Optimizing Textile Wastewater Treatment Using Electrocoagulation and Multimedia Filtration Strategies for Enhanced Efficiency

Labeba Islam

Tasfiah Kowser Lusaba

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
ISLAMIC UNIVERSITY OF TECHNOLOGY

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A Thesis By

Name of the student	**Student ID**
Labeba Islam	190051115
Tasfiah Kowser Lusaba	190051143

Supervisor:

Dr. Amimul Ahsan

A/Professor

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DECLARATION OF CANDIDATES

We solemnly affirm, under the esteemed guidance of Dr. Amimul Ahsan, that the project/thesis entitled "Optimizing Textile Wastewater Treatment: Electrocoagulation and Multimedia Filtration Strategies for Enhanced Efficiency" has been meticulously undertaken by us. We assert that this endeavor represents our original work and has not been submitted elsewhere for any academic recognition or credential, with the exception of potential publication.

Labeba Islam
Student ID: 190051115

Tasfiah Kowser Lusaba
Student ID: 190051143

MAY, 2024

APPROVAL OF SUPERVISOR

This is to certify that the project/thesis authored by Labeba Islam (ID: 190051115)and Tasfiah Kowser Lusaba (ID: 190051143) has been meticulously reviewed and deemed to meet the requisite standards. Consequently, it has been endorsed as a significant milestone towards the attainment of the Bachelor of Science degree in Civil Engineering.

SUPERVISOR

DR. AMIMUL AHSAN
A/Professor
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT)
A subsidiary Organ of the
Organization of Islamic Cooperation (OIC)
Board Bazar, Gazipur, Bangladesh

MAY, 2024

ABSTRACT

Textile production has a significant environmental impact, mainly because untreated wastewater, packed with harmful substances like dyes, heavy metals, and chemicals, finds its way into water bodies. This pollution spells trouble for aquatic life, human health, and biodiversity, causing water contamination, habitat degradation, and putting communities relying on clean water at risk. That's why it's crucial to optimize textile wastewater treatment. Electrocoagulation and multimedia filtration offer a smart solution to tackle these issues. Electrocoagulation works by using an electric current to destabilize and remove pollutants, while multimedia filtration employs various media like sand and activated carbon to filter out suspended solids and dissolved contaminants. Combining these methods boosts treatment efficiency, with electrocoagulation targeting initial contaminant removal and multimedia filtration adding a finishing touch for high-quality treated water. In this thesis, the collected effluent samples underwent rigorous parameter testing, followed by electrocoagulation using Aluminum anode and Zinc cathode, succeeded by sedimentation and multimedia filtration. This process was conducted multiple times for durations of 30, 45, and 60 minutes, with meticulous data collection after each iteration. Remarkably, the maximum removal efficiencies achieved for Turbidity, Total Suspended Solids, COD, and Color were an impressive 99.46%, 99.27%, 91.304%, and 93.98%, respectively. Following parameter testing, achieving high removal efficiency of turbidity, total suspended solids (TSS), COD, and color stands as a beacon of progress. This milestone ensures compliance with stringent regulatory standards, significantly reducing environmental pollution and safeguarding delicate aquatic ecosystems. Moreover, it elevates the quality of discharged water, mitigating adverse impacts on biodiversity and public health. This remarkable feat not only underscores a commitment to sustainable textile production practices but also aligns with corporate social responsibility and regulatory mandates. However, certain parameters such as pH, Total Dissolved Solids, Dissolved Oxygen, Salinity, and EC exhibited increased values, warranting further investigation and study.

ACKNOWLEDGEMENTS

We begin by expressing our deepest gratitude to the Almighty Allah, whose benevolence has enabled us to bring this study to fruition and complete the preparation of our project and thesis.

Titled "Optimizing Textile Wastewater Treatment: Electrocoagulation and Multimedia Filtration Strategies for Enhanced Efficiency," this endeavor represents a significant step towards fulfilling the requirements for our Bachelor of Science degree in Civil Engineering. In our unwavering pursuit of academic excellence, we have had the honor of being guided by the wise mentorship of Dr. Amimul Ahsan, a distinguished Associate Professor at the Department of Civil and Environmental Engineering (CEE), Islamic University of Technology (IUT), Bangladesh. His steadfast support, patient guidance, and invaluable insights have formed the foundation of our project, molding it into a true testament of dedication and scholarly pursuit.

Furthermore, we wish to extend our heartfelt appreciation to the dedicated lab technicians at the Environment Engineering Lab, CEE, IUT, Bangladesh, whose invaluable assistance during our practical experiments has been indispensable. Additionally, we express our profound gratitude to all faculty members of the CEE department at IUT, whose invaluable suggestions and unwavering support have played a pivotal role in the success of our project. Their collective wisdom and encouragement have enriched our learning journey and instilled within us a drive for excellence in our academic pursuits.

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CHAPTER I

INTRODUCTION

1.1 Background of the study

The textile industry plays a critical role in global manufacturing by providing essential materials for clothing, home furnishings, and various industrial uses. Despite its economic importance, the industry encounters significant challenges in managing the wastewater produced during its processes. The treatment of this wastewater is essential due to the presence of high levels of organic and inorganic contaminants, which, if not properly managed, can pose serious environmental and public health risks. This thesis aims to investigate methods to optimize textile wastewater treatment by integrating electrocoagulation (EC) and multimedia filtration techniques to improve efficiency and reduce environmental impacts.

The processes involved in textile manufacturing, such as chemical treatments, dyeing, finishing, and washing, generate wastewater that contains a wide array of pollutants. These include suspended solids, organic dyes, heavy metals, and other harmful substances, making the treatment of textile effluents particularly challenging. While conventional methods like biological treatment, chemical coagulation, and membrane filtration are commonly used, they often fall short in effectively handling the complex composition of textile wastewater.

1.2 Challenges in Textile Wastewater Treatment

Treating textile wastewater involves multiple challenges, such as addressing a variety of contaminants simultaneously, managing fluctuations in wastewater composition, and meeting strict regulatory standards. These issues require the development of innovative and flexible treatment technologies to ensure effective compliance with environmental regulations.

1.3 Electrocoagulation as an Advanced Treatment Technique

Electrocoagulation has gained attention as an advanced technology for wastewater treatment because it can address multiple contaminants at once. Utilizing electrochemical reactions, EC destabilizes pollutants, resulting in the formation of coagulant species that help in removing these contaminants. Its use in treating textile wastewater is particularly promising for removing color, precipitating metal ions, and degrading organic compounds.

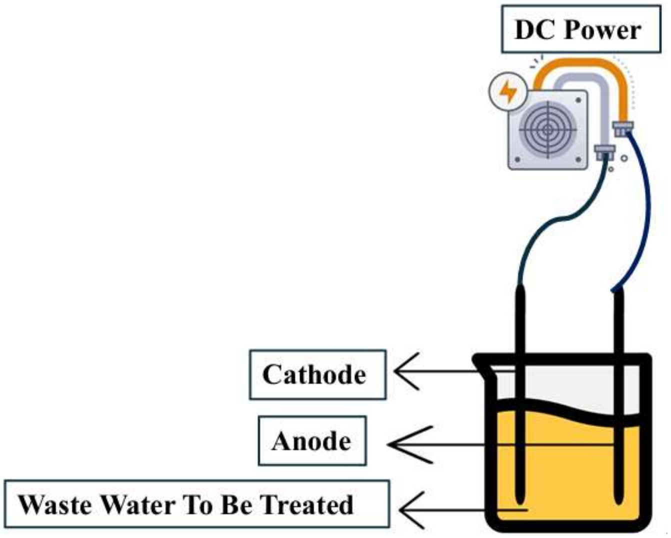


Figure 0-1.1: Electrocoagulation basic diagram

1.4 Multimedia Filtration for Polishing Effluents

After electrocoagulation treatment, wastewater typically needs additional polishing to comply with stringent discharge standards. Multimedia filtration systems, which use media like sand, activated carbon, and anthracite, provide enhanced filtration capabilities and help eliminate remaining impurities. This approach is effective in treating effluents processed by EC, as it targets suspended solids, trace organic compounds, and fine particulates.

1.5 Objectives of the study

The specific objectives of this study are:

i. To investigate the effectiveness of electrocoagulation & multimedia filtration in treating textile wastewater.

ii. To obtain the effect of various retention times in treating textile wastewater.

1.6 Scope of the study

i. The scope of this study encompasses laboratory-scale experiments aimed at optimizing electrocoagulation (EC) and multimedia filtration (MMF) processes for the treatment of textile wastewater.

ii. The study aims to provide valuable insights into sustainable wastewater treatment practices within the textile industry, fostering environmental stewardship and encouraging technological innovation.

CHAPTER II

LITERATURE REVIEW

2.1 Textile Industry and Wastewater Concerns

The textile industry, a vital part of global manufacturing, encounters substantial challenges in managing wastewater. The production processes in this industry generate wastewater that contains a complex blend of pollutants, including dyes, heavy metals, organic compounds, and suspended solids. Effective treatment of this wastewater is essential to prevent environmental damage and health risks.

2.2 Composition and Characteristics of Textile Effluents

Textile wastewater contains a wide variety of pollutants originating from dyeing, finishing, and washing processes. These pollutants include highly pigmented dyes, toxic heavy metals such as chromium and lead, surfactants, solvents, and particulate matter. The complex nature of this wastewater necessitates customized treatment strategies to achieve thorough removal of all contaminants.

2.3 Impacts of Untreated Textile Discharges

The release of untreated or inadequately treated textile effluents into natural water bodies can result in severe ecological repercussions. These consequences span from surface water contamination and groundwater pollution to the disruption of aquatic ecosystems, oxygen depletion, and the accumulation of hazardous substances in aquatic organisms. Additionally, the visual degradation caused by colored effluents can compromise recreational and aesthetic values of water resources.

2.4 Conventional Treatment Approaches and Limitations

Textile wastewater treatment typically relies on conventional methods such as physical, chemical, and biological processes. While physical processes like sedimentation and filtration excel at removing suspended solids, they may fall short in addressing dyes and heavy metals. Chemical treatments such as coagulation/flocculation and oxidation can target specific pollutants but may produce secondary wastes or necessitate extensive post-treatment steps. Biological treatments effectively handle organic matter but may struggle with toxic compounds and variations in wastewater characteristics.

2.5 Electrocoagulation (EC) as a Remediation Method

Electrocoagulation (EC) has emerged as a promising electrochemical treatment for textile wastewater due to its efficacy in removing suspended solids, color, organic compounds, and select metals. This process involves applying direct current to sacrificial electrodes, triggering the formation of coagulant species crucial for pollutant removal. Ongoing optimization efforts center on variables like current density, pH, electrode materials, and treatment duration to enhance EC's effectiveness and practicality.

2.6 Multimedia Filtration (MMF) Strategies

Multimedia filtration (MMF) systems leverage diverse filtration media to target suspended solids, organic matter, and certain dissolved pollutants in wastewater. Media variants such as sand, activated carbon, and anthracite offer unique adsorption and filtration capabilities. Research endeavors focus on optimizing media selection, bed depth, hydraulic loading rates, and backwashing protocols to sustain filtration performance consistently.

2.7 Synergistic Integration of EC and MMF

Integrating EC and MMF processes presents synergistic advantages for enhancing textile wastewater treatment. EC's role as pre-treatment to MMF proves effective in reducing fouling potential and augmenting overall treatment efficiencies. Successful integration hinges on meticulous consideration of process parameters, media characteristics, and system design to achieve optimal pollutant removal while ensuring operational reliability and cost-effectiveness.

2.8 Current Research Trajectories and Future Prospects

Contemporary research trajectories in textile wastewater treatment revolve around advancing EC and MMF technologies via innovative electrode and media designs, exploring hybrid treatment configurations, developing intelligent monitoring and control systems, and addressing sustainability imperatives such as energy optimization and waste minimization. Future endeavors encompass pilot-scale validations, techno-economic assessments for industrial scalability, and cohesive integration with emerging treatment paradigms to realize holistic and sustainable solutions for textile wastewater treatment challenges.

2.9 Final overview obtained from Literature Review

Table 2.1: Final overview obtained from literature review

Effectiveness of EC	Challenges	Future Research Goals
High efficiency in lab conditions; Specific pollutants removal	High electricity usage; Destabilizing tight emulsions in industrial settings	Optimize EC reactor economics; Improve stability in industrial applications
Optimal performance achieved with enhancements	High energy consumption; Additional waste generation; Short circuits	Experiment with varied electrodes; Reduce operational costs and waste generation
Successful suspended solids removal; Potential for new applications	Electrode passivation reduction; Cost efficiency	Quantify electrochemistry-coagulation-flotation interactions; Develop new applications
Verified efficiency in broad wastewater use	Power source optimization; Sludge generation; High electricity costs	Determine optimal conditions; Focus on reducing electricity costs
Enhanced removal efficiency; Addressed passivation challenges	Passive film thickness decrease; Corrosion rate issues	Improve anode passivation; Address corrosion challenges
Efficient wastewater treatment; Ongoing material development	Economic feasibility; Unwanted by-products; Specific energy consumption	Reduce specific energy consumption; Address cost concerns

Successful greywater treatment; Potential for larger-scale use	Electrode durability; Metal contamination; Energy optimization	Develop reusable waste forms; Improve energy efficiency for wider adoption
Enhanced removal efficiency in large-scale applications	System design optimization; Cost-effectiveness	Develop more efficient large-scale systems; Investigate cost-effectiveness further
Highly efficient and environmentally friendly technology	Operational cost optimization; Emerging pollutant removal	Explore techno-economic feasibility; Study coupling with other systems

CHAPTER III

METHODOLOGY

3.1 Introduction

The methodology for the thesis involves a systematic approach to treating effluent, beginning with the collection of representative samples. This is followed by the setup of a multimedia filter system, including the selection of appropriate filter media and calculation of media depth. Maintenance of the filter system through layer cleaning ensures consistent performance. Initial analysis of untreated effluent establishes baseline parameters. Treatment steps include electrocoagulation to remove contaminants, sedimentation for particle settling, and filtration for further purification. Subsequent parameter testing evaluates the quality of treated effluent, including pH, dissolved oxygen, salinity, conductivity, total dissolved solids, total suspended solids, color, turbidity, chemical oxygen demand, and biochemical oxygen demand, to assess the efficacy of each treatment stage.

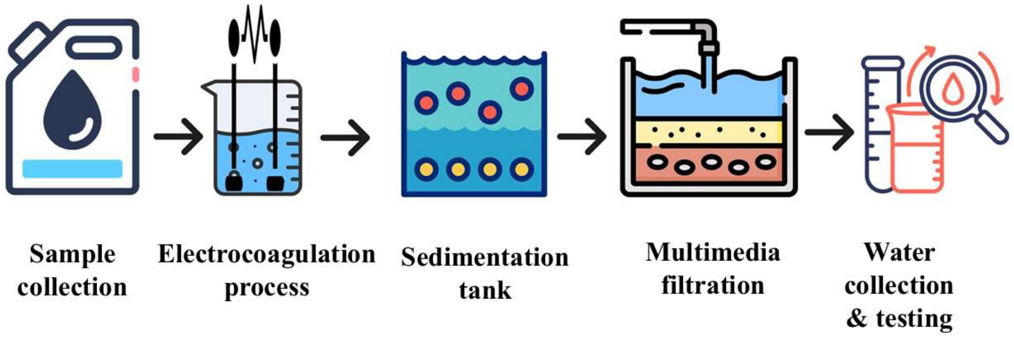


Figure 3.1: Process flow diagram of the whole methodology

3.2 Sample Collection

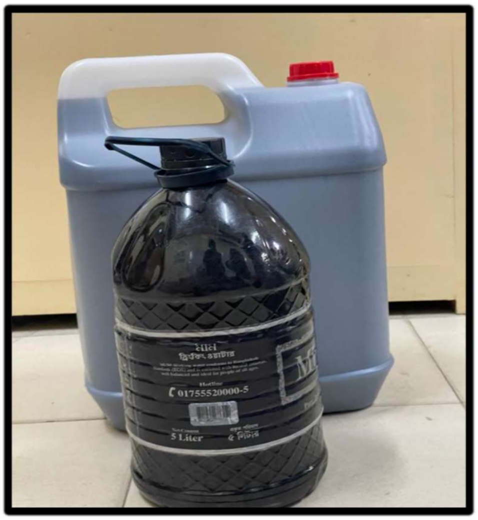


Figure 3.2: Collected sample effluent from Apex Holdings Ltd

The effluent sample was carefully gathered from Gazipur, Bangladesh's busy textile industry hub. It came from APEX HOLDINGS LIMITED, a respected company in Chandora, Kaliakoir.

Address :

APEX HOLDINGS LIMITED

FACTROY: CHANDORA,KALIAKOIR,GAZIPUR, BANGLADESH

TEL # 880-06-822-51204-6 EXT. 4123

FAX # 880-06-822-51187

E-mail: water-monitoring@apexholdings.com

3.3 Preparation of Multimedia Filter

Our multimedia filter system is designed for maximum efficiency and effectiveness. This filter has three layers : a top layer of sand, a middle layer of medium gravel, and a bottom layer of coarse gravel. The sand layer, sieved at 0.6, acts as the initial barrier, gently removing impurities from the water. Beneath it, the medium gravel layer, sieved at 2.36, continues the filtration process, effectively trapping smaller particles. Finally, the coarse gravel layer, sieved at 9.5, further enhances filtration by capturing larger contaminants. So each layer plays a vital role in turning raw effluent to clear water. With a total depth of 1'3", this filter system reflects our commitment to thorough purification. Through this innovative design, dirty water undergoes a remarkable transformation, emerging clear and pure. Each layer plays a vital role in turning raw effluent to clear water.

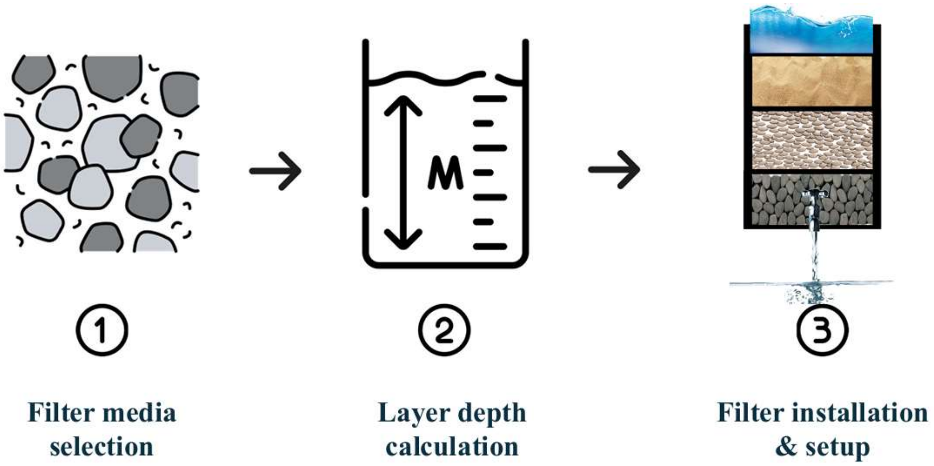


Figure 3.3: Process flow diagram of multimedia filter preparation

Figure 3.4: Multimedia filter installation and setup

3.3.1 Filter Media

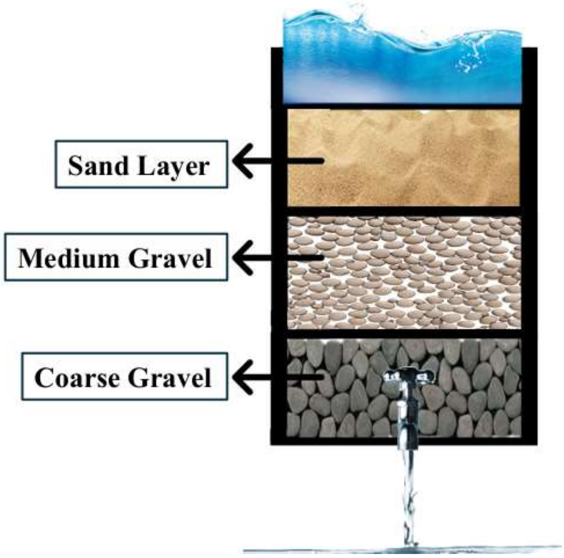


Figure 3.5: Three layers of multimedia filter (sand, medium and coarse gravel)

3.3.1.1 Sand

The sieve of this filter media is 0.6. This media is used as the top layer of the filter. The depth of this layer is 3.5”. We used sand in the first layer because sand serves as a highly effective filter media due to its natural properties and structure. With its fine particles and porous nature, sand efficiently traps and removes impurities from water. As water passes through the sand layer, contaminants such as sediment, dirt, and organic matter are physically trapped within the spaces between the sand particles. Additionally, sand provides a large surface area for adsorption and microbial activity, further enhancing its filtration capabilities. Its affordability, availability, and ease of maintenance makes sand a popular choice for various filtration applications, including water treatment, swimming pools, and aquariums. Overall, sand stands as a reliable and efficient filter media, essential for ensuring clean and safe water.

Figure 3.6: Filter media (Sand)

3.3.1.2 Medium Gravel

The sieve of this filter media is 2.36. This media is used as the middle layer of the filter. The depth of this layer is 2.75”. We used medium gravel in the middle layer because medium gravel serves as an excellent filter media due to its ability to effectively remove larger particles and provide support for finer filtration media. With its intermediate particle size, medium gravel acts as a barrier for contaminants that are too large to pass through, while allowing water to flow freely. This helps prevent clogging and ensures consistent filtration performance. Additionally, the irregular shape of gravel particles creates spaces and channels within the filter bed, promoting efficient water flow and enhancing filtration efficiency. Medium gravel is commonly used in multimedia filtration systems, where it works in conjunction with other filter media such as sand and activated carbon to achieve comprehensive water purification. Its durability, affordability, and versatility make medium gravel a valuable component in various filtration applications, including wastewater treatment, stormwater management, and aquaculture. Overall, medium gravel is an essential filter media that plays a crucial role in maintaining clean and healthy water systems.

Figure 3.7: Filter media (Medium Gravel)

3.3.1.3 Coarse Gravel

The sieve of this filter media is 9.5. This media is used as the bottom layer of the filter. The depth of this layer is 2.75”. We used coarse gravel in the bottom layer because Coarse gravel serves as an essential filter media, particularly in applications where larger particles need to be removed from water. Its robust and irregular structure allows for efficient filtration by providing ample space for water to pass through while trapping larger contaminants. As water flows through the coarse gravel layer, sediment, debris, and other particulate matter are effectively captured within the void spaces between the gravel particles. This helps prevent clogging and ensures continuous water flow, even under high filtration loads. Coarse gravel is commonly used as a pre-filter in multimedia filtration systems or as a support layer for finer filter media such as sand or activated carbon. Its durability, low cost, and resistance to compaction make coarse gravel an ideal choice for various filtration applications, including wastewater treatment, pond filtration, and stormwater management. In summary, coarse gravel plays a crucial role in maintaining water quality by providing effective filtration and ensuring the longevity and efficiency of filtration systems.

Figure 3.8: Filter media (Coarse Gravel)

3.3.2 Media Depth Calculation

<u>filter body dimension :</u>

Length = 8"

Width = 8"

Height = 15"

Volume = 8" × 8" × 15" $= 960\ in^2 = 0.0157316\ m^3$

Volume for media :

Let, 60% of total volume will be the volume for media.

$$V_{media} = 0.0157316 \times 60\% = 0.00943896\ m^3$$

Let, 60% will be gravel, 40% will be sand

$$V_{gravel} = 0.00943896 \times 60\% = 0.0056634\ m^3 = 345.60187\ in^3$$

$$V_{sand} = 0.00943896 \times 40\% = 0.003776 m^3 = 230.425658\ in^3$$

Height of media:

2 layers of gravel :

- Sieve 2.36mm,

$$H_1 = \frac{V}{L \times W} \times 50\%$$

$$= \frac{345.60187}{8 \times 8} \times 50\%$$

$$= 2.70001\ in = 2.7\ in$$

- Sieve 9.5mm,

$H_2 = 2.7\ in$

Sand layer :

1. Sieve 0.6mm,

$$H_1 = \frac{V}{L \times W} \times 50\%$$

$$= \frac{230.425658}{8 \times 8} \times 50\%$$

$$= 3.6004\ in = 3.6\ in$$

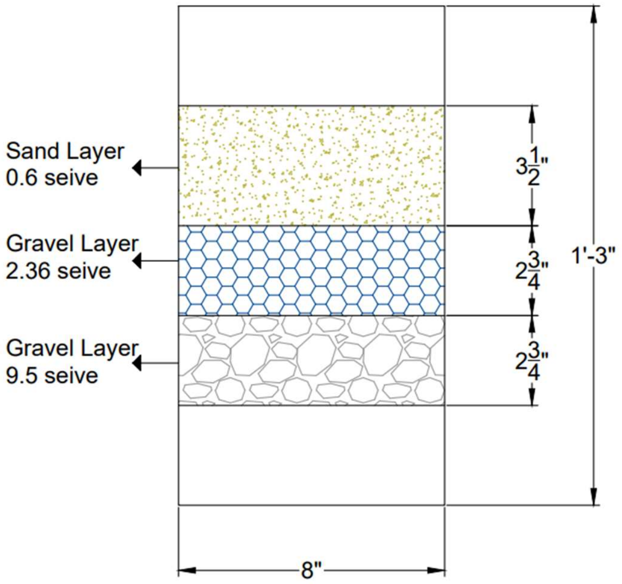


Figure 3.9: Calculated depths of different filter media

3.3.3 Filter Layer Cleaning

After collecting sand, medium gravel, and coarse gravel from the concrete lab, we encountered dusty, dirty, and clayey conditions. To ensure optimal performance of our multimedia filter, it was imperative to thoroughly clean the filter media. This involved passing clean water through the filter multiple times, effectively rinsing away any impurities and residues. Only by meticulously cleansing the filter media could we achieve our goal of producing water that is colorless, free from turbidity, and impeccably clean. Through diligent efforts and attention to detail, we have successfully prepared our filter to deliver the highest standard of water purification, meeting the stringent requirements of our application.

3.4 Electrocoagulation of Effluent

Electrocoagulation was conducted to remove contaminants from water using an electric current. 1L sample effluent was concentrated with 1g salt (NaCl). The electrocoagulation apparatus was set up, comprising two electrodes (made of aluminum and zinc), a power source, and a container holding the effluent to be treated. The electrodes were connected to the power source, ensuring proper polarity was maintained. Using the current voltmeter, the desired current and voltage levels were adjusted (apparently 25v was maintained), taking into account factors such as the type and concentration of contaminants, electrode material, and treatment duration. The electrodes were then immersed in the effluent, ensuring they were adequately spaced apart and fully submerged. The power source was activated to apply the electric current, which flowed between the electrodes, inducing electrochemical reactions that generated coagulating agents, such as aluminum hydroxides or zinc hydroxides. Throughout the treatment process, the current and voltage levels were continuously monitored using the current voltmeter to ensure they remained within the desired range. The electrocoagulation process ran for the required duration(30 minutes, 45 minutes and 60 minutes), determined based on treatment objectives and the efficiency of contaminant removal. Once treatment was complete, the power source was deactivated, and the electrodes were removed from the treated effluent.

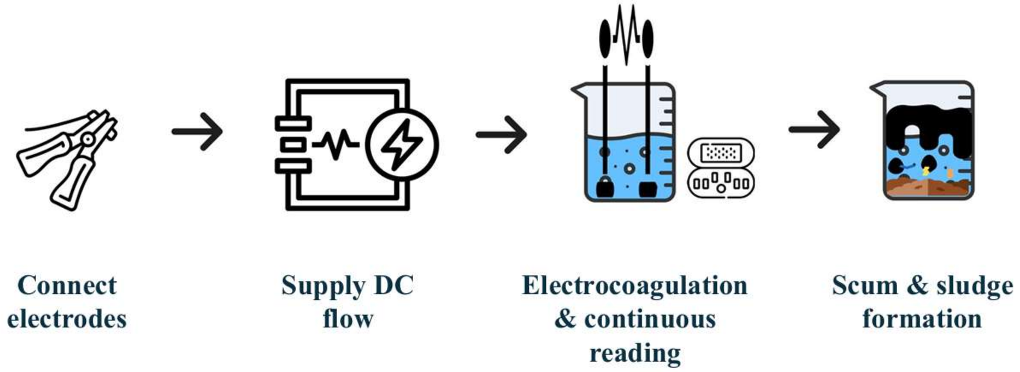


Figure 3.10: Process flow diagram of electrocoagulation

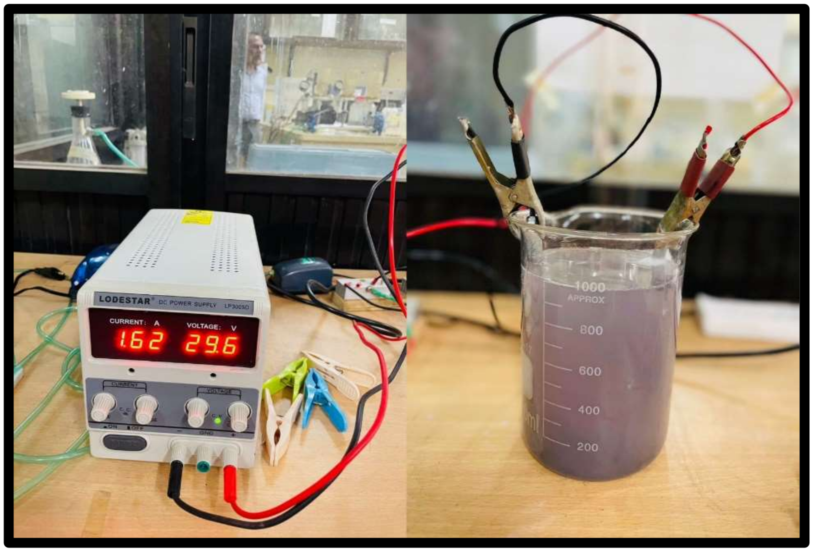


Figure 3.11: Electrocoagulation process with DC power supply

Figure 3.12: Al anode & Zn cathode

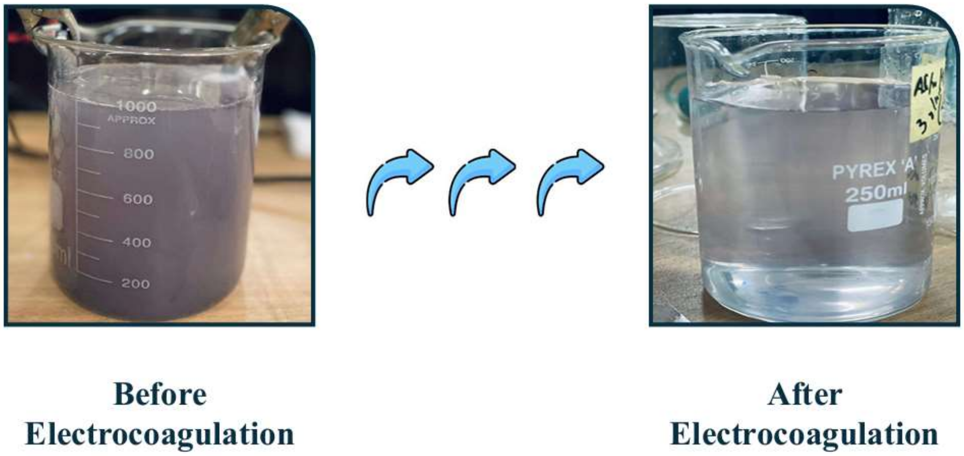
At the beginning

After 30 minutes

After 45 minutes

After 60 minutes

Figure 3.13: Scum formation in electrocoagulation process at different time interval



Before Electrocoagulation

After Electrocoagulation

Figure 3.14: Wastewater condition before & after electrocoagulation

3.5 Sedimentation

As a sedimentation basin, the beaker used in electrocoagulation was used. After electrocoagulation, the beaker was left undisturbed for a period of time to allow the sediment particles to settle to the bottom. After a sufficient amount of time had passed, the clear water above the settled sediment was carefully decanted or siphoned off, leaving behind the sediment at the bottom of the beaker. Finally, the clear water from the top was collected and analyzed for further study or disposal, depending on the purpose of the sedimentation.

Sedimentation was done after 30 minutes electrocoagulation for 1 hr, 3 hr and 6 hr, after 45 minutes electrocoagulation for 1 hr, 3 hr and 6 hr and 60 minutes electrocoagulation for 1 hr, 3 hr and 6 hr.

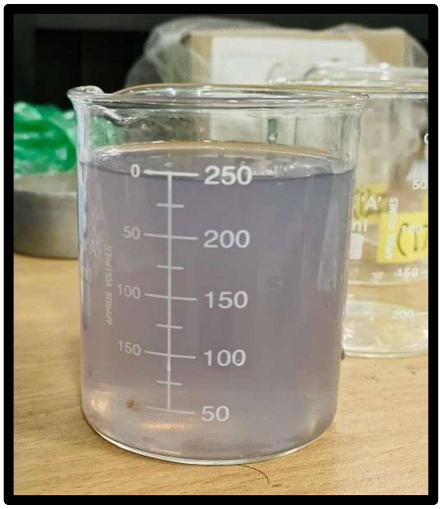


Figure 3.15: Sedimented effluent

Table 3.1: Scum and Sludge height obtained after electrocoagulation at various retention times

Electrocoagulation duration	Sedimentation duration	Scum height (Average) (cm)	Sludge height (Ave/rage) (cm)
30 minutes	1 hr	1.2	0.25
	3 hr	2.5	0.45
	6 hr	3	0.5
45 minutes	1 hr	2.3	0.3
	3 hr	3.63	0.4
	6 hr	3.87	0.5
60 minutes	1 hr	3.5	0.28
	3 hr	4.38	0.35
	6 hr	4.5	0.55

3.6 Filtration

To conduct filtration using a multimedia filter after sedimentation, the sedimentation-treated water was passed through the multimedia filter consisting of layers of sand, medium gravel, and coarse gravel. First, the sediment-treated water was poured onto the top layer of sand. Then, the water slowly trickled through the sand layer, allowing fine particles and impurities to be trapped. Next, the partially filtered water passed through the middle layer of medium gravel, which further removed larger particles and suspended solids. Finally, the water flowed through the bottom layer of coarse gravel, which acted as a final barrier to capture any remaining impurities. The filtered water collected at the bottom of the filter was then ready for further use or analysis.

3.7 Parameter Testing

Testing the parameters of both the sample effluent and treated effluent is crucial for understanding the effectiveness of wastewater treatment processes. By analyzing various parameters such as BOD, COD, pH, TDS, TSS, TS, EC, salinity, color, and turbidity, we can assess the initial state of the effluent and compare it to the treated effluent. This comparison allows us to evaluate the efficiency of the treatment process, identify any pollutants or contaminants that remain after treatment, and ensure compliance with environmental regulations. Moreover, it provides valuable insights for optimizing treatment methods and implementing measures to protect water quality and ecosystem health, ultimately contributing to sustainable environmental stewardship.

Parameter Testing for Effluent Treatment Steps:

- Sample Effluent:

Comprehensive analysis of parameters including BOD, COD, pH, TDS, TSS, TS, EC, salinity, color, and turbidity to establish a baseline for further comparison.

- After Electrocoagulation:

Specialized treatment method evaluation involves a detailed examination of parameters post-electrocoagulation, assessing its impact on the effluent's composition and contaminant removal efficacy.

- After Sedimentation:

Evaluation of sedimentation process effectiveness through parameter testing to gauge its efficiency in removing suspended solids and other impurities from the effluent.

- After Filtration:

Final stage assessment involves parameter testing post-filtration to ensure the efficiency of the filtration system in eliminating remaining contaminants, thus completing the effluent treatment process.

This systematic approach ensures thorough monitoring and optimization of each treatment step, contributing to enhanced environmental protection and sustainable wastewater management.

3.7.1 pH

To measure the pH of the effluent a pH meter was used. The pH meter was first calibrated according to the manufacturer's instructions using standard buffer solutions. Once calibrated, a sample of the effluent was collected in a clean container. The pH electrode of the meter was carefully immersed into the effluent sample, ensuring that it was fully submerged and not touching the sides or bottom of the container. The electrode was left in the sample for a few moments to allow the pH reading to stabilize. The pH value displayed on the meter was then recorded. This process was repeated for multiple samples to ensure accuracy and consistency in the pH measurements. Finally, the pH meter was rinsed with distilled water between each measurement to prevent cross-contamination.

Figure 3.16: pH Meter

3.7.2 DO, Salinity, EC, TDS

Figure 3.17: Multiparameter

To measure dissolved oxygen (DO), salinity, electrical conductivity (EC), and total dissolved solids (TDS) a multiparameter instrument was used. The instrument was first turned on and allowed to warm up according to the manufacturer's instructions. Once ready, the probe or sensor for each parameter was carefully calibrated using appropriate calibration standards.

For measuring dissolved oxygen, the DO probe was immersed in the water sample, ensuring that no air bubbles were trapped on the sensor. The reading displayed on the instrument was recorded as the dissolved oxygen concentration.

To measure salinity, the salinity probe was submerged into the water sample, and the instrument was allowed to stabilize. The salinity value displayed on the instrument was then recorded.

For electrical conductivity (EC) and total dissolved solids (TDS), the EC/TDS probe was submerged into the water sample, and the instrument was allowed to stabilize. The EC and TDS values displayed on the instrument were recorded accordingly.

After each measurement, the probes were rinsed with distilled water to remove any residue and prevent cross-contamination between samples. This process was repeated for multiple samples to ensure accuracy and consistency in the measurements. Finally, the instrument was turned off and properly cleaned and stored for future use.

3.7.3 TSS, Color

Figure 3.18: Spectrophotometer

To measure total suspended solids (TSS) and color a spectrophotometer was used. First, the spectrophotometer was turned on and allowed to warm up according to the manufacturer's instructions. Calibration was conducted using blank solutions or standards provided by the manufacturer.

For TSS measurement, a known volume of the water sample was filtered through a pre-weighed filter paper using a filtration apparatus. The filter paper with the captured suspended solids was dried and weighed to determine the initial suspended solids concentration. Then, the filter paper was placed in a suitable solvent to dissolve the solids, and the absorbance of the resulting solution was measured using the spectrophotometer at a specific wavelength. The absorbance value was then correlated with the concentration of suspended solids.

For color measurement, a known volume of the water sample was placed in a cuvette, and the absorbance of the sample was measured using the spectrophotometer at the appropriate wavelength for color analysis. The absorbance value obtained was then compared to a standard color scale or a calibration curve to determine the color intensity of the sample.

After each measurement, the spectrophotometer was properly cleaned and calibrated using blank solutions to ensure accurate readings for subsequent samples. Finally, the results were recorded and analyzed as needed for further evaluation or compliance purposes.

3.7.4 TS

Total Solids (TS) is the sum of Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). It represents the total amount of solid material present in a given volume of water.

TS=TDS+TSS

3.7.5 Turbidity

To measure effluent turbidity, the turbidity meter was powered on and calibrated using standard solutions. A transparent container was filled with effluent, and the turbidity probe was immersed without touching the container's sides or bottom. After positioning, turbidity readings were taken in NTU or equivalent units, with multiple measurements for accuracy. Between measurements, the probe was rinsed with distilled water to prevent contamination. Recorded turbidity values were analyzed to assess water quality and ensure compliance with regulations. This meticulous process provided precise turbidity measurements, crucial for environmental monitoring and regulatory compliance.

Figure 3.19: Turbidity Meter

3.7.6 COD

To measure COD of the effluent, a COD reactor or digestion apparatus was used. Effluent sample, potassium dichromate, sulfuric acid, and silver sulfate catalyst were mixed in a sealed flask, heated (150-160°C) for 2 hours. After cooling, remaining oxidizing agent was titrated with ferrous ammonium sulfate. The amount of FAS used indicated COD concentration, reported in mg/L or ppm. This process assessed organic pollutant levels, crucial for environmental impact evaluation.

Figure 3.20: COD apparatus

3.7.7 BOD

To measure Biochemical Oxygen Demand (BOD) a BOD incubator or analyzer was used. Effluent samples were diluted to ensure measurable oxygen demand, then distributed into BOD bottles with a nutrient solution (BOD seed) to foster microbial growth. Bottles were sealed to prevent oxygen exchange and incubated at 20°C for around 5 days.

During incubation, microorganisms consumed organic matter, depleting dissolved oxygen. After incubation, dissolved oxygen was measured in each bottle using a probe or titration method. The difference between initial and final oxygen concentrations indicated oxygen consumed by microbial activity, correlating with BOD.

The BOD value, expressed in mg/L, was calculated, providing insight into organic pollutant levels and biodegradable organic matter in the effluent. This process was crucial for assessing water quality and environmental impact.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Obtained Data

Table 4.1: Results obtained after 30 mins electrocoagulation, 1hr sedimentation and multimedia filtration

	Raw Wastewater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.29	8.94	8.83	8.56
TDS (mg/l)	579	1540	1467	1056
TSS (mg/l)	113	58	50	18
TS (mg/l)	692	1598	1517	1074
COD (mg/l)	200	108	89	86
Color (PtCo)	1408	798	648	336
Turbidity (NTU)	202	165	76.6	32.1
DO (mg/l)	0.81	8.65	1.87	1.6
Salinity (%)	0.59%	1.57%	1.49%	1.12%
EC (ms/cm)	1.185	2.82	2.66	1.92

Table 4.2: Results obtained from 30 minutes electrocoagulation, 3hr sedimentation and multimedia filtration

	Raw WasteWater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.21	9.56	9.54	9.3
TDS (mg/l)	621	1769	1780	1655
TSS (mg/l)	199	13	11	8
TS (mg/l)	820	1782	1891	1670
COD (mg/l)	184	47	40	36
Color (PtCo)	1000	185	184	182
Turbidity (NTU)	215	165	76.6	32.1
DO (mg/l)	3.8	8.64	8.22	7.8
Salinity (%)	0.62%	1.80%	1.81%	1.68%
EC (ms/cm)	1.253	3.43	3.45	3.22

Table 4.3: Results obtained after 30 minutes electrocoagulation, 6hr sedimentation and multimedia filtration

	Raw Wastewater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.3	9.43	9.67	9.46
TDS (mg/l)	717	2110	2068	2030
TSS (mg/l)	137	6	4	3
TS (mg/l)	854	2111	2069	2030
COD (mg/l)	171	63	60	53
Color (PtCo)	349	46	34	32
Turbidity (NTU)	28.4	3.48	2.64	1.31
DO (mg/l)	0.35	8.2	7.32	5.67
Salinity (%)	0.72%	2.15%	2.11%	2.07%
EC (ms/cm)	1.808	4.06	3.98	3.92

Table 4.4: Results obtained after 45 minutes electrocoagulation, 1hr sedimentation and multimedia filtration

	Raw Wastewater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.29	9.04	8.96	8.6
TDS (mg/l)	579	1520	1479	1400
TSS (mg/l)	113	10	9	7
TS (mg/l)	692	1529	1488	1408
COD (mg/l)	200	87	73	70
Color (PtCo)	1408	193	175	172
Turbidity (NTU)	202	9.02	7.83	6.54
DO (mg/l)	0.81	6.33	4.55	3.02
Salinity (%)	0.59%	1.55%	1.50%	1.42%
EC (ms/cm)	1.185	0.905	0.905	0.904

Table 4.5: Results obtained after 45 minutes electrocoagulation, 3hr sedimentation and multimedia filtration

	Raw Wastewater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.21	9.59	9.42	8.84
TDS (mg/l)	621	1985	1692	1558
TSS (mg/l)	199	15	5	3
TS (mg/l)	820	2000	1697	1591
COD (mg/l)	184	66	40	37
Color (PtCo)	1000	224	115	79
Turbidity (NTU)	215	10.8	8.2	2.87
DO (mg/l)	3.8	8.13	8.14	7.04
Salinity (%)	0.62%	2.02%	1.72%	1.58%
EC (ms/cm)	1.253	3.83	3.29	3.02

Table 4.6: Results obtained after 45 minutes electrocoagulation, 6hr sedimentation and multimedia filtration

	Raw Wastewater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.3	9.86	9.93	9.64
TDS (mg/l)	717	1985	1969	1874
TSS (mg/l)	137	4	1	1
TS (mg/l)	754	1989	1970	1875
COD (mg/l)	171	81	54	39
Color (PtCo)	349	60	57	26
Turbidity (NTU)	28.4	7.63	5.96	1.12
DO (mg/l)	0.35	8.38	7.08	6.04
Salinity (%)	0.72%	2.02%	2.00%	1.91%
EC (ms/cm)	1.808	3.83	3.8	3.63

Table 4.7: Results obtained after 60 minutes electrocoagulation, 1hr sedimentation and multimedia filtration

	Raw Wastewater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.29	9.18	9.14	8.74
TDS (mg/l)	579	1577	1510	1464
TSS (mg/l)	113	8	7	3
TS (mg/l)	692	1585	1517	1467
COD (mg/l)	200	85	63	41
Color (PtCo)	1408	184	167	99
Turbidity (NTU)	202	13.2	9.43	1.1
DO (mg/l)	0.81	8.47	5.2	3.29
Salinity (%)	0.59%	1.60%	1.53%	1.49%
EC (ms/cm)	1.185	3.07	2.95	2.86
BOD (mg/l)				18

Table 4.8: Results obtained after 60 minutes electrocoagulation, 3hr sedimentation and multimedia filtration

	Raw Wastewater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.21	9.71	9.59	9.28
TDS (mg/l)	621	1854	1630	1545
TSS (mg/l)	199	23	12	9
TS (mg/l)	820	1887	1646	1556
COD (mg/l)	184	45	28	16
Color (PtCo)	1000	318	149	127
Turbidity (NTU)	215	17.5	12.1	11.5
DO (mg/l)	3.8	8.94	8.66	8.53
Salinity (%)	0.62%	1.89%	1.66%	1.54%
EC (ms/cm)	1.253	3.59	3.17	3.21
BOD (mg/l)				4.1

Table 4.9: Results obtained after 60 minutes electrocoagulation, 6hr sedimentation and multimedia filtration

	Raw Wastewater	After Electrocoagulation	After Sedimentation	After Multimedia Filtration
pH	7.3	10.24	10.34	9.8
TDS (mg/l)	717	2140	2052	2011
TSS (mg/l)	137	4	1	1
TS (mg/l)	754	2144	2053	2012
COD (mg/l)	171	59	58	44
Color (PtCo)	349	59	25	21
Turbidity (NTU)	28.4	3.06	2.89	1.05
DO (mg/l)	0.35	8.46	7.31	5.79
Salinity (%)	0.72%	2.18%	2.09%	2.05%
EC (ms/cm)	1.808	4.12	3.95	3.88
BOD				3.6

4.2.2 Analysis

4.2.2.1 Removal Efficiency

Table 5.1: Summary table of removal efficiency of parameters (TSS, COD) after electrocoagulation, sedimentation and multimedia filtration at various retention times

Parameter	Electrocoagulation		Electrocoagulation &Sedimentation		Electrocoagulation, Sedimentation & Filtration
	Retention time (Minutes)	Efficiency (%)	Retention time (Hour)	Efficiency (%)	Efficiency (%)
TSS	30	49	1	56	84
	30	94	3	95	96
	30	96	6	97	98
	45	91	1	92	94
	45	93	3	98	99
	45	97	6	99	99
	60	93	1	94	98
	60	88	3	94	96
	60	98	6	99	99
COD	30	46	1	56	57
	30	75	3	78	81
	30	63	6	65	69
	45	57	1	64	65
	45	64	3	78	78
	45	53	6	69	85
	60	58	1	69	80
	60	76	3	85	91
	60	66	6	66	74

Table 5.2: Summary table of removal efficiency of parameters (Color, Turbidity) after electrocoagulation, sedimentation and multimedia filtration at various retention times

Parameter	Electrocoagulation		Electrocoagulation &Sedimentation		Electrocoagulation, Sedimentation & Filtration
	Retention time (Minutes)	Efficiency (%)	Retention time (Hour)	Efficiency (%)	Efficiency (%)
Color	30	43	1	54	76
	30	82	3	82	82
	30	87	6	90	91
	45	86	1	88	88
	45	78	3	89	92
	45	83	6	84	93
	60	87	1	88	93
	60	68	3	85	87
	60	83	6	93	94
Turbidity	30	18	1	62	84
	30	23	3	64	85
	30	88	6	91	95
	45	96	1	96	97
	45	95	3	96	99
	45	73	6	79	96
	60	94	1	95	99
	60	92	3	94	95
	60	89	6	90	96

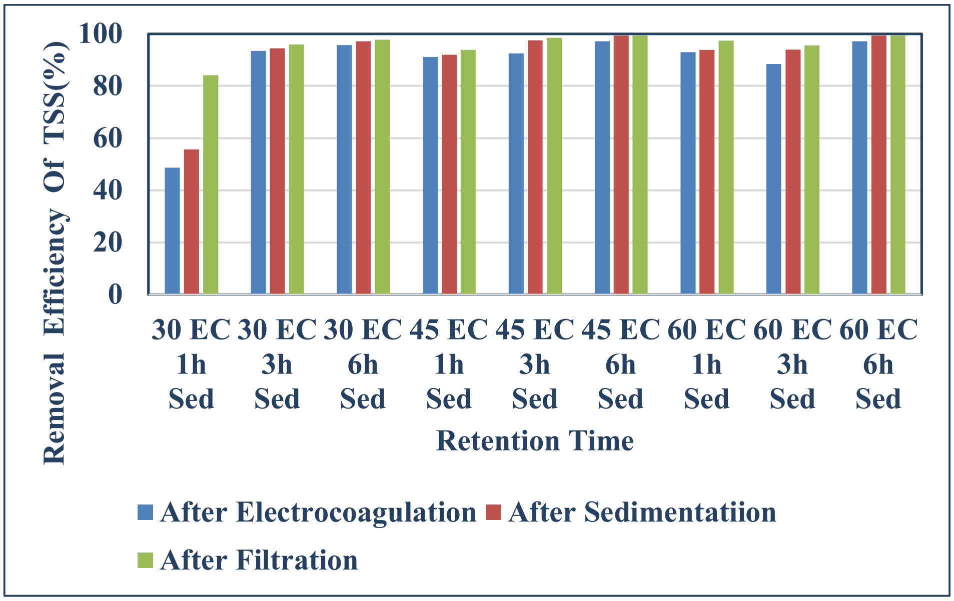


Figure 4.1: Graph showing removal efficiency of TSS(%) after electrocoagulation, sedimentation and multimedia filtration at various retention times

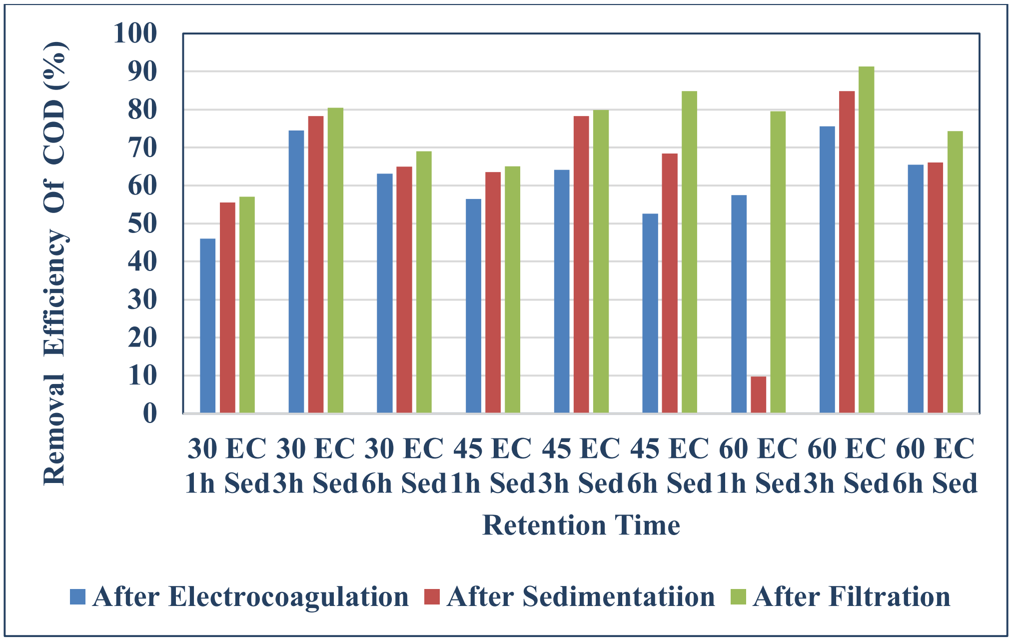


Figure 4.2: Graph showing removal efficiency of COD(%) after electrocoagulation, sedimentation and multimedia filtration at various retention times

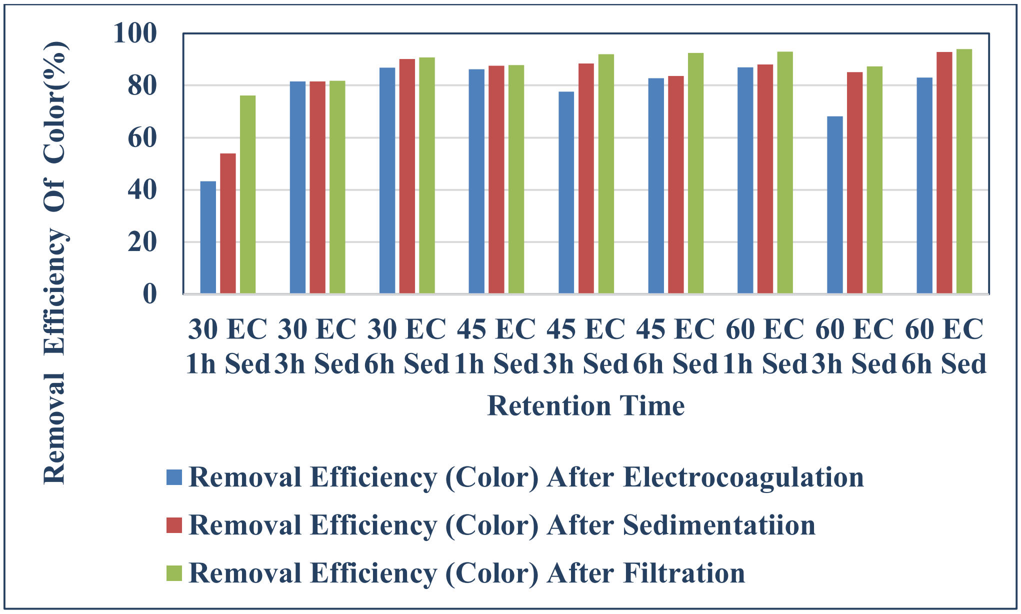


Figure 4.3: Graph showing removal efficiency of Color(%) after electrocoagulation, sedimentation and multimedia filtration at various retention times

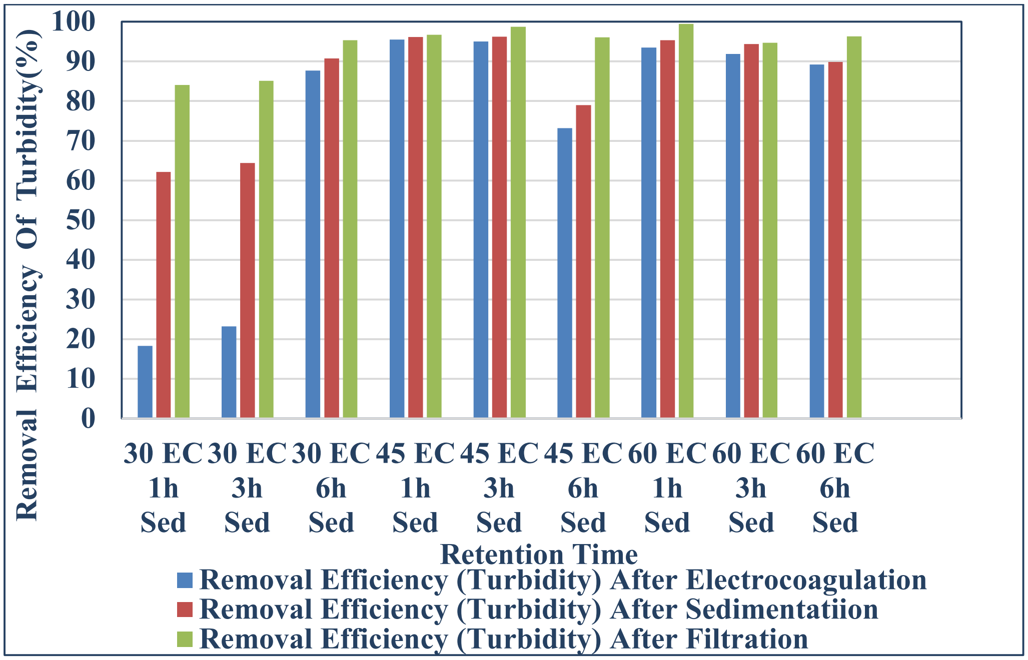


Figure 4.4: Graph showing removal efficiency of Color(%) after electrocoagulation, sedimentation and multimedia filtration at various retention times

4.2.2.2 Trend Lines

Table 5.3: Details of samples for DO after filtration

Retention time	DO (mg/l)
30 EC 1h Sed	1.6
45 EC 1h Sed	3.02
60 EC 1h Sed	3.29
30 EC 6h Sed	5.67
60 EC 6h Sed	5.79
45 EC 6h Sed	6.04
45 EC 3h Sed	7.04
30 EC 3h Sed	7.8
60 EC 3h Sed	8.53

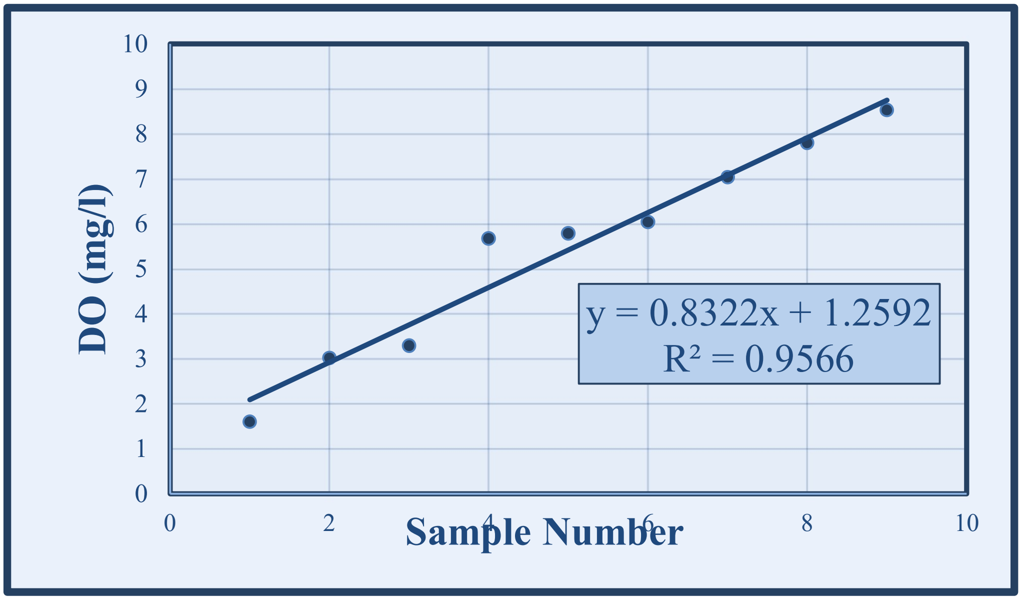


Figure 4.5: Graph showing DO trend line after filtration

Table 5.4: Details of samples for pH after filtration

Retention time	pH
30 EC 1h Sed	8.56
45 EC 1h Sed	8.6
60 EC 1h Sed	8.74
45 EC 3h Sed	8.84
60 EC 3h Sed	9.28
30 EC 3h Sed	9.3
30 EC 6h Sed	9.46
45 EC 6h Sed	9.64
60 EC 6h Sed	9.8

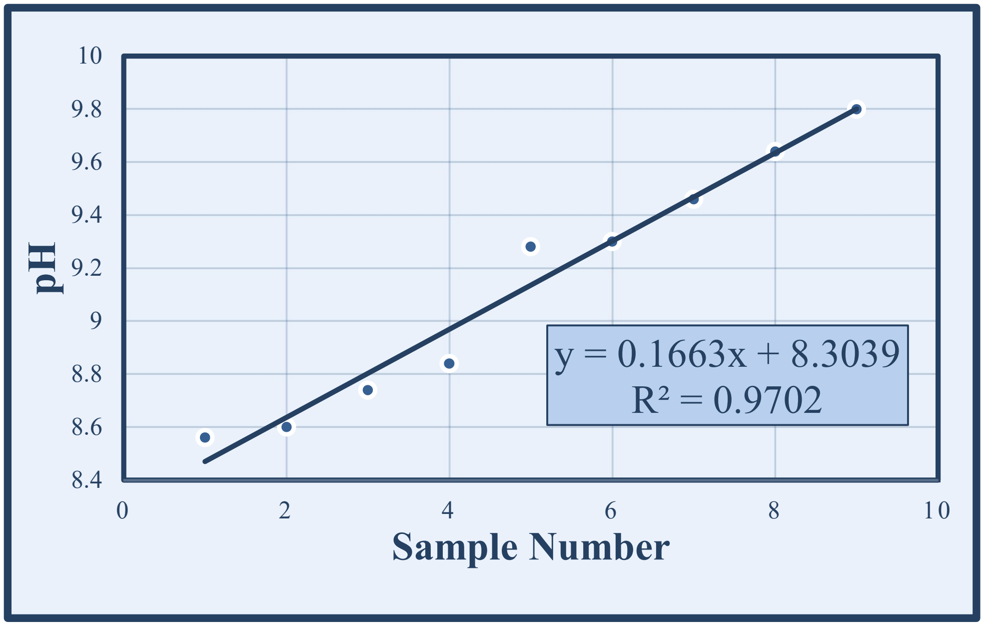


Figure 4.5: Graph showing pH trend line after filtration

Table 5.5: Details of samples for Electric Conductivity after filtration

Retention time	EC(µS/cm)
45 EC 1h Sed	904
30 EC 1h Sed	1920
60 EC 1h Sed	2860
45 EC 3h Sed	3020
60 EC 3h Sed	3210
30 EC 3h Sed	3220
45 EC 6h Sed	3630
60 EC 6h Sed	3880
30 EC 6h Sed	3920

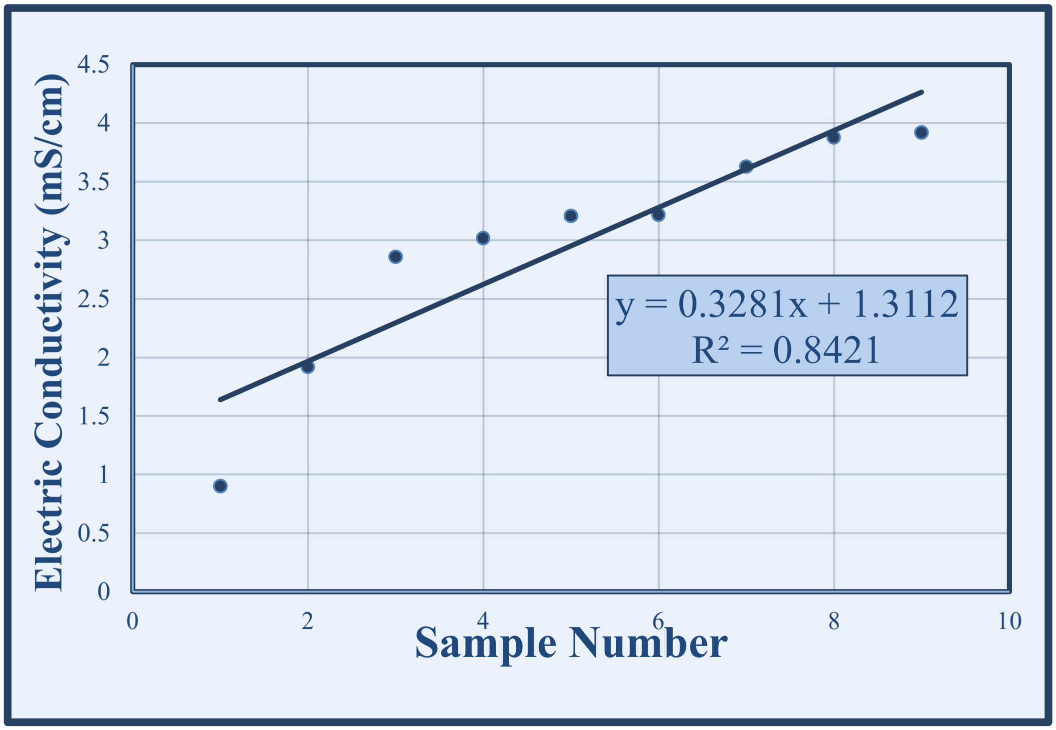


Figure 4.6: Graph showing Electric conductivity trend line after filtration

Table 5.6: Details of samples for salinity after filtration

Retention time	Salinity (%)
30 EC 1h Sed	1.12
45 EC 1h Sed	1.42
60 EC 1h Sed	1.49
60 EC 3h Sed	1.54
45 EC 3h Sed	1.58
30 EC 3h Sed	1.68
45 EC 6h Sed	1.91
60 EC 6h Sed	2.05
30 EC 6h Sed	2.07

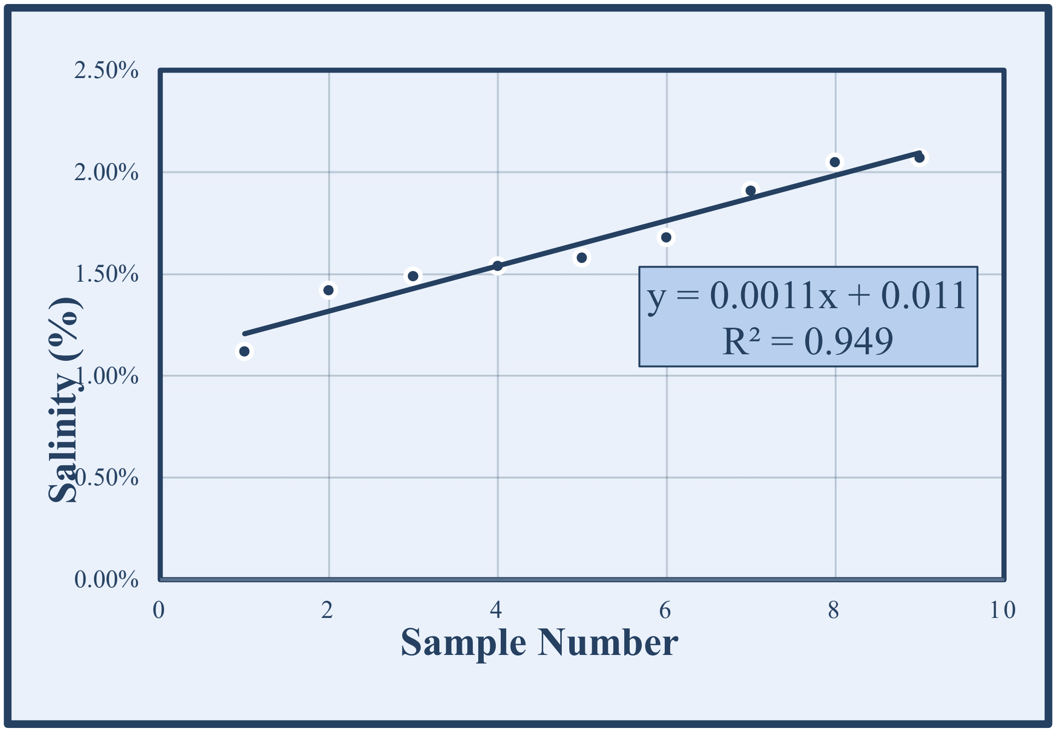


Figure 4.7: Graph showing Salinity trend line after filtration

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be drawn from this study.

i) Effectiveness of electrocoagulation & multimedia filtration

- Using Electrocoagulation process:

Highest Removal efficiency of Turbidity (96%), COD (76%), TSS(97%) and Color(87%)

- Integrating Electrocoagulation, Sedimentation and Filtration:

Highest Removal efficiency of Turbidity (99%), COD (91%), TSS(99%) and Color(94%)

ii) Effect of various retention times

Highest Removal Efficiency found at 45 minutes Electrocoagulation and 6 hours sedimentation time**.**

5.2 Recommendations

The recommendations for future study are given below.

i) Focus on cost optimization
ii) Implementation beyond Textile Industry
iii) Focus on removal efficiency of total organic carbon, heavy metal, E. coli etc.

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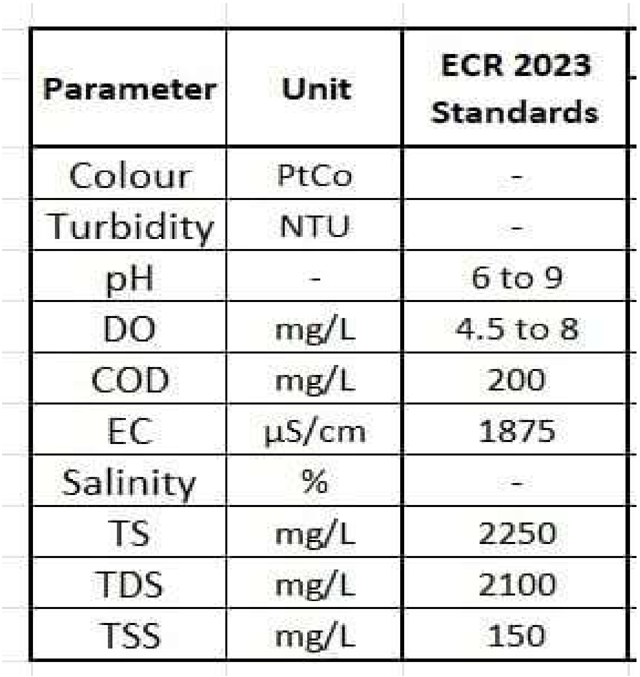
APPENDIX A

Table A.1: ECR 2023 standards



Parameter	Unit	ECR 2023 Standards
Colour	PtCo	-
Turbidity	NTU	-
pH	-	6 to 9
DO	mg/L	4.5 to 8
COD	mg/L	200
EC	µS/cm	1875
Salinity	%	-
TS	mg/L	2250
TDS	mg/L	2100
TSS	mg/L	150

Table A.2: Removal efficiency of TSS after electrocoagulation, sedimentation and multimedia filtration at various retention times

	After Electrocoagulation	After Sedimentatiion	After Filtration
30 EC 1h Sed	48.67256637	55.75221239	84.07079646
30 EC 3h Sed	93.46733668	94.47236181	95.9798995
30 EC 6h Sed	95.62043796	97.08029197	97.81021898
45 EC 1h Sed	91.15044248	92.03539823	93.80530973
45 EC 3h Sed	92.46231156	97.48743719	98.49246231
45 EC 6h Sed	97.08029197	99.27007299	99.27007299
60 EC 1h Sed	92.92035398	93.80530973	97.34513274
60 EC 3h Sed	88.44221106	93.96984925	95.47738693
60 EC 6h Sed	97.08029197	99.27007299	99.27007299

Table A.3: Removal efficiency of parameters COD after electrocoagulation, sedimentation and multimedia filtration at various retention times

	After Electrocoagulation	After Sedimentation	After Filtration
30 EC 1h Sed	46	55.5	57
30 EC 3h Sed	74.45652174	78.26086957	80.43478261
30 EC 6h Sed	63.15789474	64.9122807	69.00584795
45 EC 1h Sed	56.5	63.5	65
45 EC 3h Sed	64.13043478	78.26086957	79.89130435
45 EC 6h Sed	52.63157895	68.42105263	84.79532164
60 EC 1h Sed	57.5	9.730113636	79.5
60 EC 3h Sed	75.54347826	84.7826087	91.30434783
60 EC 6h Sed	65.49707602	66.08187135	74.26900585

Table A.4: Removal efficiency of Color after electrocoagulation, sedimentation and multimedia filtration at various retention times

	After Electrocoagulation	After Sedimentatiion	After Filtration
30 EC 1h Sed	43.32386364	53.97727273	76.13636364
30 EC 3h Sed	81.5	81.6	81.8
30 EC 6h Sed	86.81948424	90.25787966	90.83094556
45 EC 1h Sed	86.29261364	87.57102273	87.78409091
45 EC 3h Sed	77.6	88.5	92.1
45 EC 6h Sed	82.80802292	83.66762178	92.55014327
60 EC 1h Sed	86.93181818	88.13920455	92.96875
60 EC 3h Sed	68.2	85.1	87.3
60 EC 6h Sed	83.09455587	92.83667622	93.98280802

Table A.5: Removal efficiency of Turbidity after electrocoagulation, sedimentation and multimedia filtration at various retention times

Removal Efficiency (Turbidity)

	After Electrocoagulation	After Sedimentatiion	After Filtration
30 EC 1h Sed	18.31683168	62.07920792	84.10891089
30 EC 3h Sed	23.25581395	64.37209302	85.06976744
30 EC 6h Sed	87.74647887	90.70422535	95.38732394
45 EC 1h Sed	95.53465347	96.12376238	96.76237624
45 EC 3h Sed	94.97674419	96.18604651	98.66511628
45 EC 6h Sed	73.13380282	79.01408451	96.05633803
60 EC 1h Sed	93.46534653	95.33168317	99.45544554
60 EC 3h Sed	91.86046512	94.37209302	94.65116279

Laboratory Apparatus:

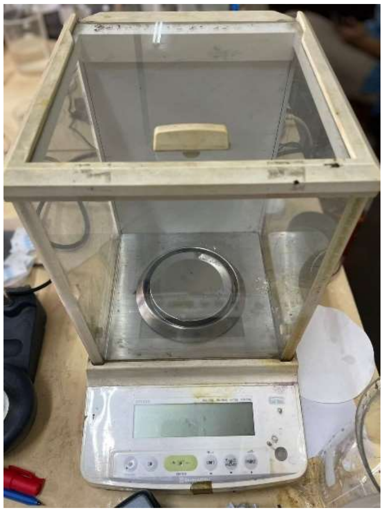


Figure A-1: Analytical Balance

Figure A-2: Sieve

Figure A-3: Distilled Water

Figure A-4: Beaker

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AUTHOR

Tasfiah Kowser Lusaba, Labeba Islam

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