Review Paper

Treatment of Leachate by Electrocoagulation Technique Using Iron And Hybrid Electrodes

Mostafa Mohammadizaroun, Mohd Suffian Yusoff*

School of Civil Engineering, Engineering Campus, University Sains Malaysia, 14300 Nibong Tebal, Penang, Malaysia
*Corresponding Author: suffian@usm.my

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Abstract. The most techniques for treating leachate and wastewater are physical, chemical, biological, advanced oxidation and electrochemical techniques. Developed oxidation techniques lead to high treatment cost and mostly are used in purifying grade waters. Among these techniques, the chemical coagulation technique not only is a slow process, but also produces a large amount of sludge. Electrocoagulation has been used for treating industrial effluent and leachate as a potential technique because of its compatibility and adaptability with environment. In this technique, a direct current source between metal electrodes plunged in the effluent is used to dissolve the electrode plates into the effluent. The metal ions with appropriate pH can create various types of coagulated species and metal hydroxides that in turn cause to rolling up and destabilizing the elements, or catalyzing and absorbing the dissolved pollutants. Therefore, the purpose of the current study is to examine the potentials of electrocoagulation in treating the leachate and wastewater by treating the heavy metals and their colour and salinity. Furthermore, the present study aims to investigate the electrocoagulation, electrochemical technologies and their design and application in treating the leachate, water, and wastewater. This work mostly dealt with the electrocoagulation (EC), electrodeposition, electroflotation (EF), and electrooxidation. It was shown that Electrodeposition is efficient in treating the wastewater stream and removing heavy metals. In addition, electrocoagulation was used for treating wastewater and producing clean water as well. It was also found that using aluminum, iron or the hybrid Al/Fe electrodes are more applicable.

Keyword: Electrocoagulation, Treatment, Leachate, Wastewater, Iron and Aluminum Electrode, Hydride electrode

1. INTRODUCTION

Electrocoagulation is an electrochemical method that is employed for both wastewater and surface water treatment. In this method, sacrificial anodes are oxidized and active coagulant precursors, such as aluminum or iron cations, are released into liquid. During this process, additional electrolytic reactions produce gas at the cathode, which is usually in the form of hydrogen bubbles (Holt et al., 2005). Drinking water that is polluted by heavy metals is dangerous for human health. One of the techniques that are used for purifying wastewater is Electrocoagulation. This technology employs electrolytic oxidation of anode materials and in-situ generation of coagulation (Wan et al., 2011). The purpose of using electrocoagulation (EC) is removing various types of pollutants such as heavy metal ions from water and wastewater effluents (Shafaei et al., 2010).

Electrocoagulation (EC) has attracted the attention of the environmental sectors largely as an efficient way to treat different types of water and wastewater during the last two decades, and especially during the last few years. The purpose of the present work is to study some related researches that were conducted mainly on the widespread use of practical electrocoagulation in treating different types of water and wastewater during 2008-2014.

Due to the large amount of wastewater coming from industry and its variety, its purification is still a noteworthy environmental problem in the world (Zodi et al., 2009). Some of these wastewater types can show evidence of high chemical oxygen demand (COD), dark color, and strong bad smell. Thus it is essential to treat the sewerage before discharging them into the environment and water sources. For this purpose, electrocoagulation has been employed to purify different types of wastewater generated by industry section in recent years (Khemis et al., 2006). Accordingly, EC method has absorb the interest of many researchers for being applied to treat the water and wastewater. It is one of the recently developed water technologies that has been used successfully in purifying different types of wastewaters (Tchamango et al., 2010).
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The applications of Electrocoagulation (EC) method in this study has been classified into nine categories including: tannery, pulp and paper industry wastewater, textile and colored wastewater, food industry wastewater, oily wastewater, laundry and dairy wastewater, other types of industrial wastewater, surface and model water and wastewater that contain heavy metals, cyanide, nutrients, and other elements, and ions. Moreover, the current study aims to outline the best conditions in the process of treatment such as treatment time, existing density and pH as well as the high level of efficiency in removing pollutants while applying the EC under discussion (Kuokkanen et al., 2013).

One of the appropriate ways for purifying dairy waste is applying Electrocoagulation with aluminum anode because there is acceptable reduction of different parameters such as turbidity, total phosphorous, and nitrogens (Tchamango et al., 2010). In addition, this process requires fewer reagents, i.e. the quantity of aluminum that is liquefied in this process is lower than the amount of aluminum salt dissolved in chemical coagulation (Tchamango et al., 2010).

By using Electrocoagulation (EC), which is a type of cheap and green method for removing heavy metals from wastewater, some chromium can be removed from industrial effluents, namely metallurgy, electroplating, leather tanning, chemical catalysts, pigments, corrosion inhibitors and printing inks (Mouedhen et al., 2009).

2. LEACHATE

Leachate is a very complex liquid with high concentration of pollution that makes its treatment very hard and providing the removal standards is difficult. Among other types of wastewaters, leachate is the most difficult one to treat because it contains complex structure that is produced within a landfill. Accordingly, the variety types of pre-treatment and mixed methods of treatment were used to treat leachate (Welander et al., 1998).

2. ELECTROCOAGULATION REACTORS FOR HEAVY METALS REMOVAL

According to the recent studies on the reactor designs and functions, it is found that the easiest way and low-cost facility for treating localized water could be a set of reactor systems that has vertical plate electrodes. In designing the reactor being made of electrolytic gas flotation, the separation of the aggregated pollutants in electrodes is the primary goal (Holt et al., 2005).

Electrocoagulation (EC) has been introduced for more than one century. Electrocoagulation with aluminum and iron has already been awarded in the US in 1909. Due to its applicability, EC has been investigated broadly in the US and Soviet Union (former USSR) during the second half of 20th century. However, despite the extensive studies in those times, its broad feasibility in treating water was not found clearly. Perhaps the main reason was the high costs of electricity and investment in those days (Chen, 2004).

Electrocoagulation (EC) has been investigated and applied for purifying the wastewater by many researchers previously and the results show that there are several differences in the processes of chemical coagulation. The review of literature demonstrates that Electrocoagulation is a useful process in treating different wastes such as soluble oils, liquid generated by food, industrial materials, and fibers and effluents come from the paper industry (Carmona et al., 2006). EC is an electrochemical method used in purifying the polluted water by which sacrificial anodes are oxidized so that active coagulant precursors such as aluminum or iron cations could be released into liquid. Additional electrolytic reactions produce gas at the cathode, which is usually in the form of hydrogen bubbles (Holt et al., 2005). An electrocoagulation reactor, essentially, is an electrochemical cell by which a sacrificial metal anode, which is occasionally made of iron and usually of aluminum, is utilized to measure the amount of polluted water by suing a coagulating agent (Holt, 2006).

Electrocoagulation (EC) application is considered as a conventional development technology with possibility to improve the space-time efficiency. It has also been used to produce water or purify wastewater. Using aluminum, iron, or the hybrid Al/Fe electrodes are found to be more applicable as well (Chen, 2004). Despite the fact that electrocoagulation technique has been introduced for more than one century, its application efficiency in purifying wastewater has found recently. The design of an industrial plant and an electrocoagulation cell are mostly based on previous empirical studies that had little attention to the electrocoagulation mechanism (Calvo et al., 2003). Electrocoagulation (EC) is known as the easy and efficient electrochemical method for treating different types of water and wastewater (Tezcan et al., 2006). The characteristics of this technique are: easy in operation, simple equipment, and decreased amount of mud. In this process, the generation of coagulant by electrolytic oxidation of a proper anode material at a proper pH leads to unsolved metal hydroxide that later removes the various types of contaminant (Adhoum and Monser, 2004).
2.1. Types of reactors used

As it was referred earlier, according to the previous studies about reactor designs and functions, it is found that the simplest method and low-cost facility for purifying wastewaters is a set of reactor system whose integral characteristic and function is separating the aggregate contaminant by using electrolytic gas flotation (Holt et al., 2005).

As it was mentioned earlier, all electrocoagulation reactors have electrochemical units. All of these reactors have an electrode set that is in contact with the polluted water. One of their specific characteristics is a coagulant production in situ. A practical probable difference between the electrodes is required for releasing the coagulant. The electrochemical half-cell reactions that occur at each electrode can reduce the potential requirements for electrodes. Each electrode will differ according to the efficient pH and the group type that exists in the system.

2.2. Electrode materials

Different materials could be used as electrodes for electrocoagulation and electrode material has been known to be an important factor influencing the performance of the electrocoagulation process. Also Iron and Aluminum or hybrid (Al/Fe) usually used as electrode in electrocoagulation process (Ratna et al., 2004). Electrode material is known to be an important factor influencing the performance of the electrocoagulation process. Different materials can be used as electrodes for electrocoagulation. Iron, Aluminum, and hybrid (Al/Fe) are usually used as electrode in electrocoagulation process as well.

3. EFFECTING OF FACTORS ON ELECTROCOAGULATION PROCESSES

3.1. Effect of temperature

According to the findings of studies done on removing waterborne bacteria from geothermal water, it was demonstrated that one of the vital affecting factors that has a significant positive effect on the process of electrocoagulation is temperature (Yilmaz et al., 2008). Yilmaz et al. (2008) found that, like many other chemical reactions, temperature helps electrochemical reaction rate enhances. They demonstrated that if the temperature reaches to 40 oC, efficiency of Borne removal increases 12% forming coagulate of flocked ions on anode surface. Thus the increase in temperature could not contributed as line effect effect factor on the process of electroquagulation (Yilmaz et al., 2008).

In studied range, temperature, in comparison with the effect of electrode charge per liter and origin pH, was slightly effective in removing natural organic matter (NOM). In fact, temperature had major effect through the various dissolving rate of the electrodes (Vepsäläinen et al., 2009) 4) In a study done by Katal and Pahlavanzadeh (2011). Electrocoagulation was examined as a possible way to reduce the color, phenol, and COD pollutants from wastewater of paper mill. It was found that efficiencies tend to constant values after 30 minutes of electrocoagulation (Katal and Pahlavanzadeh, 2011).

3.2. PH effecting

The electrolyte pH plays an important role in the operation of the electrocoagulation process (Chen et al., 2000). In order to verify the efficiency of electrolyte pH on the electro-coagulation effectiveness, many empirical studies have been carried out at different pH and various observations were obtained. The utmost percentage of removal COD was observed at the pH of 7 for mild steel. The increase in the electrolyte pH more than 7 did not get any upgrading on percentage of removal COD (Kalyani et al., 2009). This can be justified by the fact that the solvability of Fe(OH)₃ could cause the increase pH value beyonf 7 that results in forming the solvable Fe(OH)₄, this is not associated to the reduction of COD (Kobya et al., 2003). The primary pH at the beginning has a significant influence on the application of electrocoagulation process (Song et al., 2007; Wang et al., 2009). The findings showed that the increase in pH could increase the removal efficiency (Akbal and Camcı, 2011).

5) According to Can et al. (2003) and Daneshvar et al. (2003), one of the significant factors that influence the performance of electrochemical process is the initial pH. The efficiency of treatment process was very low at both high and low pH (Aoudj et al., 2010).

3.3. Distance between electrodes

The other important factor that is known to be influencing the efficiency of the electrocoagulation performance is distance between electrodes.

3.4. Effect of current density

According to the findings, it is expected that the increase amount of existing density will result in increase of removal efficiency (Akbal and Camcı, 2011). On the other words, the increase in the applied current density results in an increase in effectiveness of removing heavy metals such as Cr, Cu, Ni, and Cr for the Fe-Fe pairs of electrocoagulation (Akbal and
Camcı, 2011). Many researchers have reported that the current density has significant influence on the effectiveness of process of electrocoagulation. It can be explained by the fact that the amount of anodic dissolution increases at the high current densities, which in turn, the increased amount of hydroxocationic complex leads to increased COD removal. In addition, the rates of coagulant (flocks structure) and bubble production can be determined by the current density applied in the process. This, in turn can impact on the efficiency of the process. On the other hand, the increased density of gas bubbles with the reduced size results in increase in upwards flux that leads to increased degradation of pollutants and mud floating (Kobya et al., 2003).

Holt et al. (2002) states that the coagulant dosage rate and the bubble production rate, size, and flock growth can be determined by current density, which in turn can affect the efficiency of treatment by electrocoagulation (Holt et al., 2002).

In addition, current density is recognized as a significant operational factor that affects mechanism dominating the pollutant removal (Holt et al., 2005).

3.5. Effect of operation time

According to the Faraday’s law, the factor that can also affect the efficiency of removing Cr (VI) in the process of electrocoagulation is the reaction time. It can also determine the rate of producing Fe$^{2+}$ or Fe$^{3+}$ ions from electrodes (Mollah et al., 2004).

3.6. Effect of conductivity

The results of related studies showed that increased removal efficiency is dependent on the increase in conductivity. In addition, the decrease of spending energy and electrode results from increasing conductivity (Akbal and Camcı, 2011).

3.7. Supporting electrolyte concentration

The findings show that the increase in the supporting electrolyte density results in the increase in the COD removal efficiency. This is explainable that with the presence of chlorides in the solution, C12 and OC1 are produced. The OC1 is a strong oxidant that oxidize the organic cells existing in the water. Consequently, not only does the supporting electrolyte increase the efficiency and productivity of the process, but also it functions as a strong oxidizing factor. The similar result was reported for the percentage of efficiency in removing the color (Kalyani et al., 2009).

4. ADVANTAGES AND DISADVANTAGES OF EC

1. EC is a simple equipment and easy to work with adequate operational scope that can overcome most of the problems that may be encountered during the operation.

2. The water after purification are palatable, clear, colorless, and without odor.

3. The sludge produced during the process is ready to be set again and easy to be dried out, because they mostly contain metallic oxides and hydroxides.

4. The flocs that are produced by EC are similar to the chemical flocs; however, it is expected to be larger and contain less bound water, be more stable and acide-resistant that can, consequently, be separated faster by filters.

5. In comparison with the chemical treatment, EC produces sewage that contains less total dissolved solids (TDS) contents. Consequently, if this water is going to be reused, the low TDS level requires lower recovery cost.

6. The EC process removes the lower amount of colloidal elements, because the used electric field sets them in faster movement by which the coagulation is facilitated.

7. In EC, there is not any problem of neutralizing excess chemicals as well as the possibility of secondary pollution resulted from chemical substances that are added at high density, because unlike chemical coagulation of wastewater, EC does not use chemicals.

8. In EC, the bubbles of gas that are produced during the electrolysis process carry the contaminant to the top of the liquid and from there it can be easily collected and removed out.

9. The EC process requires less maintenance because the electrolytic processes in the EC cell are controlled electrically with no moving parts.

10. This technique can be easily applied in rural areas where even the electricity is not available because a solar board is attached to it that might be sufficient for operating the process.
5. DISADVANTAGES OF EC

1. The 'sacrificial electrodes' need to be replaced regularly due to oxidation and being dissolved into the wastewater streams.

2. Using electricity could be expensive in many places.

3. Sometimes a waterproof oxide film is located in the cathode to lessen the possibility of loss of efficiency of the process.

4. In this system, a high conductive wastewater suspension is required.

5. Sticky hydroxide sometimes tends to be dissolved in some cases (Mollah et al., 2001).

Mechanism of electrocoagulation technique

An electrocoagulation reactor, in the simplest form, has a monopolar electrode with one anode and one cathode. When the external power source is connected to it, the anode will be oxidized and flaked electrochemically, but the cathode remains passive. However, this process is not suitable for wastewater purification because for this purpose a large surface of electrodes is required in order to be able to dissolve the pollutants. This has been achievable by using cells with monopolar electrodes that are connected either in parallel or in series. A simple system of electrocoagulation (EC) cell with two anodes and two cathodes connected in parallel is illustrated in Fig. 1.

Fig. 1 shows that it, in essence, is made up of pairs of conductive metal plates that are located between two parallel electrodes and a dc power source. This investigational system also needs a resistance box to control the present density as well as a multi-meter for reading the existing values. The conductive metal plates are generally known as 'sacrificial electrodes'. The 'sacrificial anode' reduces the possibility of dissolution of the anode and lessens the passivation of the cathode. The conductive metal plates (the sacrificial electrodes) could be the same or different materials as of anodes (Pretorius et al., 1991).

Fig. 1: bench-scale Electrocoagulation reactor with monopolar electrode in parallel conccetion(Pretorius, Johannes et al. 1991)

The mechanism of EC is greatly reliant on the chemical type of watery medium, particularly its conductivity. The procedure of generating ions by EC is like iron and aluminum that are used as cathode and anode in this study. That is, in an electrolytic system, iron generates iron hydroxide. If the anode is made up of iron or steel or aluminum, for the production of the metal hydroxide, two mechanisms have been proposed (Chen, 2004).
6. APPLICATION OF ELECTROCOAGULATION IN THE TREATMENT OF PAPER MILL WASTEWATER

Katal and Pahlavanzadeh (2011) have done a study on the effectiveness of electrocoagulation on the treatment of wastewater of paper mill by using various types of electrodes with different combination of aluminum (AL) and iron (Fe). They also investigated the effect of pH, current density, and temperature on the removing process (Katal and Pahlavanzadeh, 2011).

7. APPLICATION OF ELECTROCOAGULATION IN THE REMOVAL OF CYANIDE

Because of strong affinity of cyanide with other metals, it is used widely in different industries. So free cyanide and its related compounds can be found in different forms and density in the industrial wastewater that enter into the environment (Dash et al., 2009). The aim of present study was to evaluate the efficiency of EC reactor with iron plate to remove free cyanide from wastewater. The finding showed that regarding the operational conditions, the most effective process was occurred at the voltage of 40 V, detention time of 90 min, and influent concentration
of 50 mg/l. Using EC technology for removing cyanide, in comparison with other removal methods, has many advantages economically. Despite using electrical power makes it costly, having no need to prepare chemical material, which makes storing it safer, enhances its efficiency and reliability. Due to its efficiency in removing free cyanide and its related components, EC can be used as a substitute method for removing cyanide from wastewater effluents containing cyanide (Hassani et al., 2011).

8. REMOVAL OF TEXTILE DYE WASTEWATER BY ELECTROCOAGULATION TECHNIQUE

Wastewaters that are produced by textile industries contain a great deal of toxic aromatic combinations, particularly azodyesn. Due to increased amount of effluent wastewater in the environment, the investigations done in recent years were mostly focused on purifying wastewaters by application of electrocoagulation (EC) because it is a simple and specific technique for producing drinking water and treating wastewaters (Daneshvar et al., 2005).

9. APPLICATION OF ELECTROCOAGULATION IN THE TREATMENT OF TANNERY WASTEWATER

Some characteristics of tannery wastewater are as follows: it contains high chemical oxygen demand, high total of floating solids, high biochemical oxygen demand, elevated oil and grease substances along with the high chromium concentration and unpleasant color. Based on the mentioned characteristics, tannery wastewater can be severely problematic for environment. Thus one of the functions of electrocoagulation process was removing different contaminants and chromium from tannery wastewater at the ambient temperature of the laboratory, simultaneously with other EC performances (Kongjao et al., 2008).

10. CONCLUSION

Based on the conducted investigation, the best method for leachate treating is electrocoagulation technique because leachate consists of high toxin mater such as heavy metal, cyanide, Colloid particle some of which cannot be removed by other techniques. Accordingly, due to the mentioned advantages of Electrocoagulation technique as well as its adaptability with the environment, it has been employed as a practical method for industrial effluent and leachate treatment. The results of data in Table 1 show that some of optimum conditions in electrocoagulation process are: one centimeter distance between electrodes, PH of 7-8.5, and the approximate temperature of 28

<p>| Table 1: Effect of operational parameters on pollutant removal efficiency in electrocoagulation process |
|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|</p>
<table>
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<th>Remo. efficiency %</th>
<th>Effect of temperatu re (ºC)</th>
<th>Reaction time (minute)</th>
<th>Current density A/cm²</th>
<th>PH</th>
<th>Distance between electrode (cm)</th>
<th>Type of electrodes</th>
<th>Surface of electrode Cm²</th>
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<td>NG</td>
<td>20-110</td>
<td>56-222</td>
<td>5</td>
<td>NG</td>
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<td>Cr</td>
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<td>6</td>
<td>1.5</td>
<td>Al-Fe</td>
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<td>5-7</td>
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<td>COD</td>
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<td>63.8</td>
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<td>&quot;</td>
<td>NG</td>
<td>Fe-Fe</td>
<td>80</td>
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<td>Technique in the treatment of paper mill wastewater</td>
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<td>Technique in the treatment of paper mill wastewater</td>
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<td>NG</td>
<td>140</td>
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<td>7</td>
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<td>NG</td>
<td>Cd</td>
<td>Water</td>
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<td>80</td>
<td>14</td>
<td>0.03125A/cm²</td>
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Most of EC studies carried out in tempered climate and some of them had been assessed in tropical area.

Based on the information which filled in Table 1 we can say that:

1. Al and Fe are the most common electrode that scientist use in researches
2. Fe and Al can be used in both anode or cathode
3. Each of Fe and Al could be apply in both of anode and cathode
4. Depending on the type of wastewater and removal factor, retention time will be different between 2.5 - 140 minute
5. Distance of electrodes as a critical factor could be controlled from 0.1 - 6.5 Cm to achieve different efficiency
6. Since EC is a co treatment method for potable water, so efficiency of this method should be high

**REFERENCE**


Mohammadizaroun and Yusoff
Treatment of Leachate by Electrocoagulation Technique Using Iron And Hybrid Electrodes


Mohammadizaroun and Yusoff
Treatment of Leachate by Electrocoagulation Technique Using Iron And Hybrid Electrodes

Mostafa Mohammadi Zariun is a PhD candidate in Environmental Engineering, Universiti Sains Malaysia. He has MSc in Analytical Chemistry.

Associate Professor Dr Mohd Suffian Yusoff obtained his first degree from Universiti Putra Malaysia in agricultural science in 1995. He later pursued master degree in mineral resources engineering in Universiti Sains Malaysia and graduated in 2000. Dr. Yusoff received his doctorate from Universiti Sains Malaysia in 2006 with major in solid waste management. Currently, Dr Yusoff serves School of Civil Engineering, Universiti Sains Malaysia as an academic programme chairperson (environmental and sustainability). He has published numerous refereed articles in professional journals. Dr Yusoff’s field of expertise’s are solid waste management, landfill technology and leachate treatment. Dr Yusoff also has conducted numerous consultancies and research works at the national and international level. His vast experience in landfill operation and management has enabled him to conduct numerous talks and seminars at national and international level.