microorganism growth before and after electrocoagulation, with variations of detention time (seconds) of 10, 20, 120, 600 and rapid mixing conditions (rpm) of 60, 100 and 200. The results show that the greater the rapid mixing speed and the detention time of electrolysis, the higher the removal of contaminants in liquid waste. The optimum condition of electrocoagulation was encountered at 200 rpm rapid mixing with 600 seconds of processing time. The removal efficiencies of electrocoagulation method for each parameter are TSS of 46.80%, BOD_5 of 71.33%, COD of 73.77%, Pb of 62.5%, and $\text{NH}_3\text{-N}$ of 57.92%, whereas the pH value has been increased from 8.03 to 8.95. The electrocoagulation method can reduce levels of pollutants, complying with the environmental standards.

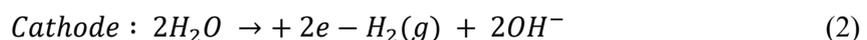
Keywords: electrocoagulation, leachate, optimum condition

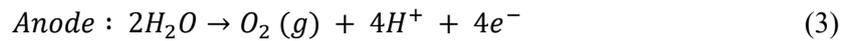
1. Introduction

Integrated Waste Treatment Site (TPST) is the location of final waste treatment established in a region, such as urban areas. One of the main problems in the operation of TPST is the emerging leachate - a liquid waste that arises from the inclusion of water into the pile of waste and dissolves chemical elements including decomposed organic matters [1], [2].

Among various methods of leachate processing, the electrochemical application of electrocoagulation can be applied to reduce organic contents in leachate through the oxidation process [3], [4]. Wholly occurred in water, electrocoagulation requires energy in the form of electricity to change the water content chemically [2], [5], [6],

An electrocoagulation reactor is an electrochemical cell wherein the anode (usually using aluminum or iron) is used as an agitation agent, according to the following reactions [7], [8].





Total reaction:



(*) the formed O_2 is so small that the decomposition of H_2O in the anode is ignored.

It can be seen in the reactions occurred in the electrocoagulation process that the cathode will produce hydrogen gas and metal ions. Meanwhile, the anode will generate halogen gas and develop flocculation deposition.

The electrocoagulation process is performed in an electrolysis vessel in which there is a cathode and an anode as direct electric current conductors called electrodes, immersed in the waste solution as the electrolyte. Since the electrocoagulation process produces gas in the form of bubbles, the dirt molded in the water will be lifted up to the water surface. The flocs have a relatively small size, but over the processing time, their size will be increased. After the water undergoes electrocoagulation, the precipitation will take place to precipitate the particles or flocs formed earlier. Subsequently, the effluent produced will be analyzed in the laboratory.

The leachate treatment by batch electrocoagulation method using variations of rotation speed and residence time has been studied deeper in this research.

2. Research Method

2.1. Reactor Description

This laboratory scale research, the electrocoagulation reactor is a container made of PVC pipe with a thickness of 4 mm (Figure 1). Inside the reactor there is a 1mm aluminum that acts as anode and stainless steel stirrer (length = 40 cm; thick = 1 mm). In addition, there is a gear motor (DC motor), connected to the ampere meter, to drive the paddle inside the reactor to process the waste inside. For the outside of the reactor itself consists of inlet and outlet taps as water channels prior to processing and after processing, as well as a gas valve to determine whether any gases are formed from the process proceeds within the reactor. There is also a voltage generator (power supply) that serves as a regulator of the speed of rotation (rpm). Volume of sample that can be processed in reactor as much as 5.5 L.

Note :

1. Aerator (Q=60L/sec)
2. Aeration Hose Connection
3. Aeration Drum
4. Aeration Stone
5. Air Bubble
6. Aeration Drum Outlet Tap
7. Reactor Inlet Tap
8. Electrocoagulation Reactor
9. Gas Valve
10. Stainless Steel Stirrer
11. Blade
12. Reactor Outlet Tap
13. Beaker Glass

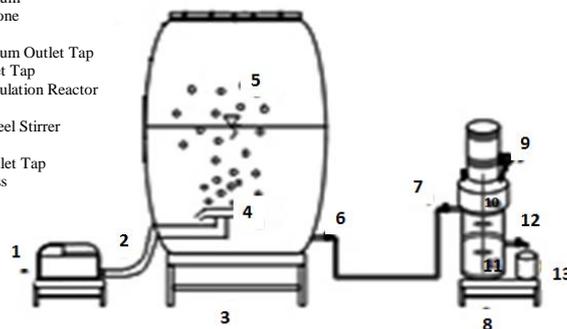


Figure 1. Design of electrocoagulation reactor.

2.2. Characteristics of leachate samples

This research was conducted on a laboratory scale using two variables (residence time and rotation speed) and eight measured parameters of nitrate (NO_3^-) and nitrite (NO_2^-) by colorimetry/spectrophotometry, ammonia (NH_3) by spectrophotometry in phenate, COD by titrimetric

closed reflux method, BOD by Winkler method, organic matter content (KMnO_4) by permanganometric titration, N-total by Kjeldahl method, and the microorganism growth (VSS).

Table 1. Leachate characteristics of TPST Bantar Gebang, Bekasi.

Parameters	Range of concentration (mg/L)
Nitrate	127,92
Nitrite	1.7–2.3
Ammonia	47,83
COD	4.043
BOD	1.462
VSS	738
KMnO_4	1.896

2.3. Aeration

The aeration process is the process of adding air oxygen gas into the waste water to remove organic or odorous substances caused by anaerobic organic compounds, eg NH_3 , H_2S and CH_4 . Before being treated in an electrocoagulation reactor, the first leachate is aerated. Aeration treatment is the traditional way to treat leachate. This method is effective in removing the dissolved organic pollutants present in the leachate. Leachate from IPAS III aerated (60L/min air supply) for 15 hours.

2.4. Electrocoagulation Reactor

Electrocoagulation reactor is a container made of PVC pipe with laboratory scale. The volume of the selected reactor is 5.5 liters. Electrocoagulation is equipped with a stainless steel 40 cm (anode), aluminum (cathode), manometer as a gas pressure gauge and inlet taps and outlets.

2.5. Operation of the Reactor

After the aeration phase is complete, core research is conducted. The purpose of this research is to know the optimum condition of leachate process by using electrocoagulation reactor with variation of rotation speed (60 rpm, 100 rpm and 200 rpm) and residence time (10 seconds, 20 seconds, 120 second and 600 second) (Figure 2).

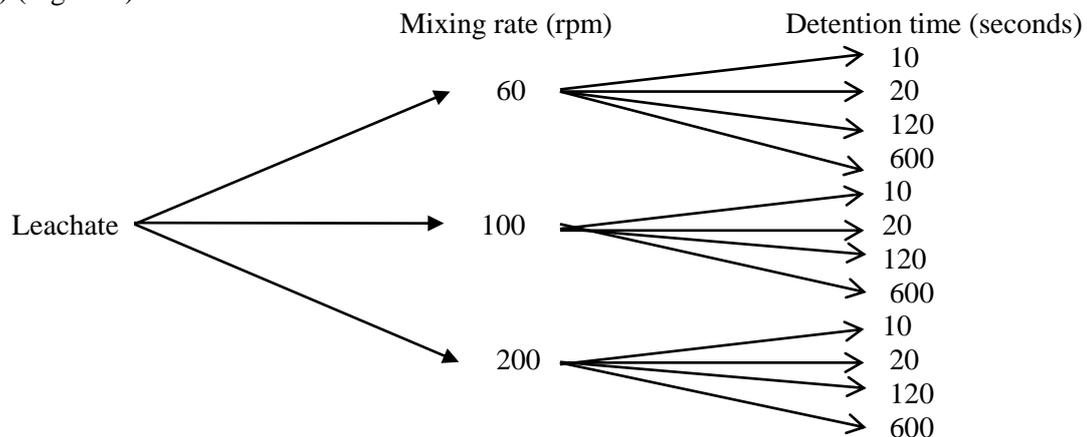


Figure 2. The electrocoagulation plan.

3. Results and Discussion

The wastewater samples were taken from the IPAS III inlet pool of TPST Bantargebang, Bekasi, by reason of location selection and the closer distance than the other IPAS locations. IPAS III inlet pools accommodate leachate produced by waste in Zone 3.

3.1. Effect of Residence Time and Stirring Rate Variation on COD

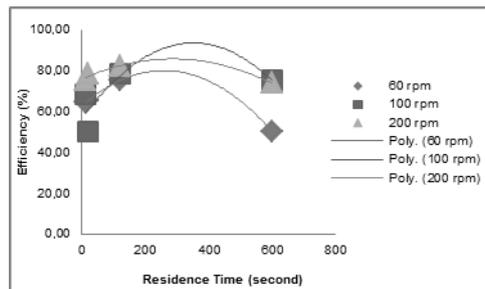


Figure 3. Relation of stirring speed variation and residence time to Efficiency (%) decrease in COD.

Based on the results of Figure 3 it can be concluded that at 200 rpm stirring speed and residence time of 120 seconds, COD concentration decreased to 714 mg/L. When compared to the Decree of Governor No. 69 of 2013 on waste water quality standards for activities and/or businesses, the concentration of COD leachate processed products is still above the standard quality of 100 mg/L. In addition to the most optimum removal efficiency pattern based on the above graph obtained by 93.24% with a stirring speed of 100 rpm and residence time of 354 seconds.

3.2. Effect of Residence Time and Stirring Rate Variation on BOD

Based on Figure 4, it can be concluded that at 200 rpm stirring rate and 60 second stay time decrease BOD concentration by 183 mg/L with removal efficiency equal to 94.67%. In addition to the optimum removal efficiency pattern based on the above graph obtained at 60 rpm stirring rate with residence time of 311 seconds with allowance efficiency of 99.79%.

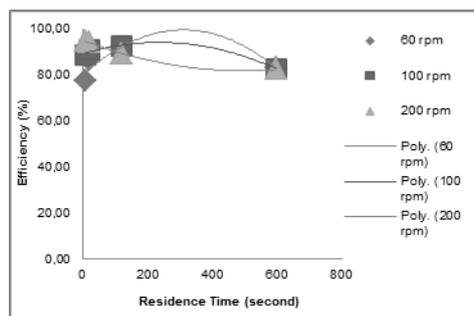


Figure 4. Relation of stirring speed variation and residence time to Efficiency (%) decrease in BOD.

3.3. Effect of Residence Time and Stirring Rate Variation on nitrate (NO_3^-)

Based on Figure 5, it can be concluded that at 60 rpm stirring speed and residence time of 20 seconds can decrease nitrate concentration (NO_3^-) of 92 mg/L with an allowance of 28.41%. For the most optimum removal efficiency pattern on nitrate removal has not occurred with a residence time of 600 seconds. That's because the H_2 gas that is formed is very small or the increase in H_2 gas is very slow. The size of H_2 gas formed is influenced by Al^{3+} formed. So it needs to do the process back with a residence time above 600 seconds to get the optimum condition of the nitrate removal percentage.

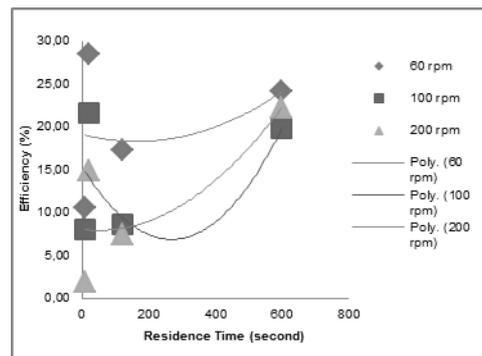
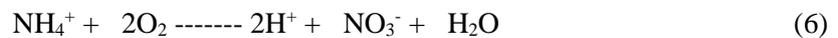


Figure 5. Relation of stirring speed variation and residence time to Efficiency (%) decrease in nitrate.

3.4. Effect of Residence Time and Stirring Rate Variation on ammonia (NH_3)

The aeration process causes ammonia (NH_3) to nitrate. As a product resulting from the aeration process, nitrate is relatively harmless to aquatic life. In detail, the picture of NH_3 change reaction is presented as follows:



Based on the aeration process performed for 15 hours, the ammonia concentration on effluent produced by air giving at a rate of 60 liters/minute decreased to 36.15 mg/L from an initial concentration of 47.83 mg/L. In the electrocoagulation process, ammonia does not change. That's because O_2 gas in the reactor is very small. In addition, H_2 gas formed in the electrocoagulation process can not react with ammonia, so there is no allowance process.

3.5. Effect of Residence Time and Stirring Rate Variation on organic matter ($KMnO_4$)

In the electrocoagulation process, organic matter ($KMnO_4$) is unchanged or unaffected by stirring rate and residence time. It can be seen from the results of organic matter analysis ($KMnO_4$), the decrease is not significant (Figure 6).

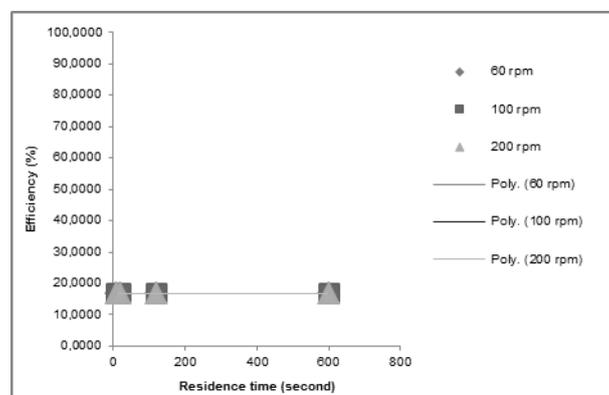


Figure 6. Relation of stirring speed variation and residence time to Efficiency (%) decrease in organic matter ($KMnO_4$).

3.6. Effect of Residence Time and Stirring Rate Variation on organism (VSS)

Based on Figure 7, it can be concluded that at 100 rpm stirring speed and residence time of 120 seconds can decrease VSS concentration of 348 mg/L with allowance removal of 52.85%. While at 200 rpm stirring speed is not likely to occur VSS large allowance because at this speed the microorganisms disrupted and did not have time to develop.

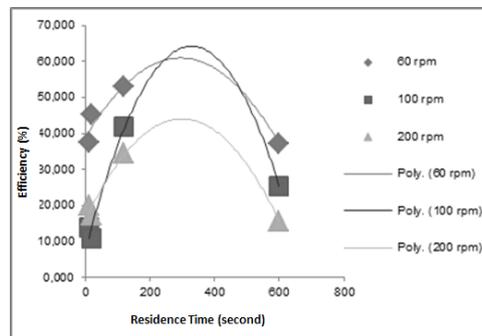


Figure 7. Relation of stirring speed variation and residence time to Efficiency (%) decrease in organism (VSS).

4. Conclusion

The results showed that the characteristic of leachate IPAS 3 TPST Bantar Gebang, Bekasi has concentration of COD, BOD, Nitrate (NO_3^-), Ammonia (NH_3), organic substance (KMnO_4) and increase of microorganism (VSS) that is equal to 4,043 mg/L, 1,462 mg/L, 127.92 mg/L, 1,896.17 mg/L, and 738 mg/L. The most optimum removal efficiency pattern with 60 rpm speed can set aside BOD parameter 99.79% for 311 second and nitrate equal to 41.12% for 288 second. For 100 rpm speed COD parameter can be set aside 93.24% for 354 seconds and VSS of 66.77% for 326 seconds.

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