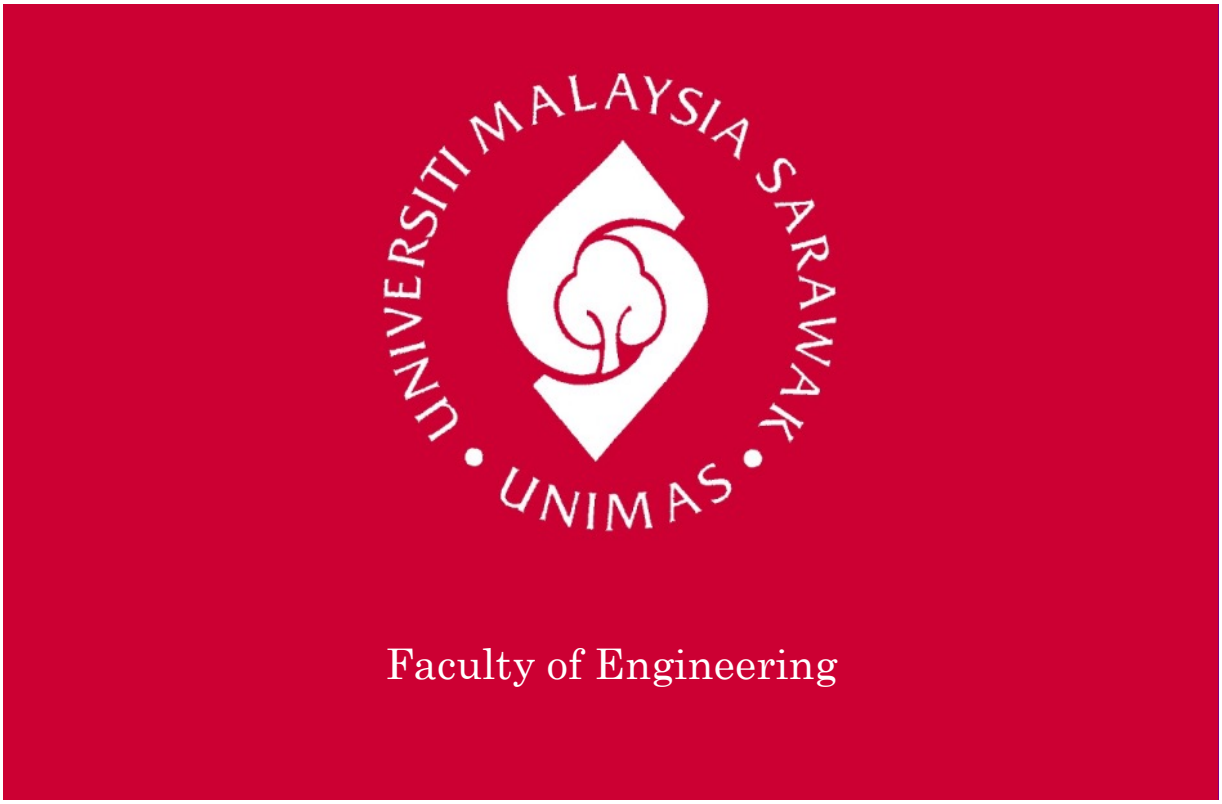

EXPERIMENTAL STUDY OF CONTINUOUS ELECTROCOAGULATION TREATMENT OF PEAT WATER IN SARAWAK WITH ALUMINIUM ELECTRODES

ALLENE ALBANIA LINUS

Bachelor of Engineering with Honours
(Chemical Engineering)
2018

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

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Final Year Project Report	√
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PhD	

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This final year project report, which entitled **EXPERIMENTAL STUDY OF CONTINUOUS ELECTROCOAGULATION TREATMENT OF PEAT WATER IN SARAWAK WITH ALUMINIUM ELECTRODE** was prepared by Allene Albania Linus (45445) as a partial fulfillment for the Degree of Bachelor of Chemical Engineering is hereby read and approved by:

_____
DR NAZERI ABDUL RAHMAN
(Supervisor)

12 JUNE 2018
Date

EXPERIMENTAL STUDY OF CONTINUOUS ELECTROCOAGULATION TREATMENT OF PEAT WATER IN SARAWAK WITH ALUMINIUM ELECTRODE

ALLENE ALBANIA LINUS

A dissertation submitted in partial fulfillment
of the requirement for the degree of
Bachelor of Engineering with Honours
(Chemical Engineering)

Faculty of Engineering

Universiti Malaysia Sarawak

2018

Dedicated to my beloved parents and my supervisor who always bestow me sustainable motivations and encouragements

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ABSTRACT

Sarawak is the largest state in Malaysia with a total area of peat land of about 2.6Mha that contribute 70% of Malaysia's total peat land. The state government is currently looking forward for the implementation of the Sarawak Alternative Rural Water Supply (Sawas) programme with purpose of providing safe and clean water to rural areas. The programme is aimed to provide clean water to about 114,000 households in the rural areas. The increasing demand of clean water and also the ageing reticulation system contributed to the low water supply especially in many rural and coastal areas. The state government also aims to look into non-revenue water programme. Since, peat land is abundance in Sarawak especially the coastal areas, the utilization of naturally found peat water is an alternative. Peat water can be associated with red-brownish colour with high humic substances contain. Thus, treatment of peat water is essential before fully utilization as clean water. Therefore, the study main aim is to develop an electrocoagulation process for treatment of peat water of rural coastal region of Sarawak with Aluminium electrodes. The focus is on the treatment of peat water in the rural coastal area of Sarawak. The model for electrocoagulation treatment system is built with materials and technology available locally. In addition, the fabrication and maintenance processes must be simple and easy. The study is conducted in the form of literature review, sampling and data analysis, design and fabrication of system and data analysis focusing on the most sustainable system for electrocoagulation as a treatment system for peat water. The continuous electrocoagulation reactor is fabricated and experimental studies in conducted on electrode distance, number of plates, treatment time and current density. Several parameters are investigated such as COD, TOC, colour, turbidity, heavy metal and pH. The developed electrocoagulation treatment system is able to remove the parameters to meet Ministry of Health Standard except for colour which is slightly higher. This is due to improper filtration system used. Last but not least, the continuous electrocoagulation treatment system is feasible with the most optimized condition of 0.5 cm Aluminium electrode spacing, 20 plates, 21 A/m^2 and treatment time of 25 minutes.

Keywords: Electrocoagulation, Aluminium Electrodes, Peat Water, Water Treatment

ABSTRAK

Sarawak adalah negeri terbesar di Malaysia dengan jumlah kawasan tanah gambut kira-kira 2.6Mha iaitu 70% daripada keseluruhan tanah gambut di Malaysia. Kerajaan negeri kini sedang mempercepatkan pelaksanaan program *Sarawak Alternative Rural Water Supply* (Sawas) dengan tujuan untuk menyediakan air bersih ke kawasan luar bandar. Program ini bertujuan untuk menyediakan air bersih kepad a 114,000 isi rumah di kawasan luar bandar. Peningkatan permintaan air bersih dan juga penuaan sistem retikulasi menyumbang kepada bekalan air yang rendah dan tidak mencukup terutamanya kepada penduduk di kawasan luar bandar dan juga kawasan persisiran pantai. Oleh kerana tanah gambut meluas di Sarawak terutamanya di kawasan persisiran pantai, penggunaan air gambut yang didapati secara semula jadi boleh dijadikan sebagai salah satu alternatif. Air gambut boleh dikaitkan dengan warna merah-kecoklatan dan bahan humic yang tinggi. Oleh itu, rawatan air gambut adalah penting sebelum dimanfaatkan sebagai air bersih. *Electrocoagulation* adalah proses rawatan air yang murah dan mesra alam. Oleh itu, matlamat utama kajian adalah untuk mencipta proses *electrocoagulation* untuk rawatan air gambut bagi kawasan persisiran pantai luar bandar Sarawak dengan menggunakan elektrod Aluminium. Tumpuan adalah mengenai rawatan air gambut di kawasan pantai luar bandar Sarawak. Model untuk sistem rawatan *electrocoagulation* dibina dengan bahan dan teknologi yang sedia ada di dalam negara. Di samping itu, proses fabrikasi dan penyelenggaraan mestilah mudah. Kajian ini dijalankan dalam bentuk kajian literatur, pensampelan dan analisis data, reka bentuk dan fabrikasi sistem dan analisis data. Reaktor *electrocoagulation* telah dibuat dan kajian eksperimen dilakukan pada jarak elektrod, bilangan plat, masa rawatan dan arus elektrik berbeza. Beberapa parameter disiasat seperti COD, TOC, warna, kekeruhan, *heavy metal* dan pH. Sistem rawatan electrocoagulation yang dibina dapat mengurangkan beberapa parameter untuk memenuhi Standard Kementerian Kesihatan kecuali parameter warna lebih tinggi sedikit. Ini disebabkan oleh sistem penapisan yang kurang baik telah digunakan. Akhir sekali, sistem rawatan *electrocoagulation* boleh dilaksanakan dengan keadaan optimum 0.5 cm jarak elektrod, 20 plat, 21 A / m2 dan masa rawatan 25 minit.

Kata Kunci: Electrocoagulation, Air Keranggas, Elektrode Aluminium

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a	-	Electricity price (RM/kWh)
A/m^2	-	Current density
b	-	Price of electrode materials (RM/kg)
c	-	Price of supporting electrolyte (RM/kg)
C_0	-	Concentration of component before treatment (mg/L)
C_1	-	Concentration of component after treatment (mg/L)
EMC	-	Electrode material consumption (kg/m3)
F	-	Faraday's constant (96485 C)
ha	-	Hectare
I	-	Current (Ampere)
m	-	Metre
M	-	Molecular weight of metal (g/mol)
mg/L	-	Milligram per litre
Mha	-	Mega hectare
NTU	-	Nephelometric Turbidity Units
OC	-	Operating cost (RM/m3)
Q	-	Volume of water treated (m^3)
R	-	Efficiency of removal (%)
SEC	-	Supporting electrolyte consumption (kg/m3)
SEEC	-	Specific electrical energy consumption ($kWh/kg_{rem.}$)
T	-	Time (hours)
t	-	Time (s)
TCU	-	True colour unit
V	-	Voltage (V)
EMC	-	Electrode material consumption (kg/m^2)
Z	-	Number of electrons involved in the oxidation or reduction reaction

LIST OF ABBREVIATIONS

AC	-	Alternating current
BOD	-	Biological oxygen demand
BP-S	-	Bipolar-series
COD	-	Chemical oxygen demand
DBPs	-	Disinfection by-products
DC	-	Direct current
DOC	-	Dissolved organic carbon
FTIR	-	Fourier-transform infrared spectroscopy
HA	-	Humic Acid
HS	-	Humic substances
KWB	-	Kuching Water Board
MLD	-	Total demand
MOH	-	Ministry of Health
MP-P	-	Monopolar-parallel
MP-S	-	Monopolar-series
SFS	-	Synchronous fluorescence spectroscopy
SS	-	Suspended solid
SWB	-	Sibu Water Board
TS	-	Total Solid
TOC	-	Total organic carbon
UV	-	Ultra-violet
UV-VIS	-	Ultra-violet visible
WHO	-	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Domestic Water

Domestic water is the water used for both indoor and outdoor household purposes. There are wide range of domestic water usage from food preparation, personal hygiene and household cleaning (Justes, Barberán, & Farizod, 2013). The percentage of consumption of water for several household appliances is shown in **Figure 1.1**. Common household appliances such as toilet, shower, faucet and clothes washer. Water consumed at the toilet is the most alongside with water used for shower. Domestic water is also used for cooking, cleaning and other necessity.

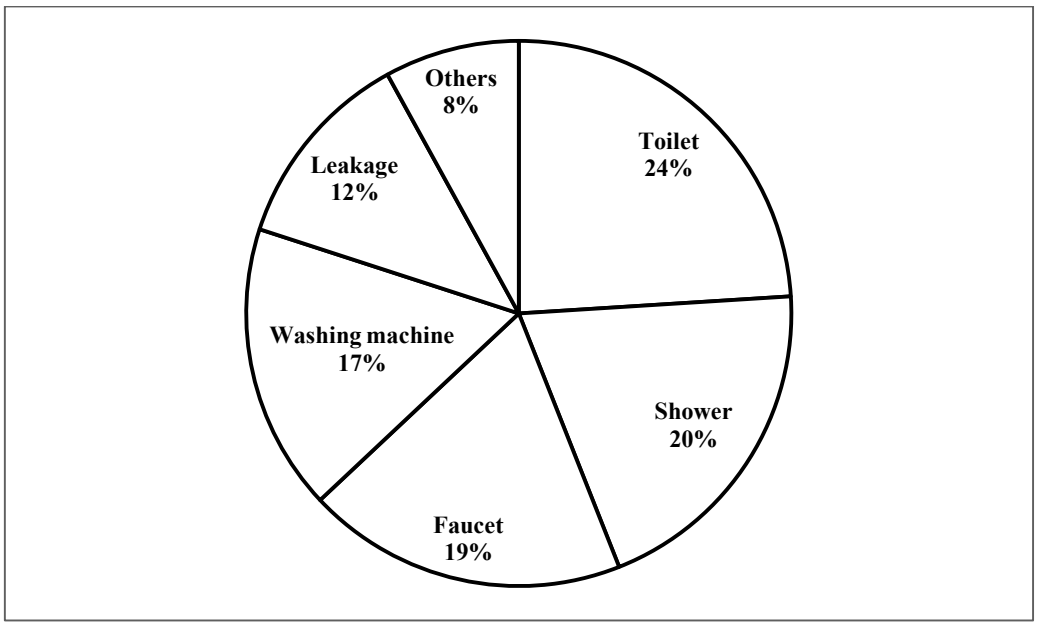

Figure 1.1: Household water consumption (United States Environmental Protection Agency, 2016)

Sources of domestic water are dependable on location of household where households in the urban area are supplied with clean water by the water board. As for households located in the rural area, the supply of clean water might be a challenge in some areas. Domestic water is usually obtained from utilization of rainwater, rivers and even underground water springs for the rural area households. The demand of domestic water is dependent on the population, cost of water and climate.

1.2 Peat Water

Peat water can be associated with water or moisture produced from peat land or peat soil. Peat soil is defined as highly organic soil with the heterogeneous mixture of partially decomposed plant remains, with some content of sand silt and clay under damp and anaerobic condition (Sa'don, Abdul Karim, Jaol, & Wan Lili, 2015). There is no specific implication of usage of peat water however rural areas community utilize peat water as domestic water due to its availability. Malaysia has approximately 2.6 Mha of peatland and Sarawak consist of over 70% of the total peatland in Malaysia (Melling, 2016). Sarawak peat soil 17Mha is about 13% of the total land. The tropical peatland is unique where both rainforest and peatland ecosystem co-exist. **Figure 1.2** shows the distribution of peat land in Sarawak and **Table 1.1** shows the approximation of the area of peat land for each division.

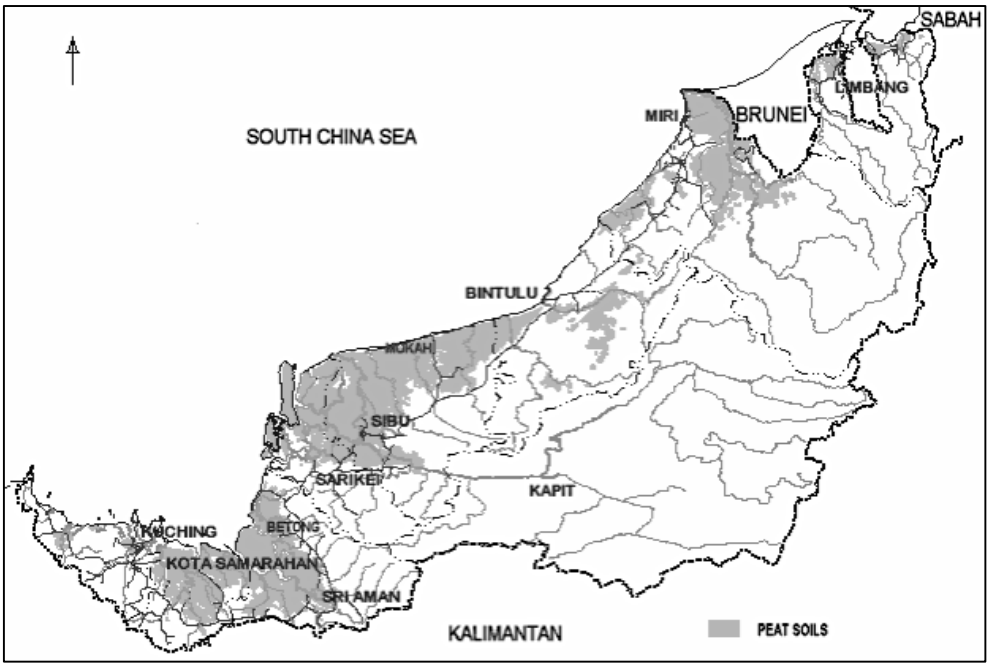

Figure 1.2: Distribution of peat in Sarawak (Department of Irigation and Drainage, 2017)

Table 1.1: Distribution of peat in Sarawak (Sa'don et al., 2015)

Division	Area (ha.)
Kuching	23 059
Kota Samarahan	192 775
Sri Aman	283 076
Sibu	540 800
Sarikei	169 900
Bintulu	146 121
Miri	276 579
Limbang	25 300
Total	**1 657 600**

Peat water can be distinctly different to other type of water for its dark brown orange colour as shown in **Figure 1.3**. The colour is associated to the humic substances present in the water which contributed to its acidic nature. Humic substances are known to be present in significant amount in the aquatic and soil environment of peat swamps (Mohamed, Padmanabhan, Mei, & Siong, 2002).

Figure 1.3: Peat water

1.3 Humic Acid

Humic acid (HA) is one of the humic substances (HS). Humic substances are chemical constituents which consist of aromatic and aliphatic structures, carboxylic, phenolic-OH, amino and quinone groups (Sakarinen, 2016). Generally, humic and fulvic acids are the final break-down constituents of the natural decay of plant and animal materials. The differences between humic and fulvic acid is that humic acid is insoluble in water whereas fulvic acid is soluble in water. The acids can be classified as organic acids and is naturally found in soils, peats, oceans and even fresh waters. Humic

substances are composed primarily of carbon, oxygen, hydrogen, nitrogen, and sulfur in complex carbon chains and carbon rings (Pettit, 2014). One of the chemical characteristics of humic substances is that it can easily react with chlorine and form carcinogenic and hazardous disinfection by-products (DBPs) such as trihalomethanes and haloacetic acids (Sakarinen, 2016). The consumption of disinfection by-products may lead to depletion of human health.

1.4 Water Treatment

Water treatment can be divided into several categories which are chemical, biological and physical treatment. Chemical treatment processes use chemicals in an array of processes to treat water. Example of common chemical treatment processes are coagulation, precipitation, ion exchange and more. In contrast with chemical processes, biological treatment utilizes wide range of microorganism and bacteria in treating water. Activated sludge process is one of the common biological treatment. As for physical treatments, the common physical treatment available are filtration, membrane and electrocoagulation. The electrocoagulation process is an electrochemical means of introducing coagulants and removing suspended solids, colloidal material, and metals, as well as other dissolved solids from water and wastewaters (Garcia-Segura, Eiband, de Melo, & Martínez-Huitle, 2017).

Electrocoagulation which is characterized by in-situ generation of coagulant and hydroxide flocs with high absorption ability is an environmental-friendly process for treating wastewater with heavy metal ions and toxic organics (Lu, Wang, Ma, Tang, & Li, 2017). Aluminium or iron is usually used as electrodes and their cations are generated by dissolution of sacrificial anodes upon the application of a direct current (Tezcan Un, Koparal, & Bakir Ogutveren, 2009). Several reactions occurred during electrocoagulation from the anode, cathode and the solution as shown in the **Equation (1.1), Equation (1.2)** and **Equation (1.3)**.

$$Al \rightarrow Al^{3+}_{(aq)} + 3e^- \tag{1.1}$$

$$3H_2O + 3e^- \rightarrow \frac{3}{2}H_{2(g)} + OH^- \tag{1.2}$$

$$Al^{3+}_{(aq)} + 3H_2O \rightarrow Al(OH)_3 + 3H^+ \tag{1.3}$$

The electrocoagulation technique is widely used in treating wastewaters. As compared to conventional methods, there are several advantages of electrocoagulation such as simple operations, less retention time, rapid sedimentation of the electro-generated flocs and less sludge production (Tezcan Un et al., 2009). According to Butler, Hung, Yeh, and Ahmad (2011), it is an alternative method to classic chemical coagulation for many reasons in which the electrocoagulation system capable of reducing the need for chemicals due to the fact that the electrodes provide the coagulant. Other than that, electrocoagulation process is an environmentally friendly process. Another advantage of the electrocoagulation process is that it is an easy process unlike other conventional methods. Electrocoagulation technique had been applied for several types of treatment of wastewater containing heavy metals, wastewater from tannery and textile industry, food industry, paper industry, refinery industry and even produced water.

1.5 Research Problems

The main concern is on the rural area domestic water problem where there is shortage of water supplies for the households. About 39% of the rural areas household which represent about 114000 households in Sarawak are yet to receive water supply coverage (Ogilvy, 2017). The existing raw water source for Simunjan is Sungai Lepong but during the dry season, the supply is not sufficient. Hence, the water treatment plant in Simunjan could not produce enough treated water supply for its population (Jabatan Bekalan Air Luar Bandar, 2017). The shortage of water is due to the high cost of implementation of water supply for rural area where the population are distributed with unpredictable pattern or randomly distributed. The ageing reticulation system in rural coastal areas which has become inadequate due to the increased in demand, also contributed to the low water supply in many rural and coastal areas (Ogilvy, 2017).

There are several problems associated with peat water. Colour is one of the main concern where the colour of peat water is quite distinct and unpleasant. Then, the acidic content of peat water which then lead to the sour taste of the water. The acidity of peat water is due to the presence of humic substances mainly humic acid, fulvic acid and humin. The consumption of humic substances may lead to dizziness and headaches. Thus, it is not advisable for peat water to be utilized as domestic water without proper treatment. Treatment of peat water by using conventional treatment system is not possible due to the formation of strong toxic during the chlorination stage (Sakarinen, 2016). Chlorination

stage is one of the stages in conventional treatment system. Thus, a proper treatment process is required to remove or reduce the amount of humic acid in peat water.

The best solution for this problem is to implement stand-alone water treatment system. The treatment system designed must be cost effective and able to treat the water effectively. However, stand-alone water treatment system has its own disadvantage especially for the fabrication process. Thus, a cheap and easy fabrication of water treatment system is in need for purification of domestic water for rural area. Electrocoagulation is one of the answer to the problem where it is proven effective in removal of specific pollutants (Moussa, El-Naas, Nasser, & Al-Marri, 2017).

1.6 Scopes of Study

The focus is on the treatment of peat water in the rural coastal area of Sarawak. The model for electrocoagulation treatment system is built with materials and technology available locally. In addition, the fabrication and maintenance processes must be simple and easy

1.7 Aim and Objectives

The main aim of this study is to develop an electrocoagulation process for treatment of peat water of rural coastal region of Sarawak with Aluminium electrodes. In order to achieve the aim of study, several objectives are taken which are:

i. **To study on the electrocoagulation treatment system in treating peat water.**

   Literature review is done on the suitability of electrocoagulation as treatment system for peat water of Sarawak. There are several parameters of removal which are taken into consideration such as COD, TOC, turbidity and colour of peat water. Thus, studies on the effectiveness of removal of several parameters by electrocoagulation and on the factors affecting the electrocoagulation treatment process is conducted.

ii. **To develop a desktop scale electrocoagulation treatment system with Aluminium electrodes.**

Desktop scale electrocoagulation treatment system is built with the purpose of treating peat water of coastal area of Sarawak. The electrocoagulation system built is based on the criteria or scopes set.

iii. **To obtained optimized parameter for number of plate, current density and treatment time of electrocoagulation process.**

Experimental studies are done on different electrode configuration, current density and treatment time. The most optimized parameter is concluded based on the most efficient in removal of COD, turbidity, colour and TOC.

iv. **To conduct economic analysis on the electrocoagulation treatment system.**

The rough estimated cost of electrocoagulation treatment system is obtained based on the amount of power used alongside with the material used during electrocoagulation treatment process.

1.8 Methodology

Methodology consist of several processes or steps that must be taken throughout the research study. The processes and steps taken are based on the aim and objectives of the research study. The sequence of the processes or steps for this study is shown in **Figure 1.4**. The methodology starts off with literature review, study visit and sampling, sample analysis, design and fabrication process, experimental studies and analysis of data. Aside that, Gantt chart is developed to keep track on the task and activities related to the aim and objectives of study. Gantt chart is also used to ensure that the objectives of study can be achieved within the time frame set. The Gantt chart of study is shown in **Appendix A**.

i. Literature review

The first step is literature review where literature review consists of studies of peat water and electrocoagulation system in purification of water. Other than that, information regarding problems of rural areas domestic water supply are