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# Electrocoagulation of Simulated Quick Service Restaurant Wastewater using Aluminum-Iron Electrode Pair

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**Abstract:** With the rapid increase in the number of Quick service restaurants (QSR) in the Philippines, they altogether pose threats to the environment as wastewater discharged from these establishments are heavy on soluble organics and animal and vegetable fats and oils. However, the small space and low initial capital requirement on QSRs deters the possibility of using conventional biological and chemical treatment technologies. This study investigated on the use of electrocoagulation (EC) technology for the treatment of simulated QSR wastewater using vertically oriented Aluminum-Iron electrode pair in a compact reactor. The simulated QSR wastewater has a COD range of 1500 to 2000 mg/L, FOGs of 1000 to 2300 mg/L and TSS of 380-490 mg/L. The effects of operating parameters such as inter-electrode distance and recirculation flow rates were observed with chemical oxygen demand (COD), total suspended solids (TSS) and fats, oil and grease (FOGs) as wastewater quality indicators. The behavior of pH during the EC process was also monitored.

**Key Words:** electrocoagulation, aluminum, iron, QSR

## 1. INTRODUCTION

Quick Service Restaurants (QSR), commonly referred to as fast food chains, are establishments such as Jollibee McDonald's, Burger King and KFC that offers inexpensive food which has been precooked and preheated. In the Philippines, QSR industry is one of the fastest growing industry with gross revenues in the top 1000 corporations in 2008 estimated at 60 billion pesos. Due to the expanding industry of QSRs, the wastewater effluents discharged by these fast food restaurants has now become an environmental concern, in particular the high concentration of soluble organics and animals and vegetable fats and oils. Although the volume of the wastewater generated in QSRs is low, the presence of oil and grease and organics is a major concern when discharged directly to bodies of waters or to sewer systems as they clog the pipe and produce foul odors (Xu and Zhu, 2004). At present, preliminary treatment of QSR wastewater involves only the use of a grease trap as required by the Code on Sanitation of the Philippines (DOH, 1976). The grease trap is insufficient to bring down the level of pollutant concentrations in wastewater, hence, restaurants are unsuccessful in complying with the

Department of Environmental and Natural Resources (DENR) effluent standards.

The available wastewater treatments are biological processes and chemical coagulation. Biological processes require large space requirement which is limited in a QSR. Many of the stand-alone QSRs have limited spaces for dining, food processing and washing area and other operational activities such as parking. Chemical coagulants, on the other hand, are not only deemed expensive but are also ineffective against oil particles prevalent in QSR wastewater (Chen et al., 2000). Hence, there is a need to look for an alternative treatment scheme that fits the space requirements of a QSR and is at the same time effective in removing target pollutants.

Electrocoagulation (EC) is one technology found to be relatively versatile, easy to operate and compact in size. EC has gained popularity due to the reported removal efficiencies in researches such as restaurant wastewater (Chen et al., 2000), tannery wastewater (Lieu, 2012), rose water (Avsar et al., 2007) and textile wastewater (Kobya, 2003). Studies by Chen et al., 2000, Xu and Zhu, 2004, Tir and Moulai-Mostefa, 2008 and Canizares et al., 2006 showed that EC is effective in the treatment of oils, TSS and COD. On top of its documented versatility and effectiveness, EC, unlike chemical coagulation, produces no secondary pollution since coagulants are produced in situ with exact dosing (Mollah et al., 2004). It also requires low maintenance cost compared to other treatment methods, with the bulk of the maintenance cost due to the replacement of the inexpensive electrodes which are usually iron or aluminum.

This study aims to investigate the effects of recirculation flow rate and inter-electrode distance in the treatment of simulated QSR wastewater in a circular reactor system using vertically oriented parallel connected monopolar aluminum and iron electrodes. Almunium was used as the anode while iron was used as the cathode. The chemical oxygen demand (COD), total suspended solids (TSS) and fats, oil and grease (FOG) were the target parameters with pH behaviour monitored.

## 2. METHODOLOGY

The procedure flow of the experiment is shown in **Fig. 1**. The reactor design used by Lieu

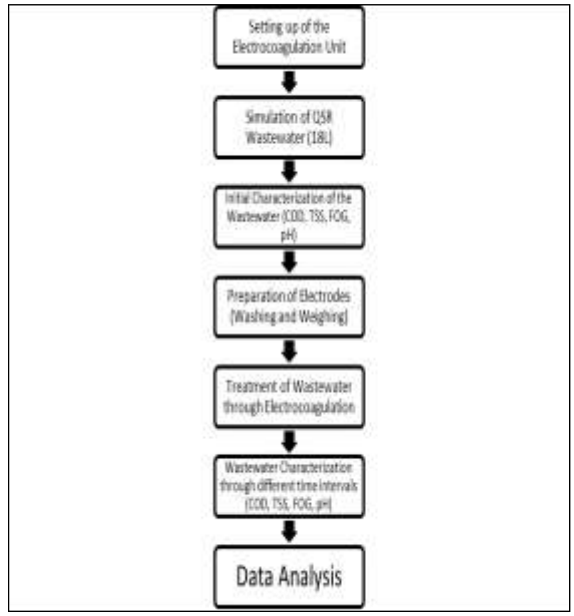


Fig. 1 Procedure Flow of Study

(2012) was adapted in this study. The experimental set-up consists of the 13-L cylindrical EC reactor, 5-L feed tank, digital power supply and submersible pump as illustrated in **Fig. 2**. The actual photograph of the EC set up is shown in **Fig. 3**.

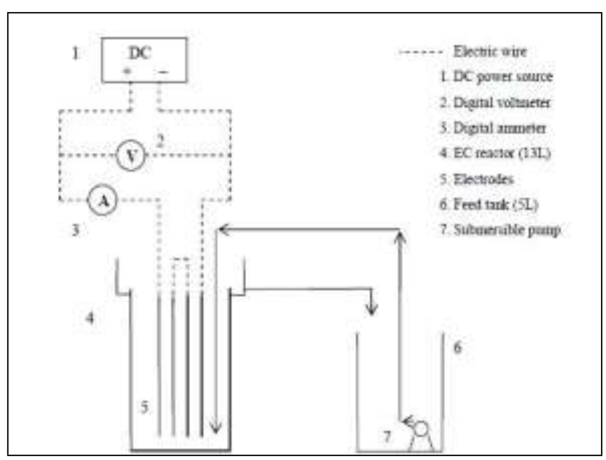


Fig. 2 Reactor Design (adapted from Lieu, 2012)

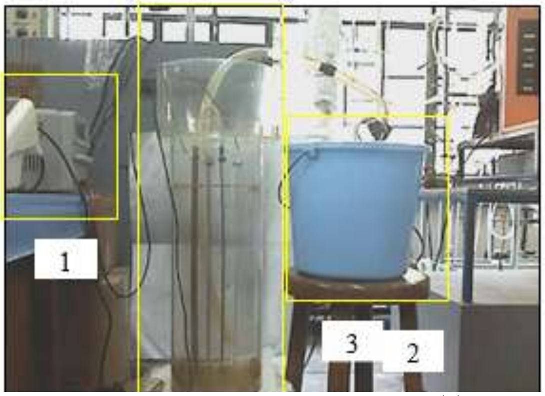

Fig. 3 Actual Photograph of EC System (1) Power Source, (2) Reactor and Electrodes, (3) Feed Tank and Submersible Pump

Four monopolar aluminum and iron electrodes (**refer to Fig. 4**), with dimensions of 18" x 3" were arranged in parallel connection. The electrodes were sourced from Livcor Technicon, Inc. The chosen electrodes were already examined by previous investigators in DLSU, Mission (2010) and Chin and Choa (2011) through SEM-EDX analysis. The aluminum was reported to be 93% pure and the impurities were composed of carbon and iron oxides. The iron, on the other hand, was contaminated with zinc oxides, carbon and aluminum oxides.

Fig. 4 Al and Fe Electrodes after washing

Before electrodes were submerged in the wastewater, they went through a cleaning process in order to wash away any surface contaminants or dirt present. The cleaning process used by Chou et al (2009) and Golder et al (2007) was applied in this study and consisted of the use of sand paper for polishing and the application of 3M $H_2SO_4$/ 3M HCl and distilled water for rinsing. The electrodes were then air-dried before mounted to the EC reactor. The electrodes were supported by two bars both at the bottom and the top part of the reactor. The bars contained slots to insert the electrodes.

The anode/cathode configuration considered was Al/Fe electrode pair. Each electrode has surface area of 0.0348 $m^2$ and the total area of the four electrodes used is 0.1044 $m^2$. Current density is measured in terms of ratio of current (amperes) divided by the effective area of the electrode (square meter). In each run, the current density remained constant, and fluctuations were addressed by manually adjusting applied voltage.

Simulated QSR wastewater was formulated based on the discharges of the La Casita Canteen in 6th Floor, Bro. Andrew Building at DLSU. Water volume discharges, leftovers and food ingredients were observed and recorded and was used as the basis for preparation of 21 L of wastewater for each run. The formulation of the simulated wastewater must comply with the range Chin and Choa (2010) reported. The simulated QSR wastewater has a COD range of 1500 to 2000 mg/L, FOGs of 1000 to 2300 mg/L and TSS of 380-490 mg/L.

The wastewater was mixed in the 5-L feed tank through up flow recirculation using a submersible pump. Experiments were conducted by batch within 60 minutes at a fixed pH of 6. Samples for COD and TSS were obtained at 15-minute intervals while samples for FOGs were taken at 30-minute intervals. Samples were left to settle for one hour prior to analyses. Wastewater analyses followed the Department of Environmental and National Resources and the American Public Health Association's established standard methods of analysis as summarized in **Table 1.**

Table 1: Standard Method of Analysis

| Parameters | Method of Analysis | Source |
|---|---|---|
| Chemical Oxygen Demand | Closed Reflux Method | APHA 5220B |
| Total Suspended Solids | Gravimetric Method | APHA 2540B |
| Fats, Oil and Grease | Gravimetric Method (Petroleum Ether Extraction) | APHA 5520B |
| pH | Glass Electrode Method | |

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of Recirculation Flow Rate on the Removal of Pollutants

Recirculation flow rate is important in the EC process as it agitates the wastewater allowing the coagulants to be equally dispersed after dosing. Recirculation flow rates were varied as 0.4 L/min, 1 L/min and 2 L/min. Based from **Fig. 5**, the highest percentage removal for COD was observed at 2L/min. The recirculation flow rate may have contributed to mixing the wastewater, allowing coagulants produced to effectively interact with the target pollutants.

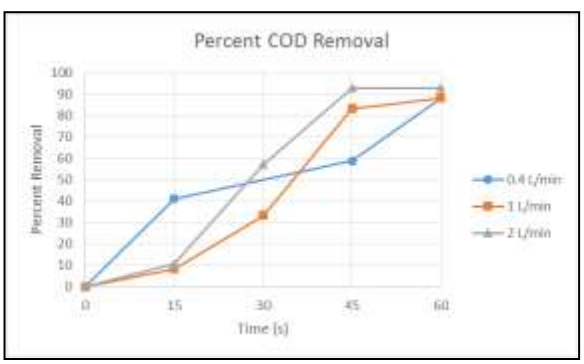


Fig. 5 Effect of flow rate on COD Removal (Al-Fe electrode, parallel connection, current density of 28.8A/m$^2$)

**Fig. 6** illustrates the pH profile of the experiment at varying flow rate. It was observed that the pH increase to basic medium is at lower recirculation flow rate. The pH may have contributed to the slow increase of COD removal since literatures have stated that at pH > 9, soluble aluminate $Al(OH)_4^-$ starts to form and no longer contributes to the coagulation. Therefore, the removal efficiency lowers. Chen et al (2000) stated that one of the mechanisms that causes the pH increase is the over saturation of carbon dioxide in the wastewater. Since the flow rate is slower, the carbon dioxide may not have been dispersed well and resulted to over saturation.

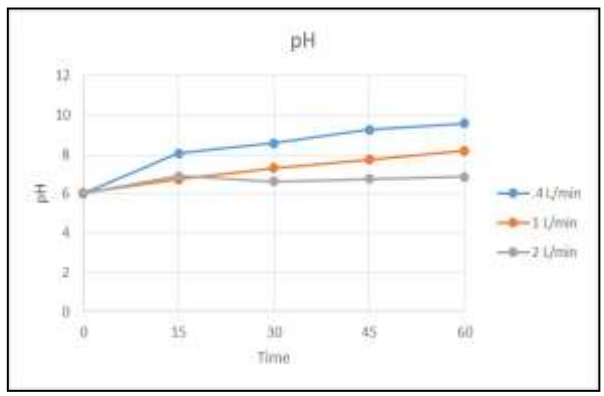


Fig. 6 pH profile at varying recirculation flow rate (Al-Fe electrode, parallel connection, current density of 28.8A/m$^2$)

Based on **Fig. 7**, it can be seen that at higher flow rate, higher TSS removal is achieved for a shorter period of time. This can be attributed the quick and effective destabilization of suspended particles with effective mixing. Prolonging the time to 60 minutes does not significantly affect the removal rate of TSS. After 60 minutes of electrolysis time, the removal ranged from 95-98% regardless of the specified flow rate.

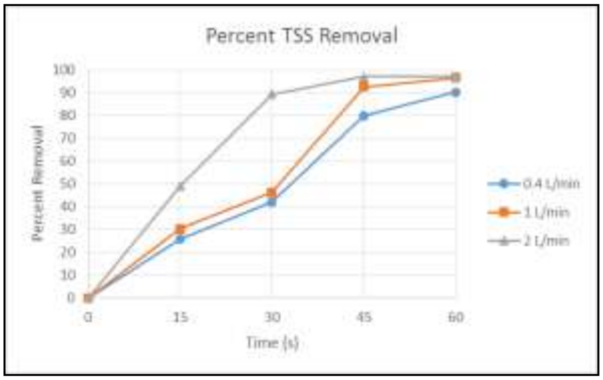


Fig. 7 Effect of flow rate onTSS removal (Al-Fe electrode, parallel connection, current density of 28.8A/$m^2$)

In **Fig. 8**, the percentage removal of FOGs is almost of the same trend as that of TSS. At higher recirculation flow rate, higher percentage removal of FOGs was achieved at a shorter period of time. But after 60 minutes, a 98-99.75% removal was achieved regardless of the flow rate. As observed by Chin and Choa (2011) and Yang and McGarrahan (2011), mixing plays a vital point in the removal rate because at higher flow rate the retention time of the wastewater is faster which makes a larger surface area of the generated hydroxides precipitated in the solution absorb the oil from the wastewater.

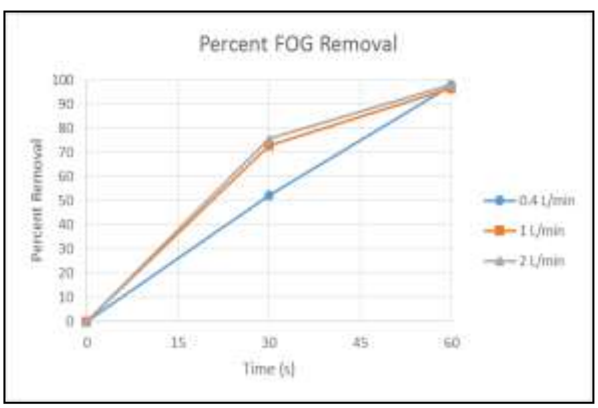


Fig. 8 Effect of flow rate on FOG removal (Al-Fe electrode, parallel connection, current density of 28.8A/$m^2$)

## 3.2 Effect of Inter Electrode Distance on the Removal of Pollutants

Inter-electrode distance affects the amount of coagulants dosed throughout the cylindrical reactor. If inter-electrode distance is too close, the coagulants may be concentrated in the immediate dosing area while if it is too large, destabilization may occur at longer period of time. In this study, two levels of inter-electrode distance was observed, one is at 25mm and the other one is at 34mm.

In **Fig. 9**, it can be observed that at 25mm inter-electrode distance, high percent removal for both COD and TSS achieved. This suggests that a closer inter-electrode distance was able to promote coagulant and pollutant interaction with little interference from electrostatic field which occurs at wider distances (Lieu, 2012).

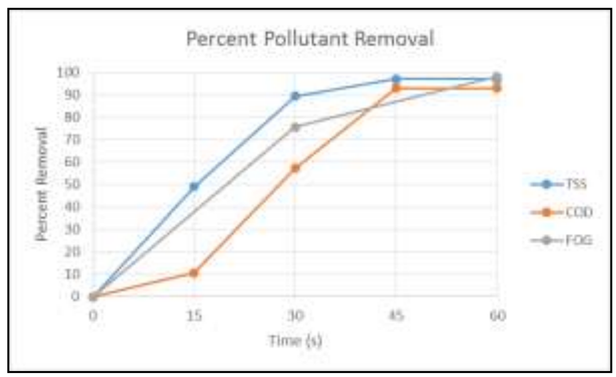


Fig. 9 Effect of Inter electrode distance on COD, FOG and TSS removal (Al-Fe electrode, parallel connection, current density of 19.2A/$m^2$, inter-electrode distance = 25mm)

## 4. CONCLUSIONS

In this study, the results showed high removal of COD, TSS and FOG in QSR wastewater with results yielding greater than 90% percentage removal. This means that EC has the potential to treat QSR wastewater in a cylindrical bench scale batch reactor.

It was also observed that the highest flow rate of 2L/min led to higher percentage removal of target pollutants however, at lower inter-electrode distance, COD did not show any progressive results. Further data will be collected to understand the interaction between the effects of inter-electrode distance with that of recirculation flow rate and Response Surface Method, Central Composite Design accompanied with D-optimal method will be used to optimize the process based on the experimental data.

## 5. ACKNOWLEDGMENTS

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## 6. REFERENCES

Abellano, J. O., Lui, E. & Soteco, E. (1999). Kitchen Wastewater Treatment Using Air Flotation for Without and with the Addition of Enzyme.

Avsar, Y., Kurt, U. & Gonullu, T. (2007). Comparison of classical chemical and electrochemical processes for treating rose processing wastewater. Journal of Hazardous Materials, 148, 340-345.

Cañizares, P., Martínez, F., Jiménez, C., Lobato, J., & Rodrigo, M. A. (2006). Comparison of the aluminum speciation in chemical and electrochemical dosing processes. Industrial and Engineering Chemistry Research, 45(26), 8749-8756.

Chen, X., Chen, G., & Yue, P. L. (2000). Separation of pollutants from restaurant wastewater by electrocoagulation. Separation and Purification Technology, 19(1-2), 65-76.

Chin, J.L.T., & Choa, C.K. (2011). Treatment of quick service restaurant wastewater by electrocoagulation. Unpublished bachelor thesis. DLSU

Kobya, M., Can, O. T., & Bayramoglu, M. (2003). Treatment of textile wastewaters by electrocoagulation using iron and aluminum electrodes. Journal of Hazardous Materials, 100(1-3), 163-178.

Lieu, U.T. (2012). The Effects of Operational Parameters on the Removal of Pollutants from a Simulated Tannery Wastewater by Electrocoagulation Process. Unpublished Masteral Dissertation, De La Salle University – Manila

Mission, E.G. (2010). Development of compact electrocoagulation reactor system for the treatment of simulated wastewater containing pharmaceutical ibuprofen. Unpublished Masteral Dissertation. De La Salle University-Manila.

Mollah, M. Y. A., Morkovsky, P., Gomes, J. A. G., Kesmez, M., Parga, J., & Cocke, D.L. (2004). Fundamentals, present and future perspectives of electrocoagulation. Journal of Hazardous Materials, 114(1-3), 199-210.

Tir, M., & Moulai-Mostefa, N. (2008). Optimization of oil removal from oily wastewater by electrocoagulation using response surface method. Journal of Hazardous Materials, 158(1), 107-115.

Xu, X., & Zhu, X. (2004). Treatment of refectory oily wastewater by electro coagulation process. Chemosphere, 56(10), 889-894.