TREATMENT OF INDUSTRIAL OLEOCHEMICAL WASTEWATER USING ELECTROCOAGULATION METHOD

REBECCA ANAK STEPHEN

Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor (Hons.) of Chemical Engineering

Faculty of Chemical & Natural Resources Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2015

ABSTRACT

Production of oleochemical products which derived from biological plant oils and animal fats which react in form of triglycerides with different composition of the alkyl chains which will form fatty acid methyl ester (FAME), fatty alcohols, fatty amines and glycerin can generates wastewater that contain fatty acids, glycerin, organic residues and inorganic acids which really need to be treated before being discharged to the environment especially into any water bodies. Therefore, a research must be conducted to find the solution for this problem. In this study, the potential to treat oleochemical wastewater using electrocoagulation (EC) process was studied. The oleochemical wastewater was collected from FPG Oleochemical Sdn Bhd which is situated in Gebeng, Pahang. The objectives of the study are to determine the optimum operational conditions such as initial pH of wastewater samples, type of electrodes, applied voltage or current density, reaction time and electrodes arrangement for the EC process of oleochemical wastewater in terms of removing the parameters of chemical oxygen demand (COD), oil and grease (O&G) and total suspended solids (TSS) of wastewater. The final pH and turbidity of treated wastewater samples also being determined. Furthermore, there is also a primary treatment or pre-treatment methods that being used to reduce the concentration of the glycerine from wastewater sample. The experiment results show that EC could effectively reduce COD, O&G, TSS and turbidity by 55.72%, 68.48%, 77.46% and 90.31% respectively using aluminium electrode at the optimum conditions of pH 6, applied voltage 20 V and reaction time of 30 minutes. In addition, the experimental results also show that the electrocoagulation can neutralize pH of wastewater. The result that will be obtained will be compared to the Standard A & B of Parameter Limit of Effluent as being outlined by Department of Environment based on Environmental Quality Act 2009.

Key words: oleochemical wastewater; electrocoagulation; COD removal; electrodes type

ABSTRAK

Pengeluaran produk oleokimia yang diperolehi daripada minyak tumbuhan biologi dan lemak haiwan yang bertindak balas dalam bentuk trigliserida dengan komposisi yang berbeza rantai alkil yang akan membentuk asid lemak metil ester (FAME), alkohol lemak, amina lemak dan gliserin tin menghasilkan air sisa yang mengandungi lemak asid, gliserin, sisa-sisa organik dan bukan organik asid yang perlu dirawat sebelum dilepaskan ke alam sekitar terutamanya ke dalam mana-mana sistem pengairan. Oleh itu, satu kajian perlu dijalankan untuk mencari penyelesaian bagi masalah ini. Dalam kajian ini, potensi untuk merawat air sisa oleokimia menggunakan elektrokoagulasi (EC) proses telah dikaji. Air sisa oleokimia yang digunakan untuk kajian ini adalah dikumpulkan dari FPG Oleochemical Sdn Bhd yang terletak di Gebeng, Pahang. Objektif kajian ini adalah untuk menentukan operasi optimum seperti pH awal sampel air sisa, jenis elektrod, voltan yang dikenakan atau ketumpatan arus, masa tindak balas dan susunan elektrod untuk proses SPR air sisa oleokimia dari segi menghapuskan parameter kimia permintaan oksigen (COD), minyak dan gris (O&G) dan jumlah pepejal terampai (TSS) air sisa. pH akhir dan kekeruhan sampel air sisa yang dirawat juga ditentukan. Tambahan pula, terdapat juga rawatan atau pra-rawatan utama kaedah yang digunakan untuk mengurangkan kepekatan gliserin daripada sampel air sisa. Keputusan eksperimen menunjukkan bahawa proses EC ini berkesan boleh mengurangkan COD, O&G, TSS dan kekeruhan sampel air sisa dengan 55,72%, 68,48%, 77,46% dan 90.31% masing-masing menggunakan elektrod aluminium pada keadaan optimum pH 6, digunakan voltan 20 V dan tindak balas masa 30 minit. Di samping itu, keputusan eksperimen juga menunjukkan bahawa elektrokoagulasi boleh meneutralkan pH air sisa. Hasil yang akan diperolehi akan dibandingkan dengan Piawaian A & B dalam Parameter Had Efluen seperti yang digariskan oleh Jabatan Alam Sekitar berdasarkan Akta Kualiti Alam Sekeliling 2009.

TABLE OF CONTENTS

SUPERVISOR'S DECLARATION IV
STUDENT'S DECLARATION V
Dedication VI
ACKNOWLEDGEMENT VII
ABSTRACT VIII
ABSTRAK IX
TABLE OF CONTENTS X
LIST OF FIGURES XIII
LIST OF TABLES XV
LIST OF ABBREVATIONS XVI
1 INTRODUCTION 1
1.1 Motivation and statement of problem 1
1.2 Objectives 5
1.3 Scope of this research 5
1.4 Main Contribution of this Study 6
1.5 Outline of This Thesis 6
2 LITERATURE REVIEW 8
2.1 Overview 8
2.2 Introduction 8
2.3 Wastewater 9
2.4 Oleochemical Industry 10
2.5 Oleochemical Industry Effluent (OCIE) 11
2.5.1 Sources of OCIE 11
2.5.2 Composition of OCIE 11
2.6 Previous Work on Wastewater Treatment 11
2.6.1 Membrane Technology 12
2.6.2 Adsorption Technology 14
2.6.3 Ion Exchange 15
2.6.4 Summary 16
2.7 Electrocoagulation Treatment 18
2.7.1 Theory and Application Principles 19
2.7.2 Factors Affecting EC Treatment 24

2.7.3 Advantages of EC 25

2.7.4 Disadvantages of EC 26

2.8 Parameters 26

2.8.1 Chemical Oxygen Demand (COD) 26

2.8.2 Oil and Grease (O&G) 27

2.8.3 Turbidity 27

2.8.4 Total suspended solid (TSS) 28

2.9 Limit of Effluent 28

3 MATERIALS AND METHOD 30

3.1 Overview 30

3.2 Introduction 31

3.3 Chemical 32

3.4 Sample Preparation 32

3.4.1 Chemical Oxygen Demand (COD) 33

3.4.2 Oil and Grease (O&G) 34

3.4.3 Total Suspended Solid (TSS) 37

3.4.4 Turbidity 38

3.4.5 pH of Sample 39

3.5 Pre-treatment Process 40

3.6 HPLC Analysis 41

3.7 EC Treatment 42

3.8 Summary 45

4 RESULT AND DISCUSSION 46

4.1 Overview 46

4.2 Introduction 46

4.3 Effect of Acidification on Concentration of Parameters 47

4.4 Effect of Pre-Treatment Process on Concentration of Parameters 48

4.5 Effect of Operational Conditions of EC process 50

4.5.1 Initial pH 50

4.5.2 Applied voltage 52

4.5.3 Reaction time 54

4.5.4 Electrode arrangement 55

4.5.5 Electrode type 56

4.6 Comparison of Treated Wastewater Sample with EQA 57

4.7 Summary 58

5 CONCLUSION 59

5.1 Conclusion 59

5.2 Future work 60

REFERENCES 61

APPENDICES 64

LIST OF FIGURES

Figure 2-1: Schematic flow of mechanisms of membrane technology 13
Figure 2-2: Schematic operation steps of activated carbon technology 14
Figure 2-3: Ion exchange mechanisms for wastewater treatment 16
Figure 2-4: Schematic diagram of bench-scale two-electrode EC cell 20
Figure 2-5: Schematic diagram of bench-scale EC reactor with monopolar electrodes in parallel connections 22
Figure 2-6: Schematic diagram of bench-scale EC reactor with monopolar electrodes in series connections 23
Figure 2-7: Schematic diagram of bench-scale EC reactor with bipolar electrodes in parallel connections 24
Figure 2-8: Parameters limit of standard A & B, EQA (2009) 29
Figure 3-1: Overall experimental study of the research 31
Figure 3-2: Dilution of untreated wastewater sample with deionized water..................... 33
Figure 3-3: The COD vials with blank (deionized water) and sample run 34
Figure 3-4: COD analysis procedure 34
Figure 3-5: Formation of two layers of n-hexane and water 35
Figure 3-6: Drained of n-hexane into pre-weighed beaker 36
Figure 3-7: O&G analysis procedure 36
Figure 3-8: Filtration of sample through fiber filter paper 37
Figure 3-9: Fiber filter paper with suspended solid 38
Figure 3-10: TSS analysis procedure 38
Figure 3-11: Turbidity analysis procedure 39
Figure 3-12: pH analysis procedure 39
Figure 3-13: Coagulation process using jar test 40
Figure 3-14: Wastewater sample obtained from coagulation-flocculation process 41
Figure 3-15: Wastewater sample obtained after separation and filtration of flocs............ 41
Figure 3-16: HPLC vials containing sample of pre-treatment process 42
Figure 3-17: Experimental set up for EC process using monopolar in series electrode arrangement connected to DC power supply 43

Figure 3-18: Experimental set up for EC process using bipolar in series electrode arrangement connected to DC power supply 44
Figure 3-19: Sample obtained from EC process 44
Figure 4-1: The variation of parameters in different pH values after acidification 48
Figure 4-2: Concentration of glycerin of untreated and after pre-treatment of wastewater sample..49
Figure 4-3: Removal efficiency of parameters for different coagulant agents..................50
Figure 4-4: Effect of initial pH on the removal efficiencies for COD, O&G and TSS using Al electrodes. Applied voltage: 20 V; reaction time: 30 min..51
Figure 4-5: Effect of initial pH on the removal efficiencies for COD, O&G and TSS using Fe electrodes. Applied voltage: 20 V; reaction time: 30 min..52
Figure 4-6: Effect of applied voltage on the removal efficiencies for COD, O&G and TSS using Al electrode. Initial pH: 6; reaction time: 30 min..53
Figure 4-7: Effect of applied voltage on the removal efficiencies for COD, O&G and TSS using Fe electrode. Initial pH: 6; reaction time: 30 min..53
Figure 4-8: Effect of reaction time on the removal efficiencies for COD, O&G and TSS using Al electrodes. Initial pH: 6; applied voltage: 20 V..54
Figure 4-9: Effect of reaction time on the removal efficiencies for COD, O&G and TSS using Fe electrode. Initial pH: 6; applied voltage: 20 V. 55
Figure 4-10: Effect of electrode arrangement on the removal efficiencies for COD, O&G and TSS using Al electrodes. Initial pH: 6; applied voltage: 20 V; reaction time: 30 min. 56
Figure 4-11: Effect of electrode arrangement on the removal efficiencies for COD, O&G and TSS using Fe electrode. Initial pH: 6; applied voltage: 20 V; reaction time: 30 min.56

LIST OF TABLES

Table 2-1: The contaminant from each sources and the effect to the environment 9

Table 2-2: Summary of wastewater treatment technologies 17

Table 3-1: Characteristics of industrial oleochemical wastewater 32

Table 4-1: Comparison of optimum operational conditions of EC using Al and Fe electrodes 57

Table 4-2: Comparison of parameters of treated wastewater with EQA, 2009 58

LIST OF ABBREVATIONS

Al^{3+}	-	Ion aluminium (3+)
APHA	-	American Public Health Association
AWWA	-	American Water Works Association
COD	-	Chemical oxygen demand
DOE	-	Department of Environment
EC	-	Electrocoagulation
EDTA	-	Ethylenediaminetetraacetic acid
EQA	-	Environmental Quality Act
Fe^{3+}	-	Ion iron (3+)
GC/MS	-	Gas chromatography-mass spectrometry
H+	-	Ion hydrogen (1+)
H_2	-	Hydrogen
H_2O	-	Water
HCl	-	Hydrochloric acid
IMP	-	Industrial Master Plan
MF	-	Microfiltration
NaOH	-	Sodium hydroxide
NF	-	Nanofiltration
O_2	-	Oxygen
OCIE	-	Oleochemical industry effluent
OH^-	-	Ion hydroxide (1^-)
RO	-	Reverse osmosis
TSS	-	Total suspended solids
UF	-	Ultrafiltration
UV	-	Ultra-violet

1 INTRODUCTION

1.1 Motivation and statement of problem

The world's chemical industries face very formidable environmental regulatory challenges in treating their wastewater effluents (Awaleh & Soubaneh, 2014). The need for clean water is particularly critical in Third-World Countries. The rivers, canals, estuaries and other water-bodies are being constantly polluted due to indiscriminate discharge of industrial effluents as well as other anthropogenic activities and natural processes (A Mollah *et al.*, 2001). The pollution of rivers and streams with chemical contaminants is one of the most crucial environmental problems. This is mainly because the waterborne chemical pollution entering rivers and streams can causes a very tremendous amounts of destruction to the water ecosystem. Although there are some kinds of water pollution can occur due to the natural processes but most of it is a result of the human activities as water is being used in every household and industries daily (Sonune & Ghate, 2004).

In addition, there has been a growing consciousness of the need to protect our environment from degradation caused by development and industrialization. This has resulted in a number of environmental policies being drawn up and more stringent governmental regulations being imposed. However, the solution strike a balance between development, industrialization and environmental concerns lies in the hands of the people involved directly or indirectly with the growing industries. Therefore, it is being believed that, throughout the world, industries have been undergoing a learning process in accepting the need for industrial waste management, wastewater management and the necessity for optimizing waste management. Other than that, it is necessary to minimize water consumption and it is also necessary to return it back to the environment with the minimum contamination load which means that it is a need of the wastewater treatment process. Unfortunately, the environmental risks associated with chemical industrial wastewaters have always being are of great concerns because of its content which are an organic and inorganic matter in varying concentrations. Many materials in the chemical industry are toxic, mutagenic, carcinogenic or simply almost non-biodegradable. This means that the production wastewater also contains a wide range of substances that cannot be easily degraded. For instance, surfactant and petroleum hydrocarbons, among others chemical products that are being used in chemical industry reduce performance efficiency of many treatment unit operations (Awaleh & Soubaneh, 2014).

In the case of oleochemical industry, the raw materials itself are chemicals derived from biological plant oils and animal fats which will be react in form of triglycerides with different composition of the alkyl chains depending on their origin (Rupilius & Ahmad, 2003). In industrial oleochemical processing, they are transferred into fatty acid methyl esters (FAME), fatty alcohols, fatty amines and glycerin by various chemical and enzymatic reactions (Gervajio, 2005). Even though it appears to be that oleochemical are biodegradable, exhibit low toxicity and are considered to be environmental friendly but the industrial process wastewater from this industry may contain fatty acids, glycerin, organic residues and inorganic acids which really need to be treated before being discharged to the environment especially into any water body (Team, 2013).

As a consequence of all these environmental problems, the reuse of wastewater has become an absolute necessity and it would be prudent for any rational water management authority to secure the purest water sources for direct human consumption and to encourage the reuse of processed water for industrial applications as well as water treatment before being discharged into the rivers or lakes. Apart from that, the demand to the cleaning domestic and industrial wastewater to avoid environment pollution and especially contamination of pure water resources are becoming national and international issues. Due to this shortage of pure water and to prevent the environmental pollutions, the innovative, cheap and effective methods of purifying and cleaning wastewater before discharging into any other water systems are needed.

In this study, I will focus on treating industrial oleochemical wastewater which being taken from the effluents of FPG Oleochemical Sdn Bhd. These effluents can cause environmental damage if being discharged without any treatment because they are glycerin contaminated wastewaters that contain high concentration of chemical oxygen demand (COD), oil and grease (O&G), total suspended solids (TSS) and turbidity. Thus, it is a must for the industrial management to treat their effluents completely to comply with the environmental regulations. For proper industrial effluent management to be achieved there is an obligation, not by the authorities to ensure that effluent standards are satisfied, but the duty should be on the industry to ensure their effluent complies with the standards set by the regulating authorities. In many cases, good effluent management also gives other positive benefits to the industry concerned. For example, by reducing water usage by preventing wastage and recycling and product recovery or purification can substantially reduce the industrial operating costs. In Malaysia, the legislative basis for the environmental control of waste discharge is the Environmental Quality Act of 1974 and Regulations issued under that Act. The enforcement authority designated by the Act is the Director General of Environmental Quality. Some of the Regulations published under this Act are Environmental Quality (Clean Air) Regulations 1978 and Environmental Quality (Sewage and Industrial Effluents) Regulations 1979. There is also the regulation being made to increase awareness of the dangers of toxic wastes which also includes regulations to ensure that such hazardous wastes are carefully managed from their disposal point. More recent, there is the EQA of 2009 which being used as the final checkpoint for this project whereby the treated wastewaters will be compared with this regulations in order to know either or not that electrocoagulation can treat this industrial oleochemical wastewater.

The typical treatment processes for industrial wastewater include chemical precipitation, activated sludge, ion exchange, chemical and biological treatment and membrane separation. In this study, the industrial oleochemical wastewater will be treated using electrochemical method. Electrochemical methods are frequently used for treating wastewater which contains organic and inorganic compounds. The application of electrochemical methods for the removal of organic pollutants has some advantages compared with chemical or biological methods. Chemical oxidation methods can be used for the oxidative decomposition of many organic pollutants but these methods require large amounts of reactive chemical reagents. Electrochemical methods have little or no harmful effects on the environment, because these techniques do not involve the use of harmful reagents (Segneanu, *et al*., 2013). On the other hand, electrochemical reactions are more or less independent of the condition of the wastewater and can proceed as long as a current is supplied to the electrode (Kuramitz *et al*., 2001). Electrochemical technologies have attracted a great deal of attention because of their versatility, which makes the treatment of liquids, gases and solids possible, and their environmental compatibility. Among all the electrochemical methods, electrocoagulation (EC) is the most innovative as well as effective in treating wastewaters (Wang *et al*., 2008)which is why it is being chosen as the treatment method for this project. EC is a process consisting of creating a floc of metallic hydroxides within the effluent to be cleaned, by electrodissolution of soluble anodes (Kashefialasl *et al*., 2005). Compared with traditional flocculation and coagulation, electrocoagulation has the advantage of removing the smallest colloidal particles since the smallest charged particles have a greater probability of being coagulated because of the electric field that sets them in motion. It has also the advantage of producing a relatively low amount of sludge (Pouet & Grasmick, 1995). The characteristics of EC method which are simple equipment and easy operation, brief reactive retention period, decreased or negligible equipment for adding chemicals and decreased amount of sludge (Gürses et al., 2002). This is the main reason why EC has received great attention and used to treat water containing food and protein wastes, oil wastes, synthetic detergent, effluent mine wastes and heavy metal-containing solutions. In recent years, EC has been successfully used to treat various industrial wastewaters. EC method is chosen for wastewater treatment for this research due to these facts:

i. **The availability or readily equipment for operation**

   EC requires simple equipment and is easy to be operated with sufficient latitude to handle most problems encountered on running. The electrolytic processes in the EC cell are controlled electrically with no moving parts which will require less maintenance.

ii. **Effectiveness of process**

   Wastewater treated by EC gives palatable, clear and odorless water where it also produces effluent with less total dissolved solids content compared to the chemical treatments.

iii. **Environmental Impact**

EC method do not require any chemicals in the process, thus there will be no problem with the neutralizing excess chemicals which means that there is no possibility of secondary pollution caused by chemical substances added at high concentration as in the chemical coagulation process of wastewater.

1.2 Objectives

The main objectives of this study are:

i. To study the optimum operational conditions of electrocoagulation process for the highest removal efficiency of the pollutant.

ii. To study the effect of organic matters (glycerin) to the concentration of chemical oxygen demand of industrial oleochemical wastewater.

1.3 Scope of this research

The following are the scopes of the study which will be done to achieve the objectives of this research:

i. The untreated and treated wastewater will be characterized for the level or concentration of COD, O&G, TSS, turbidity and final pH as well as the chemical compositions of glycerin.

ii. Introduce of pre-treatment process to reduce the compositions of glycerin in wastewater sample which being presumed to be the main contributor to the high COD in industrial oleochemical wastewater.

iii. In order to determine the optimum operational conditions for EC process, there are some EC process variables that need to be manipulated for the highest removal efficiency of pollutant such as:

- ✓ the effect of initial pH of wastewater sample at range between pH4 to pH9
- ✓ the effect of applied voltage of 10 to 30 V

- ✓ the effect reaction or contact time of 10 to 40 minutes
- ✓ the effect of electrodes arrangement either monopolar or bipolar in series
- ✓ the effect of the type of electrodes of iron or aluminium electrodes

iv. The percentage removal of the studied parameters of COD, O&G, TSS, turbidity and final pH of treated wastewater will be determined and being compared to the EQA, 2009.

1.4 Main Contribution of this Study

The following are the main contributions of this study:

i. To identify the performance or effectiveness of EC in the water and wastewater treatment
ii. Know whether EC process is effective in treating industrial wastewater
iii. Explain the principle, mechanism, advantages and disadvantages of EC process in treating water and wastewater
iv. The methods and analysis may assist another further study using EC process or any others electrochemical process

1.5 Outline of This Thesis

The structure of the reminder of the thesis is outlined as follow:

Chapter 2 provides the information of the industrial oleochemical wastewater which is the components of the wastewater and effects to the environment. A general description on the environmental risks from industrial waste and treatment methods are also presented. A summary of previous work on wastewater treatment also the comparison of the methods will be discussed in this chapter. The principles, mechanism, advantages and disadvantages of EC method in treating wastewater are also discussed in detail in this chapter. In general, this chapter will focus on principle of EC method and wastewater treatment methods.

Chapter 3 gives a review of the method approach applied for analysis of studied parameters and the EC method experimental set up. The untreated and treated wastewater sample will be compared by three parameters of study which are the concentration of COD, O&G, TSS, turbidity and pH of the sample. The analytical method and the main analysis of this research also being elaborated here. This chapter also include the description of the chemical used in the analysis also the procedure and the chosen method to analyze the parameters.

Chapter 4 will present the result of the experimental work which is the analysis of untreated wastewater sample. In general, this chapter discusses the results from experimental work where the analysis of COD, O&G, TSS, turbidity and pH were done to determine the concentration of these parameters in the wastewater sample. Discussion and comparison of the parameters of COD, O&G, TSS, turbidity and final pH of the sample with the regulation from Environmental Quality Act (EQA), 2009 are also presented.

2 LITERATURE REVIEW

2.1 Overview

This research presents the experimental study to investigate the efficiency of EC method in wastewater treatment. The studies parameters of the research will be explained in detail which including chemical oxygen demand (COD), oil and grease (O&G), total suspended solids (TSS) and turbidity. Generally, untreated wastewater contains high level of these parameters that means it is need to be treated before disposal and discharge into the water bodies. The efficiency of EC treatment mainly will be determined on the percentage removal of these parameters. EC treatment that is the principles, theory, applications and mechanisms will be discussed clearly in this chapter. Other than that, the advantages and disadvantages of EC treatment also discussed here. The factors or variables that may affect EC process in treating wastewater is being investigated and explained whereby some variables such as initial pH, applied voltage, reaction time, electrodes arrangement and type of electrodes were varied while running EC treatment. The optimum operating conditions for EC process in treating wastewater will be analyzed through the experimental work or running of process. Next, the previous work on wastewater treatment such as membrane, adsorption and ion exchange technologies will be explained, compared and summarized in this chapter. Basically, wastewater treatment technologies each have different mechanisms in treating wastewater as well as the advantages and disadvantages over each methods which is why there is a lot of new methods being investigated in order to choose the best treatment methods. In general, through this research, it can identify whether EC method is suitable for wastewater treatment. Basically, treatment methods is selected depends on the process condition itself.

2.2 Introduction

This chapter will discuss about what is the wastewater mainly is industrial oleochemical wastewater that is glycerin contaminated. For the next section, it will discuss more in detail on EC process description, principles and limitations of this method. There is also the review on the previous work on wastewater treatment and lastly shows the standard water quality index in Malaysia that must be followed to discharge treated wastewater.

2.3 Wastewater

Wastewaters are waterborne solids and liquids discharged into sewers that represent the wastes of community life. Wastewater includes dissolved and suspended organic solids which are biologically decomposable. Wastewater may be defined as a combination of liquid or water-carried waste removed from residences, institutions and commercial and industrial establishments, together with ground water, surface water and storm water. It generally contains a high load of oxygen demanding wastes, pathogenic or disease-causing agents, organic materials, nutrients that stimulate plant growth, inorganic chemicals and minerals and sediments. It may also contain toxic compounds. Wastewater may be classified into four categories (Sonune & Ghate, 2004):

1. Domestic (sewage) – wastewater discharged from residences and commercial institutions and similar facilities
2. Industrial – wastewater in which industrial waste predominates
3. Infiltration or inflow – extraneous water that enters the sewer system through indirect and direct means such as through leaking joints, cracks or porous walls. Inflow in storm water that enters the sewer system from storm drain connections, roof headers, foundation and basement drains or through manhole covers
4. Storm water – runoff resulting from flooding due to rainfall

The characteristics and composition of wastewater may be different which is mainly reflecting the different water uses. The most significant components of wastewater are usually suspended solids, biodegradable organics and pathogens. Suspended solids are primarily organic in nature and are composed of some of the more objectionable in sewage. The common wastewater contaminants from different sources and its significance (Peavy, Rowe, & Tchobanoglous, 1985) are shown in the Table 2-1 below.

Table 2-1: The contaminant from each sources and the effect to the environment

Contaminant	Source	Environmental significance
Suspended solids	Domestic and industrial wastes may due to erosion by infiltration or inflow	Cause sludge deposits and anaerobic conditions in aquatic environment
Biodegradable organics	Domestic and industrial waste	Cause biological degradation, which may use up oxygen in receiving water and result in undesirable conditions
Pathogens	Domestic waste	Transmit communicable diseases
Nutrients	Domestic and industrial waste	May cause eutrophication
Refractory organics	Industrial waste	May cause taste and odor problems as well as toxic or carcinogenic
Heavy metals	Industrial waste especially mining industries	Are toxic and may interfere with effluent reuse
Dissolved inorganic solids	Increases above level in water supply by domestic and industrial use	May interfere with effluent reuse

2.4 Oleochemical Industry

The oleochemical industry in Malaysia is an off-shoot of the palm oil industry and it is a relatively new industry. Industrial Master Plan (IMP), 1986 has once stated that despite the anticipated importance of the oleochemical industry in the near future, great attention has been given to the pollution problems arising from the effluent produced. The range of oleochemical manufactured includes fatty acid mixtures for soap making, rubber grade stearic acid to highly refine fractionated products for food, cosmetic, toilet preparations and the plastic industry also glycerin for food and pharmaceutical products. The oleochemical manufacturers in Malaysia utilize palm and palm kernel oil as their raw materials (The Malaysian Oleochemical Manufacturers Group, 1984). The effluent used in this study was taken from an oleochemical plant of FPG Oleochemical Sdn Bhd in Gebeng, Pahang. It is a big oleochemical player in Malaysia with production capacity of methyl ester, fatty alcohol, glycerin and detergents of 280000, 80000, 35000 and 60000 tons per year respectively whereby 1.5 tons of effluent produced for every tone of product obtained as of 2011. The total amount of effluent originated from the fatty acid plant and the oleochemical plant is about 52000 tons per annum. The volume of the effluent is anticipated to increase with the construction of more oleochemical plants in the next ten years (IMP, 1986).

2.5 Oleochemical Industry Effluent (OCIE)

2.5.1 Sources of OCIE

OCIE is generated at two main sources in the factory:

a) the distillation stage in the manufacturing process
b) the floor and equipment washings, leaks and drips

The process water originates from the various stages of manufacturing. Generally, throughout the process, OCIE is produced whenever vacuum distillation is carried out with a barometric condenser to manufacture glycerin, fatty acids and methyl esters. OCIE from the distillation process constitutes the major portion of the effluent, especially from the manufacture of glycerin. From the esterification process some methanol and esters are released into OCIE and nickel from the hydrogenation process is also likely to end up in the effluent water.

2.5.2 Composition of OCIE

Qualitatively, OCIE contains grease, glycerol, long-chain fatty acids and very low concentrations of ammonia nitrogen, phosphate phosphorus and sulphate. The quality of the OCIE varies daily which mainly depend on the types of manufacturing being carried out in the plant.

2.6 Previous Work on Wastewater Treatment

Nowadays, demand to the cleaning industrial and domestic wastewater to avoid environmental pollution and especially contamination of pure water resources are becoming global issues. Thus, the innovative, cheap and effective methods of treating wastewater before discharging into any other water system are needed. The most common advanced technologies for wastewater treatment process are membrane, adsorption and ion exchange technologies. Membrane separation that commonly used is ultrafiltration (UF) and reverse osmosis (RO) while the adsorption treatment is being done using activated carbon.

2.6.1 Membrane Technology

Membrane processes such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) are increasingly being applied for treating oily wastewater (Awaleh & Soubaneh, 2014). Of the three broad categories of oily wastes that are free-floating oil, unstable oil to water emulsions, and highly stable oil to water emulsions, membranes are most useful with stable emulsions, particularly water soluble oily wastes. Free oil, on the other hand, can be readily removed by mechanical separation devices which use gravitational force as the driving force. Unstable oil or water emulsions can be mechanically or chemically broken and then gravity separated. Pre-treatment to remove large particles and free oil is needed, especially if thin-channel membrane equipment is used. The membrane unit is usually operated in a semi-batch recycle. The wastewater feed is added to the process tank at the same rate as clean permeate is withdrawn, thus keeping a constant level in the tank. The retentive retention containing the oil and grease is recycled to the process tank. When the oils and grease and other suspended matter reach a certain predetermined concentration in the tank, the feed is stopped and the retentive allowed concentrating (Awaleh & Soubaneh, 2014). Usually, this result in a final concentrate volume that is only 3-5% of the initial volume of oily wastewater fed to the process tank. The system is then usually cleaned.

Among all the membrane technologies, ultrafiltration (UF) is the most common that being used in treating wastewater. In the UF process, wastewater containing emulsified oils is pumped through a membrane filter at a high flow rates and under pressure. The UF membrane allows water and other low molecular weight substances such as soaps, salts and surfactants to pass through the membrane pores and exit the system as permeate. Higher molecular weight substances such as oils and solids are retained by the membrane and remain in the wastewater feed. The flow of UF process is being illustrated in Figure 2-1 below.

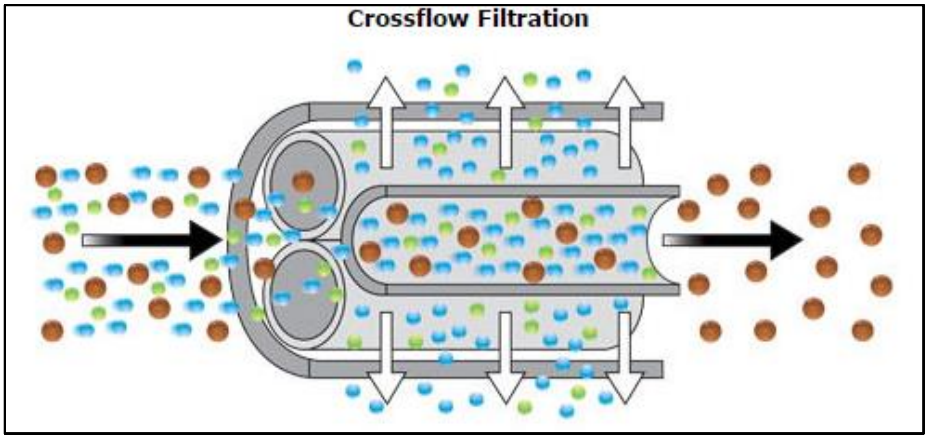

Figure 2-1: Schematic flow of mechanisms of membrane technology

Membranes have several advantages such as follows:

i. The technology is more widely applicable across a wide range of industries
ii. The membrane is a positive barrier to rejected components. Thus, the quality of the treated water (the permeate) is more uniform regardless of influent variations. These variations may decrease flux, but generally does not affect quality of its output
iii. No extraneous chemicals are needed, making subsequent oil recovery easier
iv. Membranes can be used in-process to allow recycling of selected waste streams within a plant
v. Energy costs are lower compared to thermal treatments
vi. The plant can be highly automated and does not require highly skilled operators.

The chemical nature of the membrane can have a major effect on the flux. For example, free oils can coat hydrophobic membranes resulting in poor. Hydrophilic membranes preferentially attract water rather than the oil, resulting in much higher flux. Hydrophobic membrane can be used, but usually in a tubular configuration that allows a high degree of turbulence (cross-flow velocity) to be maintained to minimize oil wetting of the membrane.

The limitations of membrane process are:

i. Scale-up is almost linear above a certain size. Thus capital costs for very large effluent volumes can be high
ii. Polymeric membranes suffer from fouling and degradation during use. Thus they may have to be replaced frequently, which can increase operating costs significantly.

2.6.2 Adsorption Technology

Adsorption is a natural process by which molecules of a dissolved compound collect on and adhere to the surface of an adsorbent solid. Adsorption occurs when the attractive forces at the carbon surface overcome the attractive forces of the liquid. The adsorption process uses forces of molecular attraction to bind soluble and gaseous chemicals to a surface. The process retains and accumulates toxic chemicals present in wastes, yet does not chemically alter them. Carbon used for adsorption is usually treated or activated to make it very porous. Activated carbon has a large surface area that can adsorb relatively large quantities of material per unit weight of carbon. Activated carbon is "spent" when it has adsorbed so much contaminant that its adsorptive capacity severely depleted. Granular activated carbon is a particularly good adsorbent medium due to its high surface area to volume ratio. One gram of a typical commercial activated carbon will have a surface area equivalent to 1,000 square meters (Awaleh & Soubaneh, 2014). Figure 2-2 shows the schematic diagram of adsorption process in wastewater treatment plant.

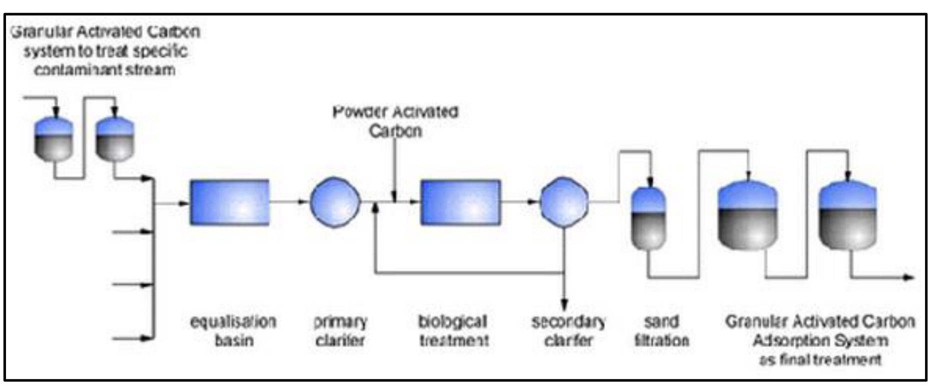

Figure 2-2: Schematic operation steps of activated carbon technology