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Electrocoagulation Process by Using Aluminium and Stainless Steel Electrodes to Treat Total Chromium, Colour and Turbidity

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Abstract

The research works involve the study of removal of Total Chromium, Colour and Turbidity contaminations in landfill leachate by electrocoagulation process. This project focused on leachate landfill from Pulau Burung, Nibong Tebal, Penang as an electrolyte solution. Heavy metals are the main factor contributing to pollution in leachate landfill. Leachate is the main pollution factors from landfill sites and must be treated before it is released into the environment[1]. Landfill leachate contain high amount of heavy metals that can cause serious health problems to human, if the wastewater that contained heavy metals is not treated properly[2]. This project tried to reduce and treat the heavy metal that contain in the landfill leachate. Types of electrodes used in this study were Aluminium (grade 5052) and Stainless Steel (grade 316). The ranges of initial pH applied were pH (3, 4, 5, 6 and 7) and voltages applied were 1.5V, 2.0V and 2.5V. At the end of electrocoagulation process, the solutions were stored and analysed using Atomic Absorption Spectroscopy (AAS) to determine the final concentration of electrolyte solution. It was found that, the difference electrodes have different effectiveness in removing Total Chromium, colour and turbidity, relies on the types of electrodes (Aluminium or Stainless Steel). Based on the result, can be concluded that Aluminium Electrodes are best for removal of turbidity and colour. Stainless Steel Electrodes is best for removal Total Chromium. The initial pH also gives the significant effect to removal of heavy metal and the maximum voltages give higher removal of heavy metal.

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Keywords: Electrocoagulation; initial pH; applied voltages; electrodes; Aluminium and Stainless Steel

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1. Introduction

Landfilling is the most common and easy way to dispose the solid waste. Generally landfill will receive the wastes from municipal that are near to a landfill. If the location of waste generated is far, the transfer station is the solution to reduce cost of waste transportation. The waste usually mixed of waste products from residential area, commercial, institutional and etc.

There are three kinds of outputs for landfills, examples gas, liquid (leachate) and inert solids[3]. Commonly, leachates may contain organic contaminants in large amounts and can be measured as Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), ammonia, and high concentration of heavy metals.It is contains high concentration of pollutants which can have adverse effects on the environment[4]. Various methods have been proposed to remove heavy metal such as ion exchange resins adsorption[5], chemical precipitation, membrane filtration[6], and electrocoagulation[7].

Electrocoagulation has been used in treating wastewater that containing, oil and grease, suspended solids and even inorganic and organic pollutants that can be flocculated. This method has been effectively applied for the treatment of the textile dye wastewater, purification of wastewater, tannery wastewater and domestic wastewater. This method is categorized by simple equipment and easy operation. The electrocoagulation processes have lesser amount of sludge[8] and having features like relatively more economic and higher treatment efficiency has been a promising method[9].

2. Materials and methods

2.1. Experimental Procedure

The procedure started with electrocoagulation cell cleaned with distilled water and dried using dryer. About 100 mL of leachate sample was poured into the electrocoagulation cell, this volume will allowed and give space for bubble from the reaction to develop since the maximum capacity for electrocoagulation cell is 150mL. The pH of the solution was taken using pH meter (Model CyberScan pH 510) and recorded. The electrodes (anode and cathode) were clamped at electrode stand. All connections in the circuit were completed by wire connection to terminal positive and negative to DC power supply (Model Topward 3306D), electrodes (anode and cathode), voltmeter and ammeter (Model Fluke 115). The electrodes were immersed in an electrolyte solution. Immediately the power supply was switched on, and the voltage was adjusted to desire a voltage that is 1.5V.

The colour of the solution of electrolyte solution was observed before and after the process occurred. The experiment was done in 60 minutes. The reading of cell potential and current, A, are taken every 5 minutes intervals. After 60 minutes, the power supplies were switched off and both electrodes were taken out carefully. The pH of the solution was taken using pH meter (Model CyberScan pH 510) and recorded. All procedure above was repeated by using other types of electrodes (Stainless Steel and Aluminium), difference of leachate sample (electrolyte solution) with varying initial pH values were pH 3, pH 4, pH 5, pH 6 and pH 7 and also difference applied voltage was used were 1.5V, 2.0V and 2.5V.

3. Results and Discussions

3.1. Effect pH on removal of Total Chromium, Colour and Turbidity

This experimental work used ranges, pH 3, 4, 5, 6 and 7. The pH 7.73 is for the control experiment and it is a raw leachate sample with addition chemical such as acid. These ranges will give the data about how acidic pH will affect the electrocoagulation efficiency in the removal of heavy metal that contain in the leachate samples.

3.1.1. Removal of Total Chromium.

As shown in Fig. 1, the removal of Total Chromium using Aluminium electrodes very efficient at pH 3 it about 72.65% at voltage 2.5V and slightly different with removal of Total Chromium using stainless steel electrodes at voltage 2.5V that are efficient at pH 7 from Fig. 4, it about 88.35%. At pH 3 and pH 4, the removal is 44.55% and 15.17% respectively. At other pH, there is no removal of Total Chromium. These result shown that the optimum condition for removal of Total Chromium. That is at pH 3 when using Aluminium electrodes at voltage 2.5V and at pH 7 is the optimum condition for removal Total Chromium using Stainless Steel electrodes at voltage 2.5V. The consequences of this result may cause by the influence of ion that has been release from different electrodes.

According to Parga et al., (2005)[10] the Chromium ion that has been released during electrocoagulation are depending on pH and the ion that has been released by the types of electrodes that are being used.

According to Rezaee et al., (2011)[11] when using Aluminum electrodes, Chromium removal increase during electrocoagulation while pH decreasing, when the initial pH is increasing, a decrease in the removal efficiency of chromium is observed. In acidic solution, Cr^{+6} ions are reduced to Cr^{+3} ions. Therefore, the removal efficiency of Chromium is significant.

According to Khandegar and Saroha, (2013)[12], they found that the pH of the solution has significant effect on the Chromium removal efficiency. They has done the experiments at different pH of the synthetic solution and achieved the maximum Chromium removal efficiency at the acidic pH. They have reported that the pH of the synthetic solution after the electrocoagulation process increased with an increase in the electrolysis time due to the generation of OH^- in the electrocoagulation process.From this experiment, effect of the pH on removal similar to the work of Anbari et al., (2012)[13] for using Stainless Steel electrodes. It can be observed that the removal efficiency of all studied ions decreased considerably upon decreasing initial pH and there is maximum removal efficiency at the pH of 7, which is almost neutral. Consequently, it can be decided that when pH is 7, the majority of iron complexes (coagulants) are formed and it's the optimum pH for carrying out the electrocoagulation.

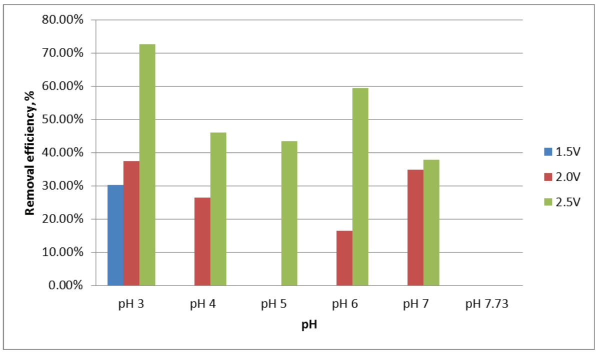

Fig. 1. Comparisons percentages of removal Total Chromium using Aluminium electrodes at differences applied voltages and at differences pH.

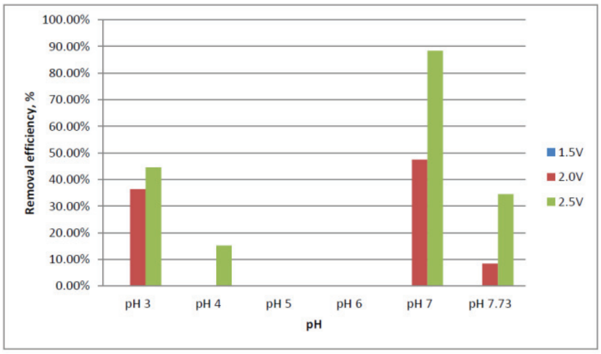

Fig. 2. Comparisons percentages of removal Total Chromium using Stainless Steel electrodes at differences applied voltages and at differences pH.

3.1.2. Removal of Colour.

As shown in Fig. 3, the influence of initial pH on the removal efficiency by electrocoagulation using aluminium electrodes. For all pH used the maximum efficiency was obtained for an initial pH of about 4 for applied voltages 2.5V, but it is clear that the efficiency used for pH of 7 is lower.

As shown in Fig. 4, when using stainless steel electrodes same result are recorded. For all pH used, the maximum efficiency was obtained for an initial pH 4 for applied voltages 2.5V. But for other pH, the patterns of removal are not same.

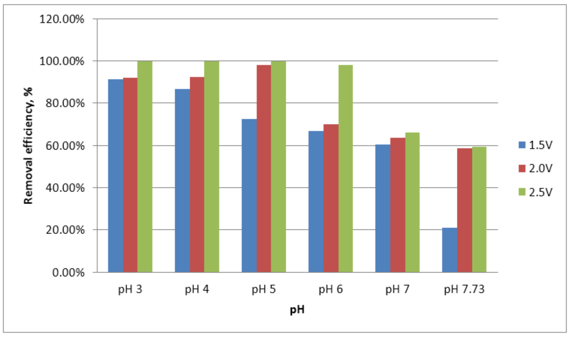

Fig. 3. Comparisons percentages of removal colour using aluminium electrodes at differences applied voltages and at differences pH.

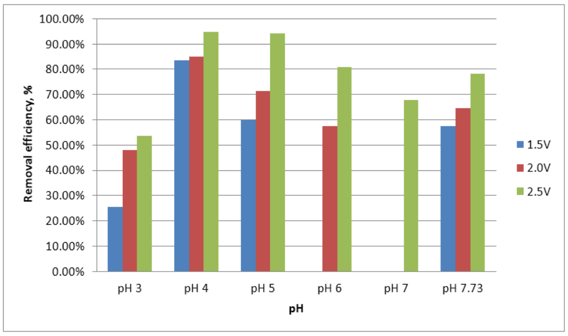

Fig. **4.** Comparisons percentages of removal colour using stainless steel electrodes at differences applied voltages and at differences pH.

3.1.3. Removal of Turbidity

As shown in Fig. 5, the removal of turbidity using Aluminium electrodes at voltage 2.5V are achieved mostly more than 65% and the most successful removal achieved at pH 3 for all voltages applied and the highest removal at pH 5 almost nearly 100%, the removal is 99.65%. At all pH values turbidity was lowered gradually with almost the same pattern.

Fig. 6 shown, the removal of turbidity using stainless Steel electrodes at voltage 2.5V, it can be clearly seen that at pH 4, turbidity has removed more efficiently (around 99.41%) compared to the other pH values.

According to Islam et al., (2011)[14] , the two main objectives of the coagulation are to settle the suspended colloidal particles in wastewater quickly, which settle very slowly, or maybe do not settle at all under normal conditions, later leading to residual turbidity, and to remove residual turbidity from the water/wastewater and consequently to obtain clearer water/wastewater, which is a natural result of the earlier.

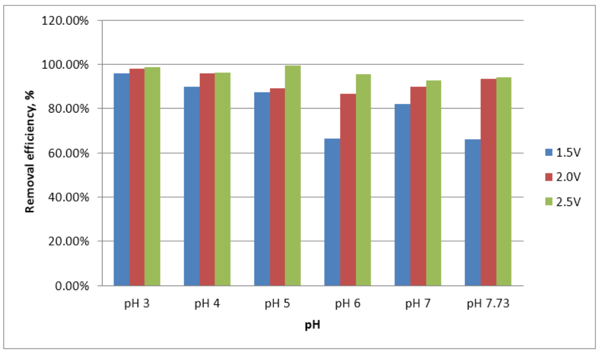

Fig. 5. Comparisons percentages of removal turbidity using aluminium electrodes at differences applied voltages and at differences pH.

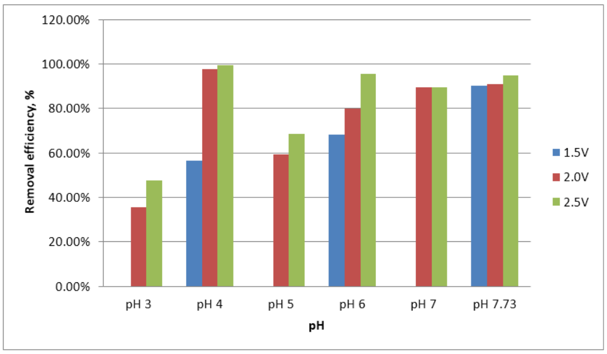

Fig. 6. Comparisons percentages of removal turbidity using stainless steel electrodes at differences applied voltages and at differences pH.

3.2. Effect of Voltages Applied on Removal of Total Chromium, Colour and Turbidity.

The voltages that had been applied are the lowest and in the range of 1.5V, 2.0V and 2.5V. The minimum range of applied voltage will give the benefit of reducing operating cost. As shown in Fig. 1 until Fig. 4 before, it showed the same pattern of removal when the applied voltages are increase in every pH that been applied. The removal is higher or maximum when the applied voltages are 2.5V and lower at 1.5V.

From the experiment, it was found that the maximum voltage give higher removal of Total Chromium, colour and turbidity. The increase of voltage is influencing the rate of removal heavy metal. The removals are increased by voltages applied for this experiment. Bouhezila et al., (2011)[15] also reported that increase the voltage may increase the removal of heavy metal. In this experiment, it was found that the result for different electrodes shown different in removal efficiency achieved. It depends on the conductivity of the materials that has been used as electrodes. The Aluminium electrodes give a better result for removal of colour and turbidity instead stainless steel electrodes but for Total Chromium the Stainless steel electrodes is the best.

3.3. Effect Types of Electrodes Material on Removal of Total Chromium, Colour and Turbidity.

Aluminium (grade 5052) and Stainless Steel electrodes (grade 316) were used because it cost cheaper than other material for electrodes so it can be commercialized and use in large scale plants.

As shown in Table 1, the highest removal of Total Chromium is recorded when using stainless steel electrodes higher than using aluminium electrodes, are 88.35% and 72.65% respectively. The colour removal is 99.78% when using aluminium electrodes and the colour removal is 94.76% when using stainless steel electrodes. The result shown that the aluminium electrodes are better than using stainless steel electrodes. The turbidity removal for aluminium electrodes is 99.65% and the turbidity removal stainless steel is 99.41%. The result shown the removal turbidity using Aluminium electrodes are better than Stainless steel.

Table 1. Comparison percentages removal of heavy metals with differences electrodes from this research work.

Types of Removal	Types of Electrode	Optimum Percentage Removal, %
Total Chromium, Cr	Aluminium	72.65
Total Chromium, Cr	Stainless Steel	88.35
Colour	Aluminium	99.78
Colour	Stainless Steel	94.76
Turbidity	Aluminium	99.65
Turbidity	Stainless Steel	99.41

Nasrullah et al., (2012)[16] also found that the stainless steel electrodes are more effective than aluminum electrodes for waste water treatment that contains other elements other than Iron. According to Murthy and Parmar, 2011[17] the stainless steel electrodes is more effective than the aluminum electrode for removal heavy metals other than Iron.

According to Top et al, (2011)[18], in case aluminium electrodes used, the high charged poly-nuclear hydroxy aluminium complexes, such as $Al_2(OH)_2^{4+}$, $Al_7(OH)_{17}^{4+}$, $Al_{13}(OH)_{34}^{5+,}$ Al3 (OH)4^{5+}, $Al(OH)_6^{3-}$, $Al(OH)_7^{4-}$ and AlO_2^-, were produced.

Actually, these poly-nuclear hydroxy aluminium complexes might coagulate colloidal solids in the samples, which was accommodating for the removal of the colour in samples. The removal of colour may comprise physically adsorption by these hydroxy aluminium complexes and changing some of the substituents which govern the colour.

4. Conclusions

Electrocoagulation studies conducted on the leachate from the Pulau Burung Landfill Site in Penang, Malaysia showed the positive result in removal of Iron and Total Chromium. It was found that the best electrodes removal of Total Chromium is Stainless Steel electrodes. The removal of Total Chromium by using Stainless Steel electrode

(SSE) is more effective than Aluminium electrodes (AE) at voltage 2.5V. The removal using SSE is 88.35% (Optimum pH is 7) and removal using AE is 72.65%. (Optimum pH is 3). The turbidity removal rates by using AE are higher than using SE at voltage 2.5V. For using AE the removal is 99.65% (Optimum pH is 5) and for using SSE is 99.41% (Optimum pH is 4). AE shown greater colour removal than using SSE at voltage 2.5V, the removal colour are 99.78% (Optimum pH is 4) for AE and 94.76% (optimum pH is 4) for SSE.

It was found that, the difference electrodes have different effectiveness in removing the Total Chromium, colour and turbidity, relies on the types of electrodes (Aluminium or Stainless Steel). Based on the result, it can be concluded that the AE are the best for removal of turbidity and colour. SSE is the best for removal Total Chromium. It initial pH also gives the significant effect to remove the heavy metal and the maximum voltages give higher removal of the heavy metal.

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