Faculty of Engineering

KINETIC STUDY AND STATISTICAL MODELLING OF SARAWAK PEAT WATER CONTINUOUS ELECTROCOAGULATION TREATMENT PROCESS BY USING ALUMINIUM ELECTRODES

ONG CHENG EE

Bachelor of Engineering with Honours
(Chemical Engineering)
2017/2018

UNIVERSITI MALAYSIA SARAWAK

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KINETIC STUDY AND STATISTICAL MODELLING OF SARAWAK PEAT WATER CONTINUOUS ELECTROCOAGULATION TREATMENT PROCESS USING ALUMIMIUN ELECTRODES

ONG CHENG EE

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

Faculty of Engineering
Universiti Malaysia Sarawak

2017/2018

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

ACKNOWLEDGEMENT

First and foremost, the author would like to express his gratitude to the Department of Chemical Engineering and Energy Sustainability, Faculty of Engineering, Universiti Malaysia Sarawak for giving the opportunity to the author for conducting the study. In addition, the author is highly indebted to the final year project supervisor, Dr. Nazeri Abdul Rahman for his professional guidance on the study, knowledge and experience sharing as well as advices and recommendations to improve the project. Special acknowledgement is also delivered to all the individuals and organizations for kind cooperated and contributed throughout the study. Besides, the author would like to express thanks to the chemical workshop and laboratory technicians of Department of Chemical Engineering and Energy Sustainability for their assistance and suggestions when conducting the experiments. Last but not least, deepest appreciation is dedicated to the author's beloved family members, partner as well as friends for their endless support, encouragement and motivation throughout the completion of the report.

ABSTRACT

In this globalization era, human population is growing drastically. Corresponding to the population growth, the demand for water is increasing and lead to the insufficient of water supply issues in Malaysia especially at the Sarawak isolated coastal area. For domestic usage purpose, the local residents have to rely on natural water resources such as rainwater and peat water. Consuming of peat water is harmful to human health as it contained humic substance, which affects the thyroid gland, Blackfoot disease (BFD) and others. Hence, peat water has to be treated before consumption in order to reach the allowable quality for domestic usage. The main aim of this study is to design an electrocoagulation process model using Aluminium electrode for the treatment of peat water in Sarawak. The function of the electrocoagulation system is to eliminate the turbidity and COD level in peat water by using pairs of Aluminium sacrificial electrodes which connected to a direct current power supply. The system is designed as a continuous flow reactor which operated together with equipments such as pump, filter, and magnetic stirrer. The dimension of the system is 100 cm x 15 cm x 25 cm. For this project, Microsoft Excel and Design Expert (RSM) software is used for kinetic studies, modelling and optimization function. Results of kinetic study indicated that the reaction rate constant for turbidity and COD removal at 5A current supplied is 0.0853 and 0.3841 min^{-1} respectively. The statistical modelling equation for both turbidity and COD removal efficiency is developed. Comparison between statistical modelling results and experimental results shows that the maximum deviation is approximately 19.27 % and 19.74% for turbidity and COD removal efficiency. The equation is verified and able to be used for scale-up function.

Keywords: Peat Water, Humic Acid, Electrocoagulation, Statistical Modelling, Optimization

ABSTRAK

Dalam era globalisasi ini, populasi manusia berkembang secara drastic. Sejajar dengan pertumbuhan penduduk, keperluan air semakin meningkat dan membawa kepada isu kekurangan bekalan air yang berlaku di Malaysia, terutamanya di kawasan kampung pedalaman. Untuk tujuan penggunaan domestic, penduduk terpaksa bergantung kepada sumber air semula jadi seperti air hujan dan air gambut. Penggunaan air gambut adalah tidak sesuai dan berbahaya kepada manusia disebabkan oleh kandungan bahan humik. Bahan humik akan mempengaruhi kelenjar tiroid, menyebabkan penyakit Blackfoot (BFD) dan lain-lain. Oleh itu, air gambut perlu dirawati untuk mencapai kualiti yang dibenarkan untuk penggunaan domestik. Tujuan utama kajian ini adalah untuk merekabentuk model proses elektrokoagulasi menggunakan elektrod Aluminium untuk rawatan air gambut di Sarawak. Fungsi elektrokoagulasi adalah untuk menghilangkan kekeruhan dan COD air gambut dengan menggunakan pasangan elektrod Aluminium yang bersambungan dengan bekalan kuasa arus langsung. System ini direkabentuk sebagai reaktor aliran berterusan yang beroperasi selaras dengan beberapa operasi unit seperti pam, penapis dan stirrer megnetik. Dimensi untuk system elektrokoagulasi ialah 100 cm x 15 cm x 25 cm. Untuk kajian in, perisian Microsoft Excel and Design Expert (RSM) digunakan untuk pembelajaran kinetik, pemodelan dan proses pengoptimuman. Hasil kajian kinetik menunjukkan bahawa kadar tindak balas untuk kecekapan penyingkiran kekeruhan dan COD pada arus 5A adalah 0.0853 and 0.3841 min^{-1}. Persamaan pemodelan statistik untuk kecekapan penyingkiran kekeruhan dan COD dihasilkan. Perbandingan antara hasil pemodelan statistik dan keputusan eksperimen menunjukkan bahawa sisihan maksimum adalah lebih kurang 19.27% dan 19.74% untuk kecekapan penyingkiran kekeruhan dan COD. Persamaan telah disahkan dan dapat digunakan untuk fungsi skala.

Kata Kunci: Air Gambut, Asid Humik, Elektrokoagulasi, Pemodelan Statistik, Pengoptimuman

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ABBREVIATION

AAS	-	Atomic Absorption Spectrometry
AC	-	Alternating Current
ANOVA	-	Analysis of Varience
A/V	-	Area per Volume Ratio
BBD	-	Box-Behnken Design
BOD	-	Biochemical Oxygen Demand
BP-S	-	Bipolar-Series
CCD	-	Central Composite Design
COD	-	Chemical Oxygen Demand
DC	-	Direct Current
DOC	-	Dissolved Oxygen Demand
I/V	-	Current per Volume Ratio
MP-P	-	Monopolar-Parallel
MP-S	-	Monopolar-Series
RSM	-	Response Surface Methodology
VOK	-	Variable-order-kinetic Model

NOMENCLATURE

A	-	Ampere
Adm^{-2}	-	Ampere per decimetre square
A/m^2	-	Ampere per meter square
Cm	-	Centimetre
°C	-	Degree Celsius
g Al/cm^{-2}	-	Gram of Aluminium per centimetre square
g/m^3	-	Gram per meter cube
g/mol	-	Gram per mole
kg/m^3	-	Kilogram per meter cube
M	-	Meter
m^2	-	Meter square
m^2/m^3	-	Meter square per meter cube
Min	-	Minutes
mg/g	-	Milli gram per gram
mg/L	-	Milli gram per liter
Mm	-	Milli meter
mV	-	Milli volt
NTU	-	Nephelometric Turbidity Unit
%	-	Percent
Ppm	-	Part per Million
RM	-	Ringgit Malaysia

CHAPTER 1

INTRODUCTION

1.1 General View on Domestic Water

Domestic water is commonly recognized as the household water that used for daily life activities. In Malaysia, 97% of the water resources are from the surface water while the other 3% is from the groundwater. The usage of domestic water can be classified into indoor usage and outdoor usage. For indoor household purposes, water can use for drinking, bathing, washing dishes, laundry, cooking, etc. While for outdoor purposes, water can be used for watering plants and garden, cleaning drain and others. In 2014, statistic showed that on average, 212 liters of water was consumed by Malaysians per day. Based on the research, 30% of the water is for consumption while 70% is for utility usage (Water and Energy Consumer Association of Malaysia, 2017). According to the data collected by East Larimer Country Water District (2017), the water consumption of household water can be classified into eight main classes. **Figure 1.1** shows the typical household water used in the residential area.

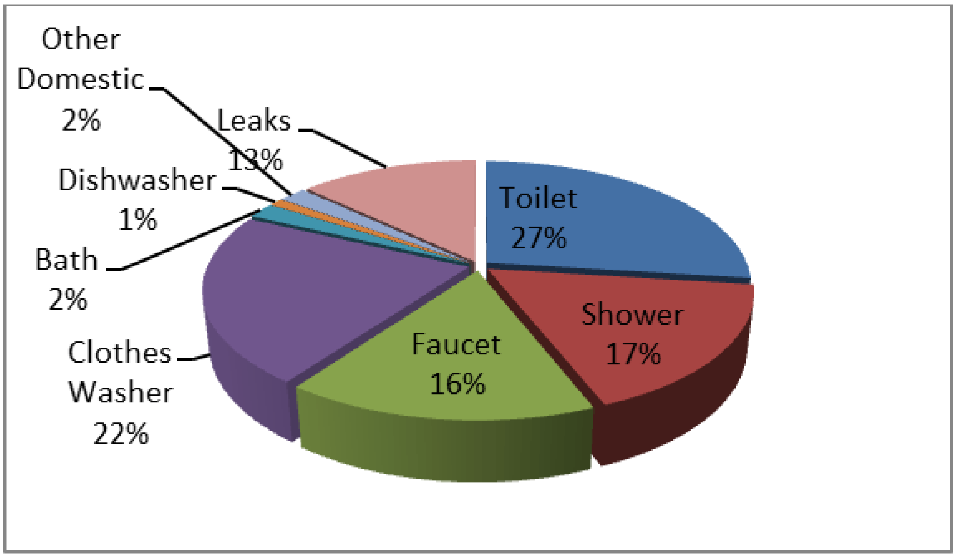

Figure 1.1: Typical Household Water Use (East Larimer Country Water District, 2017).

According to Auden (2017), an English-American poet, thousands have lived without love, not one without water. This quote had clearly interpreted the importance of having clean water in our daily life. Clean consumable water playing an important role for human being as it is the basic requirement for them to survive. Besides, 60% of the ordinary human body is water. Clean water content in the body regulate the blood circulation, promote sweating, produce saliva and others (United States Geological Survey, 2016).

1.2 Peat Water

Peat or known as turf is the organic soil which is accumulated with the heterogeneous mixture of partly decomposed vegetable matter or plant. Under water-saturated environment and anaerobic condition, peat can be formed when vegetative material does not fully decay (International Peatland Society, 2017). The content of peat is organic matter, sand, fibre, clay, humic substance and silt. According to research, peat layer is scattered around Malaysia especially East Malaysia area and about 13% of the total land area in Sarawak is covered by peatland. Generally, peat can be categorized into three layers based on the Von Post classification system. The system differentiates the peat layer based on the position of peat layer as well as the fibre percent (Sa'don, Karim, Jaol, & Lili, 2015). **Table 1.1** shows the classification of peat layer.

Table 1.1: Classification of Peat Layer (Sa'don et al., 2015)

Peat Layer Name	Von Post Classification	Position of Layer	Fibre Content
Sapric Peat	H7-H10	0.5 m to 1.5 m of the top layer	< 33%
Hemic Peat	H4-H6	Second layer. Below Sapric layer.	33% to 66%
Fibric Peat	H1-H3	Last layer which near to the bottom of peat layer	> 66%

Peat water is one of the water resources in Asia. Due to the characteristic, peat water is not suitable to be consumed. The formation of peat water is through the mixing of peat in the water source. It is usually in brown colour and acidic. Peat water is not suitable for drinking is due to five main parameters, which are the COD, pH value, turbidity, colour and iron content. All of these five parameters exceeded the limit for the drinking water quality standard (Siti, Syafalni, & Nastaein, 2014). **Figure 1.2** represents the view of peat water.

Figure 1.2: Peat Water

1.3 Humic Acid

According to Steelink (1963), humic acid is the main organic component of coal, soil (humus), and peat as well as streams, river and ocean water. The most common method for the formation of humic acid is by the biodegradation of plant matter. Through the rainfall runoff from nearby soil, humic acid enters the water resources. Humic acids are usually in dark brown or grey black colour, 4 – 6 pH value and 0.08 kg/m^3 of specific gravity. It is soluble in alkali solution but insoluble in alcohol and acidic water. For chemical properties, humic acid contained carbon, oxygen, hydrogen and 4% of nitrogen. The microbial decay rate of humic acid is up to 0.3% per year (Kussow, 2002).

In medical field, humic acid is very useful in boosting the immune system of human body. Suitable quantity of humic acid can be consumed as vitamin to strengthen the immune of illness such as flu and viral infection (WebMD, 2017). One of the main factor where peat water cannot be drank is due to the humic acid content. The higher the concentration of humic acid, the darker the water colour. The main problem of humic acid content in the drinking water resources is the unwanted water taste and colour. During disinfection process, humic acid is able to react with the chemicals and produced toxic substances such as dihaloacetonitriles, which is a carcinogenic product (Kim et al., 2016).

1.4 Water Treatment

In this globalisation era, water shortage is one of the main challenge faced by the humankind due to the increase in the human's population growth rate as well as the water consumption rate. In order to overcome this problem, environmental friendly, economic effective and high efficiency wastewater treatment system has to be developed to treat the available water resources such as groundwater and surface water so that the water can be used for domestic purposes. In general, there are three main types of water treatment technologies, which are chemical process, biological process and physical process (Moussa, El-Naas, Nasser, & Al-Marri, 2017). **Table 1.2** shows the description of each process.

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

Types	Description	Processes
Chemical	Additional of chemicals are required to react with the targeted pollutants in order to purify the water.	Ion Exchange, Coagulation
Biological	Mainly remove the organic content and nutrients in wastewater by utilizing the microorganisms for contaminants degradation.	Activated Sludge, Trickling Filters
Physical	Rely solely on physical techniques such as screening and filtering. Does not involved additional of chemicals.	Membrane Filtration, Electrocoagulation

1.5 Electrocoagulation

Electrocoagulation is one of the famous wastewater treatment method which coagulates the impurities particles and ions by using electric current. The operating concept for electrocoagulation is based on coagulation, flotation and electrochemistry. By comparing to chemical coagulation, electrocoagulation is more environmental friendly as this process does not required the addition of chemicals into the water. However, the capital cost and electricity cost of the operation of electrocoagulation system are found to be impractically high (Moussa et al., 2017).

A basic electrocoagulation system consists of an anode electrode and cathode electrode connected with a current supply source. The function of this system is to destabilize the repulsive force which causes the particles and impurities to be suspended in the solution. When electric current is connected, the anode electrode will oxidized to release metal ion while the cathode electrode will react with water to form hydroxide ion and hydrogen gas (Un, Savas, & Ogutveren, 2009). **Equation (1.1) and (1.2)** are the reaction for the electrocoagulation at anode and cathode.

At Anode: $$Al \rightarrow Al^{3+} + 3e^{-} \quad \textbf{(1.1)}$$

At Cathode: $$3H_2O + 3e^{-} \rightarrow \frac{3}{2}H_2 + OH^{-} \quad \textbf{(1.2)}$$

In order to maximize the efficiency of the system, there are several parameters which have to be studied and understand. The parameters are the current density electrode arrangement, initial pH of solution, type of power supply and others (Moussa et al., 2017). **Figure 1.3** displayed a basic ion transfer in electrocoagulation system.

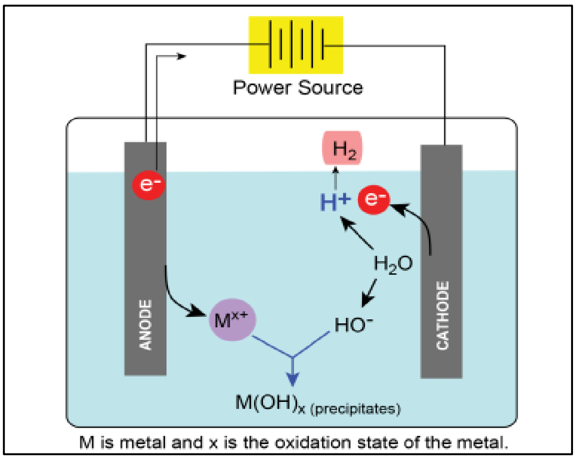

Figure 1.3: Electrocoagulation (Hoganas, 2017)

1.6 Research Problem

As one of the major state in East Malaysia, Sarawak is facing a significant crisis where there is insufficient or even no coverage of clean water supply to the isolated rural area. According to the Utilities Minister Datuk Seri Dr Stephen Rundi Utom, the coverage of water supply in rural area is less than 61% and there are around 114,000 households do not received the water supply. Besides, a huge amount of approximately RM10 billion is required for the implementation of water supply programme for isolated rural area in Sarawak (Ogilvy, 18 August 2017). According to Datuk Amar Awang Tengah Ali Hassan, Deputy Chief Minister of Sarawak, the shortage of water supply is due to several factors. For example, the rapid increment of Sarawak population, the lack of reservoir tank as well as the sparse distribution of residents' population in Sarawak which limit the pipeline coverage for water supply (Devindran, 2010). The design of water treatment