EFFECT OF ELECTRODE DISTANCE IN ELECTROCOAGULATION PROCESS TO TREAT RESTAURANT WASTEWATER

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ABSTRACT

Electrocoagulation treatment process (EC) is an effective ttreatment process that applying an electric current to enhance the oxidation and reduction take place.This project is all about the effect of operating parameters on restaurant wastewater treatment by using electrocoagulation method. In general, wastewater is all the dirty water comes from main sources either schools, restaurants, commercial establishments, hospitals, farms and factory that usually flow down enters storm drainage system. Oily and greasy wastewater from restaurant or canteen cannot be collected and discharged to municipal drainages system directly because of faultiness of the existing wastewater treatment system. Thus, in this project, the treatment of restaurant wastewater by investigate, and measure by testing the level of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). In this project, only one of the three main operating parameters have been investigated and come out with the results. The operating parameter that involve is the effect of electrode distance on restaurant wastewater treatment by electrocoagulation process has been successfully observed and investigated.

ABSTRAK

Proses rawatan Elektrokoagulasi adalah proses rawatan yang berkesan menggunakan arus elektrik untuk meningkatkan pengoksidaan dan pengurangan berlaku. Projek ini berkenaan kesan parameter pengendalian ke atas rawatan sisa buangan restoran dengan mengunakan kaedah elektrokoagulasi. Secara umum, sisa buangan adalah semua air kotor yang datang dari sumber utama samaada sekolah, restoran, penubuhan komersial, hospital, ladang dan kilang yang mengalir melalui sistem perparitan. Sisa buangan dari kantin atau restoran yang berminyak dan bergris tidak boleh dikumpul dan disalirkan terus kepada sistem pengaliran kerana kekotoran yang terdapat pada sisa buangan tersebut. Jadi, dalam projek ini, rawatan sisa buangan restoran diuji dan diukur dengan menguji aras Keperluan Oksigen Biokimia, Keperluan Oksigen Kimia, dan Jumlah Pepejal Terampai. Dalam projek ini, hanya tiga parameter yang akan dikaji dan mengeluarkan keputusan. Pengendalian parameter yang terlibat adalah kesan jarak elektrod terhadap rawatan sisa buangan restoran mengunakan elektrokoagulasi proses telah berjaya dikaji dan diuji.

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LIST OF SYMBOLS

A	Ampere
T	Time
M	Molecular Weight
Z	Electron Involved
°C	Degree Celsius
e^-	Electron
G	Gram
H^+.	Hydrogen ion
F	Faradays Constant
L	Liter
H	Hour
Mg	Milligram
mg/L	Milligram per Liter
$Fe_3{}^+$	Iron ion
$Al_3{}^+$	Aluminum ion
Alum	Aluminum sulfate
mL	Milliliter
Mm	Millimeter
Min	Minute
$FeCl_3$	Ferric Chloride
Fe_2SO_4	Ferrous Sulfate
Al	Aluminum
H_2	Hydrogen gas
pH	Potential of Hydrogen
A	Weight of filter + dried residue
B	Weight of filter
DO_i	Dissolved oxygen initial
DO_f	Dissolved oxygen final

LIST OF ABBREVIATIONS

COD	Chemical Oxygen Demand
TSS	Total Suspended Solid
BOD	Biochemical Oxygen Demand
TDS	Total Dissolved Solid
EC	Electrocoagulation
DC	Direct Current
DNA	Deoxyribonucleic acid
AC	Alternating Current
V	Voltage
PAC	Polialuminum chloride
E. coli	Escherichia coli
ULR	Ultra Long Range
HCL	Hydrochloric Acid

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

The most important substances on Earth are water. Human being, animal and all plants use water to survive. It is obvious that there will be no life on Earth without the existence of water. It is essential that water, which people use is clean water. Water that is safe for drinking is called potable water and water that is not safe for drinking is said to be non-potable water. The population in Malaysia is increasing rapidly and its places more pressure on the environment and threatening sources of fresh water supplies. It is identified that the problem from food section such as restaurant wastewater needed proper management. Moreover, thousands of people have died because of polluted water supply. This situation has lead people to take all actions for the wastewater treatment.

People are not concern on restaurant wastewater as they busy finding a profit for their business. The common factor that need to be considered before discharge the wastewater are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) andTotal Suspended Solid (TSS). Various methods for treatment process had been introduced to meet the need to protect public health and environment. Electrocoagulation is one of the good methods to treat restaurant wastewater. This project only focused on how to use the electrocoagulation process (EC) contribute effective effect when applying to treat the restaurant wastewater by using certain operating parameters.

1.2 RESTAURANT WASTEWATER IN MALAYSIA

Wastewater is anything from water that flows down the sink or toilet that enters storm drainage systems. In simple terms, wastewater is all the dirty water from municipal sources (poop, urine and faecal sludge). This includes black water, gray water and yellow water. All dirty water from all the schools, restaurants, commercial establishments, hospitals, farms, and floodwater is considered wastewater. Some wastewater contain hazardous dissolved toxins and chemicals, whiles others contain particles, sediments and suspended matter of all sizes.

Wastewater treatment processes remove a variety of contaminants from water to make it usable again. The benefits of such treatment depend on the nature of the contaminants in the water and the end use of the water treated (Dooley, 2008). In the context of Malaysia, there are many restaurants and fast-food shops that use over half a million tons of water every day. The direct discharge of wastewater from these restaurants and shops down the drain is a huge extra burden to the municipal wastewater collection and treatment works. The oil and grease contained in the wastewater aggregate and foul the sewer system and generate an unpleasant odor. Besides that, there must be highly efficient of facilities in restaurant wastewater for removing of oil and grease, cause no food contamination, and be compact in size.

1.3 WASTEWATER TREATMENT

To measure how effective the Electrocoagulation treatment, the following inputs or variables in the wastewater type, pH, current density, type of metal electrodes(aluminum, steel, iron), number of electrodes, size of electrodes, and also the configuration of metals must be considered (Hossain, Mahmud, Parvez, & Cho, 2013). These variables can leave obvious impact upon the overall treatment time, and also the removal efficiency measured.

Electrocoagulation is an alternative method to classic chemical coagulation for many reasons. With Electrocoagulation treatment, the usage of chemical consumed in treatment is reduced significantly as the metal electrodes itself supply the coagulant. But still, there are some individuals still applying extra chemical coagulants to speed up or enhance their treatment process. Depending on the volume of water treated, chemical coagulation involves the usage of alum (aluminum sulfate), ferric chloride ($FeCl_3$), or ferrous sulfate (Fe_2SO_4) which can be very expensive (Parmar, Prajapati, Patel, & Dabhi, 2011). After doping the chemical coagulant, the coagulants act as a similar role as the metal electrodes, neutralizing the charge of the particulates, thereby allow them to agglomerate and sink down at the bottom of the tank. Furthermore, electrocoagulation is also capable of reducing waste production from wastewater treatment and also reduces the time necessary for treatment (Butler *et al*., 2011).

Studied was shown that the electrocoagulation process could achieve high COD removal. However, suspended solids and color removal was not conducive for secondary sewage treatment. Nevertheless, small scale decentralized restaurant wastewater treatment is still archivable via electrocoagulation (Iswanto *et al*., 2013). Among most of the wastewater treatment available across market, coagulation is one of the most important physio-chemical reactions used in water treatment. Ions (heavy metals) and colloids (organic and inorganic) are mostly held in solution by electrical charges. The addition of ions with opposite charges destabilizes the colloids, allowing them to coagulate. Coagulation can be achieved by a chemical coagulant or by electrical methods. The mechanism of coagulation has been the subject of continual review. It is generally accepted that coagulation is brought about primarily by the reduction of the net surface charge to a point where the colloidal particles, previously stabilized by electrostatic repulsion, can approach closely enough for van der Waals forces to hold them together and allow aggregation (Vong & Garey, 2014). The reduction of the surface charge is a consequence of the decrease of the repulsive potential of the electrical double layer by the presence of an electrolyte having opposite charge. In the Electrocoagulation process, the coagulant is generated in situ by electrolytic oxidation of an appropriate anode material. In this process, charged ionic species—metals or otherwise—are removed from wastewater by allowing it to react with an ion having an opposite charge, or with metallic hydroxides generated within the effluent.

Electrocoagulation offers an alternative to the use of metal salts or polymers and polyelectrolyte addition for breaking stable emulsions and suspensions. The technology removes metals, colloidal solids and particles, and soluble inorganic pollutants from aqueous media by introducing highly charged polymeric metal hydroxide species. These species neutralize the electrostatic charges on suspended solids and oil droplets to facilitate agglomeration or coagulation and resultant separation from the aqueous phase. The treatment prompts the precipitation of certain metals and salts.

COD level reading is the most crucial parameter in measuring the organic pollution. COD level shows how much oxygen is required to oxidise all organic and inorganic matter found in the wastewater sample. BOD describes what can be oxidised biologically, with the help of bacteria and is always a fraction of COD. Usually BOD is measured as BOD_5 meaning that it describes the amount of oxygen consumed over a five-day measurement period. It is a direct measurement of the amount of oxygen consumed by organisms removing the organic matter in the waste. TSS describes how much of the organic or inorganic matter does not dissolved in water and contains settleable solids that sink to the bottom in a short time and non-settleable suspended solids. It is an important parameter as the SS can causes turbidity in the water causing clogging of filters.

Recent studied show that within electrocoagulation by considering measuring pH at locations near iron electrodes and observed that electrocoagulation was related to components such as solubility. Having analyzed components such as metal and non-metal removal, suspended solids, organic compounds, COD and BOD level result had proven that iron electrodes were more successful than aluminum electrodes for durability and cost. Other advantages of applying electrocoagulation include it only requires simple equipment and is easy to operate with sufficient operational latitude to handle most problems encountered on running.

Also, wastewater treated by electrocoagulation gives palatable, clear, colorless and odorless water. In addition, sludge formed by electrocoagulation tends to be readily settable and easy to de-water, compared to conventional alum or ferric hydroxide sludges, because the mainly metallic oxides/hydroxides have no residual charge. Output that produce effluent with less Total dissolved solids (TDS) content as compared with chemical treatments, particularly if the metal ions can be precipitated as either hydroxides or carbonates (such as magnesium and calcium. EC generally has little if any impact on sodium and potassium ions in solution.

The electrocoagulation process has the advantage of removing the smallest colloidal particles, because the applied electric field neutralizes any residual charge, thereby facilitating the coagulation. It also avoids excessive use of chemicals and so there is reduced requirement to neutralize excess chemicals and less possibility of secondary pollution caused by chemical substances added at high concentration as when chemical coagulation of wastewater is used. The gas bubbles produced during electrolysis can conveniently carry the pollutant components to the top of the solution where it can be more easily concentrated, collected and removed by a motorized skimmer. One of the most significant advantages is that the electrolytic processes in the Electrocoagulation cell are controlled electrically and with no moving parts, thus requiring less maintenance.

1.4 PROBLEM STATEMENT

Some of the wastewater sources, for example, oily and greasy wastewater from a restaurant or canteen, cannot be collected, and discharged to municipal drainages directly because of the faultiness of the existing wastewater treatment system. Otherwise, it will give a huge extra burden to the municipal wastewater collection and treatment works because they can be neither easily decomposed biologically nor simply treated by other conventional means due to their consistency (Xu & Zhu, 2004). In addition, these wastewaters tend to clog drainpipes and sewer lines, causing unpleasant odor and corrosion of sewer lines (Murthy *et al.*, 2007).

Moreover, there is a lot of conventional method that already used for wastewater treatment such as flotation, activated carbon adsorption, ion exchange, reverse osmosis, membrane filtration, advance oxidation and coagulation (Dura, 2013). However, the aforementioned method is not reliable because its need high capital and operating cost from small profit margin of restaurant. Chemical coagulation is also not practicable because of the low efficiency in removing light and finely dispersed oil particles and possible contamination of foods by chemicals.

The conventional method also takes a longer time to treat restaurant wastewater (Dura, 2013). For an example, the study of the treatment of egg processing effluent and rice mill effluent using chemical coagulation and biological method which found that the treatment efficiency of the process is low. Although they found treatment efficiency of the effluent using chemical coagulation processes is better than biological process, but it produces a considerable quantity of sludge which needs further treatment (Thite & Chaudhari, 2015).

The effectiveness of restaurant wastewater treatment can be maximized by studied the factor that effect the operating parameter towards the removal efficiency of COD, TSS and BOD towards parameter such as current intensity (low & high current), initial pH and electrode distance. Among the conventional techniques, electrocoagulation is a simple and efficient method for the treatment of many water and wastewaters (Dura, 2013). However, electrocoagulation has also a problem in treatment process. Normally, the pH value of restaurant wastewater is in the range of (6 - 8.7). According to Murthy et al. 2007 this range is not the optimum condition for restaurant wastewater treatment process. Based on the previous study, the raw wastewater from restaurant waste is taking as sample for treatment process without altered the pH value which results to low removal efficiency of COD (Guohua Chen and Xueming Chen, 2000).

The distance between electrodes is one of the main factors that can cause effect in electrocoagulation process. There are many researchers come out with their idea and their result has a few limitations. In order to overcome this problem, the range of electrode distance will should be verify which around 10mm is until 60mm. So, the best electrode distance can be choosing according to the performance in electrocoagulation process. Lastly, the current intensity can enhance the rate of reaction for oxidation and reduction in the electrolytic solution. The higher the current intensity use the higher the removal efficiency of the pollutant. Thus, 0.5A, 1.0A, 1.5A, 2.0A, 2.5A, and 3.0A were used to show the comparison between them.

1.5 RESEARCH OBJECTIVE

In general, the main objective of this research is to treat restaurant wastewater by using electrocoagulation process. This work was completed in accordance with the specifics individual objective:

1) To determine the effect of electrode distance on restaurant wastewater by electrocoagulation process towards the removal efficiency of COD, TSS and BOD.

1.6 PROJECT SCOPE

The main purposed of this project is to study the process of restaurant waste water treatment by using EC method. This project is focusing on three main operating conditions which is the effect of current intensity, the pH changes and electrode distance. For the current intensity, the effects towards the treatment process will investigate and the data will be recorded. Besides that, the amount of adsorbent is determined by the Faraday's law which is $EC = I \times t \times M/ZF$ where I is the current in (A), t is the time (s), M is the molecular weight, Z is the electron involved, and F is the Faraday constant (96485.3 C/Mol).

In order to investigate the effect of current intensity on the absorbent removal, a series of experiments need to carry out. The behavior of pH changes in this experiment will observe gradually within the time. The restaurant waste of initial pH 2, 4, 5.7, 6, 8 and 10 will use. As mentioned by (Vasudevan *et al.*, 2011), the percentage of adsorption directly proportional to the pH increasing. The electrode distance will vary from 10mm, 20mm, 30mm, 40mm, 50mm and 60mm. The most optimal electrode distance can be observed at the end of this experiment. As stated by (Xu & Zhu, 2004),the optimal electrode distance is 10 mm in consideration of the treatment cost and efficiency together. For restaurant wastewater need to vary the electrode distance until the optimal electrode distance can be found.

1.7 SIGNIFICANT OF STUDY

The restaurant wastewater is one of the huge contributions of pollution in our area especially at restaurant Gambang Damai, Kuantan,Pahang. In order to control this problem become more serious, the best action needs to take and look forward. One of the solutions is by treat the restaurant wastewater before it discharge directly to drainage system. Generally, the restaurant wastewater contains of oily and greasy waste due to the cooking oil and others. When the wastewater undergoes electrocoagulation process, the clog drainage problem can be reducing immediately and the pollution will be decrease within time. This is because the end product of wastewater will be clean water.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Wastewater can be defined as water that had contaminated by one of these wastes either with human or animal metabolic wastes, residuals from cooking, cleaning and bathing. There are no other substances that can transport, clean, and remove wastes like water does. For example, it cleans the inside and outside of our body, carries and clean various types of residue left like restaurant and industrial waste. By its pure weight, wastewater surprisingly still composed of approximately 99.9% water and 0.1% of those impurities. Despite the minority of those impurities, the 0.1% of impurities may contain organic and inorganic materials and also microorganisms (pathogen like E.coli).

Main sources of wastewater are originated from small place include homes, farms, hospitals, businesses, industry and also restaurants. Some communities have combined sewers that collect and guide the flow of both wastewater and rain water runoff from streets, lawns, farms, and other land areas. This lead to a bigger problem, the resulted wastewater might have composed of any debris from streets, waste oils, pesticides, fertilizers, and wastes from humans and animals. Wastewater from a typical household might include toilet wastes when people used water from sinks, baths, showers, washing machines, and dishwashers or anything else that can be pour the waste or residue down the drain or flushed down the toilet.

BOD and COD are common parameters that will conclude the purities of water. Indicator of mass of dissolved oxygen needed by microorganisms to degrade organic and some inorganic compounds. High BOD/COD is indirect indicator of the organic content; also the ammonia is inorganic and creates an oxygen demand. Other measurement included pH, colour, and also odor (Buchanan & Seabloom, 2004). Dissolved oxygen is consumed in the process of convert organic matter into inorganic matter. As the time goes, the oxygen in the aquatic gradually reduced and hence increases the BOD and pollutes the aquatic river or lake. The process will keep repeated until the river or lake experiences severe oxygen debt.

2.2 WHAT IS RESTAURANT WASTEWATER?

For few decades, uncontrolled disposal of restaurant waste into rivers or aquifers had been strike hard and severely damaged our ecosystem equilibrium. Small to medium size of food industry often ignored the importance of waste water treatment as conservation of environment must be concerning to secure better future for next generation. Dumping food waste without proper management or treatment in a landfill or any aquatic source can cause odour as it decomposes, dissolve and thus attracts flies and vermin, and has the potential to add BOD.

Despite the existence of several advance technologies in waste water treatment like aerobic and anaerobic biological treatment (Aquatech company) and high-end filtration devices (Dow Water & Process Solutions), rapid increment of population thus outpace those relatively complex and high cost treatments. Inappropriate technology and the responsibilities within government were not resolved to ensure the necessary hence rises the risk of ecosystem disaster (Chen, Chen, & Yue, 2000).

In the recent studied, restaurant wastewater containing high concentrations of COD, and TSS was treated by the electrocoagulation process on a pilot scale. In aspect of the operating cost calculated with respects to energy consumption, electrode depletion, and chemical consumptions, up to Hong Kong Dollar 1.3/m3 water or 52% of the concession in trade effluent surcharge can be saved, revealing the cost-effectiveness of the EC technique and its potential for full-scale implementation on small-medium wastewater treatment alternative (Chen et al., 2000).

The quality and characteristics of restaurant wastewater varies upon the type of food served, for example, Japanese, European buffet, Western and Chinese. Both the pollutant load and intensity of cooking oil content increase in the order of the food listed. Furthermore, wastewater quality can also have varied greatly over the course of a day. Hence, a biological system intended for use to treat such wastewater, specialized design of certain treatment method is essential to handle different level of quality and quantity spike loading.

Since the quantity and quality of restaurant wastewater can fluctuate widely, a large equalization tank would be needed to be prepared for the peak hours. However, most restaurants are situated in urban surroundings where space is very limited. Hence, most restaurants use physical and chemical means for treating their wastewater. This leads to the discharge of chemical sludges into the sewage system with possibly high operating costs. Most restaurants are small operations. Thus, the initial investment and operating cost for wastewater treatment must be kept low.

The electrocoagulation process, for example, consumes the aluminum electrodes at 17.7 g/m^3 to 106.4 g/m^3, and the power requirement is approximately 1.5kW h/m^3. Thus, these make the electrocoagulation process costly. Although conventional biological treatment processes have lower operating costs, they require larger land space.Wastewater from restaurants and other commercial food service facilities differs significantly from residential wastewater. In addition to higher surge volumes during peak hours, and generally-higher temperatures, restaurant wastewater is typically higher in strength than residential wastewater. This is due to higher levels of oil, grease and solid waste which led to a higher BOD. Oil and grease are the main root cause for both onsite sewage disposal systems and public sewer systems.

The problem occurs when oil and grease liquefy at the high-water temperatures used to wash dishes and later solidify in sewer lines or sensitive soil interfaces in the leaching facilities of onsite systems. The problem becomes more critical when highly efficient detergents are used to emulsify the oil and grease, keeping them in suspension until they enter the leaching field. Although conventional grease traps are supposed to prevent grease from entering the septic tank or sewer line, high grease loads, emulsified grease, and surge wastewater loadings often cause grease to bypass the grease trap and enter the leach field (Nakajima, Izu, & Yamamoto, 2001).

When grease reaches the soil absorption system it can physically clog and stuck the soil pores preventing both water flow, moment, and the free transfer of oxygen necessary to digest waste. The high BOD present in grease also promotes excessive bacterial growth which causes the formation of a thick anaerobic metabolism (without oxygen) that has less capability in treating the waste. Thus, it is resulting in premature failure of the soil absorption system. Data suggests that if soil absorption systems at restaurants are to function in the long term, design modifications must be made which take into account the much higher wastewater strength, flow variations, and oil and grease constituents found in restaurant wastewater.

Wastewater contains vast amount of foreign substances that are considered as impurities. Impurities are any substances that are not found in “pure” water. Pure water is consisted of hydrogen and oxygen. In nature, water contains many dissolved impurities. In fact, water is referred to as “the universal solvent” due to its ability to dissolve many substances. Restaurant wastewater is water that has been used for cleaning meats and vegetables, washing dishes and cooking utensils, and cleaning the floor. Due to the difference among different cuisines, the wastewater composition of Chinese restaurant is expected to be different from that of Western restaurant. Since the food served for breakfast, lunch and dinner are different, the wastewater composition would vary from time-to-time for a particular restaurant. Thus, it is very difficult to have one meaningful characterization for each restaurant.

To make matters worse, there is no collection system available. Thus, waste samples have to be scooped from the entrance of the drains at representative time. A total of 48 samples were collected from five restaurants in HKUST for the characterization purpose. As expected the oil and grease content was very high. The pollutant concentration varied in a wide range so did the conductivity. It is interesting to note that the highest COD, oil and grease values were found from wastewater discharged by an American fast-food restaurant and a Western restaurant, respectively.

The highest suspended solid content was found from student canteen serving Chinese as well as Western fast foods. However, it should be pointed out that the pollutant concentration variations are comparable for all the restaurants. In comparison with the permission standards for effluents discharged into foul sewers leading into the Hong Kong Government sewage treatment plants, the only parameter that consistently exceeds the standard is the oil and grease content although COD and BOD_5 sometimes are also a bit too high (Murthy et al., 2007).

2.3 CHARACTERISTIC OF WASTEWATER

2.3.1 Physical Properties

Since waste water has high BOD/COD contamination, they used all the oxygen available and hence left the aquatic river or lake to enter oxygen debt situation. This will lead to algae bloom and green color microorganism will cover the whole river. Thus, sun-lights are blocked from entering the aquatic bed and gradually decrease aquatic survivability. Bad odor and appearance of the aquatic environment become more critical when the flow of water become slow or completely stuck.

2.3.2 Chemical properties

Contaminated wastewater has generally high BOD and COD values as the aquatic itself require oxygen to dissolve the waste. Furthermore, higher percentage of suspended solid as the waste clog and form a larger particle hence increase in difficulty in water waste treatment. pH of the effluent also varied as the source might be alkaline (mainly domestic waste) or acidic (mainly industrial waste). The pH value fluctuated between 6-9 as the presence of soap (alkaline) also the food waste (acidic). The oil and grease composition is higher in fast food restaurant as they served food that high in fat and oil percentage.

Table 2.1: Characteristic of Restaurant Wastewater

Restaurant	Chinese restaurant	Western fast-food	American fast-food	Student canteen	UC bistro	Permission standards in H.K.
Number of samples	10	10	11	14	3	-
PH	6.62-7.96	6.94	6.30-7.23	6.82-8.76	6.03-8.22	6-10
COD(mg/l)	292-3390	912-3500	980-4240	900-3250	1500-1760	3000
BOD_5(mg/l)	58-1430	489-3500	405-2240	545-1630	451-704	1200
Oil and grease(mg/l)	120-172	52.6-2100	158-799	415-1970	140-410	100
SS (mg/l)	13.2-246	152-545	68-345	124-1320	359-567	1200
Conductivity(µS/cm)	227-661	261-452	254-706	233-1570	341-514	-

Source : (Prashant Basavaraj Bhagawati & Department, 2017)

2.4 EFFECT OF WASTEWATER DISPOSAL ON PUBLIC HEALTH AND ENVIRONMENT.

A discharge is the disposal or release of either treated or untreated wastewater into a receiving stream. A discharge may occur in a treatment plant, restaurant drainage, or from an overflow in the collection system. Untreated wastewater discharge can create several undesirable conditions. These include oxygen depletion and odor production in the stream, negative effects on human health, sludge and scum accumulations. Across the globe, including in the United States and Malaysia, health problems and diseases have often been caused by discharging untreated or incomplete treated wastewater. Such discharges are called water pollution, and result in uncontrollable spreading of diseases, fish kills, and destruction of other forms of aquatic life. The pollution of water may have many critical impact upon all living creatures and potentially generate negatively affect the use of water for drinking, household needs, recreation, fishing, transportation, and commercial (Hammer & Bastian, 1989).

However, the health effects of irrigating with wastewater can be either positive or negative side. The positive effects can be related to food security in poor areas such as Africa. Wastewater is possible (and commonly the only way) to produce food and increase income in poor areas, thus also increasing nutrition and the quality of life. Negative effects are due to the increasing presence of pathogens and toxic chemical compounds in wastewater. Irrigation with treated wastewater poses a number of potential risks to human health via consumption or exposure to pathogenic microorganisms, heavy metals, harmful organic chemicals.

In general, four groups of people are at risk. They are agricultural workers and their families, crop handlers, consumers of crops, meat, and milk, and those living near the areas irrigated with wastewater, particularly children, and the elderly. Wastewater contains a variety of excreted organisms, and the types and concentrations vary depending upon the background levels of disease in the population. Many pathogens can survive for long enough periods of time in soil or on crop surfaces and thus be transmitted to humans or animals (Van Overbeek et al., 2014). Therefore, pathogenic microorganisms are generally considered to pose the greatest threat to human health. Household sewage contains a high percentage of organic materials and pathogenic microorganisms, including bacteria, viruses, and protozoan. The diseases associated with such infections are also diverse and include typhoid, dysentery, diarrhea, vomiting, and malaria. Any human contact with the treated wastewater might be hazardous (Deepali & Joshi, 2014).

Humans "catch" diseases from wastewater in a variety of ways. Pathogens in wastewater may be transmitted by direct contact with sewage, by eating food or drinking water contaminated with sewage, or through contact with human, animal, or insect carriers. For example, direct contact might accidentally occur as a result of walking in fields fertilized with untreated wastes, playing or walking in a yard with a failed septic system, touching raw sewage disposed of in open areas, swimming or bathing in contaminated water, or working with or coming into contact with animals or wastewater without following proper hygiene and procedure (Treatment, Small, & Life, 1996).

Houseflies and vermin are commonly used to illustrate the dangers posed by disease carriers. Flies, which have taste buds on their feet, always land directly on the food they eat-and on any given day, that could mean raw sewage (a fly favorite) followed by picnic food. The hairs on a housefly's body can carry millions of pathogens, which then brush off on anything the fly touches. By making sure that wastewater is treated and disposed of properly, communities can control the spread of disease by flies and other disease carriers, such as rats, lice, cockroaches, and mosquitoes. By controlling the population of these animals and insects, communities also help to control the other, non-wastewater related diseases they may carry. But by far the most common way that people contract diseases from wastewater is through the fecal-oral route, or in other words, by eating food or drinking water contaminated by sewage or by not washing hands after contact with sewage (Winter, 1996).

In communities where wastewater treatment is inadequate or nonexistent, the opportunities for people to become infected seem endless. For example, people have become ill by drinking contaminated water, juices made with water, or other beverages made with contaminated water or ice. In addition, eating food improperly handled by infected people or carriers (often workers in restaurants or food processing facilities). Eating food exposed to flies or vermin that feed on or come into contact with sewage also one of the impact of untreated wastewater.

Bacteria, viruses, and parasites (including worms and protozoans), are the types of pathogens in wastewater that are hazardous to humans. Fungi that can cause skin, eye, and respiratory infections also grow in sewage and sewage sludge. Scientists believe there may be hundreds of disease-causing organisms present in sewage and wastewater that have yet to be identified. Bacteria are microscopic organisms that are responsible for several wastewater related diseases, including typhoid, paratyphoid, bacillary dysentery, gastroenteritis, and cholera. Many of these illnesses have similar symptoms, which vary in severity.

Most infect the stomach and intestinal tract and can cause symptoms like headache, diarrhea (sometimes with blood), abdominal cramps, fever, nausea, and vomiting. Depending on the bacteria involved, symptoms can begin hours to several days after ingestion. Often, infected people will experience only mild symptoms or no symptoms at all. However, anyone experiencing frequent diarrhea and vomiting should seek medical attention immediately. Severe dehydration and death can result with serious cases, sometimes within a day.Viruses are microscopic parasitic organisms. They are smaller than bacteria and can be seen only with an electron microscope. Some can infect people through wastewater. Viruses can't multiply outside their hosts, and wastewater is a hostile environment for them. But enough viruses can survive in water to make people sick. Hepatitis A, polio, and viral gastroenteritis are a few of the diseases that can be contracted from viruses in wastewater. Viral gastroenteritis is thought to be one of the leading causes of illness in the U.S.

There may be as many as 100 different virus types present in raw sewage, but they are difficult to identify. Much is still not known about the viruses and other pathogens in wastewater or their exact behavior and effect on humans. According to the U.S. Environmental Protection Agency, tests using DNA to help detect and identify viruses are being developed.

2.5 COAGULATION

2.5.1 Basic Theory of Coagulation

According to (Semerjian & Ayoub, 2003), coagulation is typically accomplished through chemical addition and mixing. The process is used to enhance the degree of removal of TSS, BOD , COD, and bacterial population in primary settling facilities, as well as to improve the performance of secondary treatment processes. As Semerjian has indicated that the coagulation process require metal coagulant that added to water for wastewater treatment.

The metal ion is hydrolyzed rapidly but in a somewhat uncontrolled manner, forming a series of metal hydrolysis species. Furthermore, the process is based on the formation and aggregation of a colloidal system and its further coagulation enhanced by the use of the coagulating agents. Metallic and organic pollutants are separated from the aqueous phase by their precipitation with the coagula and subsequently removed from the treated water (Pernitsky & Edzwald, 2006).In coagulation water treatment process, the addition of coagulating agents (such as Fe^{3+} or Al^{3+} salts) favors the formation of pollutant aggregates (Lee et al., 2014), their coagulation and after that (Balla et al., 2010), their physical separation from water by precipitation or flotation , allowing the removal of metal and organic pollutants from water by different coagulation mechanisms.

In previous study, (Verma et al., 2012) has point out that for water treatment, coagulation as pretreatment is regarded as the most successful pretreatment. It is obvious, the main purpose of coagulation in wastewater treatment is to remove particle of wastewater. The particulate matter or non-settling particulate matter in surface water is carrying a negative charge with them. To neutralize those negatively charged particle, add a coagulant alum/aluminum sulfate or others. Then, the positively charged coagulant will neutralize the negatively charged particles. The coagulation takes place in about one to two second. Once the charges are neutralized, the particles begin to flocculate together and become micro flock and macro flock.

2.5.2 Mechanism of Coagulation

According to the basic theory and mechanisms of coagulation, chemical coagulant is used in various mechanisms for destabilizing contaminants. These mechanisms include sweep coagulation, double layer compression, adsorption charge neutralization and inter particle bridging. Mechanism of coagulation is determined by the type of inter actions between the chemical coagulant and contaminants. The predominance mechanisms observed during conventional coagulation with metal coagulants are adsorption charge neutralization and sweep coagulation. For aluminum salts, the mechanism of coagulation is controlled by the hydrolysis speciation conventional coagulation with metal coagulants is adsorption charge neutralization and sweep coagulation. For aluminum salts, the mechanism of coagulation is controlled by the hydrolysis speciation (Dennett, Amirtharajah, Moran, & Gould, 1996) shown in Figure 2.1.

Alum is used as coagulant in the coagulation process because it is capable in achieving significant organic removal. Previous researcher, (Nasrullah et al., 2017) indicate that the pH of water during coagulation less profound influences on the effectiveness of coagulation for organic removal. Organic removal is much better in slightly acidic condition. The optimum pH for alum coagulation is influenced by the concentration of organic matter in the water. For water of higher organic content, the optimum pH is displaced to be slightly acidic value.

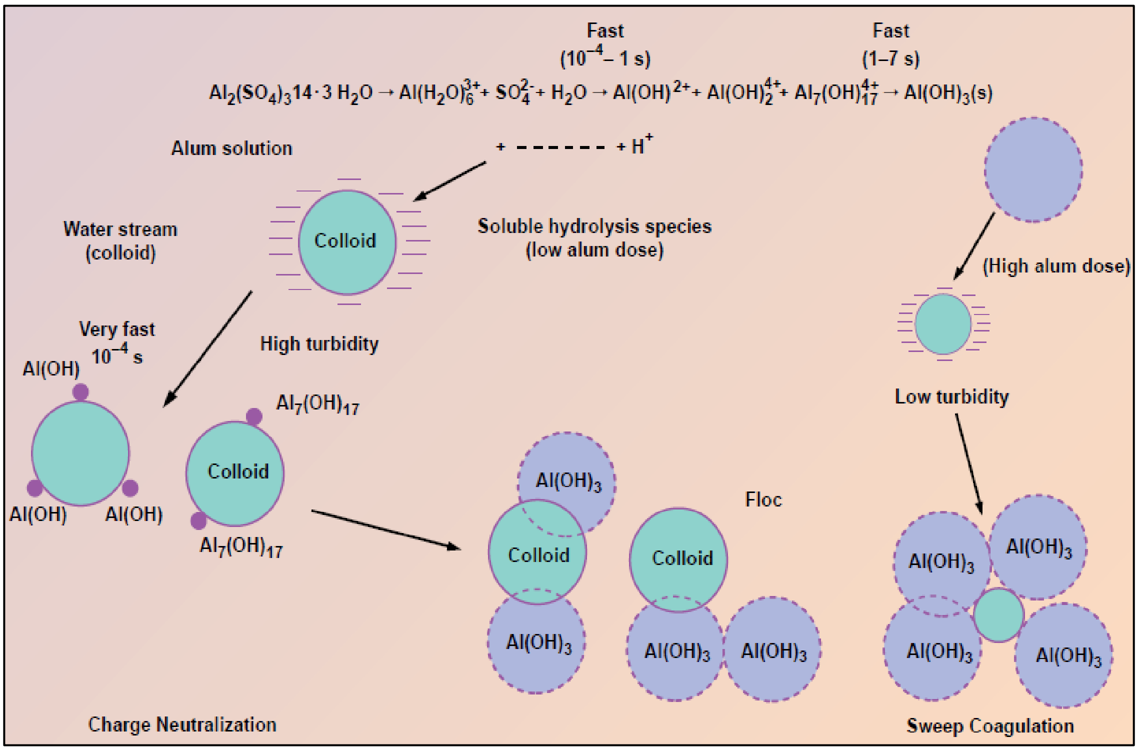

Figure 2. 1: Reaction of Schematic Coagulation

Source : (Dennett et al., 1996)

Iron compound process pH coagulation ranges and floc characteristic similar to aluminum sulfate. The cost of iron compound may offer be less than of alum. Iron salt is most commonly used as coagulant includes ferric sulfate, ferric chloride and ferrous sulfate. These compounds often produce good coagulation when conditions are too acidic for the best result with alum. Sometimes the particles are best removed under acidic conditions and iron compounds give better result (Tripathy & De, 2006).

2.6 ELECTROCOAGULATION

Electrocoagulation technology is a treatment process to treat water waste by applying electric current as a main power source. Usually the power supply used is either AC power supply or DC power supply to generate current. But according to the journal that already publish, majority of the experiment use DC power supply as their main power supply to generate current in electrocoagulation process. This is because, by using DC power supply the current can supply in more efficient way.A few years ago, several of experiment about this method has been carry out and already experimentally proved that electrocoagulation as the most suitable method in order to treat waste water. Electrocoagulation has been applied successfully to treat potable water, food and protein wastewater, yeast wastewater, urban wastewater, restaurant wastewater, tar sand and oil shale wastewater, nitrate containing wastewater solutions and arsenic containing smelter wastewater (Kobya, Can, & Bayramoglu, 2003).

In general, electrocoagulation is one of the simple and efficient methods for the treatment of many water and wastewaters around us. The huge amount of uncontrolled wastewater can cause critical air pollution problem and can produce uncomfortable situation in certain area especially in residential area. In order to reduce the amount of waste water and level of air pollution, researchers come out with suggestion which is by using electrocoagulation method. More than thousand researchers claim that electrocoagulation is the best treatment process in order to control and manage the waste water. In this world, everything has their own waste water. For example, in cafeteria or canteen, usually people tend to throw the waste water in to the drain directly without filtrate them. This automatically will cause the drainage to clog with existing of oily and grease.

Electrocoagulation has turned out to be a rapidly growing area of wastewater treatment due to its ability to remove contaminants that are generally more difficult to remove by filtration or chemical treatment systems (Al-rubaiey & Al-barazanjy, 2017). They believe that, this is the best way to treat waste water pollution due to the research and experiment that already done. This is because the end product of this method is purely clean water and can be discharge to the drainage system directly. The end product also can be recycling for daily usage or gardening used. Generally, electrocoagulation is an electrochemical wastewater treatment technology that is currently experiencing both increased popularity and considerable technical improvement (Vasudevan et al., 2011). In fact, this method has not been widely use and accept because of high initial capital costs compared to other treatment technologies nowadays. Even though this method required high initial capital cost but this method able to undergo process very quick. Only around two or three hours, the end product can be produce shortly.

2.6.1 Basic Theory of Electrocoagulation

Electrocoagulation (EC) is quite complicated process because it involving both chemical and physical phenomenon. Usually, electrocoagulation treatment involves two electrodes probe to supply ions into the waste water sample. The electrode involve is anode and cathode. The chemical reaction will take place in anode and cathode electrodes. Chemical reaction occurs when electrode attached to the waste water in the beaker. The movement of electrons and ions rapidly occurs during electrocoagulation take places. Electrodes that will be used can be choosing according to the ability of the metals to reduce and discharge ions. The higher amount of ions can discharge, the faster the reaction can take place.

Electrocoagulation is a electrochemical treatment process that operates only by using electrical current to treat waste water. According to (Al-rubaiey & Al-barazanjy, 2017), the basic process of electrocoagulation process begins when the contaminants presents in wastewater are upheld in solution by electrical charges. Then, these charged particles are neutralized with ions of opposite electrical charges provided by electrocoagulation system; they become destabilized and precipitate in a stable form. The main component that will generate the current in this experiment is the DC power supply. DC power supply can supply current within long period of time. The power supply needs to supply current more than 120 minutes non-stop during experiment take place. After certain time, the reaction will completely do. During mechanism occur, electrocoagulation utilizes aluminum or iron anodes to produce aluminum or iron hydroxide by reaction at the anodes followed by hydrolysis.

Normally, in electrocoagulation process, the most frequent electrodes that being use is either aluminum or copper. This is due to the characteristics of this metal which is can discharge ions easily. In order to make sure the process take place more efficient and faster, aluminum is one of the best electrodes. This is because, aluminum metal able to discharge ions easily and due to the position in Periodic Table. According to (Vasudevan et al., 2011), in an EC process the coagulating ions are produced ‘in situ’ and it involves three successive stages: Formation of coagulants by electrolytic oxidation of the ‘sacrificial electrode’, Destabilization of the contaminants, particulate suspension, and breaking of emulsions and Aggregation of the destabilized phases to form flocs.

Every waste water that undergoes electrocoagulation process, these three stages will be occurs before end product will produce. The time taken for every stage depends on the volume of waste water used and the electrode used. The volume of waste water is directly proportional to the time taken for electrocoagulation process completely done. To consider how effective electrocoagulation process, three parameters will be used such as current density, pH, and electrode distance. These variables would affect the overall treatment efficiency and result. According to Vasudevan et al. (2011b) , the effect of AC and DC on the removal of cadmium from water using aluminum alloy as anode and cathode was investigated. They obtained a removal efficiency of 97.5% and 96.2% with the energy consumption of 0.454 and 1.002 kWh/kL at a current density of 0.2 A/dm^2 and pH 7 using AC and DC respectively. The results indicate that the problem of corrosion formation at the electrodes can be reduced by the use of AC in place of DC in the electrocoagulation process.

According to figure 2.2, the DC power supplies directly connect to anode and cathode for supply current in the solution. The electrode probe that will be used is either aluminum or iron. The apparatus involve is DC power supply, breaker, magnetic bar and magnetic stirrer. Magnetic stirrer used to control the speed of solution in the beaker. DC power supply will supply around 12V. Magnetic stirrer is function as device that employs a rotating magnetic field that will increase the efficient of solution rotary. At the same time, it can help to make reaction take place in short time. In the other word, with the existing of magnetic stirrer the reaction can be performed quicker than normal.

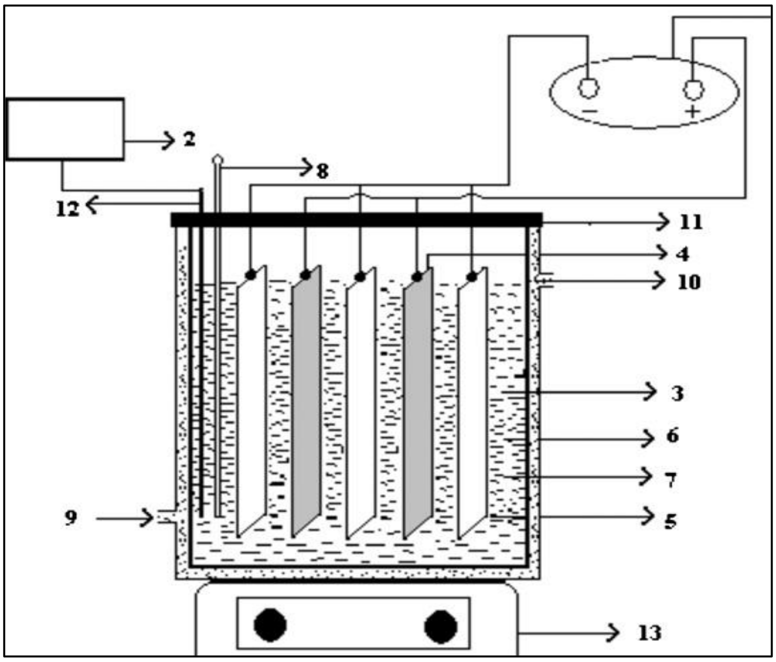

Figure 2.2: Laboratory scale cell assembly. (1) DC power supply; (2) pH meter;(3)electrochemical cell; (4) cathodes; (5) anode; (6) electrolyte; (7) outer jacket; (8)thermostat; (9) inlet for thermostatic water; (10) outlet for thermostatic water; (11) PVC; (12) pH sensor and (13) magnetic stirrer.

Source : (Vasudevan et al., 2011)

2.6.2 Mechanism of Electrocoagulation

Electrocoagulation method is the process of applying electric current in order to enhance the oxidation and reduction reactions in an electrolytic solution. To perform this work, two electrodes will be used as anode and cathode. The oxidation and reduction process begins when dissolving the electrode probe to produce ions that will act as an agent in the aqueous solution in place. Normally, the electrode used is either aluminum or iron. This because aluminum and iron very easy to find and very cheap compared to others materials. As mentioned by (Al-rubaiey & Al-barazanjy, 2017) aluminum or iron has been used usually because of the availability and low cost, in addition to their effectiveness in the process. The following main reactions take place at the electrodes during the electrocoagulation process. Anodic reactions:

$Al(s) \rightarrow Al+3+ 3e^-$ (1)

$Fe(s) \rightarrow Fe+2+ 2e^-$ (2)

$2H_2O (l) \rightarrow O_2 (g) + 4H^+ + 4e^-$ (3)

Fe^{2+} can be oxidized to Fe^{3+} by the oxygen from the atmosphere or anode oxidation:

$Fe+2 \rightarrow Fe+3+ e^-$ (4)

$2Fe+2+½O_2(g)+H_2O(l) \rightarrow 2Fe+3+2OH$ (5)

Cathodic reactions:

$2H_2O + 2e^- \rightarrow H_2 (g) +2OH^-$ (6)

According to the general equation above, the mechanism of electrocoagulation begins when wastewater passes through the electrocoagulation cell, multiple reactions take place simultaneously. Firstly, a metal ion is driven into the water when electrode anode and cathode attached to the waste water. On the surface of the cathode, water is hydrolyzed into hydrogen gas and hydroxyl groups. Meanwhile, electrons flow freely to destabilize surface charges on suspended solids and emulsified oils. As the reaction continues, large flocs form that entrain suspended solids, heavy metals, emulsified oils and other contaminants. Finally, the flocs are removed from the water in downstream solids separation and filtration process steps.

Conventional methods for dealing with wastewater consist of various combinations of biological, chemical and physical methods. During electrocoagulation process take place, mostly involve chemical mechanism. When the electrode start attached to the waste water, it will react chemically by the time. The time taken for each sample take place according to the volume of the waste water and the level of water waste pollution itself. The reading of COD and BOD concentration level of waste water also affect the performance of reaction of mechanism.

Basically, electrocoagulation consists of pairs of metal sheets called electrodes that are arranged in pairs of two-anodes and cathodes. Using the principles of electrochemistry, the cathode is oxidized (loses electrons), while the water is reduced (gains electrons), thereby making the wastewater better treated. When the cathode electrode makes contact with the wastewater, the metal is emitted into the apparatus (Butler, Hung, Yeh, Suleiman, & Ahmad, 2011).

The mechanisms in this process either oxidation and reduction is mostly takes place in the waste water solution by chemically. The end product will produce clean water. During the process take place there are a few parameters that be used to determine how the existing of parameter can affect the electrocoagulation process. The reading of COD and BOD level also will be considers in order to knowing the exactly reading before and after treatment has done. Usually, after the treatment, the reading of COD and BOD level will reduce. This is due to the chemically reaction that take place.

2.6.3 Advantage of Wastewater Treatment by Electrocoagulation

There are a lot of advantages when using electrocoagulation as one of the method to treat waste water. First of all, electrocoagulation is a simple and efficient method where the flocculating agent is generated by electro-oxidation of a sacrificial anode, generally made of iron or aluminum (Adhoum, Monser, Bellakhal, & Belgaied, 2004). According to their experiment, they already proved that electrocoagulation method more simple compared to others method. This is because the apparatus involve very easy to find and the operating cost very low.

The level of successful depends on the parameter that being used. The treatment cost of this method is relatively low because the apparatus that being use can get easily. Even though this method involve both chemical and physical process, the cost still can be affordable. Beside, DC generator is used for generate current during treatment method. The current can generate directly from DC power supply.Generally, mostly electrical part used DC power supply rather than AC power supply. This is because DC power supply can supply one direction of current while AC power supply generates alternating current. The use of DC leads to the corrosion formation on the anode due to oxidation. An oxidation layer also form on the cathode reducing the flow of current between the cathode and the anode and thereby lowering the pollutant removal efficient (Khandegar & Saroha, 2013).

Besides, electrocoagulation method is in an effective technology in order to treat water waste. This is mentioned by (Adhoum et al., 2004), a great deal of work performed in the last decades has proved that electrocoagulation is an effective technology for the treatment of heavy metal containing solutions. This is proved that electrocoagulation method more effective treatment compared to other methods.In electrocoagulation process, the coagulants are directly electro generated, thus chloride or sulfate ions are not added to the solution and consequently, eliminating competitive anions; allowing a maximum adsorptive removal. This is clearly mentioned by (Akbal & Camci, 2010).

2.7 APPLICATION OF ELECTROCOAGULATION

There are a lot of industry outside use electrocoagulation method to treat their waste water especially for the factory that produce product involving chemical and non-chemical as their waste water. Normally, the company that produces large amount of product will produce huge amount of waste water. Waste water in industry quite different compared to waste water produce by restaurant or leachate. This is because in industry the waste water that will produce normally consists of chemical compound. The chemical compound is quite dangerous when it pass freely to the drainage without treating them. In order to reduce the chemical level in the waste water, an industry must to treat their waste water.

One of the industries that used of electrocoagulation is in raw water and wastewater treatment plants. This method is used for the destabilization of pollutants so that the waste water can be removed in the subsequent separation processes. The application of electrocoagulation in this field already discuss quite detail by (Vepsäläinen, 2012). They mentioned that, the most commonly used coagulation chemicals are aluminum and iron metal salts. Electrocoagulation technology also has been proposed for the treatment of raw waters and wastewaters. With this technology, metal cations are produced on the electrodes via electrolysis and these cations form various hydroxides in the water depending on the water pH. In addition to this main reaction, several side reactions, such as hydrogen bubble formation and the reduction of metals on cathodes, also take place in the cell.

Besides, electrocoagulation method is used for treatment of dyeing wastewater and washing wastewater. According to (Tsinghua & Publishing, 2004), the researches mentioned that electrocoagulation as one of the electrical water treatment technologies; electrocoagulation is studied deepest in the mechanism and has the powerful theory support for its practical application. This is because electrocoagulation has the higher treating efficiency than the conventional physical and chemical water treating methods. It is easier to control on treating effect and time. The equipment involve is simple, easy to get and easy to produce. It needs little room to fit and is easy to operate. This technology has great potential in industrialized application in the near future. The study on water treatment by electrocoagulation was carried out. And dyeing and washing wastewater were the treating objects. The treatment standard would meet national wastewater effluent standard.

Next, electrocoagulation also able to use in dairy industry wastewater is characterized by high BOD_5, chemical oxygen demand COD, and other pollution load. The purpose of this study was to investigate the effects of the operating parameters such as applied voltage, number of electrodes, and reaction time on a real dairy wastewater in the electrocoagulation process. For this purpose, aluminum electrodes were used in the presence of potassium chloride as electrolytes. It has been shown that the removal efficiency of COD, BOD_5, and TSS increased with increasing the applied voltage and the reaction time (Bazrafshan *et al.*, 2013).

Electrocoagulation also used to treat refectory wastewater with high oil and grease contents. Different operational conditions were examined, including pH, current density, reaction time, conductivity, electrode distance and inlet concentration. The optimum current density was 10–14 Am_2 within 30 minutes depending on the wastewater properties tested. Conductivity had little effect on the treatment efficiency. Although the addition of extra salts (e.g., sodium chloride) to the wastewater did not help increase the pollutant removal efficiency, it could save the power consumption significantly. The COD Cr and oil removal efficiency descended with increasing electrode distance. The optimal electrode distance was determined to be 10 mm for this equipment in consideration of the treatment cost and efficiency together (Xu & Zhu, 2004).

Laboratory experiments were carried out to investigate electrocoagulation as electro disinfection of artificial wastewater contaminated by no pathogenic Escherichia coli species in batch culture and two surface waters using three different electrodes. Aluminum electrodes were found most efficient in E. coli cells destruction comparatively with stainless steel and ordinary steel. Only thirty minutes are required for electrocoagulation to achieve total E. coli cells removal. Electrocoagulation has shown the same efficiency toward algae and coliforms in two kinds of surface waters. The main mechanisms of electrocoagulation are charge neutralization of microorganisms by electrical field and metallic cations followed by their flotation or sedimentation (Ghernaout et al, 2008).

According to (Balla et al., 2010), the efficiency of electrocoagulation in removing of colour from synthetic and real wastewater by using aluminum and iron electrodes. These synthetic wastewaters were experimentally investigated, in order to determine the suitable operating conditions to treat the real reactive, disperse wastewaters and their mixture. Three real wastewaters have been collected: one from the ducts of acid dyestuff containing reactive dyes, the second one collected in ducts of basic dyestuff containing dispersive dyes, the third one was obtained from a tank containing a mixture of acid and basic dyestuff. The electrode that is used as anode and cathode is aluminum or iron flat electrodes of rectangular shape (250mm×70mm×1mm) respectively. Electrocoagulation is confirmed as a good process to remove a mixture of dyes. Iron anodes were more adequate for reactive and mixture (disperse + reactive) dyes, whereas the aluminum electrodes were more efficient for disperse dyes removal.

As mentioned by (Kuokkanen *et al.*, 2013), the characteristics of effluent from pulp and paper industry are blackish colour, high amounts of organic load, suspended solids(mainly fiber), COD, and BOD. Aluminum and iron very closed to each other in efficiency with the different pollutants being removed. However, aluminum was slightly better overall and was chosen as the optimum because the resulting effect treated with aluminum was found way clear and stable. However, Fe electrodes caused the water to turn green at first and then to yellow and turbid due to Fe (11) and Fe (111) species generated.

Using Fe caused color reduction to be only 62%, and when using Al, COD and phenol reductions were 77% and 91%, respectively. Wastewater from the tissue paper industry was treated by EC with an aim to obtain water quality acceptable for reuse. The results showed that a separation gap of 10 mm produces a faster build-up of sludge between electrodes. However, it yields more efficient removal of turbidity and lower energy consumption than larger gaps. EC was concluded to have proven to be an efficient method for removing turbidity from this type of wastewater, producing water of quality (8 NTU) suitable for reuse in the paper bleaching stage

As studied by (Murthy *et al.*, 2007), study the separation of pollutant form restaurant wastewater by using electrocoagulation. Characteristic of restaurant wastewater with high oil and grease is investigated. According to Murthy, aluminum is used as electrode material compared to iron. This is because the effluent that is treated by aluminum electrode is very clear and stable while the effluent with iron electrodes turn to greenish first, and then turned yellow and turbid. There is also electrode corrosion at open circuit for iron. The removal efficiency of oil and grease exceeded 94% for all wastewaters tested. The experimental results also show that the maximum removals of COD, oil and grease were observed at pH around 7as electrocoagulation can neutralize wastewater pH. The pH effect is not very significant in the range 3–10. Besides that, the optimal charge loading and current density are 1.67–9.95 F/m3 and 30–80 A/m2, depending on wastewater characteristics. The aluminum electrode consumption ranges from 17.7 to 106.4 g/m3, and the power requirement is usually B1.5 kWh/m3.

According to (Sharom, 2012), have been investigated the treatment of synthetic solutions containing mercury (11) by using electrocoagulation process. The sample of wastewater is from industrial company that discharged petroleum waste contaminated with mercury and heavy metals. Aluminum electrode is used to remove mercury ion from mercury synthetic. Three parameters were investigated in this research, which are the effects of the distance between the electrodes, charge loading on the removal efficiency and flow rate. In the research, more than 99% of the pollutant was eliminated by using Aluminum as electrodes. The distance between the electrodes gives highest removal was 5 cm. While the lowest concentration is 2ppm with the highest charge loading will be contributes to the higher percentage of removal of mercury up to 99.18%.

As indicate by (Omwene & Kobya, 2018), study the removal of phosphate by electrocoagulation using iron (Fe) and aluminum (Al) at anodes, titanium at cathode in batch reactor. The operating parameters in this study were initial pH, initial Phosphorus concentration, reaction time, current density, metal-to-phosphorus ratio, charge loading and electrode type. The optimum conditions for phosphorus removal by Fe and Al electrodes were obtained as initial pH of 3–8 and 3–8.8,current efficiency of 3–469 and 10–389 A/m2, and EC time of 8–70and 5–120 min, respectively. Also, the final pH increased with increase in EC time; when initial pH = 4, Concentration of phosphorus = 52 mg/L and current density = 20 A/m2, the final pH was 8.52 at 50 min for Al electrode and 10.62 at 100 min for Fe electrode. These studies showed Al electrodes to be more effective than iron electrodes for phosphorus removal.

As eloquently stated by (Nasrullah et al., 2017), the treatment of palm oil mill effluent has investigated by electrocoagulation with presence of hydrogen peroxide as oxidizing agent and polialuminum chloride (PAC) as coagulant-aid. The function of hydrogen peroxide and polialuminium chloride is to enhance the treatment process. The study focus on the effects of operating parameters, such as electrode material, current density, percentage of hydrogen peroxide and amount of polialuminum chloride (PAC) on COD removal of palm oil mill effluent (POME). According to Nasrullah, the iron, Fe is more effective for electrocoagulation process compared to Aluminium, Al.

By using iron electrode, the removal efficiency of COD reach its optimum level of 86.67% in just 180 min of electrolysis time as compared to the 81.11% in 210 min by using aluminum electrode. Besides that, the increment of current density from 30 to 80 mA cm−2 resulted in increment of COD removal efficiency from 72.86% to 88.25%. This can be explained by as the current density increase, the efficiency of ion production in anode and cathode also increase, leading to the percentage of removal for COD to increase.

Coagulant-aid also changes the properties of pollutant's surface charge to endorse agglomeration and enmeshment of fine particles to become larger flocs which can be easily removed by sedimentation or filtration. Moreover, 95.08% COD removal efficiency was achieved by adding 2% H_2O_2 plus 3g L−1 PAC to the electrocoagulation process. Therefore, the results show that the presence of coagulant-aid and oxidant together with electrocoagulation is very effective for treating this type of wastewater

2.8 FACTOR THAT EFFECT THE OPERATING PARAMETER

2.8.1 Effect of Electrode Distance

Distance between electrodes is one of the important parameter that will be observed in this experiment. This variable can affect the operational cost in electrocoagulation process. The effect of the distance between electrode either can cause the performance of electrocoagulation process or not. During experiment, both material of electrode are aluminum as anode and cathode.

The electrode distance will varies from 10mm, 20mm,30mm, 40mm,50mm and 60mm. The most optimal electrode distance observed at the end of this experiment. As stated by, optimal electrode distance is 10 mm in consideration of the treatment cost and efficiency together. For restaurant waste water, need to vary the electrode distance until the optimal electrode distance can be found. As mentioned by (Verma, 2017), in the case of high values of the conductivity (as in present study) of the effluent, it is recommended that, when the conductivity of the effluent is relatively high, greater inter-electrode distance be used.

This is show that, the electrode distance is very important variable in order to conduct the electrocoagulation process. The distance between anode and cathode must be adjusted in order to reduce the effect of electrode distance towards the performance of electrocoagulation efficiency. The distance of electrode must be verified until the best distance of electrode will be found according to the specific range of electrode distance.

The electrode distance also influences the COD level in wastewater. The COD removal efficiency is improved by decreasing the distance between the anodes and cathode. Since cathode is fixed and therefore increasing the distance between anodes leads to the decrease of distance between each anode and cathode (Verma, 2017). This can be attributed to the increase of electrical current associated with reducing the electrode distance resulting in higher collisions of the ions that enhance the coagulation. This is proved that, by reducing the electrode distance, the electrocoagulation process will occur quicker that far electrode distance.

The maximum pollutant removal efficiency is obtained by maintaining an optimum distance between the electrodes. At the minimum inter-electrode distance, the pollutant removal efficiency is low. This is due to the fact that the generated metal hydroxides which act as the flocs and remove the pollutant by sedimentation get degraded by collision with each other due to high electrostatic attraction (Daneshvar, Ashassi Sorkhabi, & Kasiri, 2004). According to (Janpoor *et al.*, 2011), when the author conduct the experiment, they come out with the results show that, with all other parameters constant, removal efficiencies of all pollutants increase when the distance between the plates is decreased. The author mentioned that, the main reason for this is that resistance between plates at constant voltage is decreased so the current increases thus increasing the concentration of coagulants and bubbles.Coagulation flocculation is widely used in many treatment processes. However, wastewater treatment by using coagulation involves the addition of polymers that clump the small, destabilized particles together into larger aggregates so that they can be more easily separated from the water.

Coagulation is a chemical process that involves neutralization of charge whereas flocculation is a physical process and does not involve neutralization of charge. The factors that effecting in the consequences of coagulation process are the pH, alkalinity, turbidity, types and amount of coagulant and coagulant aids, temperature, detention time for flocs formation and the rate of speeding mixture (Jamil, 2005).

2.9 CONCLUSION

In a nutshell, there is a few of limitation that can be identify from the result that shown by a few researchers. To overcome this limitation, the operating parameters that will be use should be more in wide range. This is because, the value of range that will be use will affect the result and efficiency of the electrocoagulation process taken place. The operating parameters that will be use are including current intensity, pH changes and electrode distance. For example, when to investigate the effect of current intensity toward the electrocoagulation, the previous researchers only used certain range of current intensity. But in order to improve the ability of the system, the high current intensity also will be use and the effect of it will be observed and measured in this project.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter described about method and materials used in the recent study which involves electrochemical cell, electric cable, DC power supply, 1000ml of beaker and aluminum plate with dimension (60mm x 40mm x 3mm). This chapter presents the materials, experimental setup, condition and procedures used to treat the effluent form restaurant wastewater. In this project, set of experiments were conducted to determine the effect of operating parameters of electrode distance. The level of COD and TSS were determined by using standard HACH method while BOD level was measured by using standard method 5520 B.

3.2 PROJECT DESIGN

3.2.1 Experimental Setup

The experimental set up used consist of a beaker of 1500 ml as a reactor to hold a sample of 1000 ml. Aluminum plates with dimension of 60mm x 40mm (length x width) were used as electrodes. The thickness for electrode is used 3mm. The electrode plate was mechanically cut by heavy machine to get the desired dimension. The 10% of concentration of HCL was used to remove the dirt and corrosion on plate. The area of electrodes dipped into the solution was 50 mm x 40 mm and the remaining area was prevented from exposure with lacquer. The anode and cathode were positioned vertically and parallel to each other and connected to an external power source.

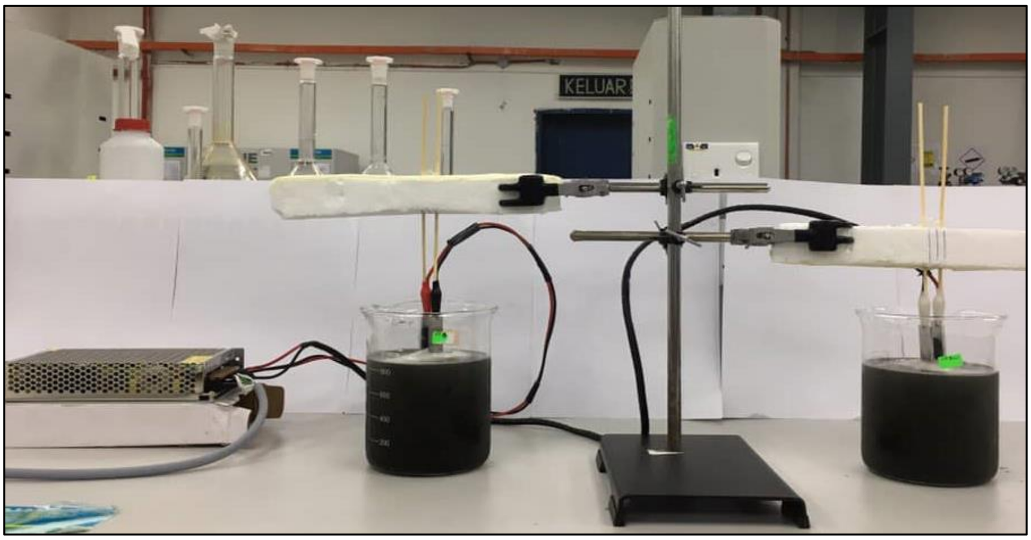

Figure 3. 1: Experimental Set Up

Figure 3. 2: Variation of Electrode Distance

A DC power source, a rheostat to keep the current invariant, an ammeter and voltmeter to read the values of current and voltages were used. The spacing between two electrodes in electrocoagulation cell was varied from 10mm, 20mm, 30mm, 40mm, 50mm, and 60mm. All experiments were performed at a room temperature.The aluminum plates were cut by using hydraulic shearing machine for huge sample and hydraulic notching machine for small sample with dimension of 60mm x 40mm x3mm respectively. Then, the acrylic plate were cut according to the electrode distance for 10mm, 20mm, 30mm, 40mm, 50mm, and 60mm approximately. After that, manually put the glue on aluminum plate to combine them. Before decide to use acrylic plate, 10mm of double tape was used. But it does not practically to use due to the ability when touched with water, it will broke and give effect to the reaction. Besides, to set up an experiment by using double tape, it take time to get 10mm approximately and need to measure frequently to make sure the upper part and the lower part are in same distance.

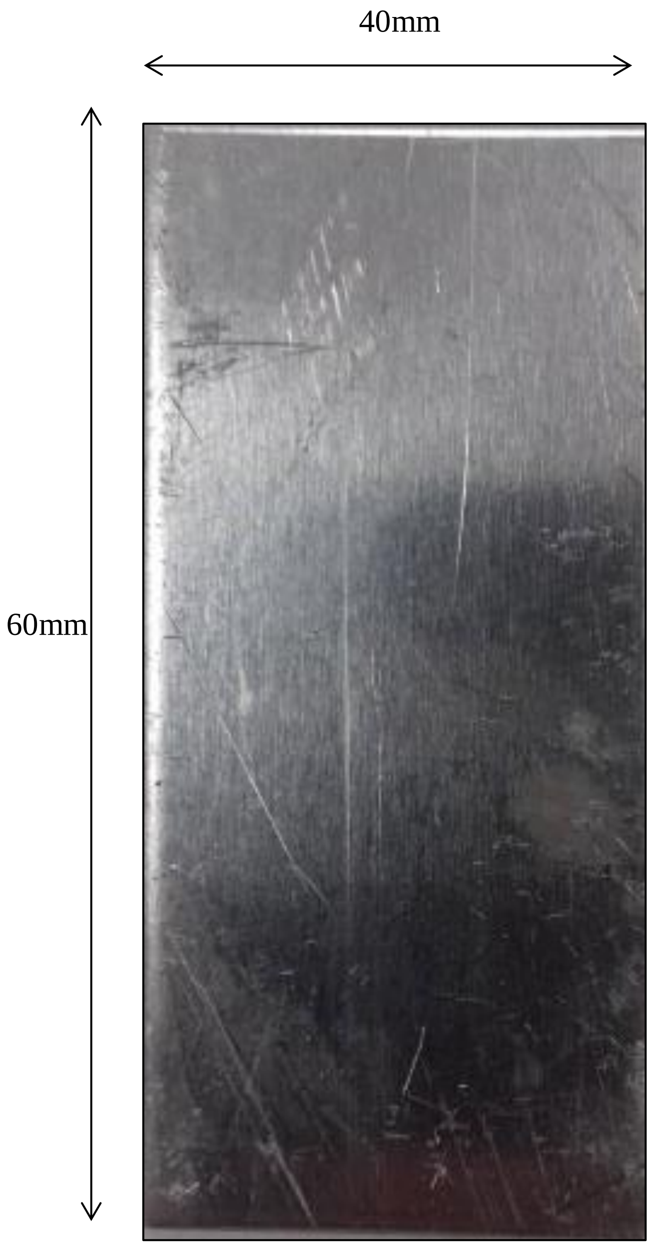

Figure 3.3: Dimension of Aluminium Plate

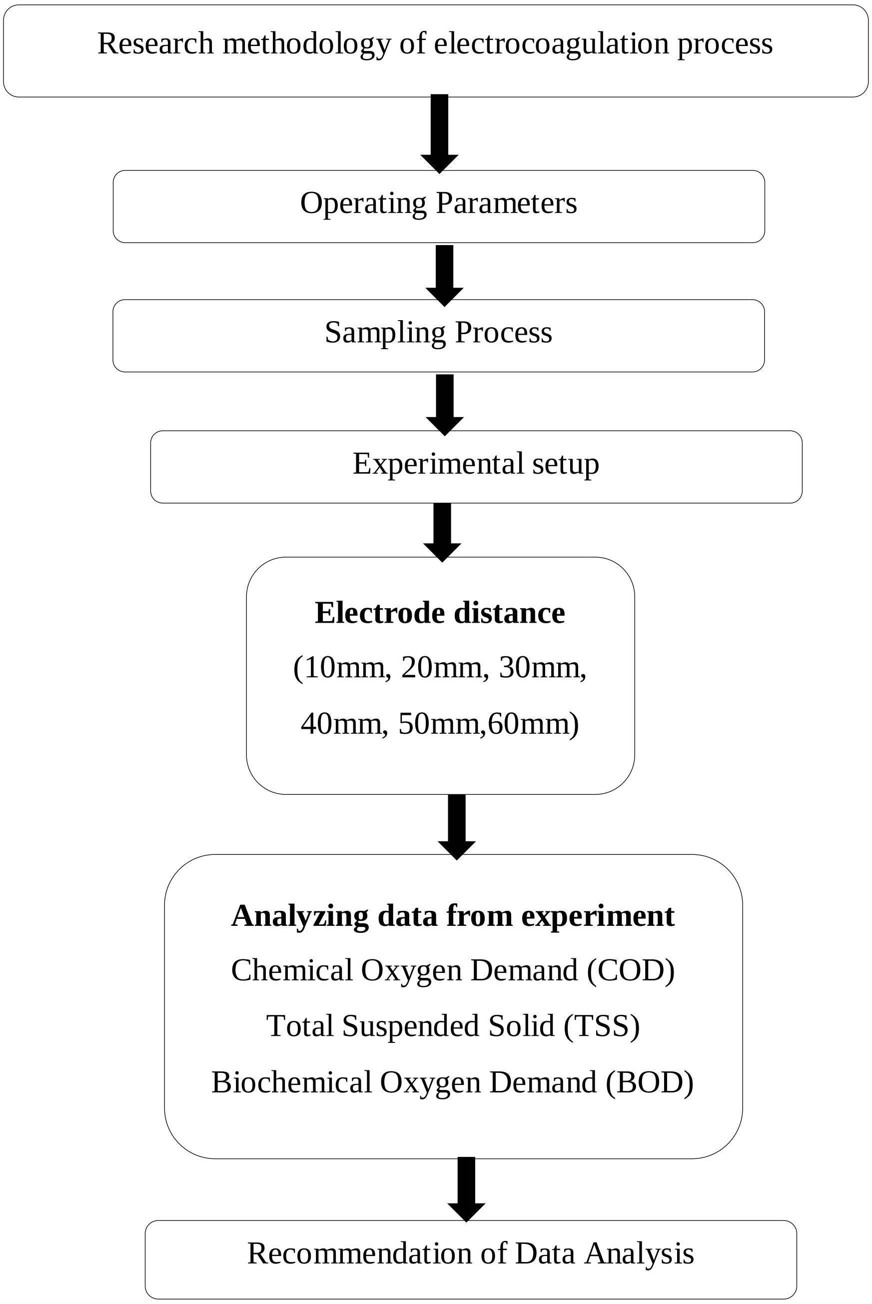

Figure 3.4: Research Methodology for Electrocoagulation Process

3.2.1 Chemicals and Instruments

The following chemicals reagents will be used in this project and will be provided by Faculty of Engineering Technology (FTeK), UMP Gambang. All the reagents that used for this project will be at analytical and laboratory grade.

Table 3.1: Chemicals and Instruments

Parameter	Instrument	Chemical	Standard Method
pH	pH meter	-	APHA 4500-H
Chemical Oxygen Demand (COD)	DR 1900 DRB 200 reactor with 13-mm wells	COD Digestion Reagent vials	HACH,2014
Suspended Solid	Filter paper	-	HACH,2014
Biochemical Oxygen Demand	-	N-Hexane, Acetone,Sodium Sulphate, Stearic Acid, Hexadecance	Standard Method 5520B

3.3 SAMPLING PROCESS

The sample of restaurant wastewater was collected from the discharge point at restaurant Gambang Damai, Kuantan, Pahang. The constituents of sample need to be maintained until the experiment was conducted. A bottle was used as storage to keep the restaurant wastewater when the process collection of solution sample. It is not possible to conduct the experiment exactly after taking the solution. Then, the sample was kept in refrigerator to keep the condition of sample is same when comes to treatment process.

3.4 DETERMINATION ON THE EFFECT OF OPERATING PARAMETER

There would be 3 factors that affect the operating parameter which is current intensity, initial pH and electrode distance. The experiment was conducted for electrode distance in different batches. If the study for determination of electrode distance was investigated, the current intensity and initial pH of wastewater were constant. After each 30 minutes treatment process, the experiment was continued for determined the BOD, COD, and TSS. It was repeated until 120 minutes or approximately two hours of treatment.

3.4.3 Determination of Electrode Distance

The electrode distance plays a significant role in the electrocoagulation as the electrostatic field depends on the distance between anode and cathode. Thus, gap between two electrodes can affect the removal efficiency of BOD, COD, and TSS. The electrode distance between anode and cathode was varied from 10mm, 20mm, 30mm, 40mm, 50mm and 60mm. Then, six set of an experiments were conducted according to each of electrode distance. The current intensity and initial pH of sample solution were constant at 5A and used pH raw respectively. The time needed to complete the experiment taken approximately 120 minutes. Then, a sample after treatment for each 30 minutes time interval was taken to test the removal of COD, BOD and TSS.

3.5 DATA ANALYSIS

3.5.1 Measurement Chemical Oxygen Demand (COD)

Apparatus use:

The apparatus that will be use is DRB200 Reactor, pipet and beaker.

Test procedure (HACH, 2014)

1. Preheat the DRB200 Reactor to 150 °C.
2. Remove the cap from a vial for the selected range. Use a clean pipet to add 2.00 mL of wastewater sample to the vial.
3. Remove the cap from a second vial for the selected range. Use a clean pipet to add 2.00 mL of deionized water to the vial.
4. Close the vials tightly.
5. Hold the vials by the cap, over a sink. Invert gently several times to mix.
6. Put the vials in the preheated DRB200 reactor. Close the lid.
7. Heat the vials for 2 hours.
8. Let the vials cool in the reactor for approximately 20 minutes to 120 °C or less.
9. Invert each vial several times while it is still warm.
10. Put the vials in a tube rack to cool to room temperature.
11. Start program 431 COD ULR, 430 COD LR or 435 COD HR.
12. Insert the blank sample into the cell holder.

13. Push ZERO. The display shows 0 or 0.0 mg/L COD.
14. Insert the prepared wastewater sample into the cell holder.
15. Push READ to show the results.

3.5.2 Measurement of Total Suspended Solids (TSS)

Apparatus use:

The apparatus that will be to conduct the testing measure is glass fiber filter, petri dish, and pipet.

Test procedure (HACH, 2014)

1. Insert glass fiber filter disk with wrinkled side up into filtration apparatus. Apply vacuum and wash disk with three successive 20-mL volumes of reagent-grade water. Continue suction to remove all traces of water. Discard washings.
2. If only total dissolved solids are to be measured, heat clean dish to 180 ± 2°C for 1 h in an oven. Then, weigh immediately before use.
3. Choose sample volume to yield between 2.5 and 200 mg dried residue.
4. Stir sample with a magnetic stirrer and pipet a measured volume onto a glass-fiber filter with applied vacuum. Wash with three successive 10-mL volumes of reagent-grade water, allowing complete drainage between washings, and continue suction for about 3 minutes after filtration is complete. Transfer total filtrate to a weighed evaporating dish.
5. Dry evaporated sample for at least 1 h in an oven at 180 ± 2°C, cool in a desiccator to balance temperature, and weigh.

Calculation:

$$\text{Total Suspended Solid (TSS)} = \frac{\text{A} - \text{B} \times 1000}{\text{sample volume, mL}} \quad (7)$$

Where:

A = weight of filter + dried residue, mg

B = weight of filter, mg

3.5.3 Measurement of Biochemical Oxygen Demand (BOD)

Test procedure (Standard Method 5520B)

1. Identify five sample volumes to use for this test.

2. Gently stir the sample.
3. Use a pipet to add the sample volumes to five 300-mL BOD bottles.
4. Fill each bottle with prepared dilution water. To prevent air bubbles, pour the water down the inner surface of the bottle.
5. Carefully insert a stopper in each bottle to prevent trapped air bubbles. Push down on the stopper. Invert the bottles several times to mix.
6. Prepare the blank: Fill another 300-mL BOD bottle with the prepared dilution water. To prevent air bubbles, pour the water down the inner surface of the bottle.
7. Use a probe to measure the dissolved oxygen concentration in each bottle.
8. Carefully insert a stopper in each of the prepared sample bottles to prevent
   trapped air bubbles. Add dilution water above the stopper of the BOD bottles to make a water seal.
9. Add a cap or wrap the head of BOD bottle with aluminum foil to prevent evaporation.
10. Keep the prepared sample bottles in an incubator at 20 °C.
11. After 5 days, measure the remaining dissolved oxygen in each of the prepared samples.

Calculate BOD_5 as follows;

$$BOD_5 mg/L = (DO_i - DO_f) \div P \quad (8)$$

DO_i = Dissolved oxygen initial

DO_f = Dissolved oxygen final

P=decimal fraction of sample use

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This project has been carried out to study the effect of operating parameters on restaurant wastewater treatment by electrocoagulation process in term of electrode distance. In this chapter, the removal percentage of electrocoagulation process was measured based on three main parameters which is COD, BOD and TSS. The sample was tested every 30 minutes for each electrode distances.

4.2 EFFECT OF ELECTRODE DISTANCE

The distance between two electrodes that being used which is anode and cathode is one of the operating parameters that give huge impact in electrocoagulation process. In general, a closer distance between electrodes is desirable, because electrical resistance increase with an electrode gap distance (Phalakornkule, Polgumhang, & Tongdaung, 2009). Therefore, a specific experiment was carried out in order to study the effect of electrode distance on restaurant wastewater by electrocoagulation process. The removal percentage of COD, BOD and TSS were compared by plotting the graph of removal percentage against time.

According to the graph in Figure 4.2, even though the trend of the removal percentage shows there were a few point shows that fluctuated, this occurred due the error during take the sample in order to complete COD, BOD and TSS test. In general, during electrocoagulation process, the wastewater divided into three partitions which is the upper part called as flocculation, the middle part called wastewater that undergoes electrocoagulation process, and the lower part called sludges.

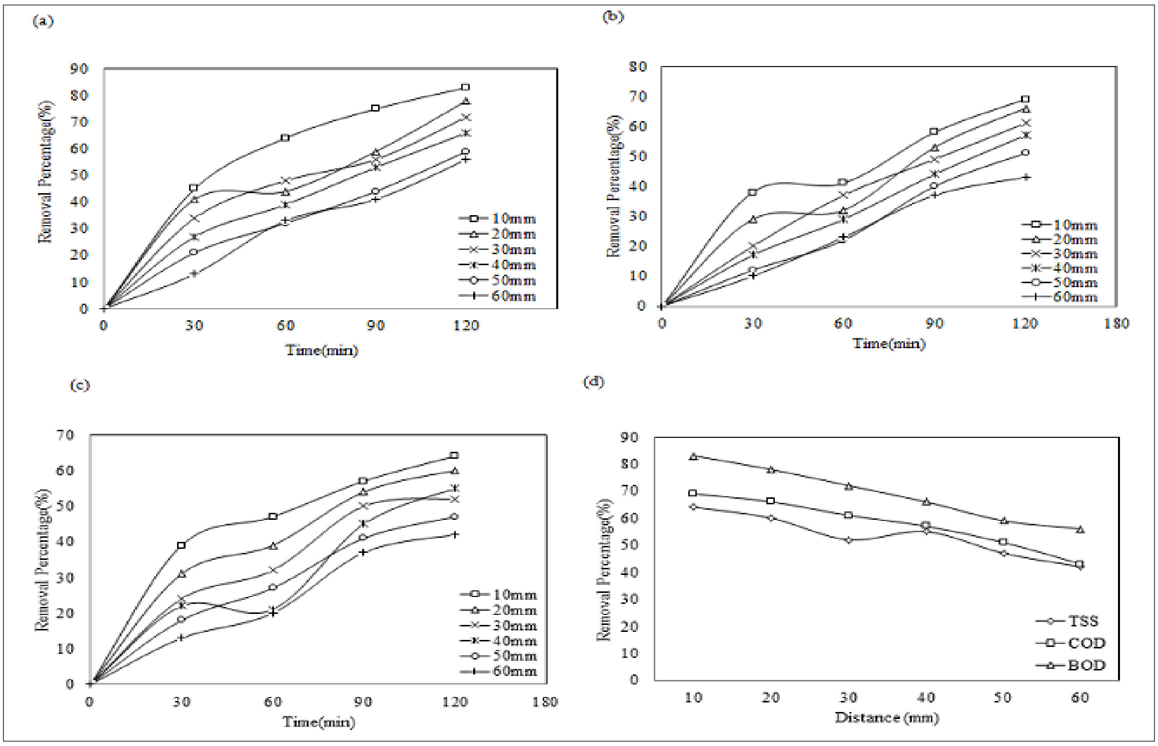

Figure 4.1: (a) Graph of BOD level, (b) Graph of COD, (c) Graph of TSS level, (d) Graph of BOD, COD and TSS level at 120 minutes.

Figure 4.2, showed the removal percentage of COD,BOD and TSS with time for 10mm, 20mm, 30mm, 40mm, 50mm, and 60mm electrode distances. From the figure, it was found that, by increasing the electrode distance, resulted in the decreased removal percentage of COD, BOD and TSS removal. The gap between anodes and cathodes of 10mm, 20mm, 30mm, 40mm, 50mm and 60mm were able to remove 83, 78, 72, 66, 59 and 56% of BOD; 69, 66, 61, 57, 51, and 43% of COD; and 64, 60, 52, 55, 47, and 42% of TSS respectively in 120 minutes. As shown in figure 4.2, (a), (b), (c) and (d), 10mm shows the best removal percentage level in COD, BOD and TSS. This occurred due to the formation of electrostatic between anode and cathodes. The decreasing of removal percentage at electrode distance more than 20mm and above was due to the weak molecule interactions with both oxidants and coagulants. The interaction of oxidants and coagulants in the process were related to the conductivity of the sample substance. As mentioned by (Daneshvar et al., 2004) , this probably occurs because the electrostatic effect depend on the interelectrode distance, so when this distance increases, the movement of produced ions would be slower and they would have more opportunity to aggregate and produce flocs. Consequently, these flocs were able to adsorb more restaurant wastewater molecules.

When the sample has been taken, may be the sample contain sludge that appear at the surface of wastewater. When this condition happen, it cause the reading of COD, BOD and TSS does not accurate and cause the result slightly different compared to theoretical. Besides, sludges that forms at the bottom of beaker actually very sensitive with any movement of sample of wastewater. During take the sample by using pipette, need to extra careful to avoid the touch the sludge.

Figure 4.2 : Formation of Floatation

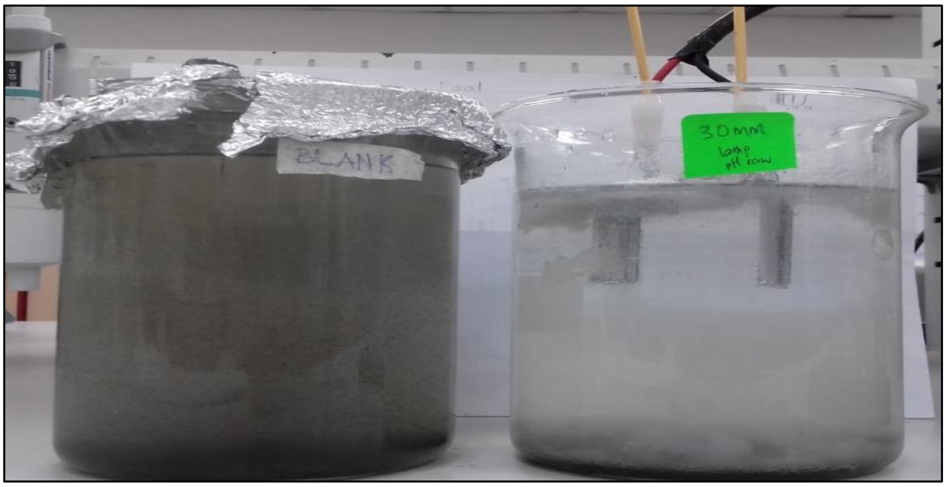

Figure 4.3 : Resturant Wastewater Before and After Treatment

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter concludes all the findings that obtain during electrocoagulation process to treat restaurant wastewater and to make sure the objective was achieved.

5.2 GENERAL CONCLUSION

Restaurant wastewater is one of the waste needs to treat in good ways. This is due to the huge number of restaurant does not pay attention towards their restaurant wastewater. Normally, small and medium restaurant owner does not care about the waste that comes from their restaurant. So, electrocoagulation process is one of the most effective ways to treat wastewater in order to avoid the drain become clog and to reduce the river pollution. The high level of COD, BOD and TSS can cause harmful to aquatic life and also give negative impact to us. By implementing electrocoagulation method, the level of COD, BOD and TSS were reduced tremendously. This is because; the end product of this treatment is clean water with obeying the environmental standard.

A set of an experiment has been successfully design by focusing on electrode distance. In order to determine the best electrode distance, six times experiment was done by using various distance of electrode. The result that obtain were plotted and observed in graph. From the graph, it can conclude that, the best electrode distance was 10mm due high ability of removal percentage. Overall, the objective was accomplished where the effect of electrode distance on restaurant wastewater treatment by electrocoagulation has been determined according to the level of COD, BOD and TSS removal percentage.

As a conclusion, electrocoagulation (EC) is an attractive alternative for the treatment of restaurant wastewater. It has high removal efficiency and provides a reliable, simple, and economical way to treat wastewater without any need for additional chemicals and subsequent secondary pollution(Song, Yao, He, Qiu, & Chen, 2008)**.**

5.3 RECOMMENDATION

Electrocoagulation process has been successfully used as a treatment of restaurant wastewater. However, future implementation should take as following direction.

1) Apply solar panel to generate electric current in order to reduce cost consumption.

2) Build a system by using Graphic User Interface (GUI) to store and save the data that obtained.

3) Apply suitable sensor at the refrigerator to stop reduce the temperature and sent reminder to user for come pick up the BOD bottle after 5 days.

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APPENDIX A

ELECTRODE DISTANCE RESULTS

Biochemical Oxygen Demand

Distance= 10mm				
Time(minutes)	DO_i (mg/L)	DO_f (mg/L)	BOD_5(mg/L)	Percentage Removal (%)
0	10.08	9.44	95.52	0
30	9.17	8.82	52.24	45
60	8.18	7.95	34.33	64
90	7.83	7.67	23.88	75
120	6.77	6.66	16.42	83

Distance= 20mm				
Time(minutes)	DO_i(mg/L)	DO_f(mg/L)	BOD_5(mg/L)	Percentage Removal (%)
0	10.08	9.44	95.52	0
30	9.65	9.27	56.72	41
60	8.86	8.5	53.73	44
90	7.77	7.51	38.81	59
120	7.01	6.87	21.01	78

Distance= 30mm				
Time(minutes)	DO_i(mg/L)	DO_f(mg/L)	BOD_5(mg/L)	Percentage Removal (%)
0	10.08	9.44	95.52	0
30	9.64	9.22	62.69	34
60	9.21	8.88	49.25	48
90	8.07	7.79	41.79	56
120	8.01	7.83	26.87	72

Distance= 40mm				
Time(minutes)	DO_i(mg/L)	DO_f(mg/L)	BOD_5(mg/L)	Percentage Removal (%)
0	10.08	9.44	95.52	0
30	9.75	9.28	70.14	27
60	9.42	9.03	58.21	39
90	8.38	8.08	44.78	53
120	8.22	8.00	32.84	66

Distance= 50mm				
Time(minutes)	DO_i(mg/L)	DO_f(mg/L)	BOD_5(mg/L)	Percentage Removal (%)
0	10.08	9.44	95.52	0
30	9.78	9.27	75.46	21
60	9.53	9.09	64.95	32
90	9.35	8.99	53.49	44
120	8.63	8.43	39.16	59

Distance= 60mm				
Time(min)	DO_i(mg/L)	DO_f(mg/L)	BOD_5(mg/L)	Percentage Removal (%)
0	10.08	9.44	95.52	0
30	9.82	9.26	83.58	13
60	9.72	9.29	64.18	33
90	9.34	8.96	56.72	41
120	8.98	8.69	42.28	56

Chemical Oxygen Demand (COD)

Distance=10mm		
Time(min)	COD(mg/L)	Percentage Removal (%)
0	237	0
30	147	38
60	140	41
90	100	58
120	73	69

Distance=20mm		
Time(min)	COD(mg/L)	Percentage Removal (%)
0	237	0
30	168	29
60	161	32
90	111	53
120	81	66

Distance=30mm		
Time(min)	COD(mg/L)	Percentage Removal (%)
0	237	0
30	190	20
60	149	37
90	121	49
120	92	61

Distance=40mm		
Time(min)	COD(mg/L)	Percentage Removal (%)
0	237	0
30	197	17
60	168	29
90	133	44
120	102	57

Distance=50mm		
Time(min)	COD(mg/L)	Percentage Removal (%)
0	237	0
30	209	12
60	185	22
90	142	40
120	116	51

Distance=60mm		
Time(min)	COD(mg/L)	Percentage Removal (%)
0	237	0
30	213	10
60	182	23
90	149	37
120	135	43

Total Suspended Solid (TSS)

Distance=10mm				
Time(min)	Weight of filter(mg)	Weight of filter +dried residue (mg)	Removal residue (mg/L)	Removal Percentage (%)
0	108.2	113.10	98.0	0
30	107.9	110.89	59.8	39
60	108.5	111.09	51.8	47
90	107.2	109.31	42.2	57
120	107.8	109.56	35.2	64

Distance=20mm				
Time (min)	Weight of filter(mg)	Weight of filter +dried residue (mg)	Removal residue (mg/L)	Removal Percentage (%)
0	108.2	113.1	98	0
30	107.8	111.18	67.6	31
60	108.2	111.19	59.8	39
90	107.5	109.75	45	54
120	107.8	109.76	39.2	60

Distance=30mm				
Time (min)	Weight of filter(mg)	Weight of filter +dried residue (mg)	Removal residue (mg/L)	Removal Percentage (%)
0	108.2	113.1	98.0	0
30	107.9	111.62	74.4	24
60	107.5	110.83	66.6	32
90	108.2	110.65	49.0	50
120	107.8	110.15	47.0	52

Distance=40mm				
Time (min)	Weight of filter(mg)	Weight of filter +dried residue (mg)	Removal residue (mg/L)	Removal Percentage (%)
0	108.2	113.1	98	0
30	107.9	111.72	76.4	22
60	108.5	112.37	77.4	21
90	107.2	109.9	54	45
120	107.8	110.01	44.2	55

Distance= 50mm				
Time (min)	Weight of filter(mg)	Weight of filter +dried residue (mg)	Removal residue (mg/L)	Removal Percentage (%)
0	108.2	113.1	98	0
30	107.3	111.32	80.4	18
60	107.5	111.08	71.6	27
90	108.4	111.29	57.8	41
120	106.8	109.4	52	47

Distance=60mm				
Time(min)	Weight of filter(mg)	Weight of filter +dried residue (mg)	Removal residue (mg/L)	Removal Percentage(%)
0	108.2	113.1	98	0
30	106.4	110.66	85.2	13
60	107.5	111.42	78.4	20
90	108.9	111.99	61.8	37
120	108.4	111.24	56.8	42

Time(min)	TSS Removal Percentage (%)					
	10mm	20mm	30mm	40mm	50mm	60mm
0	0	0	0	0	0	0
30	39	31	24	22	18	13
60	47	39	32	21	27	20
90	57	54	50	45	41	37
120	64	60	52	55	47	42

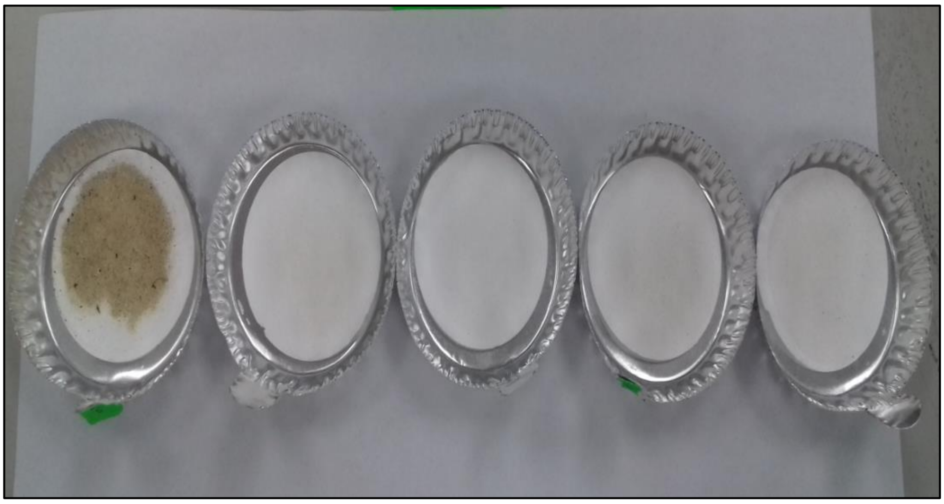
Time(min)	BOD Removal Percentage (%)					
	10mm	20mm	30mm	40mm	50mm	60mm
0	0	0	0	0	0	0
30	45	41	34	27	21	13
60	64	44	48	39	32	33
90	75	59	56	53	44	41
120	83	78	72	66	59	56

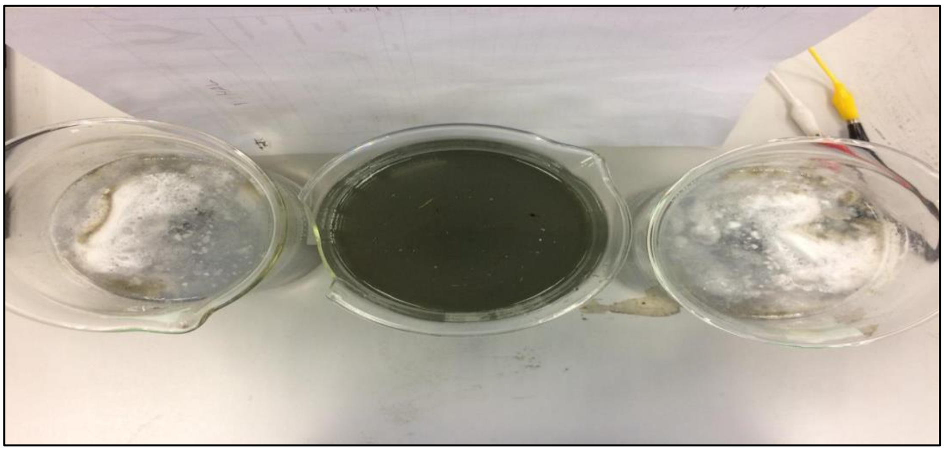
Time(min)	COD Removal Percentage (%)					
	10mm	20mm	30mm	40mm	50mm	60mm
0	0	0	0	0	0	0
30	38	29	20	17	12	10
60	41	32	37	29	22	23
90	58	53	49	44	40	37
120	69	66	61	57	51	43

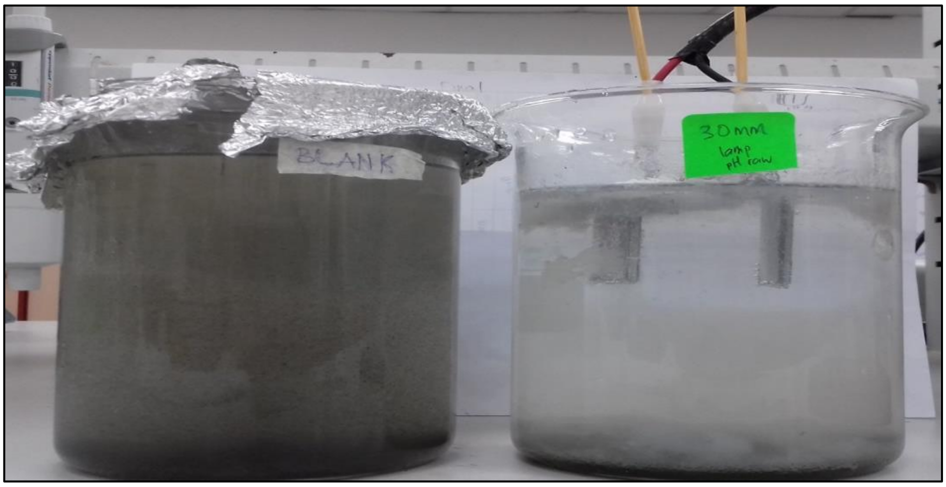
Distance (mm)	Removal Percentage at 120 minutes (%)		
10	COD	BOD	TSS
20	69	83	64
30	66	78	60
40	61	72	52
50	57	66	55
60	51	59	47

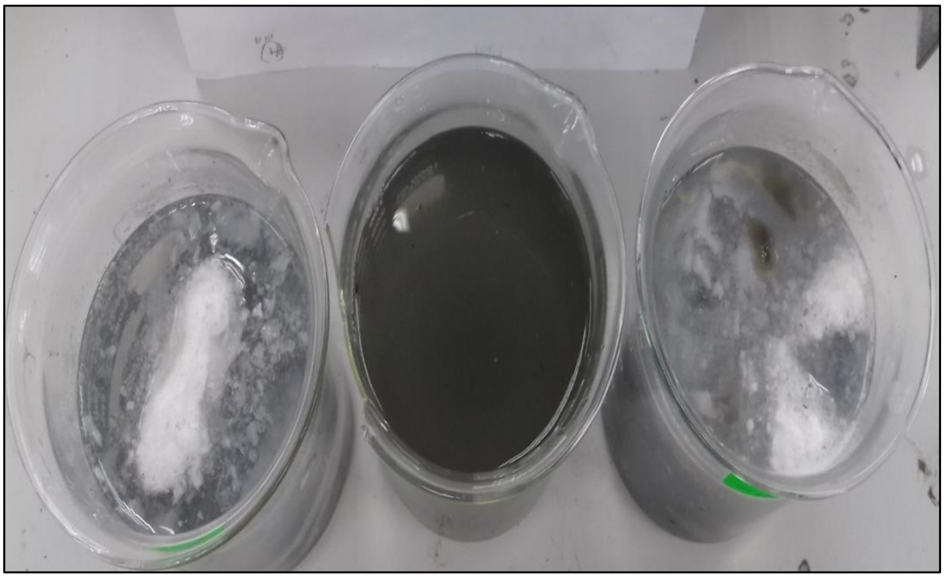
APPENDIX B

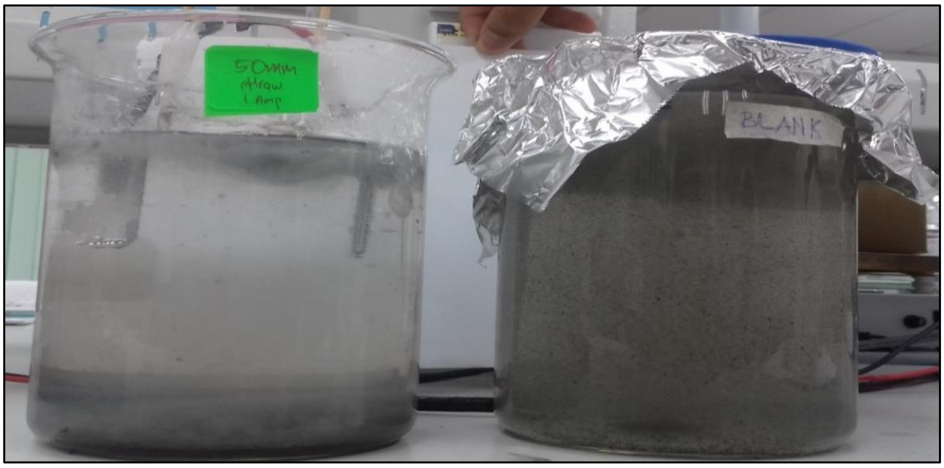
RESULT AFTER TREATMENT PROCESS






BLANK
30mm
lamp
pH raw




50mm
pH raw
Lamp
BLANK