Faculty of Engineering

BATCH ELECTROCOAGULATION TREATMENT OF SUNGAI KUAP IN RELATION TO SAMA JAYA FREE INDUSTRIAL ZONE, KUCHING, SARAWAK.

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Bachelor of Engineering with Honours

Chemical Engineering

2022

UNIVERISITI MALAYSIA SARAWAK

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(Supervisor)	

WAN WAFI SHAHANNEY BIN WAN BORHAN

A dissertation submitted in partial fulfilment
of the requirement for the degree of

Faculty of Engineering

Universiti Malaysia Sarawak

2022

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

ACKNOWLEDGEMENT

The author wishes to thank all individual, parties, and organizations that have contributed and cooperated throughout this Final Year Project especially the Department of Chemical Engineering, Faculty of Engineering, Universiti Malaysia Sarawak for this invaluable opportunity to conduct the study. Special thanks are dedicated to Dr. Nazeri Abdul Rahman for his willingness to share his knowledge and experience, as well as the invaluable supervision towards the completion of this final year project. The author also would like to express her appreciation and gratitude toward her beloved family for the support and motivation throughout the project. Lastly, the author would like to thank also the technicians from the Department of Chemical Engineering as well as the senior Ms. Allene Albanius Linus and Mr. Calvin Anak Jose Jol for always being supportive and helpful towards the completion of the final year project.

ABSTRACT

Domestic water sources are a necessary element of human life. Approximately about 39% of the rural areas households in Sarawak are yet to access a reliable water supply. It has become a significant challenge amongst the community to obtained reliable water sources, where some of the populations are relying on desalinated and surface water for their daily water consumption. River water pollution is a significant problem for the population living nearby the industrial zone. This problem arises due to industrial effluent being discharge into the river water contains various organic and inorganic pollutants. Among these contaminants are heavy metals, which may be harmful or carcinogenic to humans and other living organisms. The high efficiency and low cost of electrocoagulation as a method of eliminating contaminants has recently attracted a lot of interest. Thus, the study is conducted to investigate the water quality at downstream, midstream and upstream of the Sungai Kuap in relation to the water pollution from the Sama Jaya Free Industrial Zone, Kuching, Sarawak by using the batch electrocoagulation treatment with an aluminum electrode. The research study includes the literature review on the availability clean water supply in rural areas in Sarawak and the principle of the electrocoagulation treatment system. The water quality analysis for the downstream, midstream and upstream of the Sungai Kuap is conducted including the Turbidity, Colour, Total suspended solid (TSS), Total dissolved solid (TDS), Total organic carbon (TOC), and Chemical oxygen demand (COD). Besides, the factors affecting the pollutants removal efficiency also being analyse such the current supply and also the treatment times. The analysis of the untreated and treated water as well as the floc composition also being investigated. The kinetic modelling and statistical modelling are developed and conducted for the electrocoagulation treatment of Sungai Kuap. Lastly, the economic analysis is performed to analyse the energy operating cost of the batch electrocoagulation treatment in removing the pollutants as well as treating the untreated water from the downstream, midstream and upstream Sungai Kuap.

Keywords: *River Water, Electrocoagulation, Heavy Metal*

ABSTRAK

Sumber air domestik adalah elemen penting dalam kehidupan manusia. Kira-kira 39% daripada kawasan luar bandar di Sarawak masih belum mendapat bekalan air yang boleh dipercayai. Ia telah menjadi cabaran besar dalam kalangan masyarakat untuk mendapatkan sumber air yang boleh dipercayai, di mana sebahagian daripada populasi bergantung kepada air penyahgaraman dan air permukaan untuk penggunaan air harian mereka. Pencemaran air sungai merupakan masalah besar bagi penduduk yang tinggal berhampiran zon perindustrian. Masalah ini timbul kerana efluen industri yang dibuang ke dalam air sungai mengandungi pelbagai bahan pencemar organik dan bukan organik. Antara bahan cemar ini ialah logam berat, yang mungkin berbahaya atau karsinogenik kepada manusia dan organisma hidup yang lain. Kecekapan tinggi dan kos elektrokoagulasi yang rendah sebagai kaedah menghapuskan bahan cemar baru-baru ini telah menarik minat ramai. Justeru, kajian dijalankan untuk menyiasat kualiti air di hilir dan hulu Sungai Kuap berhubung dengan pencemaran air daripada Zon Perindustrian Bebas Sama Jaya, Kuching, Sarawak dengan menggunakan rawatan elektrokoagulasi dengan elektrod aluminum. Kajian penyelidikan termasuk tinjauan mengenai ketersediaan bekalan air bersih di kawasan luar bandar di Sarawak dan prinsip sistem rawatan elektrokoagulasi. Analisis kualiti air untuk hilir dan hulu Sungai Kuap dijalankan termasuk Kekeruhan, Warna, Jumlah pepejal terampai (TSS), Jumlah pepejal terlarut (TDS), Jumlah karbon organik (TOC), dan Keperluan oksigen kimia (COD). Selain itu, faktor-faktor yang mempengaruhi kecekapan penyingkiran bahan pencemar turut dianalisis seperti jumlah aliran elektrik dan juga tempoh rawatan. Analisis air terawat dan juga komposisi flok juga akan disiasat dengan lebih teliti. Pemodelan kinetik dan pemodelan statistik dibangunkan dan dijalankan untuk rawatan elektrokoagulasi air Sungai Kuap. Akhir sekali, analisis ekonomi dilakukan untuk menganalisis kos operasi tenaga bagi rawatan elektrokoagulasi kelompok dalam menyingkirkan bahan pencemar serta merawat air yang tidak dirawat daripada air hilir, tengah dan hulu Sungai Kuap.

Kata Kunci: *Air sungai, elektrokoagulasi, logam berat*

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AN	Ammoniacal Nitrogen
CCD	Central Composite Design
COD	Chemical Oxygen Demand
DC	Direct Current
DO	Dissolved Oxygen
DOE	Department of Environment, Malaysia
EC	Electrocoagulation
KWB	Kuching Water Board
LPCD	Litres per capita per day
MLD	Millions of litres per day
MOH	Ministry of Health, Malaysia
NOM	Natural Organic Matter
NWQS	National Water Quality Standard
SAWAS	Sarawak Alternative Rural Water Supply
SEEC	Specific electrical energy consumption
SWB	Sibu Water Board
TOC	Total Organic Matter
TSS	Total Suspended Solids
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter introduces the background of the research project. The chapter also covers the research problems, the scopes of study, the main aim and objectives of the research, the research methodology, and the significance of this study. In addition, the structure for this project report is also briefly described at the end of this chapter where the report will be structured based on the outline aim and objectives of the research.

1.2 Domestic Water

People have a right to an equal amount of clean, acceptable, easily available, and economical water for personal and domestic usage as declared by the United Nations Committee on Economic and Social Rights (2003). In general, children will suffer the most consequences of the negative effects on their health caused by the lack of access to clean water and sanitation. Every year, about 54 million Disability Adjusted Life Years (DALYs) and 1.73 million deaths are attributed to diarrheal diseases caused by insufficient water supply, sanitation, and hygiene (Al-Hemoud et al., 2018). Diseases including trachoma, schistosoma disease, trichuriasis, hookworm disease and malaria as well as the Japanese encephalitis are significantly worse by poor water, sanitation and hygiene. Sustainable healthy living conditions necessitate a minimal amount of water should be supplied for drinking, food preparation, personal cleanliness, and sanitation such as showers. The World Health Organization (WHO) specifies that the standard water consumption is between 20 to 50 liters per capita per day (LPCD) for humans, where it is limited to off-site tap accessibility and does not include households that have a piped water supply (WHO, 2003).

According to Athuraliya et al. (2012), there is a wide range of domestic water consumption for indoor and outdoor household uses such as drinking, cooking, cleaning clothing and dishes as well as watering the yard and garden. Ab Rashid et al. (2021) stated that the domestic water consumption in Malaysia is approximately 61.6 % of the overall treated water, which indicates a high level of domestic water consumption as it exceeds 50 % of total treated water. This is also mentioned by Hafizi Md Lani et al. (2018), where Malaysia is classified as a country with high domestic water consumption, ranging between 209 to 228 litres per capita per day (LPCD), which surpasses the WHO's recommended standard of 165 LPCD. According to the data from the National Water Services Commission (SPAN), Malaysians use an average of 201 liters of water per day, which is the equivalent to 134 bottles where each bottle has the capacity of 1.5 litre (Nadasan, 2021). **Figure 1.1** below illustrates the Malaysian domestic water consumption in million liters per day (MLD) from 2003 until 2020 based on the data obtained from the Jabatan Perangkaan Malaysia (2020). Based on the statistic outlined by Jabatan Perangkaan Malaysia, approximately 7,165 million liters per day of water was consumed for domestic use in 2020. Malaysia recorded an increase of 63.05% in 2020 for the metered water consumed for domestic use compared to 2003.

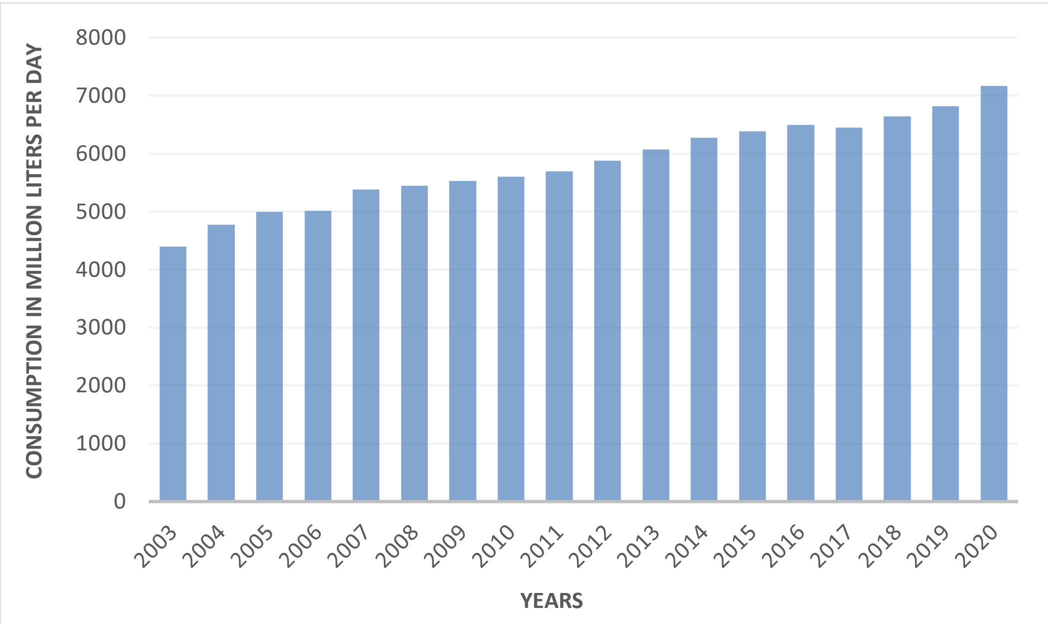

Figure 1.1: Domestic water consumption in Malaysia from 2003 until 2020.

8,000 people out of a total population of 25,000 in Sarawak are supplied by Kuching Water Supply system in 1887, making it as the state’s first domestic water supply system (Mahyan & Suhaiza, 2016). The nearby Sarawak stream serves as the water source for this water supply system. Sarawak’s population growth is predicted to result in an increase in both raw and treated water demand. Due to unforeseen flooding that occurs during the wetter months of December to February, it is vital to ensure that the water supply is sufficient to meet the state's water needs throughout the year. Rainwater harvesting is often used as an alternative water source in remote rural areas of Sarawak due to the state’s heavy rainfall and poor accessibility to piped water supply. In Bair Long House, Betong, Sarawak, part of the rural community relies on a rainwater harvesting system as an alternative water source (NAHRIM, 2011). Apart from that, some rural areas in Sarawak are also relying on desalinated and surface water for their daily water needs (Mahyan & Suhaiza, 2016). This is also highlighted by Kuok et al. (2011), where the surface water in Sarawak serves as a life-sustaining water supply for the population living along the stream particularly river water.

1.3 River Water

In order for the Earth's ecosystems to thrive, water must be available in sufficient quantities to support life on the surface of the earth (Nowak et al., 2018). In view of the rising demand for water resources, the supply-demand gap has become worse. As a result, surface water resources must be utilised and conserved to larger extents (Kazi et al., 2009). As described by Liu et al. (2021), surface water is distinguished from groundwater and atmospheric water since it is can be found on the earth’s surface, such as in streams, rivers, lakes, wetlands, and oceans. It is possible to replenish non-saline surface water by rainfall and recruitment from underground sources. It evaporates, seeps into the ground, and can be utilised by plants for transpiration or extracted by humans for agriculture, domestic use, and also industry, as well as discharged to the sea where it becomes saline. Even though surface water and groundwater are two completely different things, both are integral parts of a system which interdependence is critical when water demand outpaces availability.

It has been stated by Yidana et al. (2011) that rivers may be described as a huge stream of water that flows into an ocean, lake or other body of water and also being supplied by converging tributaries throughout its course. In some of cases, a river might run out of water at the end of its course because it has not reached another body of water along the way since the water is flowing into the ground. When a river originates at a watershed or many watersheds, it drains all of the streams in its drainage basin, travels down to a river course also known as a riverbed, and finally empties into a river mouth which is confluence or river delta (Baigun, 2016). A river's water is normally restricted within a narrow strip of land between its banks. Floodwaters that overtop the channel create a bigger floodplain in larger rivers. There might be some floodplains that are much larger than the river channel itself. When the floodplains of rivers are developed, the boundary between the river channel and the floodplain may be obscured, especially in densely populated areas where the floodplain of the river channel can completely be developed by housing and industry. Generally, the river water is flow from the upstream of the river to the downstream of the river. As explained by Endreny (2020), “upstream” of the river can be refer to the direction towards the river's source, which is in opposition to the river's current flow direction meanwhile the “downstream” of the river on the other hand, refers to the direction in which the current moves toward the river's mouth as shown in **Figure 1.2** below.

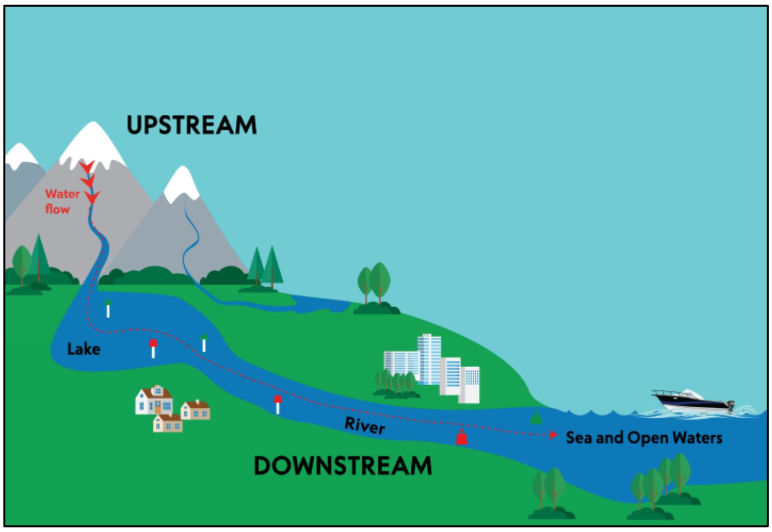

Figure 1.2: Overview of the Upstream and Downstream of the river water.

There are numerous reasons that why rivers are significant in this earth. One of the most important things are the rivers play a critical role in transporting substantial quantities of water from the land to the ocean, where the seawater rapidly evaporates. As a consequence, water vapour will condense as clouds. Clouds transport water vapour over the land, where it condenses and release it as precipitation. After that, the precipitation will flow into the rivers and smaller streams, causing it to expand. The flow of water between the land, sea and the air are known as water cycle. Freshwater, which is required by almost all living organisms is continually replenished through the Earth's water cycle. The water that falls at the higher elevations is diluted and decomposed pollutants more quickly in rivers and streams compare to stagnant water, however polluted rivers and streams may very well be found all around the world where the fundamental reasons for this is due to the three major sources of pollution which includes the industry, agriculture, and domestic are situated nearby the rivers or streams. Typically, industries and municipalities have been spotted near rivers because rivers provide transportation and have historically been a suitable option for waste disposal (Sandow Mark et al., 2011).

1.4 Semiconductor Industry

Semiconductors are a core part of the electronic industries' production. The semiconductors are utilised in a variety of technologies, including computers, telecommunications, consumer electronics, electronic control devices, scientific, and medical diagnostic equipment. Electronic devices have become more popular in recent years, and the worldwide semiconductor industry have made significant progress in research and development (Bang et al., 2016). However, the rapid growth of the semiconductor sector also presents significant environmental problems, such as the creation of enormous volumes of effluent and a high demand for water (Huang et al., 2011). Wong et al. (2013) stated that semiconductor manufacturing involves a series of complex and highly mere operations, such as silicon growth, doping, photolithography, etching and stripping, planarization, metallization and cleaning. More than two hundred organic and inorganic chemicals were used in the manufacturing of semiconductor integrated circuits. Water back grinding, sawing, die attachment, wire bonding, encapsulating, electroplating, trim and shape, and marking are some of the sequences' processes (Needleman, 2004). The list of chemicals required in each unit operation, including semiconductor manufacturing and processing, is shown in **Figure 1.3** below.

Unit Operation	Typical EPCRA Section 313 Chemicals
Photolithography	Xylenes, ammonia, N-methyl-2-pyrrolidone, glycol ethers, phosphoric acid, methyl ethyl ketone, ethylbenzene, dichloroethylene
Thin Films	Ammonia (silicon nitride film deposition), copper
Cleaning/Etching	Ethylene glycol, glycol ethers, methanol, N-methyl-2-pyrrolidone, sulfuric acid aerosols (spray etching/cleaning), hydrochloric acid aerosols (spray etching/cleaning), hydrogen fluoride, phosphoric acid, nitric acid, nitrate compounds, ammonia
Doping	Arsenic, antimony, phosphine
Chemical Mechanical Planarization	Nitrate compounds, copper

Figure 1.3: Chemical compounds that commonly encountered in Semiconductor Industry (United States Environmental Protection Agency, 2013).

Due to the massive amount of water used in the chemical-mechanical polishing (CMP) process for planarizing the silicon wafer, a large volume of wastewater comprising both organic and inorganic contaminants is produced throughout the semiconductor plant operation (Neffati & Marzouk, 2010). In semiconductor manufacturing, metals are quite essential. Some common trace metals employed in these industries are accumulating in wastes and wastewater, despite treatment prior to discharge, due to the fast development of numerous advanced technologies (Edelman, 1990). According to Baysal et al. (2013), Cadmium (Cd), Lead (Pb), Manganese (Mn), Cooper (Cu), Zinc (Zn), Chromium (Cr), Mercury (Hg), Arsenic (As), Iron (Fe), and Nickel (Ni) are the primary heavy metals released in wastewater. Consequently, heavy metal contamination has become a severe and rising hazard to aquatic ecosystems worldwide. To make things a bit worse, people are particularly susceptible to contamination when toxins enter aquatic food webs and build up in species that can tolerate them, such as oysters, or reach groundwater used for domestic consumption or farming. According to Malaysia's Environmental Quality Regulations 2009, heavy metals released in industrial wastewater are required to be treated to meet the standard discharge limit. A sustainable and cost-effective treatment approach is needed to address the aforementioned problem of heavy metal pollution, particularly in emerging countries such as Malaysia.

1.5 Electrocoagulation

Electrocoagulation can be described as the electrocoagulation process of conducting an electrical current throughout water to remove the contaminants (Abdul Rahman et al., 2020a). This is also mentioned by Lu et al. (2017), where the electrocoagulation can be distinguished by the formation of high-absorbency coagulant and hydroxide flocs in situ is an environmentally friendly approach for treating the wastewater containing the heavy metal ions and harmful organic compounds. As illustrates in **Figure 1.4**, the anode electrodes in electrocoagulation process dissolve the metal cations, whereas the cathode electrodes generate hydrogen gas and hydroxyl ions. Electrocoagulation may be performed by using a set of electrodes designated as the anode and cathode, with both electrodes interconnected to the power source (direct current) as shown in **Figure 1.4**. When a current is passed through a metal electrode, the anode undergoes oxidation, forming its cations, meanwhile the cathode undergoes reduction, converting water to hydrogen gas and hydroxyl ion (Kabdaşlı et al., 2012). In order to remove colloidal particles from water, metal cations introduced into the