EUROPEAN JOURNAL OF LIFE SAFETY AND STABILITY (EJLSS)
ISSN 2660-9630
www.ejlss.indexedresearch.org

Electrochemical Method for Wastewater Treatment of Textile Production Enterprises by Electrocoagulation

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Abstract: *This research originally attempts to highlight the significance of electrode as one of the alternative method to conventional chemical coagulation, electrocoagulation has received widespread recognition for the intelligent technique which effectively remove the pollutant in wastewater. Electrocoagulation has proven to be simple, affordable and efficient to treat highly polluted wastewater. Another advantage of using electrocoagulation is this process is easy to operate, involved in simple equipment, offered a short retention time and required a small space which contributes to low operating costs in industrial applications as compared to conventional ponding system or chemical coagulation.*

Keywords: *metal salts, wastewater, aluminium, anode, electrodeas, Electrocoagulation*

INTRODUCTION

The use of metal salts or polymers in chemical coagulation process can be replaced with electrocoagulation as this process also generate coagulant in the form of metal hydroxides. The metal hydroxides then work as same as the coagulant produced by chemical coagulation which is destabilizing the pollutant, aggregating the suspended particles and forming a precipitate. However, to achieve an effective wastewater treatment, it is crucial to properly design the best electrochemical cell for electrocoagulation process. The basic electrochemical cell is mainly made of an enclosure and at least a pair of electrodes. This enclosure must be a non-conductive tank in which the treatment of wastewater takes place. While for the design of electrode, several factors such as the orientation, arrangement and selection of material also have to be considered. Most of the researchers have only studied an electrocoagulation process in vertical electrode orientation, such as in the removal of organics from bilge water, nitrate from water solution, and treatment of poultry slaughterhouse wastewater. However, there are also some researchers whose study the comparison between vertical and horizontal electrode configuration such as in Cr(VI) removal and separation of oil from wastewater. Those studies indicate that the electrode orientation has greatly influence the treatment and the selection of it is depends on the type of wastewater used.

The configuration of electrode can either be simply composed of an anode and a cathode or be composed of many anodes and cathodes. The complex electrode arrangement can be classified in monopolar (MP) and bipolar (BP). The choice of the appropriate electrode connection whether monopolar-parallel (MP-P), monopolar-series (MP-S) and BP are normally determined by the removal efficiency. These connections have been investigated in several studies such as the treatment of laundry wastewater, can manufacturing wastewater, decolourization of dye solution, and $Cr3+$ removal from aqueous solution.

Electrode material determines the electrochemical reactions that take place in electrocoagulation process. Aluminium and iron types of electrode are mostly used as the electrode material in electrocoagulation systems. Aluminium dissolves as Al3+ and yet, there is no general agreement on the nature of the iron species, with both Fe2+ and Fe3+ proposed as the dissolved species. The selection of the electrode materials depends on the pollutants to be removed and the chemical properties of the electrolyte. In some studies, aluminium have been employed as the electrode material and resulted in better removal performance than iron such as from the treatment of leachate and phosphate from wastewater. However, there are several studies that show the application of iron is more effective than aluminium such as the study from textile wastewater treatment, Cr (IV) removal from aqueous media, and highly soluble acid dye. Studies regarding electrode design are limited, especially in treatment of highly polluted effluent like Palm oil mill effluent (POME). POME is well known to have high concentration of chemical oxygen demand (COD), biochemical oxygen demand (BOD) and suspended solid (SS), therefore direct discharge of this effluent to the water body will cause severe damage to the environment. Therefore, the focus of this study is to combine the best criteria for electrode design in order to enhance the effectiveness of electrochemical cell which is determined by achieving high treatment efficiency. The present study also introduce a novel steel wool as a new electrode material, which has a very large electrode surface area. 2. Material and methods

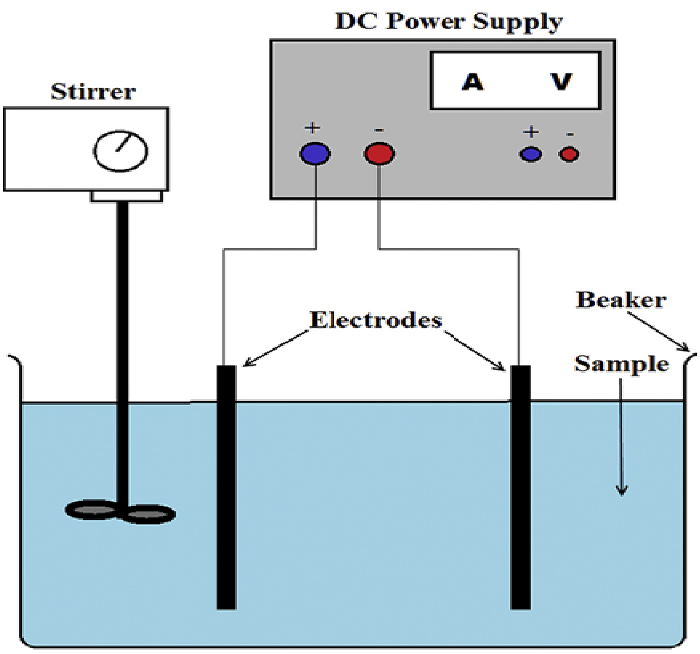

Fig 1 Schematic diagram of the experimental setup

Table 1 Characteristic of raw POME

Parameter	Concentration
Biochemical oxygen demand (BOD)	15,600 ± 100
Chemical oxygen demand (COD)	25,500 ± 100 pH 4.6 ± 0.1
Total carbohydrate	10,000 ± 100
Total nitrogen	800 ± 50
Ammonium–nitrogen	20 ± 10
Total phosphorus	90 ± 1
Phosphorus	14 ± 1
dyes	2,000 ± 50

Total solid	20,000 ± 300
Suspended solid (SS)	12,300 ± 200
Total volatile solid	17,500 ± 200
Conductivity (µS/cm)	158 ± 4

All values are in mg/L except pH and conductivity.

The experimental setup is shown in Fig. 1 which mainly consist of a 1000 mL glass beaker as a reactor to hold a sample of 700 mL, a power source, electrodes, POME sample and a mechanical stirrer. The electrode orientation, arrangement, material and structural type are determined according to the experiment purpose. The dimension of aluminium, iron plates and steel wool were 30 mm × 60 mm each. The thickness for those electrodes were 4 mm each. The electrodes were mechanically cut according to the size and all the dirt and corrosion on the plates were removed using hydrochloric acid (HCl) with concentration of 35% and then with hexamethylenetetramine 3%. The area of electrode dipped into the solution sample was 30 mm × 50 mm whereas the remaining was prevented from exposure by applying the lacquer on top of every electrodes. All the electrodes were drown into the hydrochloric acid (HCl) with concentration of 35% and then with hexamethylenetetramine 3% for about 5 min and washed with tab water before every experiment operated. All experiments were conducted triplicate in batches mode. The experiments were performed in 120 min by using initial current intensity of 5 A and 20 mm of inter-electrode distance. Three types of electrode orientations were used in this study which are vertical orientation, horizontal orientation with anode on top and horizontal orientation with anode at the bottom. The experiment was conducted using a pair of aluminium plate as anode and cathode to determine the best electrode orientation in treating raw shows the orientation set-up for the electrodes that were used in this study.

In this study, parallel, series, monopolar and bipolar aluminium electrode arrangements were used to find the best arrangement in electrocoagulation process. shows the design of electrode arrangement for monopolar parallel (MP-P), monopolar series (MP-S) and bipolar (BP). For MP-P connection, anodes and cathodes are in parallel order and all electrodes are connected to power source. In this configuration, the current is divided between electrodes in relation of individual cells. The parallel connection need a lower potential difference compared to serial connection. For MP-S connection, the two outermost electrodes are connected to the power source forming anode and cathode while a pair of the inner electrodes are connected to each other without any connection to the power source. The inner electrodes are known as the sacrificial electrodes (Moussa et al., 2016). In this configuration, the cell voltage is added giving a higher potential difference. The BP connection shows two sacrificial electrodes are place in between two parallel electrodes without any connection to the power source and also without connected to each other. In this configuration, the electrical current is passed through the sacrificial electrode and transformed it into charged electrode, which undergo opposite charge with the parallelled electrodes nearby.

This experiment was carried out to determine the appropriate electrode material among aluminium plate, iron plate and steel wool in treatment of POME wastewater. Aluminium plates, iron plates and steel wools were fabricated with the same dimension of 30 mm × 60 mm as showed in Fig. 2(c). At the end of each run, the electrode were rinsed with HCl solution to remove any oxide film formed onto the surfaces during experiments shows the electrode used in the experiment. The criteria of electrode design for electrochemical cell has successfully been determined by selecting vertical electrode orientation, MP-S arrangement and steel wool as electrode material due to the highest treatment efficiency. However, the iron-based material applications exhibit smaller size of sludge particles (mostly below than 1 µm), whereas the application of aluminium exhibits more than 1 µm particle size.

Conclusions This fine coagulant generated from iron has larger surface area whichcan trap more pollutant particles. EDX analysis results show more percentage of Fe element (about 66%) obtained from steel wool compared to iron (about 34%). XRD analysis results show that the main product of sludge for iron plate and steel wool application were maghemite, while the main product of sludge treated by aluminium was bayerite and boehmite. FTIR analysis result show that most of functional groups present in the raw wastewater sample were disappeared after electrocoagulation process. In economic study, vertical orientation, MP-P arrangement and iron plate application show the lowest cost operation as a function of COD removal. This study can give freedom to research experts out there to choose the electrode design whether they are more favourable in high treatment efficiency or more economical method.

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