Electrocoagulation Treatment of Synthetic Wastewater Containing Methyl Orange Dye and Rhodamine Blue Dye Using Aluminium Electrode: A Comparative Study

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DECLARATION

I declare that this thesis entitled "Electrocoagulation Treatment of Synthetic Wastewater Containing Methyl Orange Dye and Rhodamine Blue Dye Using Aluminium Electrode: A Comparative Study" is the results of my own research except as cited in the references.

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ABSTRAK

Electrocoagulation is a potential method for treating and eliminating contaminants from water or wastewater. It is a water treatment technique that integrates the concepts of coagulation with electrochemistry. The electrocoagulation approach was used to treat synthetic wastewater containing Methyl orange and Rhodamine b dyes, using aluminum electrodes. The studies were conducted using electrochemical cells that were outfitted with monopolar aluminum electrodes that were linked in parallel. The research investigated the efficacy of electrocoagulation treatment in removing Methyl orange and Rhodamine B dyes from synthetic wastewater. Aluminum electrodes were used for this purpose. The findings demonstrated a link between the type of dyes and the initial dye concentration, which directly impacted the effectiveness of treating synthetic wastewater. The Rhodamine B dye had the greatest treatment effectiveness % at an initial concentration of 500ppm, but the treatment efficiency percentage for Methyl orange was comparatively lower. The statistical data derived from experimental outcomes was analysed using statistical analysis using General Full Factorial Design (GFFD). The quadratic model is considered suitable due to its high coefficient of determination (R2 = 0.910) and statistically significant p-value (≤ 0.003) for Methyl orange, and (R2 = 0.842) and statistically significant p-value (≤ 0.000) for Rhodamine B dye, indicating the model's importance. The experimental findings suggest that electrocoagulation is a more effective treatment approach for synthetic wastewater containing Methyl orange and Rhodamine B dye compared to the adsorption methodology.

Keywords : Methyl Orange, Rhodamine Blue, synthetic wastewater

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ABSTRAK

Elektrokoagulasi merupakan kaedah yang berpotensi untuk merawat dan menghapuskan pencemar dari air atau air sisa. Ia merupakan teknik rawatan air yang menggabungkan konsep koagulasi dengan elektrokimia. Pendekatan elektrokoagulasi digunakan untuk merawat air sisa sintetik yang mengandungi pewarna Methyl orange dan Rhodamine B, dengan menggunakan elektrod aluminium. Kajian ini telah dijalankan dengan menggunakan sel elektrokimia yang dilengkapi dengan elektrod aluminium yang dihubungkan secara selari. Penyelidikan ini mengkaji keberkesanan rawatan elektrokoagulasi dalam mengeluarkan pewarna Methyl orange dan Rhodamine B dari air sisa sintetik. Elektrod aluminium digunakan untuk kajian ini. Dapatan kajian menunjukkan kaitan antara jenis pewarna dan kepekatan pewarna awal, yang secara langsung memberi kesan kepada keberkesanan rawatan air sisa sintetik. Pewarna Rhodamine B menunjukkan keberkesanan rawatan tertinggi pada kepekatan awal 500ppm, tetapi kecekapan rawatan bagi Methyl orange adalah lebih rendah secara relatif. Data statistik yang diperolehi daripada hasil eksperimen dianalisis menggunakan analisis statistik dengan Reka Bentuk Faktorial Penuh Umum (GFFD). Model kuadratik dianggap sesuai kerana mempunyai pekali penentu yang tinggi (R2 = 0.910) dan nilai p yang statistik signifikan (≤ 0.003) untuk Methyl orange, dan (R2 = 0.842) dan nilai p yang statistik signifikan (≤ 0.000) untuk pewarna Rhodamine B, menunjukkan kepentingan model tersebut. Dapatan eksperimen menyarankan bahawa elektrokoagulasi adalah pendekatan rawatan yang lebih berkesan untuk air sisa sintetik yang mengandungi pewarna Methyl orange dan Rhodamine B berbanding dengan metodologi penyerapan.

Kata Kunci : Methyl orange, Rhodamine Blue, air sisa

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LIST OF ABBREVIATIONS

MO	Methyl Orange
RhB	Rhodamine Blue
EC	Electrocoagulation
Al	Aluminum
MF/UF	Microfiltration/ultrafiltration
BOD	Biological oxygen demand
DC	Direct Current
RB19	Reactive Blue 19
ANOVA	Analysis of Variance
GFFD	General Full Factorial Design
At	Atomic
Wt	Weight
SEM/EDX	Scanning Electron Microscope/ Energy Dispersive X-ray Spectroscopy
UV-Vis	Ultraviolet – visible spectroscopy

LIST OF SYMBOLS (optional)

%	Percentage
° c	Degree Celsius
v	Voltage
ml	Milliliter
L	Liter
g	Gram
A	Ammeter
ppm	Parts-per-million
C_i	The initial degradation of dyes
C_f	The degradation after each treatment
nm	Nanometer
r^2	R-squared
mA/cm^2	Current Density

CHAPTER 1

INTRODUCTION

1.1 Background of Study

One of the main environmental issues facing the world today is water contamination. Due to the release of wastewater containing dye into the water source, the textile industry is one of the main drivers of water pollution. Untreated dye effluent discharge into water sources has the potential to lead to serious environmental issues, such as aesthetic pollution, oxygen depletion, and aquatic life poisoning. Methyl orange (MO) and Rhodamine Blue (RhB), a dyes frequently used in the textile industry, are known to have cancer-causing potential and others. Therefore, removing these dyes from wastewater is essential to stop water contamination and protect public health.

Membrane filtration is a common method used to degrade pollutants from wastewater, especially dye. This method is used in various sectors, including water treatment, food and beverage processing, medicines, and biotechnology. Filtrations are widely used to remove large amounts of pollutants due to their easy operation (Chenxi Hu et al., 2020). The capacity of the membrane to selectively allow some substances to flow through while preventing others depending on size, shape, and other qualities is the fundamental concept of membrane filtration. However, membrane filtration may require chemical additives for pretreatment or cleaning, contributing to chemical usage. Chemical additives for membrane filtration depend on the application, feedwater, and membrane type.

Membrane filtration is a typical method, but it has limitations, such as chemical additives. Therefore, the electrocoagulation (EC) method can reduce the reliance on specific chemicals because the electrochemical process causes coagulation and flocculation. More than two decades of research in developing EC systems and wide applications of EC to remediate wastewater have solved numerous environmental problems (Othmani et al., 2022). EC is a preferred treatment method for degrading synthetic wastewater of MO and RhB dyes. This is because of its high removal efficiency, versatility in treating various dye compositions, rapid treatment rates, self-sustaining process, reduced sludge generation, oxidation potential, scalability, adaptability, and environmental compatibility. EC is a process that uses aluminum as electrodes. The findings of this research will contribute to the development of a water treatment system that is both cost-effective and efficient for the treatment of wastewater that includes colors. The operational parameters, such as the types of dye and the initial concentration, are some factors that determine the effectiveness of the pollutant treatment. Therefore, the primary emphasis of this study will be on using the EC approach to evaluate the effectiveness of treating wastewater that contains MO and RhB dyes by employing an aluminum electrode.

1.2 Problem Statement

Wastewater from the textile industry is recognized to provide several major challenges owing to the nature of the processes involved and the materials that make up the wastewater. Various chemicals, including dyes, pigments, surfactants, acids, alkalis, and finishing agents, are also included in textile effluent. These chemicals are utilized at different phases of the manufacturing process. On top of being poisonous and persistent, these compounds may also harm the health of humans and aquatic ecosystems. They are a contributor to water pollution and have the potential to pollute water sources when they are released without sufficient treatment, which may have an impact on users and ecosystems farther downstream.

Membrane filtration has a few problems that limit its use in water treatment operations. A typical problem is fouling, which collects particles and organic compounds on the membrane surface, resulting in lower permeate flow and higher maintenance requirements. Another issue is scaling, which occurs when minerals precipitate, reducing membrane performance and increasing energy usage. Damage to the membrane, whether mechanical or chemical, may impair its integrity, enabling pollutants to flow through and impacting water quality. Chemical compatibility concerns may cause membrane deterioration, decreasing the lifetime and effectiveness of the membrane. Furthermore, certain membrane processes, especially those requiring high pressure, may be energy-intensive, increasing operating expenses. Handling these challenges requires creative methods that reduce chemical dependence in membrane filtration procedures while preserving or improving treatment efficiency. The evolution of environmentally friendly and economically viable water treatment technologies will be aided by developing sustainable and cost-effective techniques to reduce chemical dependency in membrane filtration.

For this project, EC method is proposed method to degrade the MO and RhB dyes using aluminum electrodes instead of the technique used by the researcher, which is membrane filtration. Electrocoagulation (EC) outperforms membrane filtration in several water treatment applications. Since they use cheaper materials than membrane filtration, EC systems are cost-effective. Flexible EC may be utilized on several water sources. It efficiently eliminates metals, suspended particles, and other contaminants. Due to reduced fouling, the technology may run continuously without cleaning. Additionally, electrocoagulation systems may be scaled up or down to meet different flow rates. They may be more energy-efficient than high-pressure membrane filtration. Membrane filtering uses more chemicals than EC to remove contaminants. This improves dye removal, especially for highly soluble colors. Electrocoagulation or membrane filtration depends on the water's parameters, pollutant characteristics, and treatment objectives.

Furthermore, several researchers use MO and RhB dyes in their studies on EC treatment. However, a comparative analysis between these two colors has yet to be conducted in the context of EC treatment. If a comparison is being made, it is solely focused on comparing two type of dyes, with the methods and type of dyes being different from the one being studied (Chen et al., 2019).

1.3 Objective

1. To compare the electrocoagulation (EC) treatment efficiency of synthetic wastewater containing Methyl Orange (MO) and Rhodamine Blue (RhB) dyes using aluminum electrodes.
2. To correlate the type of dyes and the initial dye concentration due to wastewater treatment efficiency.

1.4 Scope of Study

The investigation of MO and RhB dyes degradation using aluminum as a electrodes utilizing the electrocoagulation (EC) method is the exclusive focus of this work. The investigation will use synthetic wastewater with known MO and RhB dyes concentrations.

In this study, the type of dyes and the initial concentration will all be examined as parameters. The study aims to investigate these parameters' effect on the EC process's dye treatment efficiency. To comprehend how dyes is removed from the wastewater in the EC process, the physicochemical characteristics of the wastewater before and after treatment will be examined.

The study will provide a better option for applying the EC approach to treating wastewater containing dyes, as well as its potential use in the textile sector. Although it won't be done experimentally in this work, investigating the scalability of the EC approach will be restricted to theoretical analysis.

1.5 Significance of Study

MO and RhB dyes were a commonly used textile dye that poses a significant environmental risk due to its persistence and toxicity. By investigating the EC method for its degradation, the study aims to provide an effective and sustainable solution for removing this hazardous dye from synthetic wastewater. Successful degradation of MO and RhB dyes using an aluminum electrode in EC can contribute to a comparative study in reducing the environmental impact of textile industry wastewater discharges.

The EC method has shown promise in treating various pollutants, including dyes. Studying the degradation of MO and RhB dyes using this method in synthetic wastewater allows for evaluating its treatment efficiency and effectiveness. The findings can provide insights into the optimal operating conditions, such as type of dyes and the initial concentration, to achieve efficient dye degradation. This knowledge can be valuable in designing and optimizing electrocoagulation (EC) processes for industrial wastewater treatment.

CHAPTER 2

LITERATURE REVIEW

2.0 Textile Industry Wastewater

The textile industry's wastewater is a challenging environmental issue. The wastewater is produced throughout several steps in the textile manufacturing process, such as printing, dyeing, finishing, and washing chemicals. Textile mills and their wastewater have grown in proportion to the increase in demand for textile products, causing a major pollution problem worldwide (Azanaw et al., 2022). Its color intensity, toxicity, and high chemical and biological oxygen demands distinguish it. The rapid increase in toxic dye wastewater generated by various industries continues to be a serious public health issue and a major environmental concern, posing a significant challenge to existing conventional water treatment systems (Azanaw et al., 2022).

Coloration and oxygen depletion are one of the main topics in water pollution. Textile wastewater contains a variety of dyes that give the water source into which it is discharged great color. The color inhibits light penetration, impacting photosynthesis and aquatic plant development. The biological oxygen demand (BOD) in receiving water bodies increases when organic contaminants, such as those found in textile effluent, are present. As bacteria and other microorganisms break down these contaminants, oxygen is consumed, which harms aquatic creatures.

Next is the ecosystem disruption. Aquatic ecosystems may suffer serious harm if wastewater from the textile industry is discharged into the water environment. The toxicity and oxygen deprivation of wastewater can cause the decrease or extinction of many species, upsetting the ecological balance.

To reduce its environmental impact and maintain sustainable practices in the textile business, wastewater treatment, and management must be done effectively.

2.1 Conventional Treatment

The physical process is frequently used in conventional treatment procedures to remove dye pollutants from wastewater. Membrane filtration is one of the processes in physical treatment. These methods have limited use since they have poor decolorization efficiency and produce a substantial amount of sludge (Halepoto et al., 2022). It involves utilizing semi-permeable membranes to separate and purify liquids based on particle or solute physical size and characteristics. To meet strict wastewater discharge standards, a conventional activated sludge process is used to biologically treat wastewater for organics/nutrients removal, followed by a microfiltration/ultrafiltration (MF/UF) process to produce high-quality permeate water (Direct membrane filtration for wastewater treatment and resource recovery: A Review 2019). The membranes function as barriers, allowing certain chemicals to pass while inhibiting others. Size exclusion is the primary cause of separation, with the membrane functioning as a physical filter.

In the physical process of membrane filtration, membranes have holes or gaps of different sizes. The membrane eliminates or blocks larger particles or solutes, allowing smaller molecules to flow through. Pressure is frequently used to drive membrane filtering systems. A particular pressure is applied to the liquid (feed or influent), forcing it through the membrane and separating the required components from the undesirable ones. Direct membrane filtering systems are usually compact, requiring a minimal footprint. (Direct membrane filtration for wastewater treatment and resource recovery: A Review 2019)

Even though this membrane filtration is common use, it has a limitation. Chemical dependency reduction in membrane filtration systems is a significant objective in sustainable water treatment. While membrane filtration is a successful water purification technique, reliance on external chemical additives for coagulation, flocculation, and maintenance entails costs, environmental impact, and operational complexity. The restrictions associated with reducing chemical reliance on membrane filtration could threaten the overall efficiency and sustainability of water treatment systems. Resolving these limitations requires creative methods that reduce chemical dependence in membrane filtration procedures while preserving or improving treatment efficiency. Alternative technologies, such as electrocoagulation (EC), that may offer effective coagulation and flocculation without external chemical additives should be the focus of research and development efforts. The evolution of environmentally friendly and economically viable water treatment technologies will be aided by developing sustainable and cost-effective techniques to reduce chemical dependency in membrane filtration.

2.1.1 Membrane filtration fouling

Membrane filtration fouling is the process by which undesired chemicals gather or deposit on the surface of a membrane used in filtering procedures. Membrane filtration is a method of separation that employs a semi-permeable barrier, known as a membrane, that separates particles and solutes from a liquid flow depending on their size, shape, or charge. Fouling arises when the membrane is covered or obstructed by particles, colloids, organic materials, or other things found in the fluid being filtered (Lu Wang a b et al., 2023). The fouling may have a negative impact on the efficiency and effectiveness of the membrane filtering process. Membrane fouling causes a decline in permeate flow, an increase in transmembrane pressure, and a drop in total filtration efficiency. Effectively managing and reducing fouling is essential for preserving the effectiveness of membrane filtering systems. Methods to combat fouling include periodic cleansing of membranes, fine-tuning operational parameters, using pre-treatment procedures, and carefully choosing suitable membrane materials and configurations (Md Kawser Alam et al., 2023). Continual research and development are being conducted to create cutting-edge membranes and technologies that resist fouling. The goal is to improve the effectiveness and lifespan of membrane filtering systems. Nevertheless, the accumulation of inorganic salts or minerals on the surface of the membrane might result in scaling, hence decreasing permeability. This is one of the several processes that contribute to membrane fouling.

2.1.2 Membrane filtration scaling

Membrane filtration scaling refers to the deposition and buildup of inorganic salts or minerals on the surface of a membrane used in filtering procedures. Scaling is the process in which salts surpass their solubility limitations and form solid deposits on the surface of the membrane or within its pores. The amount of precipitation may result in the creation of solid deposits, which have a negative impact on the functioning of the membrane filtering system. Typical compounds used for scaling include calcium carbonate, calcium sulphate, silica, and several metal oxides. Scale development may arise from variations in temperature, pressure, pH, or the concentration of scaling ions in the input water. When these circumstances lead to the salts beyond their saturation levels, they form solid particles and stick to the surface of the membrane. Scaling is a common problem in water treatment procedures, and it is crucial to tackle it in order to guarantee the dependable and effective functioning of membrane filtering systems. To effectively tackle membrane filtration scaling in wastewater treatment, a thorough strategy is necessary, which integrates appropriate pre-treatment, chemical dosing, monitoring, and maintenance techniques. This aids in guaranteeing the enduring efficiency and dependability of membrane-based wastewater treatment systems. Hence, the electrocoagulation (EC) technique is an alternative approach to overcome these issues occurred in membrane filtration.

2.2 Electrocoagulation (EC)

Electrocoagulation is an electrochemical process that involves destabilizing and removing contaminants from water or wastewater using ions generated by the dissolution of sacrificial electrodes (Holt et al., 2005; Tahreen et al., 2020). It is a water treatment technique that combines the principles of electrochemistry and coagulation. EC is a simple and easy method for reducing various organic and inorganic pollutants. (Riyanto & Puspitasari, 2018). In EC, a direct current (DC) is applied to a pair of electrodes immersed in the water or wastewater to be treated. The electrodes are typically made of materials from aluminum. When the current is passed through the electrodes, metal ions are released into the water. These metal ions act as coagulants and destabilize the suspended particles, colloids, and dissolved pollutants present in the water. The efficiency of the EC treatment method depends on operating parameters such as the type of dyes and the initial concentration. Therefore, the next literature review will discuss the operational parameters.

2.3 Type of Dyes

The textile industry is critical to the world economy, especially for employment and economic development. The sector is also linked to environmental issues, especially the discharge of dye-containing wastewater. Dye wastewater release endangers water resources, ecosystems, and human health. Despite advancements in wastewater treatment technology, the textile sector needs help. Untreated or improperly treated dye waste products from textile manufacturing operations pose a serious hazard to aquatic environments. Certain colors' persistence and toxicity can cause long-term environmental harm, affecting biodiversity and disturbing ecological equilibrium.

2.3.1 Methyl Orange Dye (MO)

Methyl Orange (MO) is synthetic dyes commonly used in the textile industry for coloring fabrics (Huang et al., 2008). Methyl orange is water-soluble and, when released as wastewater, may quickly pollute natural water bodies. This pollution impacts aquatic ecosystems such as rivers, lakes, and seas. Water bodies containing methyl orange can be hazardous to aquatic life, including fish and other species. It can alter aquatic animals' metabolic and reproductive activities, resulting in population reduction and ecological disturbance (Xiangjing Liu et al., 2022). Methyl orange and other related colors may cause problems during conventional wastewater treatment procedures. Because of the dye's resistance to degradation, it may be removed only partially during treatment, releasing effluent containing residual dye components.

2.3.2 Rhodamine Blue Dye (RhB)

Rhodamine B (RhB) is a synthetic dye of the xanthene class. Its usage in various applications, including textiles, inks, and research, can result in wastewater containing this dye. RhB dye wastewater can pollute drinking water sources if not adequately handled (Osamah Aldaghri a et al., 2023). Drinking water containing rhodamine B or its breakdown products may pose human health concerns. Therefore, discharging rhodamine blue dye wastewater without sufficient treatment might result in violations of environmental infractions and water quality standards. Industries need to stick to discharge restrictions to avoid legal ramifications and penalties.

2.3.3 Reactive Blue 19

Reactive Blue 19 (RB19) is a synthetic dye that falls within the category of reactive dyes. Reactive dyes are often used in the textile sector to colour natural fibres such as cotton, wool, and silk (Priyanka Doondani a et al., 2024). RB19 has high water solubility and possesses resistance to biodegradation, resulting in its prolonged presence in water bodies and consequent adverse effects on aquatic ecosystems. RB19 may have a harmful effect on aquatic organisms when present in high quantities, impairing their growth, reproduction, and overall survival. Moreover, RB19 dyes have the potential to cause waterbodies to become discoloured, which may negatively affect their aesthetic appeal and recreational worth. The presence of RB19 in water leads to organic pollution, which may result in a decrease in dissolved oxygen levels and cause damage to aquatic ecosystems. Efficient treatment is required to safeguard our water resources and ecosystems due to the existence of RB19 in wastewater. Continuing research provides encouraging ideas for addressing this dilemma and establishing sustainable methods in textile manufacturing.

2.3.4 Methylene Blue Dye

Methylene Blue is a synthetic dye that falls within the category of thiazine dyes. This dye is classified as a dye that is cationic due to its positive charge, and it is widely used in several industries. Methylene Blue is renowned for its strong blue colour and has use in both the medical and scientific settings (Shivani S. Vedula et al., 2021). The flexibility of Methylene Blue in staining and its capacity to undergo chemical reactions make it very beneficial in several scientific and medical applications. Nevertheless, it is crucial to acknowledge that while it has medicinal applications, its ingestion or utilisation should be conducted under the guidance of healthcare experts, and it should not be used haphazardly owing to possible adverse reactions.

In this project, many researchers have explored the significance of treatment efficiency on wastewater containing MO, RhB, RB19 and Methylene Blue separately using any kind of the methods. However, electrocoagulation treatment effectively shows that it can removes MO, attaining a remarkable efficiency of over 90%, including total decolorization. The efficiency of iron electrodes may be enhanced by improving factors such as current density and pH (Sonia Akter et al., 2022). Although it is defined by its simplicity, efficiency, and eco-friendliness, this technology encounters obstacles such as energy consumption and electrode degradation. EC is a very effective method for addressing the persistent wastewater contamination by RhB, a tough dye. Studies demonstrate clearance rates above 95%, often attaining total decolorization. Factors such as current density, treatment period, and beginning dye concentration are significant, similar to methyl orange (Osamah Aldaghri a et al., 2023). The brilliance of EC rests in its ability to create metal hydroxide flocs that effectively catch and eliminate the dye. Although oxidation may also play a role, the distinguishing features of EC are its simplicity, efficiency, and eco-friendliness.

Nevertheless, enduring issues such as energy consumption and electrode deterioration remain. In order to achieve optimal performance, EC requires more development to effectively address a wider range of dye and wastewater treatment applications. Ongoing research is steadily revealing the whole capabilities of this technology, rendering it a promising promise for a more environmentally friendly future. Currently, no study compares the treatment efficiency of MO with RhB dyes in a single trial utilizing the EC approach. As a result, MO and RhB dyes were chosen for this study to compare the differences in treatment efficiency between the two colors. The type of dyes was used as a parameter in this experiment to see if the performance of treatment efficiency is affected by the type of dyes. Other than that, apart from the types of dye, treatment efficiency also depends on the initial concentration of the wastewater.

2.4 The Initial Concentration

The initial concentration of contaminants in synthetic wastewater is an important factor impacting the effectiveness of various treatment procedures. It is important to determine the efficacy of treatment methods and analyze the capabilities of various technologies. As a result, the initial concentration became a crucial factor in this experiment to compare the treatment effectiveness of MO and RhB dyes. The initial concentration is an initial evaluation of the concentration of pollutants in synthetic wastewater before treatment. This measurement is critical for measuring the level of contamination and the efficacy of the treatment procedure. The starting concentration of contaminants is critical in determining synthetic wastewater treatment efficiency. The adsorption of dye molecules on the produced metallic hydroxide flocs is one of the most significant paths of elimination by electrocoagulation. Because flocs have a finite adsorption capacity, only a certain number of dye molecules may be adsorbed (K.S. Padmavathy a et al., 2016). As the concentration of dye increases, the number of flocs formed becomes inadequate to adsorb all dye molecules, and hence, dye removal diminishes (Almaz Negash et al., 2023). The initial concentration data may be used to adjust parameters such as the type of dyes and other aspects in order to obtain the most efficient and cost-effective treatment possible. This information is critical for environmental protection and the safe disposal of treated wastewater. The concentration of dyes in effluent varies (Iwaponline.com). Hence, the initial concentration significantly influences the characteristics of dyes, since each dye variant has a distinct concentration.

2.5 Statistical Analysis

Statistical analysis proves essential in analyzing and understanding the performance of synthetic wastewater treatment methods. It provides a solid framework to evaluate the credibility and significance of treatment outcomes, allowing researchers to reach correct findings and make good decisions. ANOVA-2 methods and PCA were used to find the most important wastewater treatment type and factors impacting virus eradication. Over 25% of virus eradication from wastewater research were from the recent two years, according to bibliometrics. This influenced how SARS-CoV-2 was addressed. Over 15 viruses and/or genotypes and 20 specific/non-specific viral eradication procedures were statistically examined (Plaza-Garrido et al., 2022). This statistical approach measures the removal effectiveness of various dyes, including organic materials, nutrients, and particular dye molecules such as methyl orange and rhodamine B. This is accomplished by comparing the starting and final concentrations and computing parameters such as removal percentage, degradation rate, and color removal. For example, membrane filtration is reliable and adaptable in wastewater treatment. Statistical analysis optimizes its effectiveness as a smart strategist. Under diverse situations, regression models predict permeate flow, pollutant rejection rates, and membrane fouling like crystal balls. With this foresight, membrane selection and process design can be customized to filter every drop perfectly. The strength continues. The watchful sentinel of statistical process control monitors pressure and feedwater quality, recognizing performance issues before they become disasters. After membrane failures and failure analysis, a competent investigator intervenes. It helps enhance lifetime and operational dependability by carefully reviewing failure data to identify membrane breach causes. Statisticians provide membrane filtration the intelligence it needs to flourish, turning it into a smart, clean water sentinel (Lemmons, 2023). This statistical study is also performed to see if the treatment efficiency of Methyl Orange and Rhodamine B Dye changes significantly.

2.6 Summary

The literature review summarizes the state of the art in treating textile wastewater. Textile wastewater has several adverse effects on the environment. The EC technique was chosen because of its success in purifying wastewater. According to our findings, membrane filtration is a standard method for treating wastewater to eliminate dye pollutants. However, there are significant restrictions on this approach. The EC method was selected as a means of remedying the situation. The type of dyes and the initial concentration are two components of this approach, and the parameters' efficacy in treating wastewater for contaminants is conducted using these parameters.

CHAPTER 3

MATERIALS AND METHODS

3.1 Research Flowchart

The research flow chart was divided into three stages. Stage 1 is material preparation, stage 2 is the electrocoagulation treatment process, and stage 3 is for analysis, evaluation, and comparison of the obtained experimental data, as shown in Figure 3.1.

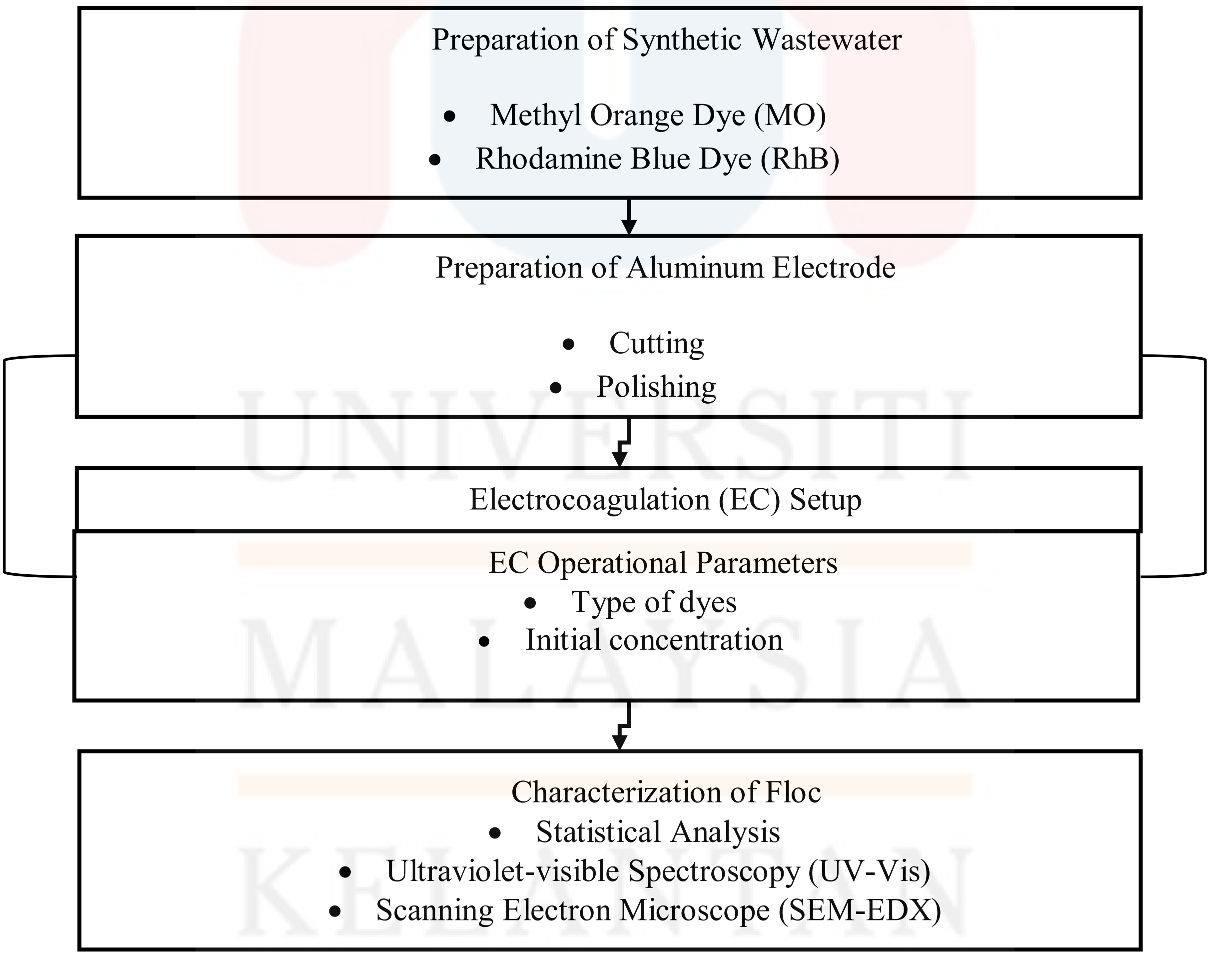


Figure 3.1: Research flow for Electrolysis research project

3.2 Synthetic Wastewater

The 0.5g of methyl orange powder was used to make the concentration of 1000 ppm for the stock for 500 ml synthetic wastewater. The powder was poured into the 1L beaker with 500 ml of deionized water. It was mixed using the digital magnetic stirrer with a heat of 50°c and speeds of 800, 500, and 1000 for 15 minutes. The steps were repeated for the rhodamine blue synthetic wastewater.

3.3 Electrocoagulation (EC) Setup

Synthetic wastewater colored with methyl orange and rhodamine blue color was utilized. When experimenting, we will return to the findings (Bajpai et al. (2021)). The EC reactor tank will be a 1 L cylindrical glass beaker manufactured from borosilicate glass. The electrode rods' diameter is 10 mm, and the materials being studied are aluminum (Al) rods. The quality of electrodes is more than 98%. To minimize electrical resistance, the space between the anode and cathode electrodes is kept at a constant 3 cm. The regulated DC power supply will generate the electrical potential, which has a voltage range of 0-30 V and a current range of 0-40 A. The following parameters will be varied during the experiments:

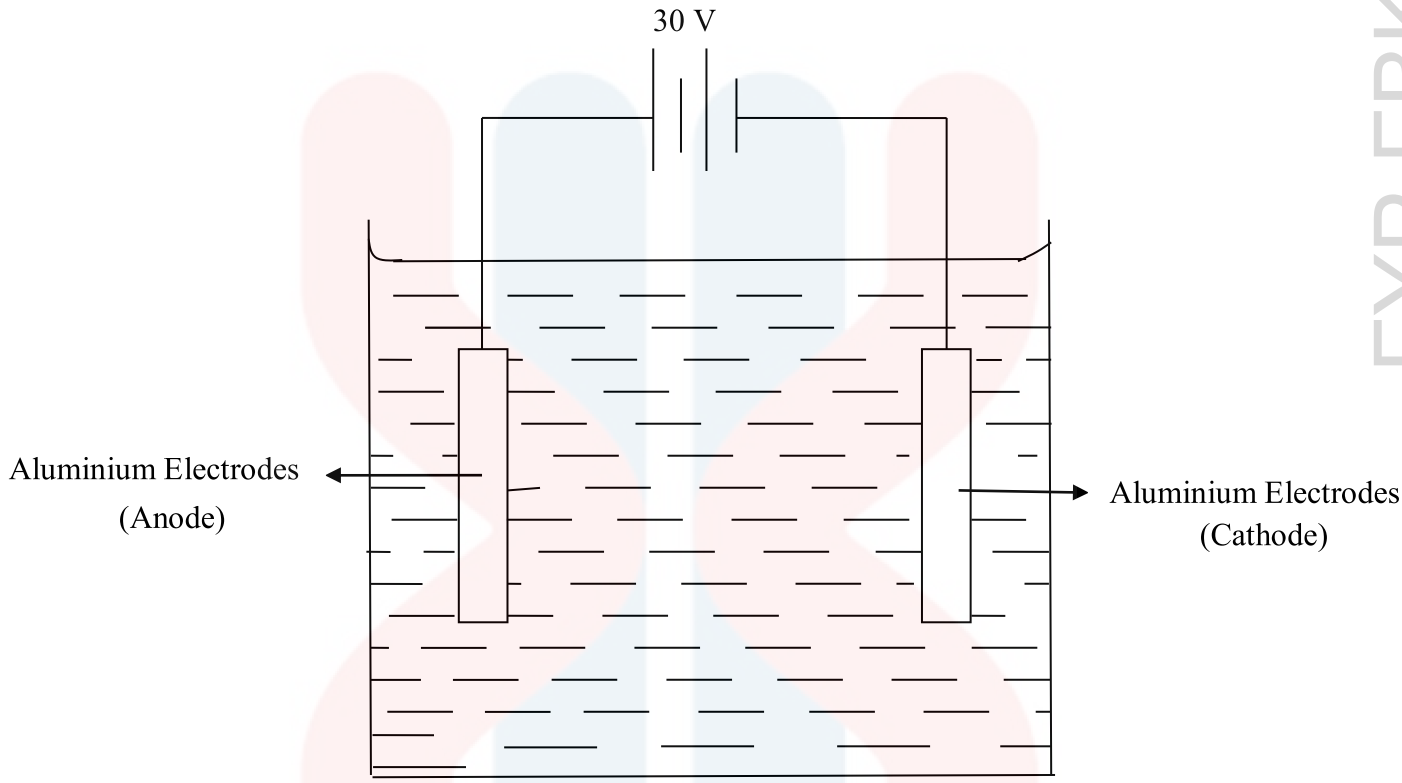


Figure 3.2 : The electrocoagulation (EC) Setup for Methyl Orange/ Rhodamine Blue Dyes Wastewater

In general, the effectiveness of EC treatment for contaminants in wastewater depends on operational factors such as the type of dyes and the initial concentration.

3.4 Type of Dyes

Synthetic wastewater of MO and RhB dyes.

3.5 The Initial Concentration

The initial concentration was defined as treatment objectives, such as making regulatory compliance or minimizing pollutant concentrations. The treatment goals determine the initial concentration selection and the overall design of the electrocoagulation procedure. The ideal initial concentration for the specified water matrix and contaminants can only be determined by preliminary tests. Finding out how well the system works in a real-world environment may be aided by doing preliminary tests. Table 3.1 shows the value of the concentration standard solution.

Table 3.1 : The value of concentration standard solution.

Stock solution (1000 ppm)	Concentration Standard Solution (ppm)	Volume Standard Solution (L)	Volume from 1000 ppm (mL)
1000	100	0.05	5
1000	500	0.05	25
1000	10	0.05	0.5
1000	20	0.05	1
1000	30	0.05	1.5
1000	40	0.05	2
1000	50	0.05	2.5
1000	60	0.05	3

After treating wastewater containing the Methyl Orange and Rhodamine Blue dyes color, the statistics analysis is run before the UV-vis spectroscopy to get more accurate results later. The UV-vis spectroscopy will assess the degree to which the dye has degraded precisely.

Equation V : Treatment Efficiency of Dyes

$$\text{Treatment efficiency } (\%) = \frac{c_i - c_f}{c_i}$$

C_i is the initial degradation of Methyl Orange/Rhodamine Blue dyes-color wastewater, and C_f is the degradation after each treatment, evaluated by UV-vis. After EC, floc was collected. Vacuum-filtered and oven-dried.

3.6 Statistical Analysis

Minitab16 was implemented in this work to analyze the comparative treatment effectiveness of the EC method between Methyl Orange and Rhodamine B dye. It includes an experimental design matrix, model adequacy testing, analysis of variance (ANOVA), and graphs for main effects and interactions. This statistical analysis calculates the elimination efficiency of contaminants such as organic waste, nutrients, and particular dye molecules such as Methyl Orange and Rhodamine B dye. This is accomplished by comparing beginning and final concentrations and determining parameters such as removal percentage, degradation rate, and color removal. This statistical study is also performed to see if the treatment efficiency of Methyl Orange and Rhodamine B Dye changes significantly. Table 3.2 show the table of experimental design matrix for electrocoagulation wastewater treatment design.

Table 3.2 : Experimental design matrix for electrocoagulation wastewater treatment design (including values for all response)

	Factor		Response
Run Order	Types of Dye	Initial Concentration of Dye (ppm)	Treatment Efficiency (%)
1	1	2	
2	2	2	
3	1	2	
4	1	2	
5	1	1	
6	1	1	
7	1	1	
8	2	1	
9	2	2	
10	2	2	
11	2	1	
12	2	1	

*For factor ‘A’ (types of dyes), ‘1’ and ‘2’ represent treatment efficiency respectively.

*For factor ‘B’ (initial concentration of dye), ‘1’ and ‘2’ represent treatment efficiency respectively.

CHAPTER 4

RESULT AND DISCUSSION

4.1 General full factorial design

One of the statistical experimental design strategies is General Full Factorial Design (GFFD). The main objective is to study the main effects and interactions of variables (parameters evaluated) operated at various levels. Applying a comprehensive full factorial design in electrocoagulation wastewater treatment is crucial for methodically assessing the influence of different parameters on the effectiveness of pollutant elimination. In this experimental design framework, types of dye and the initial concentration of dyes are systematically changed to determine their effects and correlations. We utilised a general multilevel factorial design with two independent variables or operating factors to statistically assess the impact of various operating factors and their interactions on anticipated types of dye and the initial concentration, of dyes denoted as 'A' and 'B'. Factors A represents as types of dye with code of '1' as Methyl Orange (MO) and '2' as Rhodamine Blue (RhB) and Factor B as the initial concentration of dye coded with '1' as 100 ppm and '2' as 500 ppm. Therefore, it was meant to compare the treatment efficiency of synthetic wastewater containing methyl orange dye and rhodamine blue dye using electrocoagulation methods and to correlate the types of dyes and initial concentration of dye due to the treatment efficiency wastewater using statistical software package MINITAB 16. Several statistical analyses had to be performed in the experimental design, including analysis of variance (ANOVA), normal probability plot, residual versus fits plot, main effects plot, and interaction plot.

4.1.1 Experimental design matrix

Table 4.1 shows the experimental design matrix and the experimental responses derived from a total of 12 random experimental runs, with two applications. As previously stated, coding was used to indicate the amount or range of each examined element on a standardised scale, with factors A represents as types of dye with code of '1' and '2' and Factor B as the initial concentration of dye coded with '1' and '2'.

Table 4.1 : Experimental design matrix for electrocoagulation wastewater treatment design (including values for all response)

	Factor		Response
Run Order	**Types of Dye**	**Initial Concentration of Dye (ppm)**	**Treatment Efficiency (%)**
1	1	2	88.84
2	2	2	98.64
3	1	2	89.12
4	1	2	89.12
5	1	1	48.46
6	1	1	47.04
7	1	1	48.51
8	2	1	93.30
9	2	2	98.70
10	2	2	98.71
11	2	1	93.56
12	2	1	93.36

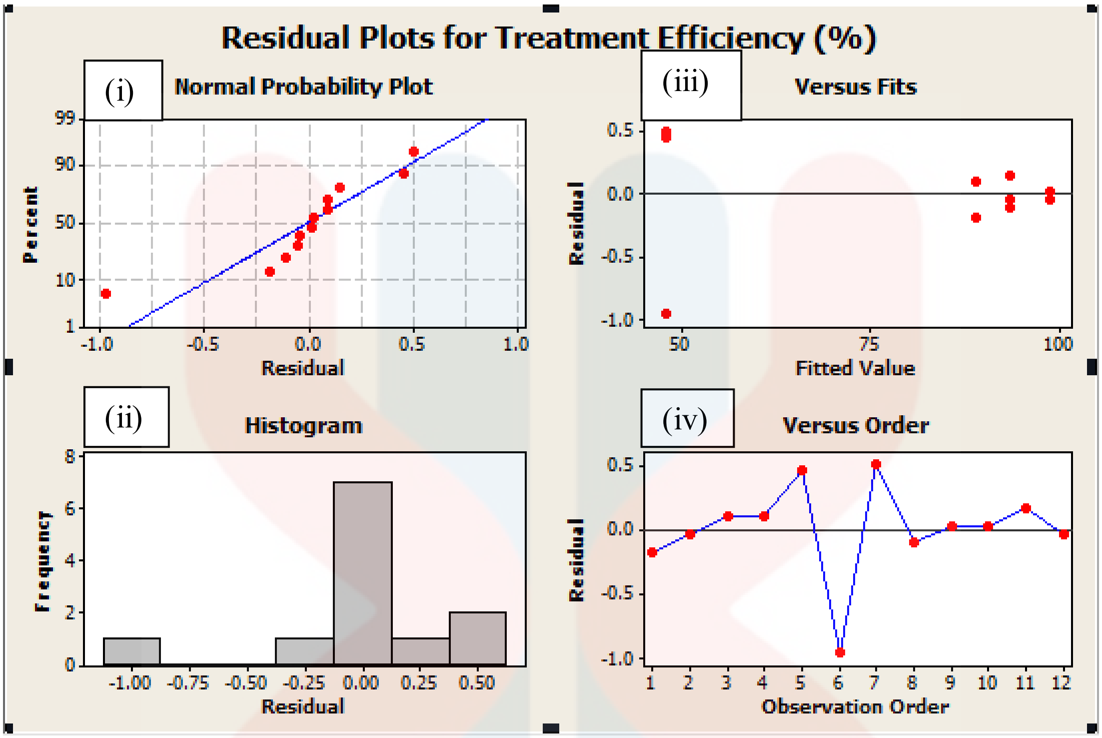
*For factor 'A' (types of dyes), '1' and '2' represent treatment efficiency respectively.

*For factor 'B' (initial concentration of dye), '1' and '2' represent treatment efficiency respectively.

Following that, a series of statistical analyses were conducted for each answer, including ANOVA, normal probability plot, residual versus fits plot, main effects plot, interaction plot and contour plot. These analyses are shown in Table 4.1 and Figure 4.1, 4.2, and 4.3.

4.1.2 Model adequacy checking

Evaluating adequacy is a crucial stage in statistical modelling and experimental design, which entails determining if a selected model is suitable for accurately representing the underlying patterns in observed data. (Jun Zhang a et al., 2014). In this situation, the observed response values were obtained from the experiment, as shown in Table 4.1, whereas the anticipated response values were derived from an equation derived using regression analysis. Evaluating assumptions, such as (i) the assumption of normality of residuals, (ii) the assumption of constant variance of residuals, and (iii) the assumption of independence of residuals. The full examination of model adequacy involves detecting important data points or outliers, taking into account the assumption of independence in residuals, and doing overall model diagnostics. Various statistical residual plots, including the normal probability plot of residuals, the histogram of frequency versus residuals, the plot of residuals versus fitted or predicted values, and the plot of residuals in chronological or observational order, can be employed to validate the veracity of the three assumptions.



Figures 4.1 : Residual plots for treatment efficiency; (i) Normal probability plot, (ii) Histogram of frequency versus residual, (iii) Residual versus fit, (iv) Residual versus observation order of data

The residual plots of electrocoagulation wastewater treatment for the treatment efficiency are shown in Figures 4.1. After evaluating the normal probability plots, it was seen that the majority of the residual points deviate somewhat from the straight line. Despite this, the data for the treatment efficiency had a normal distribution, satisfying the first criteria for assessing model adequacy. Furthermore, the histogram plot revealed an asymmetrical distribution of the histogram bar. Furthermore, residual versus fitted value graphs indicated that the allocation of treatment efficiency was randomized to maintain a consistent residual variance. Furthermore, the symmetrical reflection of the residual points indicates that it is in a state of equilibrium. The residual against the observation order indicates that regardless observation order, the residual points are entirely. This also suggests that the residual was independent of each other in keeping with the third premise.

4.1.3 Analysis of variance (ANOVA)

The analysis of variance (ANOVA) approach is often used in statistical experimental design to assess the substantial impact of operational parameters on the qualities or reactions of a certain created product or application. In this scenario, the significant impacts of types of dye and the initial concentration of dye on treatment effectiveness may be established using ANOVA. This is done by observing the probability value, also known as the ‘p-value’, throughout the analysis. The experimental design and data were evaluated using the MINITAB 16 Statistical Software. The p-values are used to verify the statistical hypothesis for a given model. When assessing a statistical hypothesis for a specific model, the p-value, or probability value, indicates the likelihood that the statistical summary will be greater than or equal to the observed results. This summary could be, for example, the absolute mean difference between two groups in the sample that the p-value must be less than 0.05. Subsequently, it was shown that the quadratic model is statistically significant. (Fatin Mohamati, 2023).

Table 4.2 : ANOVA for treatment efficiency

Source	P-value
Types of Dye	0.00
Initial Concentration of Dye	0.003
Types of Dyes * Initial Concentration of Dye	0.000

Based on the table 4.2, the ANOVA treatment efficacy for electrocoagulation wastewater treatment. The dye’s initial concentration at the start is 100 ppm and 500 ppm, resulting in a p-value of 0.003, which is below the significance level of 0.05. The treatment effectiveness will vary depending on the starting concentrations used, namely 100 ppm and

500 ppm. Using a single dye, altering the beginning concentration will have a significant impact on the treatment efficiency. The research revealed that the p-value for the types of dye and the initial concentration of dyes as linear factors for treatment effectiveness is 0.003 each. The p-value indicates that it is statistically significant at a level below 0.05. This indicating that the types of dye and the initial concentration of dyes applied have an impact on the treatment efficiency. The treatment efficiency will be discussed in section 4.2.

4.1.4 Main effect and interaction plots

Main effects plots demonstrate the effect of a factors (with different levels) to the changes in a particular response. As mentioned previously, in this general factorial design, the main factors evaluated were types of dye and the initial concentration of dye. Meanwhile, interaction plot illustrated the combination effect of both main factors (with different level) of the particular response (treatment efficiency). Figures 4.2 (a) and Figure 4.2 (b) shows the main effect and interaction plot for treatment efficiency.

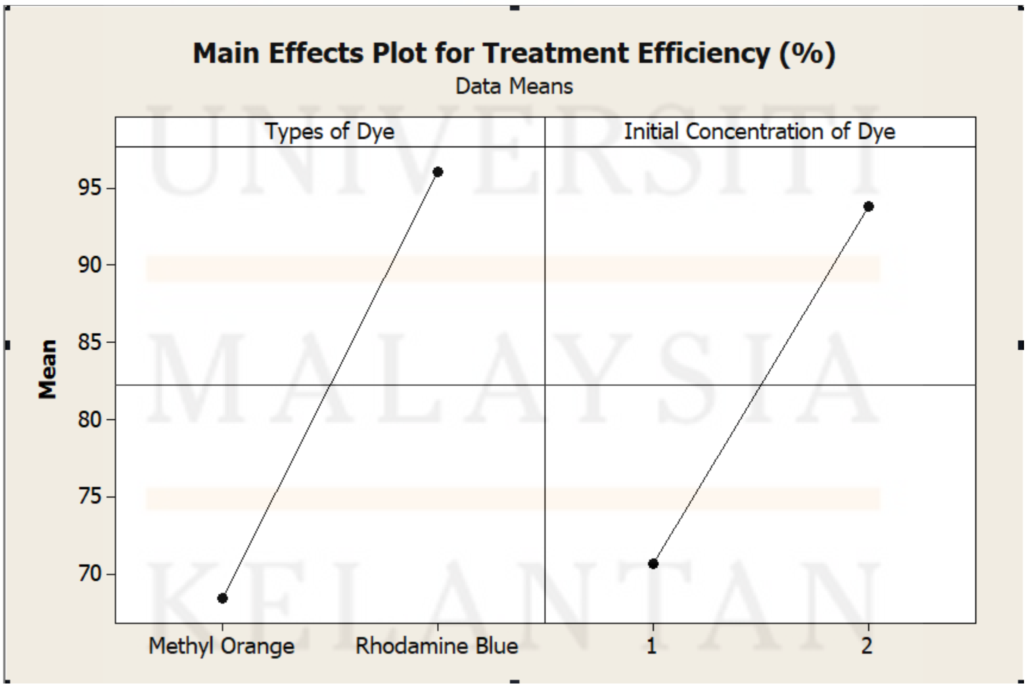


Figure 4.2(a) : Main effect plots for treatment efficiency (%)

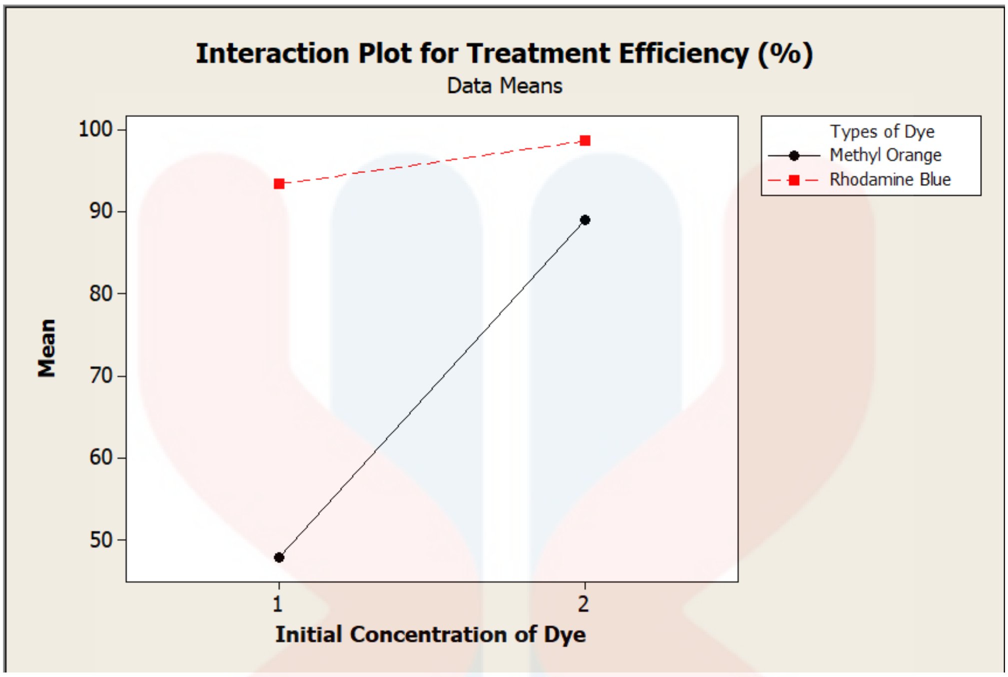


Figure 4.2 (b) : Interaction plot for treatment efficiency (%)

According to Figure 4.2 (a), when transitioning from MO dye to RhB dye, the use of different dyes leads to an enhancement in treatment effectiveness for RhB. The treatment efficacy for RhB is superior to that of MO dye. Regardless of the initial concentration, the treatment efficiency for RhB is consistently greater.

Conversely, the interaction plots (figure 4.2 (b)) is simultaneously include two components. At an initial concentration of 100, the treatment efficiency for MO is rather low, whereas the treatment efficiency for RhB is greater than that of MO. Moreover, the treatment efficiency for MO is greater at an initial concentration of 500 compared to an initial concentration of 100. However, similar to the treatment efficiency of RhB, when the initial concentration is 500, the treatment efficiency of RhB surpasses that of MO. The initial concentration data may be used to optimize parameters, such as the selection of dyes and other factors, to achieve the most efficient and cost-effective treatment (Iwaponline.com). The graph's shows that two lines exhibit non-parallelism. This implies that the gradient varies and both elements are interdependent or mutually reliant. Ultimately, the combination of both factors demonstrates its significance.

4.1.5 Contour Plot

A contour plot is a visual representation used to examine the collective impact of two or more factors on a certain treatment result. It resembles a cartographic representation including interconnected points of equivalent worth. However, instead of indicating altitude, the lines represent a range of the dependent variable based on the combination of the independent variables. The contour plot for treatment efficiency is shown in Figure 4.3.

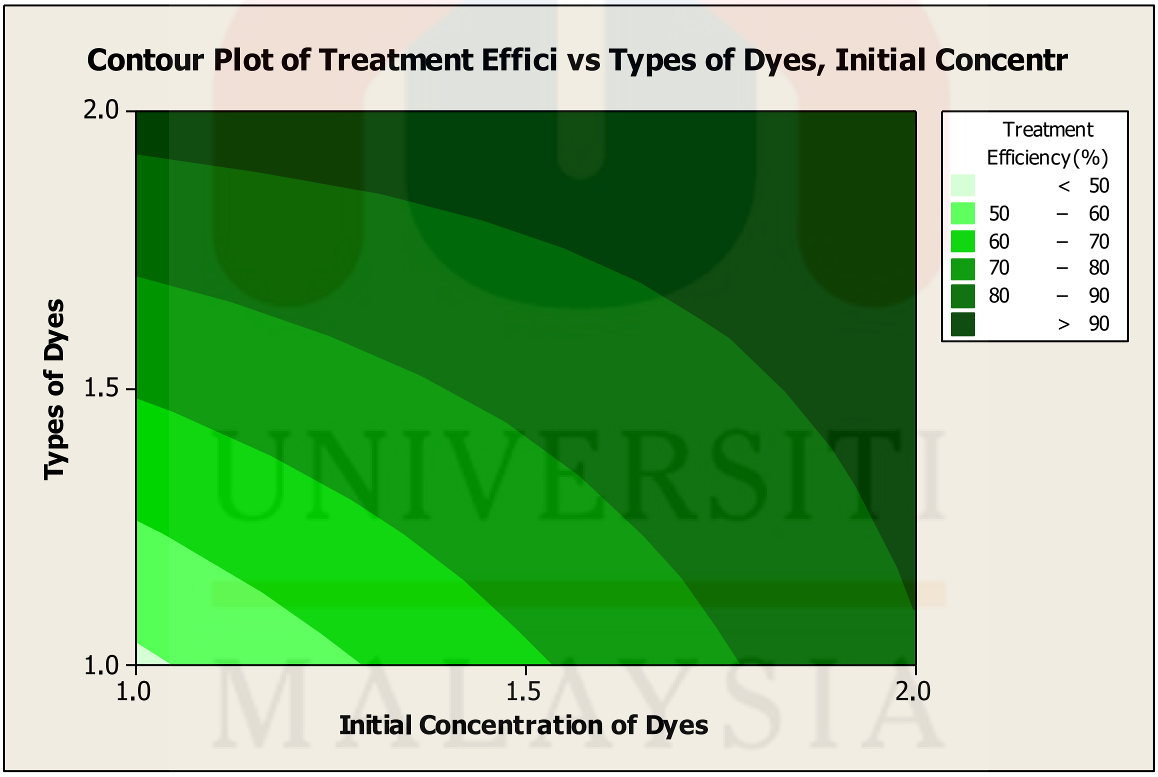


Figure 4.3 : The contour plot of treatment efficiency vs types of dyes, initial concentration of dyes

The contour plot exhibited a series of contour lines, which were either straight or curved. This provides more evidence for the existence of the type of dyes (with 1.0 is MO and 2.0 is RhB) and the initial concentration of dye (with 1.0 is 100 ppm and 2.0 is 500 ppm). Figure 4.3 demonstrates that the optimal treatment efficiency is achieved when an initial concentration of 500 ppm is used and the type of dye is RhB.

Therefore, a general full factorial design is capable of identifying parameters, such as the initial concentration, that have a substantial influence on UV-Vis spectra or the response of the analyte. This aids in directing optimisation efforts towards crucial factors. By systematically exploring different combinations of factors, one may identify the best settings that provide the highest levels of sensitivity, selectivity, or repeatability in UV-Vis measurements. The design outcomes provide mathematical models that forecast reactions according to factor settings that are more precise and dependable.

4.2 Treatment efficiency

4.2.1 Ultraviolet-visible spectroscopy (UV-vis) analysis of treated dyes synthetic wastewater

UV-Vis spectroscopy is essential in order to study for quantitative of absorbing species concentrations treatment of the synthetic wastewater containing methyl orange dye and rhodamine blue dye. Having a comprehensive grasp of UV-Vis analysis helps facilitate the prediction and regulation of results, therefore guaranteeing consistent and accurate measurements. This enables customisation of UV-Vis protocols for particular samples or circumstances, resulting in time and resource savings. UV-Vis procedures guarantee accurate outcomes even in the presence of minor fluctuations in experimental variables. The concentration of the synthetic wastewater is shown in Figure 4.4 (a) and Figure 4.4 (b).

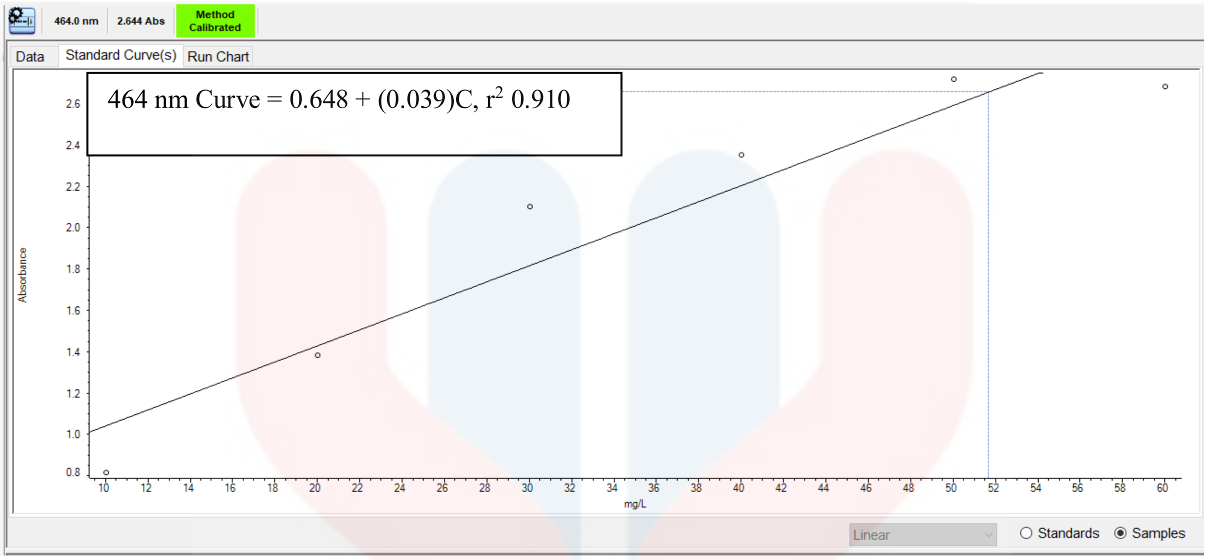


Figure 4.4 (a) : The concentration treatment of the synthetic wastewater containing Methyl Orange Dye

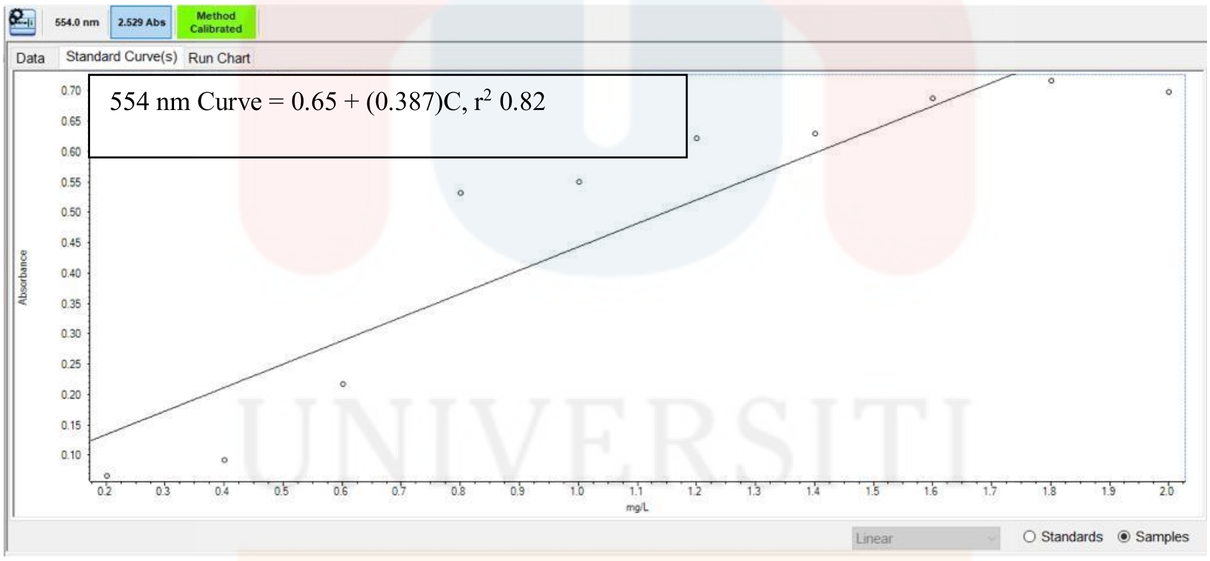
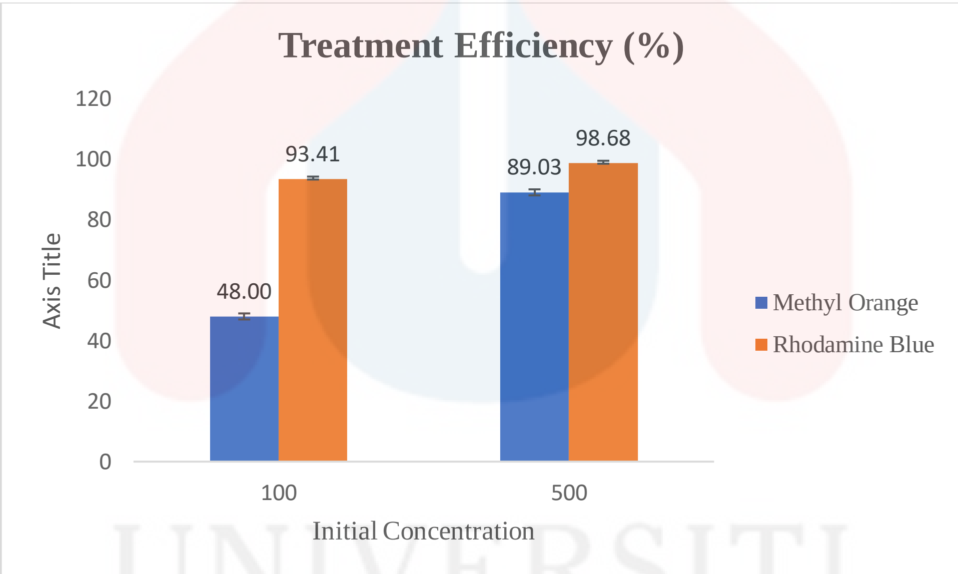


Figure 4.4 (b) : The concentration treatment of the synthetic wastewater containing Rhodamine Blue

Figure 4.4 (a) and Figure 4.4 (b) illustrates a linear connection between dye concentration and absorbance. This indicates that the concentration of the produced synthetic wastewater has reached the target level. By measuring the absorbance at 464 nm in Figure 4.4 (a) and 554 nm in Figure 4.4 (b), the line of best fit may be used to determine the concentration of the dye in a sample of wastewater. Using the equation for the curve at 464nm is 0.648 + (0.039)C, with an r^2 value of 0.910 while the equation for the curve at 554nm is 0.055 + (0.387)C, with an r^2 value of 0.842 can proved the concentration of the produced synthetic wastewater has reached the target level of Methyl Orange dye and Rhodamine Blue dye synthetic wastewater. As a result of the linear connection between dye concentration and absorbance seems to be efficient and predictable to get the wanted initial concentration. It is crucial to point out, yet, that the results may differ for real wastewater, which might be more complicated and varied than synthetic wastewater.



Figures 4.5 : The treatment efficiency of Methyl Orange and Rhodamine Blue dyes (%)

The Figure 4.5 shows the efficacy of the electrocoagulation technique in treatment both methyl orange and rhodamine blue from wastewater. At the greatest current density (2 mA/cm²), the clearance effectiveness for both dyes exceeds 90%. These findings indicate that electrocoagulation has potential as an effective technique for the treatment of wastewater containing these particular colour dyes. The efficacy of treatment for both dyes improves as the current density rises. The reason behind this is because an increased current density produces a greater number of coagulant ions, which in turn may effectively eliminate a larger quantity of dye molecules from the wastewater. Nevertheless, it is crucial to acknowledge that too high current density might result in increased energy consumption and electrode degradation (Dhar & Lee, 2014). The data indicates that the treatment effectiveness of rhodamine blue is marginally superior to that of methyl orange across all current densities. The applied analytical technique enabled the quantification of methyl red at very low levels in wastewater samples, showing exceptional accuracy and precision. (Atsever et al., 2021). The variation in chemical characteristics between the two dyes could be the reason for this. Rhodamine blue is classified as a cationic dye, while methyl orange is classified as an anionic dye. Electrocoagulation is a superior method for eliminating cationic dyes compared to anionic dyes (Castañeda-Díaz et al., 2017). Moreover, it is crucial to highlight that this investigation was carried out with a synthetic wastewater solution. The findings may not have direct relevance to actual wastewater, which may exhibit more complexity and include a diverse range of additional pollutants.

In summary, the data indicates that the electrocoagulation technique has great potential as a viable solution for the treatment of wastewater that contains dyes like methyl orange and rhodamine blue. The meticulous examination of UV-Vis data derived from the treatment of methyl orange and rhodamine b dye wastewater is reinforced by the supplementary EDX findings, so augmenting the accuracy and dependability of the assessment of treatment effectiveness.

4.2.2 EDX Analysis of Floc Generated during Treatment

During the electrocoagulation (EC) treatment, the formation of floc is observed. A floc refers to the combination of small particles that have solidified in a liquid or solution. It usually manifests as a massive huge quantities or structure like a cloud. Flocs are essential for the elimination of suspended particles and contaminants. This process results in the formation of bigger flocs, which can settle more easily or be filtered out with greater efficiency. Therefore, Figure 4.6 shows the floc after wastewater treatment of MO and RhB dyes.

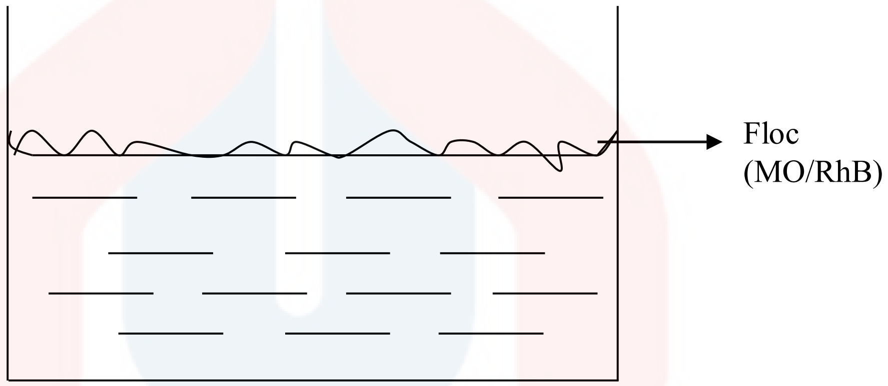


Figure 4.6 : The floc after wastewater treatment Methyl Orange / Rhodamine Blue dyes

Based on the Figure 4.6, it can be seen that the floc is generated during the wastewater treatment process, whereby the aluminum reaction effectively draws negatively charged contaminants including phosphate and organic materials. Furthermore, an elevated current density enhances the rate of floc production, but it might result in smaller and less stable flocs that have worse settling characteristics. Figures 4.7(a) and 4.7(b) shows the formation of floc resulting from the treatment of wastewater containing MO and RhB dye using the EC approach. The initial concentrations of the dye were 100ppm and 500ppm, respectively.

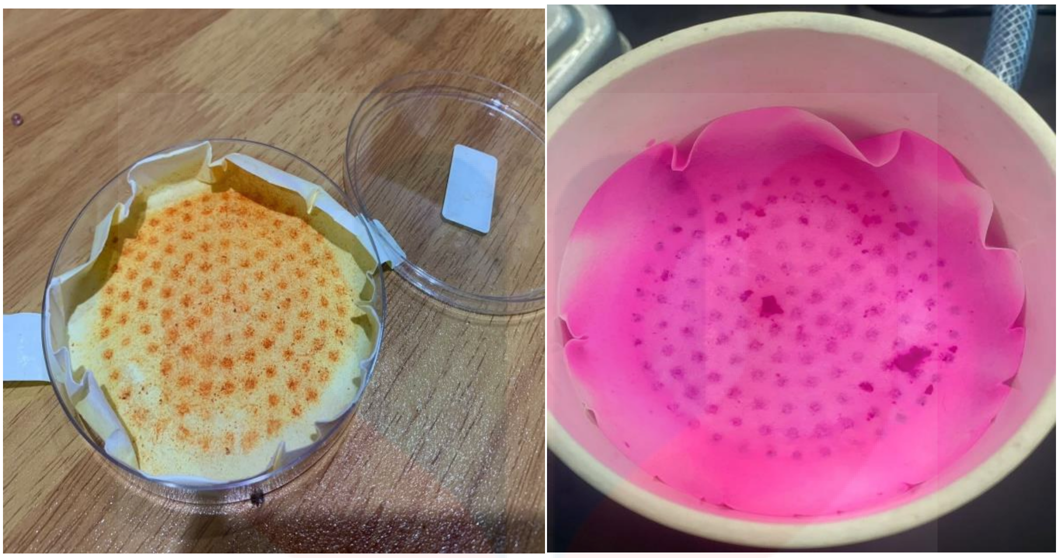


Figure 4.7(a): The floc generated after wastewater treatment of MO and RhB dyes at the initial concentration of 100 ppm.

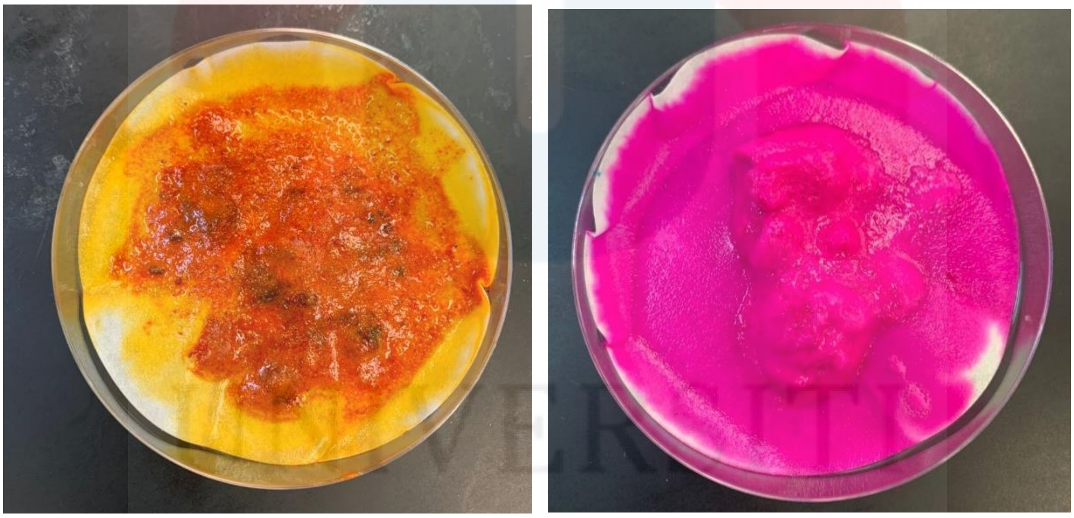


Figure 4.7(b): The floc generated after wastewater treatment of MO and RhB dyes at the initial concentration of 500 ppm.

After analysing Figures 4.7(a) and 4.7(b), it can be seen that the visual evaluation of the produced floc remains uniform in terms of colour and powder shade throughout the starting concentrations of 100 ppm and 500 ppm. In addition, an increased current density speeds up the pace at which flocs are produced. However, this might result in the generation of smaller and less stable flocs that have worse settling properties (Zhang et al., 2023). It is crucial to understand that the composition could change as a result of variations in experimental settings. According to De Lange et al. (2023), changes in testing conditions might affect the effectiveness of therapy and lead to variations in the composition of flocs. In order to provide evidence for this assertion, an EDX study has been performed.

The treatment efficiency sample that was selected for this analysis were wastewater treatment from the MO (with the initial concentration of 100 ppm and 500 ppm) and RhB (with the initial concentration of 100 ppm and 500 ppm) dyes. The selection was made with the intention of examining the morphology of treatment efficiency across various type of dyes and the initial concentrations. The elemental composition determined by EDX analysis of the wastewater floc confirms the presence of the possible functional groups and organic compounds discovered by the UV-vis analysis. This enhances our overall knowledge of the composition of the treated wastewater and the effectiveness of the treatment process. Figures 4.8 shows the morphology of treatment efficiency using EDX.

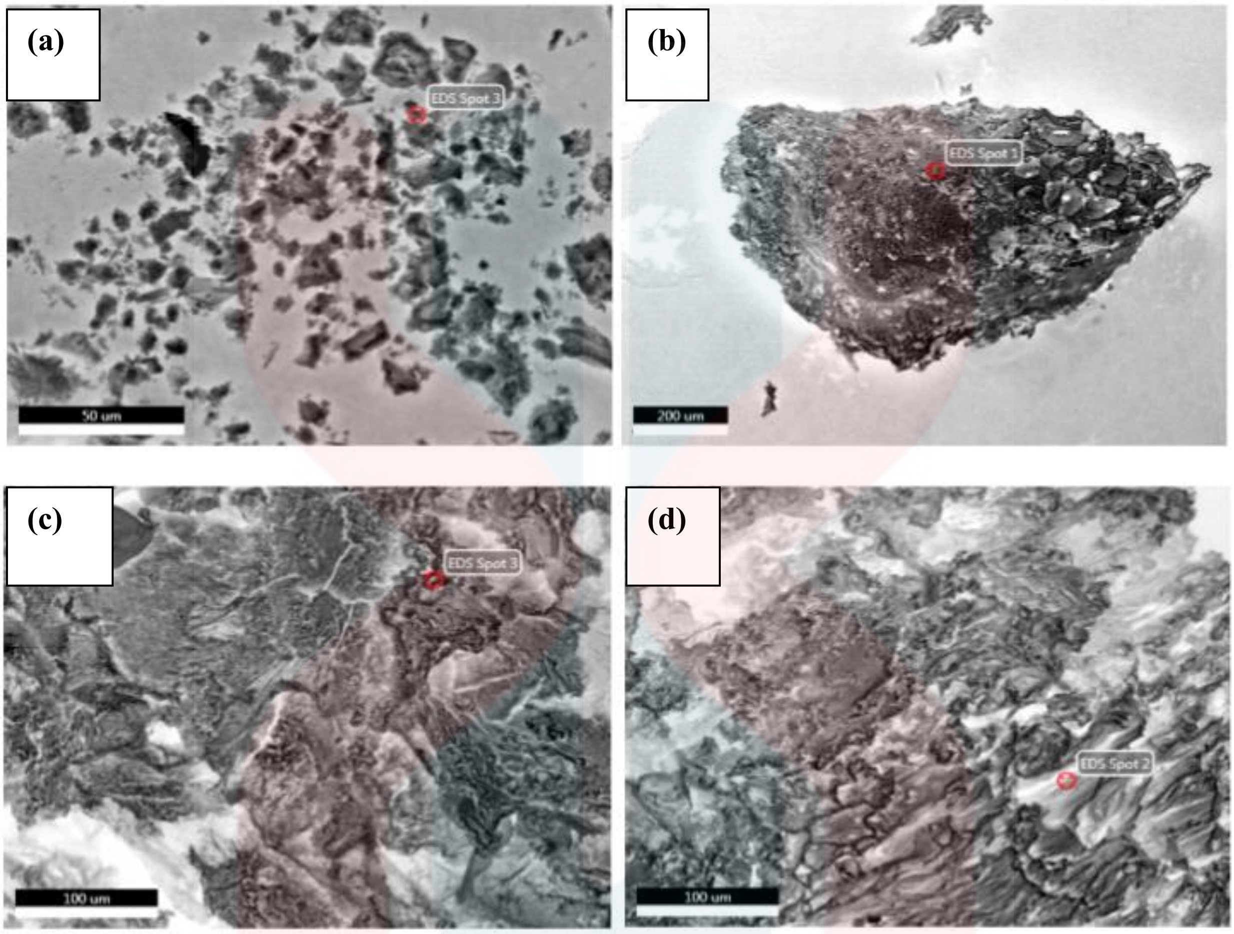


Figure 4.8 : EDX images of wastewater treatment with (a) MO at 100 ppm initial concentration, (b) RhB at 100 ppm initial concentration, (c) MO at 500 ppm initial concentration, and (d) RhB at 500 ppm initial concentration.

Tables 4.3, 4.4, 4.5, and 4.6 provide the quantitative composition, represented by atomic (At) and weight (Wt) percentages, of the elements present in the floc produced by EC.

Table 4.3: Quantitative composition of the elements presents in the floc generated by EC for MO at 100 ppm

Element	C K	N K	O K	NaK	AlK	S K	CuK
Weight %	0.01	0.00	40.08	1.58	31.73	23.44	3.16
Atomic %	0.02	0.01	55.28	1.51	25.95	16.13	1.10

Table 4.4: Quantitative composition of the elements presents in the floc generated by EC for RhB at 100 ppm

Element	C K	N K	O K	AlK	CuK
Weight %	0.00	0.00	48.54	48.90	1.23
Atomic %	0.00	0.00	61.78	36.91	0.39

Table 4.5: Quantitative composition of the elements presents in the floc generated by EC for MO at 500 ppm

Element	C K	N K	O K	NaK	AlK	S K
Weight %	0.01	0.00	23.51	0.00	57.74	18.74
Atomic %	0.02	0.01	35.03	0.00	51.01	13.93

Table 4.6: Quantitative composition of the elements presents in the floc generated by EC for RhB at 500 ppm

Element	C K	N K	O K	AlK	S K	ClK
Weight %	0.02	0.01	41.45	55.98	2.47	0.07
Atomic %	0.03	0.01	54.58	43.71	1.62	0.04

The surface of the flocs developed resulting from the EC treatment was analysed using EDX analysis. This analysis provides a quantitative composition of the elements contained in the floc, including oxygen and aluminum. The results may be found in Table

4.3, 4.4, 4.5, and 4.6. Table 4.3 indicates the percentages of the main elements found in the floc produced by EC for MO at a concentration of 100 ppm. The major elements include oxygen at 40.08wt%, aluminum at 31.73wt%, and sulfur at 23.44wt%. Additionally, minor elements such as carbon, nitrogen, sodium, and copper were detected with percentages of 0.01wt%, 0.00wt%, 1.58%, and 3.16wt% respectively. For the RhB dye (Table 4.4), the dominant elements in the floc produced by EC at a concentration of 100ppm were oxygen at 48.54wt% and aluminum at 48.90wt%. Carbon, nitrogen, and copper were also found as minor elements, with weights of 0.00wt%, 0.00wt%, and 1.23wt% respectively.

The quantitative composition of the components in the floc formed by EC for MO at a concentration of 500 ppm is shown in Table 4.5. The floc formed by EC treatment consisted mostly of oxygen, aluminum, and sulfur. The weight percentages of the elements were 23.51wt%, 57.74wt%, and 18.74wt% correspondingly. Minor elements, namely carbon with a weight percentage of 0.01wt% and nitrogen with a weight percentage of 0.00wt%, were discovered. Table 4.6 displays the composition of RhB dye at a concentration of 500ppm. The principal components present are aluminum at 55.98wt%, oxygen at 41.45wt%, and carbon at 0.02wt%. Minor elements such as nitrogen at 0.01wt%, chlorine at 0.07wt%, and sulfur at 2.47wt% were also discovered.

The strongest elements identified are referred to as Al, which are the main components of Aluminum. Al has the highest peak. It may be inferred that the EDX study was conducted on the aluminum electrode subsequent to electrocoagulation. The presence of oxygen in the floc may originate from either the oxide layer on the surface of the aluminum electrode or from organic molecules adsorbed from the wastewater. The presence of carbon in the wastewater may be attributed to either organic pollutants or the breakdown of MO and

RhB during electrocoagulation. Sulfur in the wastewater may originate from sulfate ions, which may undergo reduction to become sulfide during electrocoagulation.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

At the end of this project, the electrocoagulation treatment of synthetic wastewater containing Methyl Orange and Rhodamine Blue using aluminum electrode as a comparative study was shown to be immense. The General Full Design (GFDD) Statistical Approaches may be effectively used to improve the type of dyes and the initial concentration in order to enhance the effectiveness of wastewater treatment. Several conclusion were made based on the result presented and discussed in Chapter 4 :

(a) Electrocoagulation (EC) treatment utilizing aluminum electrodes demonstrates higher efficacy in treating synthetic wastewater containing Rhodamine Blue (RhB) dye compared to Methyl Orange (MO).

(b) There is a correlation between the type of dyes and the initial concentration of the dye. The effectiveness of wastewater treatment increases as the starting concentration of a certain color decreases.

5.2 Recommendations

The findings of this research on electrocoagulation treatment for synthetic wastewater containing Methyl orange and Rhodamine B dyes suggest numerous suggestions to improve the effectiveness and suitability of this treatment approach. Firstly, further study should be undertaken to investigate the optimal operating parameters for electrocoagulation treatment, such as using larger concentrations, higher voltages, and longer durations. Will these recommendations increase the percentage of treatment efficiency? The objective is to enhance the process and optimize treatment efficiency. Furthermore, it is advisable to experiment with stainless steel as an electrode to determine whether the treatment effectiveness gained is higher compared to that achieved with aluminum electrodes, as previously investigated in this study. Providing the study results and experiences regarding electrocoagulation treatment by scientific papers, conferences, and workshops will promote information sharing and cooperation among researchers, practitioners, and stakeholders in the wastewater treatment area. The purpose of these guidelines is to optimize the efficiency, efficacy, and sustainability of electrocoagulation-based wastewater treatment procedures, hence leading to enhanced water quality and environmental protection.

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