Faculty of Engineering

KINETIC STUDY & STATISTICAL MODELLING OF SARAWAK PEAT WATER ELECTROCOAGULATION SYSTEM

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Bachelor of Engineering with Honours

(Chemical Engineering)

2019

UNIVERSITI MALAYSIA SARAWAK

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Final Year Project Report	√
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This final year report which entitled **Kinectic Study & Statistical Modelling of Sarawak Peat Water Electrocoagulation System** was prepared by Nurhidayah Kumar binti Muhammad Firdaus Kumar (50839) as a partial fulfillment for the Degree of Bachelor of Chemical Engineering is hereby read and approved by:

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DR NAZERI ABDUL RAHMAN

(Supervisor)

6th May 2019

Date

KINECTIC STUDY & STATISTICAL MODELLING OF SARAWAK PEAT WATER ELECTROCOAGULATION SYSTEM

NURHIDAYAH KUMAR BINTI MUHAMMAD FIRDAUS KUMAR

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

2019

To my dearest Ibu and Abah,

For all their love and prayers that have always nourished and sustained me

ACKNOWLEDGEMENT

In the Name of Allah, the Most Beneficent and the Most Merciful. First and foremost, all praises and thanks is to Allah the Almighty for bestowing the author opportunity, determination, and strength to do this project. The author wishes to express her profound sense of gratitude to the Department of Chemical Engineering and Energy Sustainability, Faculty of Engineering. A sincere phrase of thanks are dedicated to Dr. Nazeri Abdul Rahman for his guidance, advice, and encouragement throughout the whole journey of this Final Year Project. Deepest appreciations are dedicated to all individuals and organizations that have contributed and cooperated in completing the project. Warm regards and thanks to the workshop and laboratory technicians of Department of Chemical Engineering and Energy Sustainability for all the valuable assistance and suggestions shared when conducting the experiments. Last but not least, the author would love to express her appreciation to her beloved parents, family and friends for their endless supports and motivations. This project would not have been possible to complete without their continuous support.

ABSTRAK

Penduduk di kawasan pedalaman di Sarawak terpaksa menggunakan air gambut sebagai kegunaan harian kerana bekalan air tidak mencukupi. Penggunaan air gambut yang tidak dirawat boleh membawa kepada pelbagai penyakit air seperti cirit-birit, dan penyakit serius lain seperti kepialu dan disentri. Oleh itu, sistem rawatan air seperti sistem elektrokoagulasi dapat dibangunkan untuk meningkatkan mutu air gambut supaya dapat digunapakai oleh penduduk di pedalaman. Sistem elektrokoagulasi dipilih kerana tidak ada penggunaan koagulan kimia, hanya memerlukan peralatan yang dapat dioperasikan dengan mudah, dan kos yang efektif. Tujuan utama kajian ini adalah untuk membangunkan kajian kinetik dan model statistik untuk proses electrokoagulasi rawatan air gambut di Sarawak. Fokus kajian ini adalah kepada rawatan air gambut menggunakan sistem electrokoagulasi. Sistem electrokoagulasi direka mengikut beberapa kriteria iaitu teknologi untuk pembinaan dan bahan yang digunakan untuk membina sistem electrokoagulasi mudah diperoleh, pembuatan yang mudah serta kos rendah untuk pembinaan dan operasi. Untuk kajian ini, Response Surface Methodology *dalam perisian* Minitab *dan* Microsoft Excel *digunakan untuk kajian kinetik, model statistik, dan pengoptimuman proses. Pengoptimuman proses dijalankan untuk meminimumkan penggunaan tenaga dan kekeruhan air gambut. Keadaan optimum bagi sistem elektrokoagulasi kelompok adalah 14.899* A/m^2 *dan 41.818 minit dan sistem elektrokoagulasi terus adalah pada 3.861* A/m^2 *dan 37.778 minit.*

Kata Kunci: *Air Gambut, Electrokoagulasi, Kajian Kinetik, Model Statistik, Pengoptimuman Proses*

ABSTRACT

Due to insufficient water supply, the residents of Sarawak rural area are forced to use peat water as daily use of domestic water. The consumption of untreated peat water can lead to various waterborne diseases such as diarrhea, and other serious illnesses such as typhoid and dysentery. Water treatment system such as electrocoagulation system can be developed to improve the water quality of the peat water as electrocoagulation requires simple equipment that can be operated easily, no usage of chemicals coagulant, producing less sludge and cost-effective treatment system. The main aim for this study is to develop a kinetic study and statistical modelling for electrocoagulation process of peat water treatment in Sarawak. This study focuses on the peat water treatment using electrocoagulation system. The fabricated electrocoagulation system is designed according to the characteristics in which the technology for building and the material used for constructing the electrocoagulation system should be available locally, the electrocoagulation system should be easy to fabricate and maintain, as well as low cost for construction and operation. For this study, Response Surface Methodology in Minitab software and Microsoft Excel are used for kinetic studies, statistical modelling, and process optimization. Process optimization is carried out to minimize energy consumption as well as the turbidity and TSS level. The optimum condition for batch and continuos electrocoagulation system are 14.899 A/m^2 and 41.818 min, and 3.861 A/m^2 and 37.778 min respectively.

Keywords: Peat Water, Electrocoagulation, Kinetic Study, Statistical Modelling, Process Optimization

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LIST OF ABBREVIATION

AC	-	Alternating Current
ANN	-	Artificial Network Approach
ANOVA	-	Analysis of Variance
BBD	-	Box-Behnken Design
BP-S	-	Bipolar-Series
CCD	-	Central Compoite Design
DC	-	Direct Current
MP-P	-	Monopolar-Parallel
MP-S	-	Monopolar-Series
RSM	-	Response Surface Methodology

LIST OF NOMENCLATURE

%	-	Percentage
A/cm^2	-	Ampere per Centimeter Square
C/ mol	-	Coulombs per Mole
g of M/cm^2	-	Gram of Metal per Centimeter Square
ha	-	Hectares
k	-	Rate Constant
km	-	Kilometer
mA/cm^2	-	Mili Ampere per Centimeter Square
Mha	-	Million Hectares
R^2	-	Correlation Coefficient of Langmuir Adsorption Isotherm

CHAPTER 1

INTRODUCTION

1.1 Domestic Water

Domestic water supply means the source and infrastructure that provides water to the households. In Malaysia, 97% of water resources are surface water meanwhile another 3% is groundwater (Abdullah, 2015). The source for domestic water can be from a stream, a spring, a rainwater collection system, a well, and a piped water supply with tap stand. Domestic water is used for the household daily purposes. Different sources of water may be used for different purposes and the availability of water sources are depending on the seasons. According to the Water & Energy Conservation Systems, the typical global usage of domestic water can be classified into five different classes as shown in **Figure 1.1**.

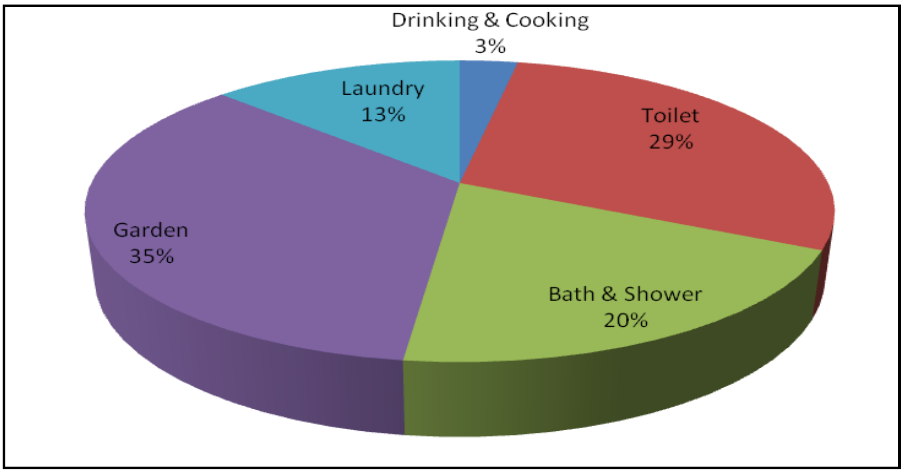

Figure 1.1: Typical Domestic Water Consumption (Ansie, 2011)

The usage of domestic water can be categorized into indoor usage and outdoor usage. For indoor household usage, water can be used for drinking, cooking, laundry, cleaning cooking utensils, food preparation, bathing, showering, and brushing teeth. Meanwhile, for outdoor household usage, water can be used for watering the yard and garden, washing cars, and others. Malaysia Kini reported, the average of water consumption by Malaysians is 212 litres per person daily and 30% of the water usage is for consumption while 70% is for utility usage.

1.2 Peat Water

Peats that are organic-rich, fibrous, pale-brown and black material is commonly identified due to the fertile organic deposits, plant residues, and hydrophytic vegetation. Peat can be defined as highly organic soil with the heterogeneous mixture of partially decomposed plant remains, with some contents of clay, sand, and silt under damp and anaerobic condition. According to Raghunandan and Sriraam (2017), throughout the world, peatlands are distributed in patches with approximately 2.4 million hectares deposits spanning in Malaysia including 1.65 million hectares in Sarawak and smaller areas in Peninsular Malaysia and Sabah. Sarawak peat land usually situated 2 to 4 km inward in the primal lowlands and along the coast where most of the lands are found in the central region of the State. Based on the investigation, the layer of the peat can be classified according to the Von Post classification system (Sa'don, Abdul Karim, Jaol, & Wan Lili, 2014). **Table 1.1** shows the differences of the peat layer.

Table 1.1: Classification of Peat Layer (Sa'don et al., 2014)

Peat Layer Name	Von Post Classification	Position of the Layer	Fibre Content
Sapric Peat	H7 – H10	Top layer with the thickness of 0.5m to 1.5m	Less than 33%
Hemic Peat	H4 – H6	Second layer, under the sapric peat	33% to 66%
Fibric Peat	H1 – H3	Bottom layer of the peat before the grey layer of mangrove clay	More than 66%

In Asia, especially in rural areas, peat water is an abundant water resource. Due to the physical and chemical characteristics, peat water is not suitable to be used as a commercial water supply. There is a need to treat the peat water before being consumed (Siti, Syafalni, & Nastaein, 2014).

1.3 Water Treatment

Water scarcity or commonly referred to as water shortage is currently one of the greatest challenges faced by the humankind due to the world's increasing population and the water consumption rates gradually increasing. In order to overcome the problem, cost-effective, easy maintenance, and environmentally friendly water treatment technology have to be developed so that the water from various sources can be used for domestic purposes. Water treatment technologies can be categorized into three groups namely physical process, chemical process, and biological process (Moussa, El-Naas, & Al-Marri, 2017). **Table 1.2** describes the difference between each process.

Table 1.2: Classification of Water Treatment Technologies (Moussa et al., 2017)

Types	Description
Physical	Depends on the physical separation such as filtration of pollutants from the water
Chemical	Requires addition of chemicals such as coagulants to remove contaminants and unwanted sediments
Biological	Uses microorganisms for biodegradation of contaminants

1.4 Electrocoagulation

Electrocoagulation is a developing technology in water treatment, as it combines the benefits of coagulation, flotation, and electrochemistry. Electrocoagulation is a method of water treatment that coagulates the contaminants in the water using electric current. The dissimilarity of conventional coagulation and electrocoagulation is the type of coagulants used. In conventional coagulation, metal salts act as coagulants while for electrocoagulation, the coagulants are generated in-situ by the electrocoagulation process (Liu, Xu, & Qu, 2010). A basic electrocoagulation system as shown in **Figure 1.2** consists of an anode electrode and cathode electrode that are connected to the current supply source. The electrocoagulation process mainly involves the simultaneous formation of hydroxyl ions and hydrogen gas at the cathode with the dissolution of metal cations from the reactor anode when current is passed through as described in **Equation 1.1** and **Equation 1.2** (Işık Kabdaşlı, Arslan, Ölmez-Hancı, Arslan-Alaton, & Tünay, 2009):

$$2H_2O_{(l)} \rightarrow OH^- + H_{2(g)} \quad (1.1)$$

$$M = M^+ + ne^- \quad (1.2)$$

Where;

M	=	Metal electrode
M^+	=	Metal ion
ne	=	Number of electrons loss
$H_2O_{(l)}$	=	Electrolyte
OH^-	=	Hydroxyl ion
$H_{2(g)}$	=	Hydrogen gas

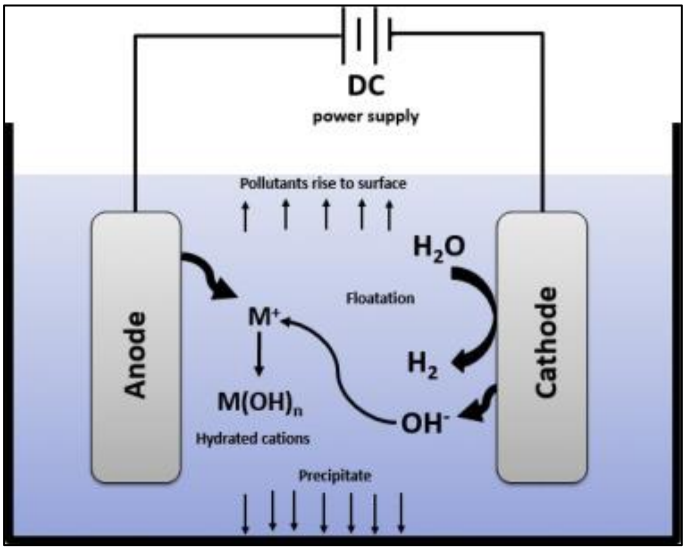

Figure 1.2: Main Reaction of Electrocoagulation (Moussa, 2017)

During the electrocoagulation process, the charged metal ions are removed from the water by allowing it to react with an ion of opposite charge or with generated metallic hydroxides floc. The system is able to remove metals, colloidal solids and particles, and soluble inorganic pollutants from aqueous media by increasing the charge of polymeric metal hydroxide species. From the aqueous phase, these species neutralize the electrostatic charges on suspended solids and oil droplets to enable the coagulation and filtration process (Mollah, Schennach, Parga, & Cocke, 2001).

1.5 Process Optimization

Optimization includes the field of science, engineering as well as business. Most problems in chemical engineering have many possible solutions. In orders to obtain the optimal solution, the optimization stage of the engineering design is a systematic process using design constraints and parameters (Kelley, 2010). Hence, optimization is to choose the best parameter among the entire set by efficient quantitative methods using computers and associated software that is cost-effective. Optimization is carried out to improve the process performance, reduce the cost and energy usage, and maximize the efficiency of the system (Edgar, Klein, & Glandt, 2001). In order to maximize the efficiency of the electrocoagulation system, several parameters have to be studied and understand. The parameters include the current density, electrode arrangement, initial pH of the solution, and reaction time (Khorram & Fallah, 2018; Ozay et al., 2018).

1.6 Research Problem

Electrocoagulation is a complex process that involves many chemical and physical phenomena using consumable electrodes for supplying ions into the water stream (Mollah et al., 2004). Electrocoagulation modelling is suggestively helpful to enhance the design and lessen both equipment and operating costs. Electrocoagulation modelling can predict the process performance in a wide range of operational conditions. In most studies of electrocoagulation water treatment, the optimization process has been conducted by manipulating one parameter while other parameters are kept constant at a specific condition (Abuzaid, Bukhari, & Al-Hamouz, 2002; Koparal & Ogutveren, 2002; Kumar, Chaudhari, Khilar, & Mahajan, 2004). This common practice of optimization for electrocoagulation process requires numerous experimental runs and sets of data. Due to disregarding the interactions among the parameters, poor optimization of the process can be realized such as underestimation and overestimation on the effect of the electrocoagulation process parameters performances (Hakizimana et al., 2017).

In Sarawak, 13% of its total land area is covered with peat which is commonly referred as peatland. Among the division of Sarawak's district, Sibu division has the most peatlands which cover 70% of the division follows by Sri Aman and Miri with 283,076 hectares and 276,579 hectares respectively (Sa'don et al., 2014). Due to insufficient water supply, the residents of the rural area are forced to use peat water as daily use of domestic water. The main concern of the peat water consumption is that the acidic content of the peat water cause the sour taste of the water. Furthermore, the color of the peat water also distinct and unpleasant. The consumption of untreated peat water can lead to various waterborne diseases such as diarrhea, and other serious illnesses such as typhoid and dysentery. Water treatment system such as electrocoagulation system can be developed to improve the water quality of the peat water. In addition, optimization of the treatment process should be carried out by focusing on the process performances of the system. An optimization tool can be used to optimize conditions for desirable responses in order to maximize the efficiency of the electrocoagulation system.

1.7 Aim, Scope, and Objectives of Study

The main aim for this study is to develop a kinetic study and statistical modelling for electrocoagulation process of peat water treatment in Sarawak. This study focuses on the peat water treatment using electrocoagulation system. Electrocoagulation treatment is an alternative to the conventional method of treating different types of water. Electrocoagulation requires simple equipment that can be operated easily, no usage of chemicals coagulant, producing less sludge and cost-effective treatment system (Khorram & Fallah, 2018). Different types of the electrode may give different outcomes.

The main goal of the study is to treat the peat water so that the residents in Sarawak rural area can have a clean water supply. In order to achieve the aim of the study, some objectives have been set. The objectives of this project are as follows:

i. **To design & fabricate electrocoagulation system using aluminium and copper electrodes for domestic utilization in Sarawak.**

   Small-scale batch and continuous electrocoagulation systems are designed for peat water treatment in Sarawak. The electrocoagulation system technology and