REMOVAL OF FATS, OILS, AND GREASE FROM FOOD AND BEVERAGES WASTEWATER BY USING SONO-ELECTROCOAGULATION TECHNIQUE

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ELECTROCOAGULATION TECHNIQUE

by

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ABSTRAK

Air sisa segar sisa pepejal perbandaran, ialah satu bentuk air sisa organik berkekuatan tinggi, jadi selalunya berkemungkinan membawa kepada bioaktiviti mikroorganisma yang cepat dan besar. Air sisa segar biasanya diklasifikasikan sebagai air sisa yang berbahaya dan sangat tercemar. Oleh itu, penyelidikan ini disasarkan untuk menyiasat rawatan air sisa segar daripada Sisa Pepejal Perbandaran melalui proses Sono-Electrocoagulation dengan dua aplikasi elektrod besi untuk memaksimumkan penyingkiran COD dan minyak dan gris. Pengaruh suhu (30 °C ,40 °C dan 50 °C), pH (7.0–9.0), dan tempoh bekerja (0–60 min) ke atas rawatan air sisa telah dikaji untuk mencapai kecekapan rawatan yang optimum. Kecekapan penyingkiran maksimum minyak dan gris dan permintaan oksigen kimia (COD) di bawah pengaruh suhu diperolehi sebagai 87% dan 92%, masing-masing, pada pH 6 (pH awal), suhu 50 °C, dan masa tindak balas 30 minit . Di bawah kawalan pH, kecekapan penyingkiran maksimum minyak dan gris dan permintaan oksigen kimia (COD) telah dicapai masing-masing sebanyak 96% dan 83%, pada pH 7, suhu 30 °C (keadaan awal), dan tempoh tindak balas 30 minit. Terdapat penurunan dalam peratusan penyingkiran parameter selepas mencapai parameter optimum. Ini mungkin berkaitan dengan saiz-saiz zarah menjadi lebih ketara dengan peningkatan masa tindak balas. Oleh itu, tahap tenaga zarah meningkat, dan kadar penggumpalan zarah menurun. "Sono-electrocoagulation" telah terbukti berkesan dalam rawatan air sisa segar dan pendekatan mesra alam untuk penyingkiran bahan pencemar menyeluruh.

ABSTRACT

Fresh wastewater of municipal solid waste (MSW), is a form of high-strength organic wastewater, so often likely lead to quick and huge bioactivity of microorganisms. Fresh wastewater (FW) typically classified as a dangerous and extremely contaminated wastewater. Thus, this research targeted to investigate treatment of fresh wastewater from Municipal Solid Waste by Sono-Electrocoagulation process with dual application of Iron and Iron electrodes for maximize the removal of COD and oil and grease. The influence of temperature (30 °C ,40 °C and 50 °C), pH (7.0–9.0), and working period (0–60 min) on the treatment of wastewater were studied to achieve optimal treatment efficiency. The maximum removal efficiencies of oil and grease and chemical oxygen demand (COD) under influenced of temperature were obtained as 87% and 92%, respectively, at the pH 6 (initial pH),temperature 50 °C, and reaction time of 30 min . Under controlled by pH maximum removal efficiencies of oil and grease and chemical oxygen demand (COD) were achieved as 96 % and 83 % , respectively, at the pH 7,temperature 30 °C (initial condition), and reaction duration of 30 min. There were decline in the percentage removals of the parameters after achieving an optimum parameters. This is may relate to the particle size size becones more significant with increasing reaction time. Hence, the particles' energy level rises, and the coagulation rate of the particles lowers. Sono-electrocoagulation is proven to be effective in fresh wastewater treatment and environmental friendly approach for total pollutant removal.

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LIST OF ABBREVIATIONS

FOG	Fats,Oil and Grease
FS	Food Service Enterprise
SSWOs	Sewage Sewer Overflows
IWK	Indah Water Konsortium
EC	Electrocoagualtion
SEC	Sono- Electrocoagualtion
COD	Chemical Oxygen Demand
FFA	Free Fatty Acid
TAGs	Triacylglycerol
GTs	Grease Traps
MSW	Municipal Solid Waste
USM	Universiti Sains Malaysia
DO	Dissolved Oxygen
BOD	Biochemical Oxygen Demand
TSS	Total Suspended Solids
MEQA	Malaysia environment Quality Acts

CHAPTER 1

INTRODUCTION

1.1 Background

Water is very necessary for the continued existence of life on our planet. In living things, it plays the role of a medium for all of the metabolic events that take place. It has applications in agricultural, manufacturing, and domestic settings. It is also widely used in several industrial applications. There is a substantial volume of wastewater that is discharged by industries. As a consequence of inadequate wastewater treatment, contaminants are being discharged into natural water resources at an alarming rate. As a direct consequence of this, the pollution of water sources has developed into a critical issue on a global scale. Industrialisations resulted in the discharge of many contaminants into groundwater resources. These contaminants include organic and inorganic chemicals, heavy metals, pesticides, surfactants, oils, and paints. In addition, industrialization as resulted in the consumption of vast quantities of water (Daud et al., 2018). The very high toxicity of these substances presents a significant risk to human health and the environments in which other species live (Dragoi et al., 2020). FOG (fat, oil, and grease) is a major environmental issue.

The most prevalent places where FOG may be found are in food service enterprise (FSE) and other facilities used for food preparation (Aziz et al., 2010). FOG may take the form of either a solid or a liquid with a high degree of viscosity, depending on the saturation of the carbon chain. Fatty acids, triacylglycerol, and lipid-soluble hydrocarbons are the building blocks of oils and fats, which are a form of lipid. Fatty acids, triacylglycerol, and lipid-soluble hydrocarbons are all small but substantial components of FOG. When these wastes are discharged directly into the plumbing system of the facility, they have the potential to produce FOG build-up in the sewer system, which can lead to an increase in the amount of blockage that occurs in a town's sewer system as a result of FOG deposition (Garza et al., 2004). In addition, FOG is to blame for as much as 70 % of all sanitary sewer overflows (SSOs) in Malaysia. According to reearch, the quantities of FOG that were found in the wastewater of Asian restaurants in Thailand varied from 730 to 1100 mg/L. The wastewater from fast-food restaurants is the primary contributor to this significant quantity of FOG. These restaurants' menus predominantly include of items that are high in FOG, such as fried chicken, seafood, French fries, and salad dressings. In 2010, a total of 22,184 questions about blockages were sent to the Indah Water Konsortium (IWK), which is Malaysia's wastewater municipality.

1.2 Problem Statement

The treatments available for conventional waste water may be categorized into the following three groups: (a) leachate transfer: recycling and combined operation with domestic sewerage; (b) biodegradation: anaerobic and aerobic processes; (c) physical and chemical procedures: chemical oxidation, Fenton oxidative treatment, adsorption, chemical precipitation, coagulation/flocculation, air stripping, flotation/sedimentation, and membrane processes. The production of hydroxyl radicals and their subsequent use are the fundamental aspects of AOPs. Hydroxyl radicals are notoriously volatile and reactive substances due to the high oxidation potential of this kind of radical.

In recent years, it has become apparent that electrochemical catalytic oxidation provides a variety of benefits to its users. Electrocoagulation (EC) is a well-known electrochemical catalytic oxidation process. It involves a complex mix of chemical and physical treatment processes, such as oxidation, coagulation, flocculation, precipitation, sedimentation, flotation, and air stripping. In addition, electrocoagulation (EC) is referred to as an electrochemical oxidation process. The use of the EC method comes with a number of benefits, some of which are listed below: the absence of external chemical reagents; the absence of secondary pollutants; the method's simplicity, reliability, non-selectivity, and minimal sludge formation; the method's applicability; and the method's cost-effectiveness. Nevertheless, there is a dearth of research into the electrocoagulation (EC) process.

Researchers are working to find ways to combine different strategies and processes in order to improve the effectiveness of therapy while also reducing the costs of administration. Sonication is one of the processes whose application is being considered in conjunction with the application of other procedures. During the sonication process, the energy of sound is used to excite particles present in samples for a number of different objectives. Within a medium, isolated high-energy microenvironments may be created by ultrasound due to the frequency of the sound. To enhance the system, it is integrated with an electrochemical process. Within the scope of this research, an investigation into the impact that temperature and pH have on the efficiency of the sono-electrocoagulation process for treating waste water will be carried out. In sono-electrocoagulation processes, temperature and pH play a significant role as two of the most relevant parameters. Fluctuations in temperature have a variety of effects on the elimination of contaminants; as a result, it has been a topic of study for a very long time. Additionally, the significance of the role of pH on the energy consumption factors and the optimal space-time limit in the system cannot be overstated.

1.3 Objectives

The purpose of this study is to analyze the treatment performance of wastewater by using the sono-electrocoagulation (SEC) technology. More specifically, these are the targets of this research project:

1. To investigate the effect that temperature and pH have on the amount of material that can be extracted from wastewater.
2. Evaluate the effiency the sono-electrocoagulation method removes fatty acids, oils, and grease from wastewater, and assess the method's effectiveness.

1.4 Scope of the Study

Two separate samples of wastewater were collected from the Lembaran Café on the Engineering Campus of the Universiti Sains Malaysia. After that, we proceeded to describe them. In order to carry out sono-electrocoagulation, it was necessary to have a reactor system that was composed of the same series of aluminum electrodes serving as both the anode and the cathode. Beaker of 1 liter capacity, crocodile clip, DC power supply, ultrasonic device and probe, and magnetic mixer. The effectiveness of the process, as well as the removal of fats, oils, and grease, was evaluated using a batch study. COD and Oil & Grease were the two wastewater metrics that were examined.

1.5 Dissertation Outline

The thesis is categorized into five chapters, namely introduction, literature review, methodology, results and discussion and conclusion and recommendations.

Chapter 1: Introduction- This chapter explains the research project and gives an overview of what is being achieved. It reviews the background of treating wastewater, the study's problem statements, the objectives, and the expected outcome.

Chapter 2: Literature Review- With references to previously published research articles, this chapter provides a full description of technical terms, findings, subjects, and outcomes linked to the research. It can provide researchers with some suggestions and instructions to help them better comprehend the topic and conduct their research.

Chapter 3: Methodology- This chapter mainly focuses through the methodology for obtaining the desired outcomes as well as ways to meet the program objectives in detail. The specific equipment, techniques, or materials employed in this study are specified fully.

Chapter 4: Results and Discussions- This chapter summarizes all of the research's findings and outcomes. Data analysis, whether quantitative or qualitative, is used to condense a large amount of data in order to answer research questions, test theories, evaluate issues, and investigate hypotheses. In this chapter, the findings will be analysed and discussed in order to answer the study questions. The findings are likely to be similar to those of prior studies conducted in a similar situation. However, because the studies use different methodologies and data to arrive at their conclusions, some differences are to be expected.

Chapter 5: Conclusion and Recommendations- This chapter summarises all of the research's results and findings. All objectives and expected outcomes will be addressed, as well as the research question. Recommendations for action are made based on the findings and relevant literature, with the limits of both taken into account.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Fats, Oils and Grease

The environmental problem known as FOG (fat, oil, and grease) seems to get worse. The majority of food-borne illness outbreaks are traced back to food service enterprises (FSE) or other facilities that prepare food. Some of the by-products and wastes produced by this FSE include meat, sauces, gravy, dressings, deep-fried meals, baked goods, cheeses, and butter. Other examples include: All of these pollutants are referred to as FOG and have the potential to produce FOG build-up in the facility's sewage systems when they are discharged directly into the plumbing system of the facility (Iman, 2014).The capacity of the sewage system is decreased when FOG solidifies and deposits on the inside walls of the sewer, since this causes pipes to get clogged and limits the amount of wastewater that can be discharged. It is certain that clogged sewers caused by FOG will collapse, which would result in sewage overflowing from manholes and contaminating state water sources. Flooding and clogged sewers may be the source of further environmental problems, which can affect the surrounding area as well as the premises itself (Aziz, 2010). Surrogates are frequently selected for choosing, planning, and validating performance due to the expense and difficulty of suspended and emulsified FOG measurement nowadays. Since diesel oil has a far lower specific gravity than ordinary FOG and is frequently used as a substitute in validation testing for passive gravity separators, its relevance is questioned (Jefferson, 2018). The sewage pipe both before and after the deposition of FOG is seen in Figure 2.1.

Figure 2.1 The sewer pipe before and after deposition of FOG. (Indah Water Konsortium, 2010)

2.1.1 Definition of Fats, Oils and Grease

The terms FOG stands for "fat, oil, and grease," and it refers to a heterogeneous group of chemicals that include tri-, di-, and mono-glycerides, sterols, non-volatile hydrocarbons, waxes, and other complex lipids that can exist in a combination of free and emulsified forms. FOG also refers to a variety of different materials, both liquid and solid, that can be found in both liquid and solid states (Gurd, 2018) .The by-products of cooking are known as fats, oils, and grease (FOG), which are frequently referred to as brown grease. Food scraps, beef fats, lard, tallow, cooking oil, butter, margarine, sauces, gravy, dressings, deep-fried foods, baked goods, cheeses, and butter are some of the typical components that make up FOG. Depending on the saturation of the carbon chain, FOG has the potential to either take the form of a solid or even a viscous liquid. There is a subclass of lipids known as oils and fats. Lipids are made up of fatty acids, triacylglycerol, and lipid-soluble hydrocarbons, all of which are necessary but relatively insignificant components of FOG (Voet et al.,2012).

2.1.2 Chemical Composition of Fats, Oils and Grease

- **Free fatty acids (FFAs)**

Free fatty acids (FFA) are hydrolysis products of triglycerides (TG) in vegetable oils. They mostly arise in edible oils throughout the processes of making and storing the oil as well as, more generally, during the handling of the raw material. Additional sources of FFA include lipid deterioration mechanisms (Maria, 2020). Carboxylic acids that have a long-chain hydrocarbon substituent are known as FFAs. The esterified form of FFAs is the most common form found, since they are the primary constituents of lipids. However, only around 20 of these naturally occurring fatty acids are widely used in the food science industry, making the total number of natural fatty acids somewhere around 1000. The majority of normal FFAs are linear chains that range in length from 8 to 22 carbon atoms and typically include one or more unsaturated centers, often known as double bonds. Because of the chemical reactivity, FFAs are especially important components of FOG. Additionally, Waste oil may be loosely categorized into two groups based on its FFA content: yellow grease, which has less than 15% FFA, and brown grease, which has more than 15% FFAs (Mićić et al., 2019).

- **Triacylglycerol**

The majority of fatty acids are found in the form of glycerol esters known as triacylglycerol (TAGs) (sometimes termed triglycerides) TAGs are molecules that are regarded to be a kind of abundant lipids. They are non-polar and insoluble in water. Glycerol is characterized by the presence of three carbon atoms, all of which are attached to hydroxyl groups ($HOCH_2CH$ (OH) CH_2OH). The composition of fatty acids in fats and oils is very variable, depending on the organism that produced them. Fats and oils are complicated mixtures of triacylglycerol. The lower melting temperatures of plant oils reveal that plant oils typically have a larger concentration of unsaturated fatty acid residues than animal fats do. This is the case even though animal fats have higher melting temperatures. Therefore, oils often take the form of liquids, while animal fat is typically solid when it is at room temperature (Gunstone, 2004). Animal fatty acids include hydrogen atoms saturated on the carbon atoms. The molecules will pack neatly into a solid structure as a result, allowing them to lie straight. In plants, kinks in the fatty acids are brought on by missing hydrogen atoms. This maintains the molecules liquid at ambient temperature and limits the amount of possible intermolecular bonding.

- **Ester waxes**

Wax is composed of a wide variety of medium- and long-chain compounds, some of which are as follows: hydrocarbons (TCH_3), alcohols (RCH_2OH), aldehydes (RCHO), acids (RCOOH), and esters (RCOOR'). Waxes come from a variety of natural sources, including plants and animals (Madan, 2013). The wax esters are mostly saturated and monoenoic alcohols, frequently with the 18:1 fatty alcohol as the predominant constituent, after being esterified to the regular spectrum of saturated, monoenoic, and polyunsaturated fatty acids found in fish (William, 2020)

- **Phospholipids**

Phospholipids ability to be amphiphilic confers upon them a number of unique properties, including those that give them importance in the food, cosmetics, and pharmaceutical industries. Major membrane lipids called phospholipids are made up of lipid bilayers. In addition to serving as a barrier to defend the cell from many environmental irritants, this fundamental cellular structure also makes it possible for several cellular functions to take place in subcellular compartments (Dai et al., 2021). Even though phospholipids are removed during the refining process of oil, they are still present in vegetable oils in very trace levels, and as a result, they will be found in the FOG mixture (Solomons, 2013).

- **Sterols and sterol esters**

Sterols, which include cholesterol, are not lipids; nonetheless, you may find them in a variety of oils and fats, and they have some of the same physical characteristics as lipids. Processes involving oxidation have the potential to transform sterols into long-chain fatty acids. The majority of crude oils include concentrations of phytosterol ranging from 0.1 to 2.2 %. Phytosterol may be found in two different forms: free sterols and sterols esterified with FFAs. The proportion of esterified sterols to free sterols might vary, although in most cases, free sterols make up the majority (40–80 %) (Patrick, 2012). In general, they are minor components relative to the free sterols other than in leaf surface waxes. Although stigma sterol may be present in comparatively smaller amounts, the sterol constituents of sterol esters are typically similar to those of free sterols (Bill, 2019).

2.1.3 Physical Properties of Fats, Oils and Grease

FOG is a slick material that may take the shape of either a liquid or a solid at different times. In its purest form, FOG lacks color, odor, and taste. It also has no discernible smell. In addition to this, FOG is insoluble in water but soluble in organic solvents such as hexane, chloroform, and ether (Sincero et al., 2003). Since FOG is less dense than water (having a specific gravity greater than 1), it is able to float on the surface of the water. When soap or other emulsifying agents are present, FOG will create emulsions with aqueous media and get suspended in them (Madan, 2013). The percentage of fatty acids present in FOG as well as the number of double bonds both have an effect on the substance's viscosity. The viscosity of FOG is reduced whenthere are more double bonds in the carbon chain than there are single bonds because the more double bonds there are, the more loosely packed the structure is (Firestone, 2006).

2.2 Sources of Fats, Oils and Grease in the sewer system

The three most prevalent places where FOG may be found are in residences, slaughterhouses, and facilities that serve food. Either by direct dumping or through the escape of grease from grease traps (GTs), which are often placed in commercial kitchens like restaurants, FOG components make their way into the sewage system. The GTs (interceptors), which are located before the sewage system, are intended to collect the vast majority of the FOG that is present in the restaurant's effluent and keep it separate from the sewage (Aziz et al., 2011). On the other hand, the frequency with which the GT is maintained is a significant factor in the efficiency of the vehicle (Wong et al., 2007). In addition, if the dishes are washed in a dishwasher or with water that is heated to a high temperature, the FOG may melt and emulsify in the wastewater phase, which would enable it to bypass the GT. As a consequence of FOG's subsequent entry into the sewage pipe, the flow of wastewater may be impeded because the FOG may eventually solidify and form particles on the surface of the sewer pipe (Keener et al., 2008).

2.3 Effects of Fats, Oils and Grease

FOG may cause sanitary sewer overflows by adhering to the inside surfaces of drain and sewer pipes, which causes the pipes to become clogged and restricts the flow of sewage (SSOs). SSOs cause nasty aromas as well as infestations of insects and rats. Additionally, sewage has the potential to find its way into water sources, contaminating both soil and water. They are very upsetting, and local governments have a responsibility to move swiftly in order to remove the deposition as soon as possible in order to calm public anxiety. In addition, when anaerobic conditions are present, FOG deposition has the potential to induce corrosion in sewage line pipes, which shortens the pipes lifespan and makes early maintenance and replacement necessary.

2.4 Treatment of Fats, Oils and Grease

Industrialization has resulted in the release of various pollutants into groundwater resources, including organic and inorganic compounds, heavy metals, pesticides, surfactants, oils, and paints. This is in addition to the massive volumes of water that are used in the process of industrialization (Vasseghian et al., 2020). The very high toxicity of these substances poses a significant risk to both human health and the habitats in which other species live (Hassani et al., 2018). Because of the growing number of people living in the world and the limited availability of clean water sources, wastewater treatment has assumed a degree of significance that is necessary for its reuse (Kobya et al., 2020). In addition, because of the large potential for contamination, it is necessary to develop solutions that are both effective and efficient in the treatment of wastewater from industrial sources (Khataee et al., 2018).

In Countries that are experiencing drought have a far greater need for effective pollution control, water treatment, and recycling programs (Moradi et al., 2016). Fresh wastewater, which is collected from municipal solid trash in waste collection trucks and is a strong organic wastewater, has the potential to result in rapid and significant bioactivity of microorganisms as well as other important chemical contaminants. The term "fresh wastewater" refers to the robust wastewater that results from the treatment of municipal solid waste (MSW). This kind of wastewater is known to have significant concentrations of ammonia-nitrogen, heavy metals, organic debris, and/or inorganic salts. As a consequence of this, its severe degradation may arise from its direct discharge into the receiving water and soil (Biglari et al., 2016). Microorganisms may be responsible for the degradation of some pollutants; however, due to the limitations of common biological processes (degradation accounts for only a small percentage of COD, and bio-refractory organic pollutants are only partially eliminated), complying with related discharge requirements has become increasingly difficult (Ghasimi, 2008).

In recent years, it has come to light that electrochemical catalytic oxidation provides a selection of beneficial outcomes (Biglari et al., 2017). Electrocoagulation (EC) is a well-known electrochemical catalytic oxidation process. It involves a complex mix of chemical and physical treatment processes, such as oxidation, coagulation, flocculation, precipitation, sedimentation, flotation, and air stripping. In addition, electrocoagulation (EC) is referred to as an electrochemical oxidation process. It would indicate that EC has a role in the decomposition of organic pollutants found in wastewater. It has been revealed that hydroxyl radicals play an important role in the process of electrochemical catalytic oxidation. The use of the EC technique comes with a variety of benefits, some of which are listed below: the lack of external chemical reagents; the absence of secondary pollutants; the simplicity, dependability, non-selectivity, and little sludge formation; its application and cost-effectiveness; and so on (Yang et al., 2014).

Researchers are striving to combine a variety of approaches and processes in order to improve the effectiveness of therapy while also reducing the amount of money spent on administration (Steter et al., 2014). Sonication is one of the methods that may be used in conjunction with a variety of other procedures (Weng et al., 2013).

During the sonication process, the energy of sound is used to excite particles present in samples for a number of different objectives. Within a medium, isolated high-energy microenvironments may be created by ultrasound due to the frequency of the sound. In order to improve the system, an electrochemical process has been included into it (Lakshmi et al., 2013). It is also capable of producing radicals, which can boost the efficacy of electrocoagulation or coagulation processes by chemically cleaning the surface of the flocs. It is possible that it will make a significant contribution to electrocoagulation operations by improving flocculation through vigorous mixing (Raschitor et al., 2014). Cavitation and improvements in mass transfer are the two factors that contribute to the effectiveness of ultrasonic irradiation. The process of hydrodynamic cavitation involves the formation of microbubbles, their production, and their abrupt bursting, all of which take place simultaneously. Aqueous solutions benefit from these gas bubbles' ability to speed up the thermal dissociation of water molecules into H+ and OH-. The presence of this powerful oxidant is what causes the challenging oxidation conditions (Souza et al., 2015).

Sono-electrocoagulation was studied by (He et al., 2016) in a double reactor with aluminum electrodes. After 60 minutes of electrolysis at a current density of 18 mA/cm^2 and the removal of RB19 for the whole hour. Sono-electrochemical oxidation was investigated by (Tran et al., 2015) for the purpose of removing ibuprofen from municipal wastewater. The researchers discovered that by employing 40 W of ultrasound power and a treatment duration of 120 minutes, they were successful in removing 77 % of the substance. The sono-electrochemical treatment of fresh leachate from municipal solid waste was explored in this work. The treatment was carried out using a novel type of pair electrodes that applied iron, and it was carried out while the pH and temperature were being controlled.

2.5 Sono-electrocoagulation process

Electrocoagulation provides a variety of features that conventional treatment techniques do not, including a low rate of sludge formation, an efficient functioning, simple equipment, cheap capital and operating expenditures, and a low expense overall (Dizge et al., 2018). In spite of the fact that it is effective at removing pollutants, the EC approach has a number of serious limitations, one of which is the formation of a passivation film at the surface of the electrode, which both raises the amount of energy required and decreases how well it removes pollutants (Afsharnia et al., 2018). The most significant drawback associated with electrocoagulation was the relatively ineffective removal of contaminants, which was caused by the accumulation of silt on the surface of the electrode.

In addition, the use of ultrasound as a technique for preventing the passive coating deposition on the electrode surface is a viable option. Ultrasound is used in this technique, which increases the production of radicals. As a direct consequence of this, a quicker response rate and the degradation of pollutants are both feasible (Rad et al., 2020). In addition to this, ultrasonic waves may be irritating to a material's particle size, solubilization, creation of refractory compounds, and structural makeup of organic substances (Nasseri et al., 2006). As a consequence of this, improving electrode performance by a combination of EC and US is possible. The ultrasonic method was at one time researched for the destruction of a variety of compounds; however, the ultrasonic technique was shown to be ineffective in treating wastewater. The process of sono-electrocoagulation is based on the dissolution of positively charged metal ions from the surface of the electrode. These positive charges, which come from the reduction of repulsive interactions between the particles, attract particles that have the opposite charge, which results in the formation of flocculants. The neutrally charged flocculants may be extracted from the solution by the processes of flotation or sedimentation. The reactions that take place at the surface of the cathode electrode are accompanied by the production of hydroxyl radicals and hydrogen gas. (The Equations (2.1) and (2.2)) The sono-electrocoagulation process is shown in a schematic flow diagram which may be seen in Figure 2.2 (Moussa et al., 2017).

$$M^{n+}(aq) + nOH^{-}(aq) \rightarrow M(OH)_n(s) \tag{2.1}$$

$$2H_2O + 2e^{-} \rightarrow 2OH^{-} + H_2 + 2H^{+} + 2e^{-} \rightarrow H_2 \tag{2.2}$$

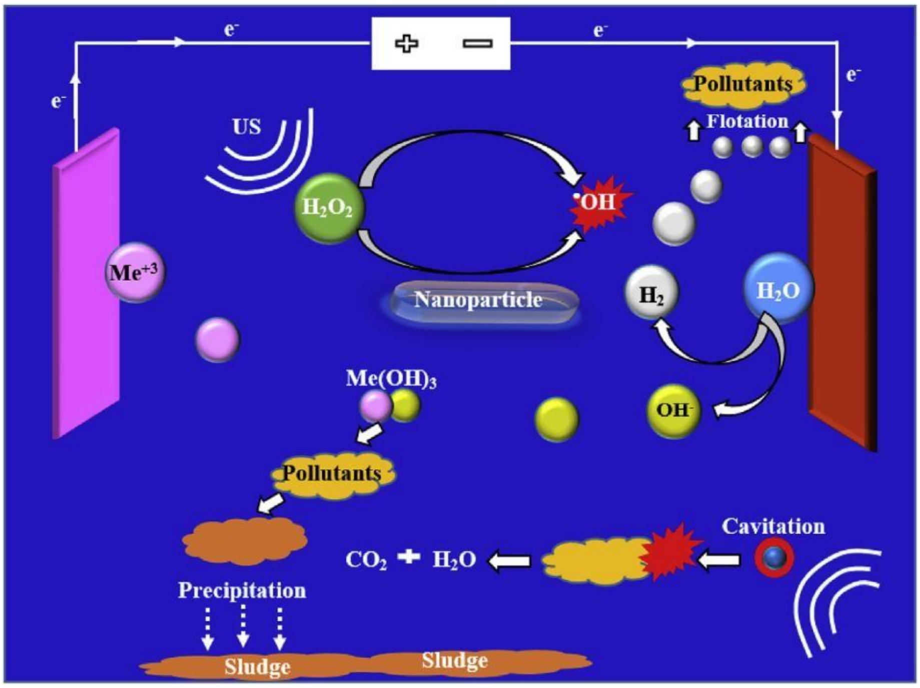

Figure 2.2 Schematic flow diagram of the sono-electrocoagulation process (An et al., 2017)

In the last several years, sono-electrocoagulation has seen a lot of research due to the stringent restrictions that have been put in place for recycling wastewater in water and wastewater treatment. In addition, research was conducted to determine the efficacy of a sono-electrocoagulation system in the elimination of pollutants for the purpose of this activity.

CHAPTER 3

METHODOLOGY

3.1 Flow Chart (Methodology)

Figure 3.1 presents the flow chart of the methodological procedures that were used for the project. The flow chart presented a representation of the classification of waste water in its many forms. It showed the characterization parameters that were associated with the samples. After that, the samples were evaluated using batch studies, and the findings from those evaluations were correlated with the experimental data obtained from batch studies.

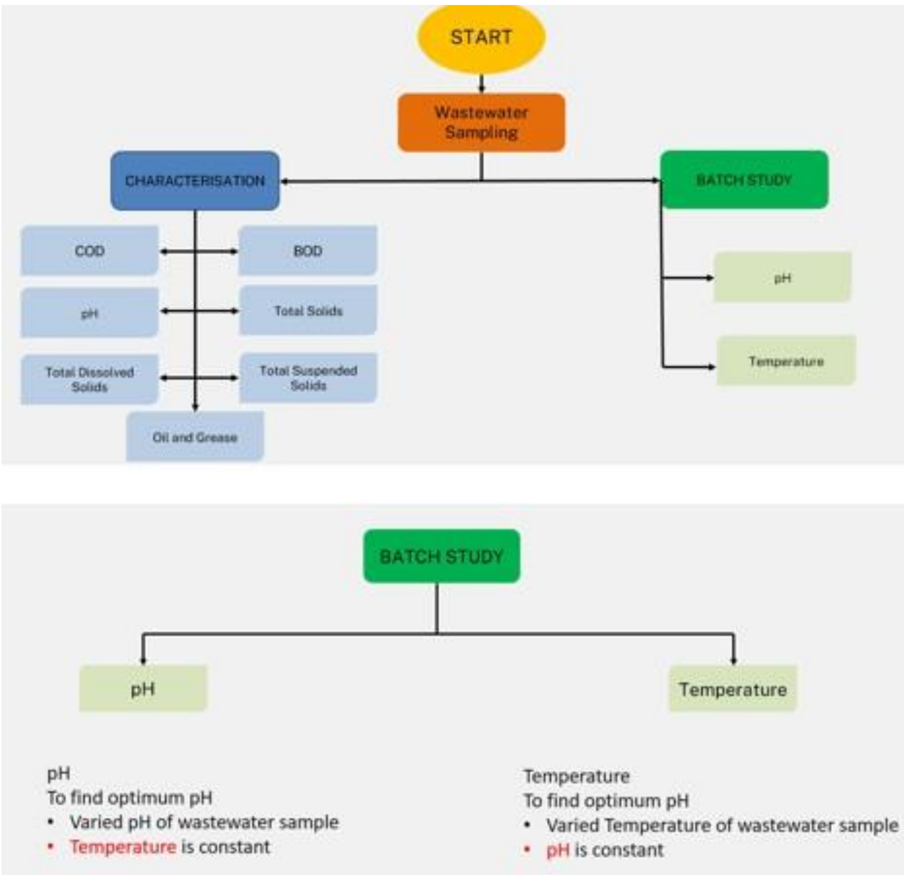

Figure 3.1 Flow Chart (Methodology)

3.2 Preparing real samples

The Café Haleem Lembaran provided the location for the collection of raw wastewater samples. It was situated on the USM Engineering Campus in Nibong Tebal, Pulau Pinang, Malaysia, at a coordinate point of 5° 9'3.39"N, 100°29'42.52"E. The samples were collected in HDPE plastic bottles, brought to the laboratory, and stored at 4 degrees Celsius in order to reduce the likelihood of biological and chemical reactions occurring. During the course of the experiment, the leachate was gathered for collection on two separate occasions: on the 16th and 17th of March 2022, respectively. Figure 3.1 showed the wastewater sampling at behind Café Haleem Lembaran. Figure 3.2 showed The Café Haleem Lembaran.

Figure 3.2 The wastewater sampling at behind Café Haleem Lembaran

Figure 3.3 Food and beverages wastewater in a beaker before batch study

3.3 Wastewater Characterization

In accordance with the Standard Methods for the Examination of Water and Wastewater, the samples were analyzed for pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), turbidity, oil and grease, and color. These measurements were taken from the samples (APHA, 1992). Figure 3.3 shows the characterization of wastewater leachate on site using YSI meter.

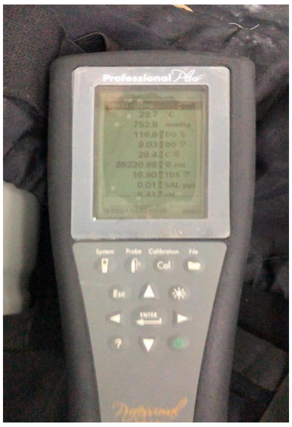

Figure 3.4 The characterization of wastewater leachate on site using YSI meter.

3.3.1 pH

On the pH scale, which was a logarithmic scale used to measure the acidity or basicity of an aqueous solution, a value of 7 indicated neutrality, with lower numbers indicating more acidity and higher ones indicating greater alkalinity. The pH of the wastewater at the site was measured using a YSI Pro Plus Multi-Parameter Water Quality Meter, and the pH of the leachate was measured in the laboratory with a pH meter. Both meters were calibrated with standard solutions. The pH meter was calibrated with a buffer solution that had a pH of 4.01, 7.01, and 10.01 before the actual test was performed. Before and after every single test, the electrode of the pH meter was wiped out with distilled water and patted dry with tissue paper. The pH level of the waste water was measured by placing the electrode from the pH meter into the waste water and reading the reading.

3.3.2 Temperature

The pH, dissolved oxygen, suspended particles, and turbidity data were all supported by temperature measurements in wastewater applications, making temperature readings a significant backup variable. The temperature, which was a key parameter, had an effect on the ability to remediate the wastewater. For the purpose of determining the temperature of the effluent, a YSI Pro Plus Multi-Parameter Water Quality Meter was employed.

3.3.3 Dissolved Oxygen (DO)

The term "dissolved oxygen" refers to the quantity of oxygen that has been dispersed throughout water. On-site testing of the DO was carried out with the use of a YSI Pro Plus Multi-Parameter Water Quality Meter.

3.3.4 Biochemical Oxygen Demand (BOD)

It is most typically used to quantify waste loadings to treatment facilities and to evaluate the plants BOD removal efficacy. BOD testing is used to determine the relative oxygen needs of wastewaters, effluents, and polluted waterways. During BOD testing, the amount of molecular oxygen that is used to biochemically degrade organic material is measured (referred to as the carbonaceous demand), the amount of oxygen that is used to oxidize inorganic material (such as sulphides and ferrous iron), and/or the amount of oxygen that is used to measure the amount of oxygen that is used to oxidize reduced forms of nitrogen, unless an inhibitor is added to prevent such reduction. The BOD test includes measuring the amount of oxygen that bacteria consume under controlled laboratory settings (5-days incubation at 20^{o}C).

3.3.5 Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) was a measurement that was used to determine the ability of water to consume oxygen during the process of the breakdown of organic matter and the oxidation of inorganic substances. A blank solution was carried out in order to calculate the COD. The blank solution consisted of 1.5 milliliters of potassium dichromate ($K_2Cr_2HgSO_2$), 2.0 milliliters of distilled water, and 3.5 milliliters of silver sulfate (Ag_2SO_4). After that, each of the tubes was put into a COD reactor and heated to a temperature of 150 degrees Celsius for two hours, followed by one hour of cooling. In the end, a DR 2800 HACH, USA spectrophotometer was used to calculate the COD in milligrams per liter (mg/L). COD removal efficiency was calculated by equation below:

$$COD\ Removal\ Efficiency = \left(\frac{COD\ initial - COD\ final}{COD\ initial}\right) \times 100\% \qquad (3.1)$$