

Application of Electrocoagulation In Various Wastewater And Leachate Treatment- A Review

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Abstract. Electrocoagulation is a method that has a great ability on various wastewater and leachate treatment. It has a potential in removing various pollutants such as chemical oxygen demand, turbidity, ammonia, color, and suspended solid. The effectiveness of electrocoagulation method depends on several factors such as electrode, current density, operation time and pH. The aim of this paper is to review the relevant literature that publishes from 2000 to 2015 on the factor that influence Electrocoagulation (EC). The review describes, discussing and compare the factors that influence the EC process in various wastewater and leachate treatment.

1. Introduction

One of the major problems facing by the world today is to provide clean water for human population. The increasing of human population day by day give a shock matter due to the corresponding improvement in the total quantity of industrial and municipal solid waste [1] [2]. According to Mogens Henze and Yves Comeau [3], generally there are two type of wastewater which are generated from society (domestic wastewater, wastewater from institutions, industrial wastewater, infiltration into sewers, storm water, leachate, septic tank wastewater) and wastewater generated internally in treatment plants such as (thickener supernatant, digester supernatant, reject water from sludge dewatering, drainage water from sludge drying beds, filter wash water and equipment cleaning water).

According to previous study, treatment methods that have been used widely around the world to treat wastewater are biological and physical-chemical process [4]. Biological process is a process that uses a natural process which is rely on bacteria, nematodes, small organism. While physical- chemical process required additive of chemical in it process. One of the physical –chemical process that not required any additive of chemical is electrocoagulation (EC). EC is a unique method for water and waste water treatment and had been tested on various industrial effluent such as food industries, tannery, mechanical workshop (soluble oil), polymerization manufacture and wastewater textile industry [5].

According to Thakur and Chauhan [6], in an EC process, the coagulating ion mostly generated continuously, and it consist of a few consecutive steps. First step is the coagulation formation by electrolytic oxidation of the sacrificial anode, second steps are the destabilization of the pollutant, particulate suspension, and emulsion breaking and for the last steps is an aggregation of the destabilized phase to form floc. Nowadays, EC method has been commercial, and it shows a better benefit compare to current treatment process in terms of equipment simplicity, portable, clear, colorless and odorless treated product [7]. Other advantages of EC are less treatment time, reduction of chemical addition, ease of operation, rapid sedimentation of electro generated flocs and less amount of sludge production.



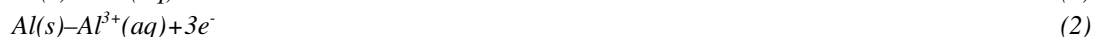
Thus, EC provides more advantages compared to others coagulation methods. The review is basically a discussion on EC studies conducted from 2000 until 2015.

2. Electrocoagulation

Electro-coagulation process has been practiced since the 20th century with limited success [8]. The successful application is very limited at that time. Basically, electrocoagulation process is a process to form a floc with the help of oxidized metal in wastewater where it needs to be cleaned by electro-dissolution of soluble anode [9]. Electrocoagulation can also define as a process to remove the suspended solid from wastewater by using electricity to neutralize the negative particles by the formation of hydroxide complexes in water to gather the suspended solid, help bridge, bind and strengthen the floc for sedimentation due to gravity force [10]. This process gathers the suspended solid in water without coagulant, the coagulation happened when the direct current was applied it capable in removing the small particles and setting them into motion [11]. Several factors that influence the efficiency of electrocoagulation process are type of electrodes, gap between electrodes, number of electrodes, size of electrodes, configuration of metals, current density, charge loading, pH of sample, addition of supporting electrolyte and operation time [12]. The electrodes that are usually used are iron, aluminum and stainless steel. This pairs of metal sheets are known as anode and cathode [13]. During the electrocoagulation process cathode is oxidized (loses electrons) and the water is reduced (gains electrons) resulted in treated water and easy to settle floc [10].

2.1 Electrocoagulation Process

Basically, EC is an electrolysis process for wastewater treatment that using pair of metal sheet (electrodes) and arranged by pair of two -anode and cathodes [5]. Electrodes used in electrocoagulation process can be arranged in monopolar or bipolar. Electrochemical mechanism in aqueous solution is quite complex [14]. Generally, this process involves three types of mechanisms of electrocoagulation, electro-flotation and electro-oxidation [15]. The use of different electrode gives variety effect to the removing mechanism such as pH, density, COD, ammonia, color, suspended solid(SS). Electrode produced coagulant in the water sample are made from either aluminum or iron. Aluminum and iron cations dissolve from the anode according to Eqn 1 and 2 and cathode according to Eqn 3 [16]. Positive charged are attracted with the negative charged hydroxides in this solution and it produces ionic hydroxides that make a stronger attraction toward dispersed particle as the counter ions cause coagulation [17]:



The principle of EC is shown in Figure 1. Metals adsorbed on the anode are useful for generating ions continuously to the anode surface. This will generate ferric hydroxide, and it will follow by a buildup of negative colloidal charged through an electric field near the anode [18]. Then these particles will relate to iron hydroxide and indirectly eliminated through electrostatic attraction [8]. The electric field potential of colloidal particles to coagulate is higher than through the use of chemicals. Thus, the electrocoagulation process increases the rate of coagulation [19]. Treatment systems using electrocoagulation method will be more complete if followed with sedimentation and filtration process [20]

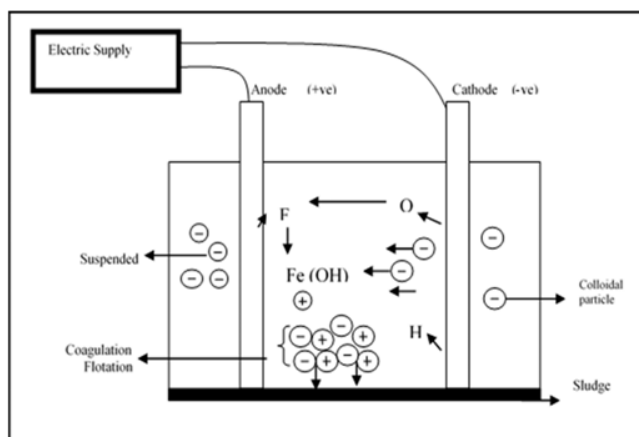


Figure 1 : Principle electrocoagulation

3. Application of Electrocoagulation

3.1 Wastewater treatment

Table 1, show application of EC on various wastewaters such as wastewater from distribution network, restaurant wastewater rich with oil and grease, textile wastewater consists of small suspended particle, synthetics wastewater from factory and potato chips wastewater. Electrocoagulation process was run on different type of electrode to determine the efficiency removal. Several studies had investigated the factor affecting the performances of EC such as the type of electrode. A recent study by previous researchers have stated that using aluminum and iron electrode are the best choice because of they are cheap and easy to find [21]. In this study, the researcher found that aluminum (Al) electrode give a better performance compare to iron (Fe) electrode.

Furthermore, aluminum electrode does not give effect of color to supernatant. However, different researchers stated that iron electrode has more efficiency in nitrate removal than aluminum electrode [22]. The researcher found that high density of ions hydroxide produces from iron electrode give the advantages in removing of nitrate. However, advantages of iron electrode are imparting. Several researchers had studied the effect of current density. Malakootian et.al [22], reported that increasing electrical potential will increase the nitrate removal performances and it will produce higher floc in high voltage. This is in line with Kobya study. Kobya et.al [21] found that current density gives a huge effect on COD removal and turbidity when the charge loading is increased. The percentage removal efficiency increased from 38% to 62% for COD and 56% to 98% turbidity. As the electrode and energy consumption increased higher performance of EC was recorded especially for aluminum electrode. The higher the voltages and charge loading applied in EC process the bigger energy consumption will occur. Adhoumm et.al [23] stated that current density factor gives an effect on the coagulant dosage rate and the production of bubble and size produced. These processes significantly affecting the performances of EC. It can be concluded that with higher current density, the bubble density become high, the floc increased and resulted in removal of the coagulant by flotation. According to Bazrafshan et.al [24], when applied voltage from 10 V to 40 V the COD and BOD₅ removal slightly increase to 99%. Based on past researcher, current density basically one of the factor effecting the performances of EC.

According to Malakootian et.al [22], pH is also one of the factor affecting the EC performances. Chen et.al [25] stated pH did not affect the removal efficiency significantly in term different type of wastewater. Vice versa, Kobya et.al [21], found out that pH playing important role in the EC process. It stated that when pH is higher than 6, removal efficiency of COD decreased. Adhoum et.al [23] recorded the removal efficiency of copper, zinc reach high value when pH is exceeding 4 and at the same time condition removal of chromium reached at maximum value about 83%. From the previous review show that the pH factor influenced the EC performances and the best pH value are indicated at alkali condition permissible limit 400mg/L for leachate discharge. Thus, proper treatment need to be considered for leachate discharge to avoid any pollution accrued.

Table 1: Application by electrocoagulation process of various wastewater

Sample	Current density	Operation time (min)	Dose coagulant (mg/L)	Electrodes / Chemical coagulant	Percentage removal (%)		Author
synthetic (pH 4)	40A/cm ²	15	NA	aluminum electrodes	99 (Cu)	83 (Cr)	Adhoum et al. (2004)
potato chips (pH 5)	20 mA/cm ²	30	NA	aluminum electrodes	60 (COD)	98 (ss)	Kobya et al. (2006)
	20 mA/cm ²	30	NA	iron electrodes	50 (COD)	80 (ss)	
textile water (EC pH 6.9) (CC pH 5.5)	10 mA/cm ²	20	NA	aluminum electrodes	63 (COD)	NA	Can et al. (2005)
	10 mA/cm ²	10	0.8 Kg/m3	aluminum electrodes + polyaluminum chloride	80 (COD)	NA	
	10 mA/cm ²	10	0.8	aluminum electrodes + alum	65 (COD)	NA	
	NA	NA	0.32	polyaluminum chloride	78 (COD)	NA	
	NA	NA	0.32	alum	72 (COD)	NA	
slaughter house (Ph 7.31)	40V	60	25	aluminum electrodes + polyaluminum chloride	80	50	Bazrafshan et al. (2012)
	NA	NA	25	polyaluminum chloride	37 (COD)	47 (TSS)	
distribution network (pH 10)	24A/m ²	60	NA	iron electrodes	98 (calcium)	97 (total hardness)	Malakootian et.al (2010)
Restaurant (pH 6-10)	30-80 A/m ²	NA	NA	aluminum electrodes	90 (COD)	94 (oil and grease)	Chen et.al (2000),

Table 2: Application by electrocoagulation process of leachate sample

Sam ple	Curr ent densit y	Operat ion time (min)	Dose coagu lant (mg/ L)	Electrodes/ Chemical coagulant	Percentage removal (%)		Author
Leac hate pH 4	10V	100	NA	aluminum electrodes	74 (COD)	NA	Jotin et al. (2012)
Leac hate Ph 5	75 mA/c m ²	NA	NA	aluminum electrodes	48 (COD)	NA	Tezcan and Adunco (2014)
Leac hate (pH 5.8)	9V	35	NA	aluminum electrodes	96 (COD)	97 (turbid ity)	Shivayog imath and Watawati (2013)
Leac hate (pH 6)	60 mA/c m ²	30	NA	iron electrodes	81 (COD)	72 (colou r)	Moayerik ashani et al. (2012a)
leac hate (pH 6.5)	2.98 mA/c m ²	30	NA	iron electrodes	33 (COD)	25 (ammo nia)	Li et al. (2011)
	2.98 mA/c m ²	30	NA	aluminum electrodes	21 (COD)	20 (ammo nia)	
	4.96 mA/c m ²	90	2319	iron electrodes + sodium chloride	93 (COD)	39 (ammo nia)	
Leac hate (pH 8.65)	10V	120	1.5%(w/v)	charcoal composite electrodes (C70- PVC30) + sodium chloride	82 (COD)	69 (ammo nia)	Jumaah and Othman (2015)
leac hate (pH 8.2)	34.8 mA/c m ²	30	NA	aluminum electrodes	59 (COD)	NA	Ilhan et al. (2008),
				iron electrode s	33 (COD)	NA	
	NA	NA	1500	Alum	31 (COD)	NA	

3.2 Leachate treatment

Table 2 shows the percentage removal of leachate sample by electrocoagulation process with different type of electrodes, supporting electrolyte to increase current conductivity and addition of chemical or natural coagulant to enhance formation of floc. Several authors were compared the percentage removal by electrocoagulation process with coagulation and flocculation process. In the treatment of leachate by EC, the main factor is the current density.

According to Ilhan et.al [4], current density effecting the COD removal efficiency. The result shows the treatment changed with the increasing of current density from 348 to 631 A/m². The COD removal efficiency obtained from this research increasing from 45.5% to 59%. Li et.al [26] show the removal efficiency of COD increasing from 28% to 93% as current density increased from 1.98 mA/cm² to 4.96 mA/cm². Moayerikashani et.al [27] stated that with current density 60 mA/cm² the optimum reduction of COD removal is 81%. Moayerikashani et al [27] also conclude that the decreased current density resulted in reduction of COD removal. According to Shivayogimath and Watawati [28], the current density has affected the COD and turbidity removal. This proof that current density gives a huge effect to the removal of pollutant.

According to Li et.al [26], pH factor has important rule in performance of the EC process. The pH value mostly influent by the cathodes. Increasing current density will affect the pH as well [4]. Referring to Li et.al [26], pH is the one of the major factor affecting the .al performances of EC. Based on Moayerikashani et, [27] studies, COD removal is 81% at pH 6 and when the pH value increases to acidic condition, the COD removal decreased.

However, Shivayogimath and Watawati [28] found out that, when the pH is in alkaline condition it removed removal 95.8% of COD and at pH 4 o 73.6% of COD was removed. By referring to Jotin.et al [29] maximum COD removal efficiency can be obtained at range pH 4 until pH 8 with 59% until 74%. Thus the best COD removal is at range pH 4-8. According to Ilhan et.al [4], iron and aluminum electrode have different performances in removing of COD. The result shows that aluminum gives effective performances than iron based on COD and NH₃-N removals. According to Li et.al [26], different type of electrode gives different effect to the EC performances. Li et.al [26], shows that iron perform better than aluminum and the settlement of particle of iron are better than Al. By referring to Mansooreh et.al [30], stated that iron electrode is more economical in terms of energy consumption and suitable with economic evaluation. However, many researchers found that using aluminum electrode are more efficient than iron electrode and suitable to use in electrocoagulation application because it produce Al (III) [30,31,32].

4. Conclusion

Different electrodes materials resulted in different percentage removal COD, turbidity and ammonia. From the review, aluminum electrode performs better than iron electrode which is higher percentage removal was recorded in COD and suspended solid removal for various wastewater treatment. Moreover, for leachate treatment, aluminum electrode also shows a better efficiency in term of percentages removal efficiency than iron electrode on color, turbidity and COD. Current density is one of the major factor for EC performances. High current density produced a better removal of COD due the production of bubble and floc. Other than that pH factor is also considered as the important factor for EC performances. The activities of cathode also influent the pH value. Higher efficiency of EC can be obtained if current density, type of electrode and pH is considered in the treatment process

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