Study on Reuse Potential of Textile Effluent in Bangladesh

Sadman Siam (180051102)

Adib Hossain Sijan (180051115)

A THESIS SUBMITTED FOR THE DEGREE OF BACHELOR OF SCIENCE IN CIVIL ENGINEERING

Department of Civil and Environmental Engineering
Islamic University of Technology (IUT)
2023

PROJECT REPORT APPROVAL

It is hereby certified that the thesis entitled "Study on Reuse Potential of Textile Effluent in Bangladesh" submitted by Sadman Siam and Adib Hossain Sijan has been found as satisfactory and fulfilling the requirements for the Bachelor of Science Degree (Bsc.) in Civil & Environmental Engineering.

SUPERVISOR

Professor Dr. Md. Rezaul Karim

Dean

Faculty of Science and Technical Education (FSTE)

Islamic University of Technology (IUT)

Board Bazar, Gazipur, Bangladesh

DECLARATION OF CANDIDATE

We hereby state that the undergraduate research in this thesis was carried out by us under the guidance of Professor Dr. Md. Rezaul Karim and that this work has not been submitted elsewhere for any reason (aside from publication).

Name of the Candidates:

Sijan

Sadman Siam
Student ID: 180051102
Academic Year: 2021-22
Date: 07-06-23

Adib Hossain Sijan
Student ID: 180051115
Academic Year: 2021-22
Date: 07-06-23

Supervisor

Prof. Dr. Md. Rezaul Karim
Professor
Dept. of Civil & Environmental Engineering
Islamic University of Technology (IUT)
Gazipur, Bangladesh
Date:

DEDICATION

We want to convey our sincere gratitude to our parents, whose steadfast support, priceless advice, and selfless sacrifices have played a crucial role in forming us into the people we are today. Their unwavering commitment, in terms of both time and resources, has been crucial to our journey.

Additionally, we wish to sincerely thank our outstanding supervisor, Professor Dr. Md. Rezaul Karim. Through the course of this project, we have benefited much from his knowledge and mentorship. He has been a consistent source of encouragement because of his unwavering dedication to our academic advancement.

We dedicate our thesis to our parents and Professor Dr. Md. Rezaul Karim in honor of their significant influence they had on our life and academic endeavors.

ACKNOWLEDGEMENTS

"In the name of Allah, Most Gracious, Most Merciful"

We would like to start by expressing our sincere gratitude to The Almighty Allah, whose limitless blessings have served as our lighthouse during our research voyage and allowed us to successfully complete it. We should be eternally grateful to our parents for their unwavering love, support, and care.

Additionally, we wish to sincerely thank our superb supervisor., Professor Dr. Md. Rezaul Karim. His direction and priceless counsel were crucial to the effective execution of this endeavor. Conducting our studies under his guidance has undoubtedly been a great honor and privilege.

We also like to thank the professors in our department. Their helpful recommendations, perceptive comments, and steadfast support throughout the research process have been very beneficial.

A particular thanks goes out to Md. Abdul Kadir, whose cooperation in the sample collection process was crucial. Working alongside him we learnt a lot of useful things.

Last but not least, throughout this research, our friends, juniors, seniors, and other classmates have been pillars of support. They have our gratitude for their inspiration and assistance.

ABSTRACT

Being a developing country, achieving effective wastewater treatment in textile industry has proven to be a difficult task in Bangladesh. Many industries do not have adequate treatment facilities and untreated or poorly treated wastewater is discharged in nearby lands causing environment pollution. Traditional treatment processes of ETP being costly is one of the main reasons for this. Adsorption is a commonly used method for dye removal. Activated carbon is a widely-used effective low-cost absorbent for treating industrial wastewater. Using Lime or $Ca(OH)_2$ along with activated carbon can further increase its effectiveness. In this research work, the removal of color from Bangladeshi textile industry effluent has been investigated. Both batch and fixed-bed column experiments have been conducted in this study. After multiple trials and errors, the optimal dosage of activated carbon was determined from the batch reaction. Freundlich and Langmuir isotherms were derived for the ease of determining the appropriate dosage of carbon to obtain desired color keeping lime dosage constant. There was reduction of color up until 24 hours in case of batch reactions and up until 6 hours in case of fixed-bed column studies. No significant change in color was found afterwards in both cases. Changes in other parameters such as turbidity, TDS and pH were also noticed. The removal efficiency of color obtained from fixed bed column was 98% for 6-inch bed height and 94% for 3-inch bed height. However, usage of lime has caused an increase in pH value for the treated water. From the results, it is clear that using activated carbon and lime together might be a successful method of reducing color and turbidity from wastewater used in the textile industry.

Key words: Textile effluent, color removal, fixed bed column, batch reaction, activated carbon

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1. Introduction

1.1 Background

Approximately 82% of Bangladesh's entire export revenues, which reach close to 28 billion USD annually, come from the textile industry. If nothing changes, the amount of wastewater produced by the textile industries in 2016 will likely increase by 2021. However, wastewater volume might be lowered by 23% by 2021 by slowly implementing better technologies and cleaner production. (Hossian et al., 2018). However, the garment industry still accounts for 50% of the nation's industrial employment and almost 77% of its current foreign exchange earnings (European Commission, "Guide book for European investors in Bangladesh). According to Berg et al.'s (2021) estimation, Bangladesh accounts for 84% of the nation's total export. Women play a prominent part in these businesses, which employ around 4.2 million people and considerably contribute to the GDP (Jeny et al., 2018).

Two studies on the disposal of trash from a company that produces chemicals and one that makes paint (color) were conducted by Sarkar and Sarkar in 2018. The environmental standards for treated wastewater were met by both plants. Compared to the paint manufacturing facility (1,300,000 BDT), the chemicals production (800,000 BDT) facility's effluent treatment system had cheaper installation and operating expenses. The industrial sectors of Bangladesh, such as the textile, tannery, steel, and paper industries, use roughly 95,000,000 m^3 of groundwater per day (or nearly 98% of the total national water supply), while the textile industry contributes by using 40,130,00 m^3 (42% of this amount) each day. (Haque et al., 2021). In the ESTex (Environmental Sustainability in Textile Industries) study report, it was determined that the textile industry's yearly water footprint from 2012 to 2016 was 1.8 billion m^3. About 3000 gallons of water are required to create only one cotton shirt. Around 93 billion cubic meters of water are used annually for textile production (including cotton farming), accounting for 4% of the world's freshwater withdrawal (Water and Clothing, 2019).

To assure access to clean drinking water from groundwater sources, many manually operated tube wells have been erected in Bangladesh's rural districts. There are roughly 10 million of them in the entire nation. These tube wells, the majority of which are privately owned, may draw water from alluvial aquifers that are located between 10 and 60 meters below ground level (mbgl). Because of this, the level of groundwater is dropping by 2-3 meters every year. According to the analysis, by 2050 the groundwater table will be between 110 and 115 meters below sea level (Anwar Zahid, 2015). A considerable amount of waste and wastewater are continuously produced by the home and industrial sectors at an alarming rate, and they are typically disposed of without effective management and treatment (Varjani et al. 2019).

Although industry makes a substantial contribution to the growth of the national economy, it also has an effect on the environment and human health. According to a study conducted by Sharma and Imran in 2011, several chemicals have the potential to induce allergic dermatitis, skin irritation, and adverse effects on vital organs such as the kidneys, liver, brain, reproductive system, and central nervous system. The accumulation of non-biodegradable heavy metals found in wastewater from the textile industry poses a significant concern. Over time, these metals build up in crucial organs of the body, leading to the development of various disease symptoms as they persist and worsen (Khan and Malik, 2014). Along with the colors, the greasy scum also contains colloidal stuff that increases turbidity, gives the water a poor odor and appearance, and prevents the sunlight needed for photosynthesis from penetrating. (Singha et al., 2021).

Textile effluents include high BOD, COD, total dissolved solids, total suspended solids, and low dissolved oxygen (DO) value in addition to being strongly colored. (World Bank, 2010). Multiple chemicals and dyes cause a variety of water quality metrics to degrade from their ideal state. There are many distinct types of dyes, including fiber tracing, general-purpose dyes, all-natural dyes, disperse dyes, azoic dyes, direct dyes, and vat dyes (Gordon, 1990; Textile Infomedia, 2021).

1.2 Research Significance

1.2.1 Color Removal Technologies

Depending upon which parameter to change, multiple types of traditional dye removal treatments have been intensively investigated in recent decades. Color is the most disagreeable of all the effluent parameters since it is a prominent one that may be immediately noticed (Bryant 1992; EPA 1999). According to Crini (2006), less than one ppm of color in water is highly visible and intolerable. Textile effluent waste has a significant amount of color. Some dyes contain hazardous and harmful properties (Eren & Acar, 2006). This color can be of two types- true color and apparent color. True color is caused by the presence of soluble chemical elements, while apparentcolor is caused by the presence of colloidal and suspended particles (Cheremisinoff, 2002; Spellman 2020). Chemical oxidation, coagulation and flocculation, filtration, nano filtration, adsorption, biological process are some widespread methods of color removal (Critteden *et al.*, 2005; Bidhenhi *et al.*, 2007; Naimabadi *et al.*, 2009). Turbidity is characterized by the presence ofsolid particles. For turbidity removal, electrocoagulation is an effective and efficient method (Islam *et al.*, 2011). Jalal *et al.* (2021) stated that Aluminium based coagulants can be efficient inremoving turbidity, color and COD. A biological approach by Krishnaswamy (2021) configuring phytoremediation helped to reduce s good amount of COD, BOD and TDS. So, all these processesgenerally has their effect on removing various parameters.

1.1.1 Adsorption Process

Specific fluid phase components are attracted to the surface of a solid adsorbent through the formation of physical or chemical interactions during the process of adsorption.. Thereby removing the componentfrom the fluid phase (Foo & Hameed, 2009). According to Tanthapanichakoon *et al.* (2005), the properties of absorbent materials and the absorbent surface with the effect of other ions, particle size, solution, pH, temperature and contact time can all influence the quality of the liquid phase adsorption process. Due to this, activated carbon (AC) has been shown to be an excellent adsorbentfor the removal of different organic and inorganic contaminants dissolved in aqueous medium or in the gaseous environment (Gomez *et al.*, 2007). Bangash & Manaf, (2005) stated that dependingon the type of carbon the characteristics of the wastewater, activated carbon adsorption treatmenthas been shown to be an efficient replacement for combined biological and chemical treatment. This is a preferable method for recycling effluent's wastewater from several easily available materials like rice husk (Van & Thuy, 2019), coconut tree sawdust (Kadirvelu *et al.*, 2000), sugarcane bagasse (Mahanta *et al.,* 2019), grape seed (Okman *et al.,* 2014), date palm (Ahmad, 2012), neem leaves (Qadir & Chhipa, 2017), banana peel (Chafidz, 2018) are used as a source to produce activated carbon (Ho & Khan, 2020). In Bangladesh, there is little research using activatedcarbon for recycling effluent.

1.2 Objectives

The main objectives of the study are:

- Study the Development of Treatment Process for the removal of Colour from the effluent of Textile Industries
- Assess the suitability of the treated effluent for irrigation purpose

1.3 Organizations of the Thesis

The research endeavor is structured into distinct chapters to ensure the accomplishment of the established objectives and to facilitate comprehension of the work's progression. A brief overview of each chapter in the thesis is provided as follows:

Chapter 2: Literature Review - This chapter delves into past studies that align with the current research, setting a framework for the study's scope and direction.

Chapter 3: Methodology - This chapter delineates the methodological approach deployed in conducting the research, detailing the process from its inception.

Chapter 4: Results and Discussion - This chapter presents the findings derived from the conducted experiments and offers an analysis of the data gathered.

Chapter 5: Conclusions and Recommendations - This final chapter encapsulates the study's achievements and its overall efficacy, alongside providing insightful recommendations for future research undertakings.

2. Literature Review

There are multiple studies done before for the adjustment of various water quality parameters and this chapter gives a brief about a few of those studies. While some of the processes can be implied on real life situations in case of Bangladesh, however, almost each shows many constraints. To get beyond these limitations and create a more practical and effective strategy, we made the effort to conduct our research:

There are many widely used methods for treatment. Four categories can be used to categorize these processes:

1. Physico-chemical Method: Membrane separation, ion exchange, adsorption, and coagulation-flocculation are a few examples. These techniques physically segregate color.
2. Chemical Method: A vital tool for comprehending the molecular world and maximizing its potential for useful applications is the chemical approach. Two commonly used techniques are ozonation and chemical oxidation. By dissolving the dye and removing the chromophore that produces the color, these processes remove color.
3. Biological Method: In biological treatment, contaminants are broken down or removed from wastewater, soil, or other contaminated environments using living organisms like bacteria, fungi, or plants. The three most frequent biological treatments are aerobic, anaerobic, and anaerobic-aerobic.
4. Electrochemical Method: Electrochemical methods involve the application of an electric current to induce chemical reactions or separate compounds in a solution. These processes, which include electroplating, electrorefining, and electrochemical synthesis, are made possible by the use of electrodes and an electrolyte. They are useful for a variety of applications, such as wastewater treatment, energy storage (such as batteries), and metal purification, because to their benefits including precise control, excellent selectivity, and the ability to function in ambient temperatures.

According to a study by Hossain and Sarker (2018) the textile industry is a vital part of Bangladesh's economy, but it also brings environmental challenges due to the pollution caused by textile effluents. This study focused on analyzing data from 2011 to 2016 and projecting the pollution impacts of the textile dyeing industry until 2021. It is anticipated that by 2021, the industry will generate a substantial amount of wastewater containing pollutants like TDS, TSS, BOD, and COD. Further research is needed to comprehend the effects of these pollutants on local rivers and wetlands. To address water-related issues, treating textile effluents, adopting cleaner production methods, implementing waterless dyeing technologies, and promoting the reuse of treated water are crucial steps.

A study by D'Antoni, Mirko & Iracà, F. & Romero, Manuel. (2017) focuses on the classification of dyes and techniques used for their removal in textile industry effluent treatment plants (ETPs). ETPs aim to meet discharge standards for color and organic compounds. Different methods are combined based on specific dyes and desired effluent quality. However, conventional activated sludge, anaerobic, aerobic, physical (adsorption, membrane filtration), electrochemical (electrocoagulation), and chemical (ozonation, AOPs) methods are discussed. Photocatalytic degradation with TiO2 shows promise for denim effluent treatment.

In 1999, Terras, Vandevivere, Verstraete studied on the development of advanced treatment methods including filtration, chemical oxidation, and flocculation, being driven by the new rules and ecolabels that textile wet processors must comply with. Though, handling concentrated streams, such dyebath effluents, is still difficult. Lin and Chen (1997) also showed that chemical processing is used to prepare dyeing and finishing mill effluent for reuse. Color, turbidity, and COD can be successfully reduced using electrochemical and chemical coagulation techniques. In contrast to chemical coagulation, hydrogen peroxide improves electrochemical treatment and allaies settling issues. Ion exchange using anionic and cationic polymers enhances water quality even further. The treated effluent has a high quality that is on par with deionized water.

To remove color from a methylene blue solution, Bari and Sultana (2016) did an experiment utilizing hardwood charcoal, banana leaf ash, and rice husk ash (black and white). One factor at a time was used to evaluate various particle sizes of each material. The findings showed that the ash from banana leaves could successfully remove color from effluents that were tinted industrially. It is crucial to remember that although the study assumed the mixing duration was set, it may really be adjusted. Banana leaves must also be burned in the presence of oxygen in order to be turned into ash, which has negative environmental effects.

Vajnhandl and Valh in 2014 showed that it is essential to work together in research and innovation to create a "Water efficient Europe." The European Innovation Partnership on Water (EIP) aims to foster the creation of commercial possibilities and innovative approaches to water-related problems. The textile industry takes an active part in the EIP, especially when it comes to converting wet textile processes into dry, energy-efficient ones. With case studies highlighting best practices, water reuse and recycling are gaining popularity in the textile sector.

A study by Malakootian and Fatehizadeh (2010) showed the rise of the pH of the water treatment process employing jar equipment, lime, and NaOH as softening agents. At various pH levels, color removal was accomplished by using alum and ferric chloride coagulants to increase floc size. According to the study, removing 75% of the color required 40 mg/L of alum and ferric chloride. However, it was discovered that the treatment boosted the water's electrical conductivity. The study also refuted Coro and Laha's (2001) conclusions of color reduction to less than 15 units. In this work, the researchers used large concentrations of ferric chloride coagulants, organic polymers, and activated silica to the water to achieve color reduction below 15 units.

Research by Bhuiyan et al. in 2015 shows the investigation into the use of gamma irradiation to remediate textile effluent revealed effective color and organic pollutant degradation. It was determined that the treated wastewater may be recycled for irrigation and fabric processing. With regard to performance, cotton fabric manufactured from wastewater that had been treated was safe. Reusing irradiated effluent after dyeing can save a lot of fresh water, which is good for the environment and helps the textile sector conserve resources.

The research from Popuri and Pagala in 2019 describes the efficacy of various methods and environmental factors for color removal from green dye effluent. Using an ideal RPM of 150, a time frame of 90 minutes, a dosage of 1.5 gm, and a pH of 8.9, the coagulation process produced a maximum color removal of 99.72%. While the adsorption method produced a maximum color removal of 87.47% with an ideal RPM of 90, a processing duration of 120 minutes, a dosage of 2 gm, and a pH of 2.55, it did so with a lower dosage and longer processing time. With ideal RPM of 90, period of 120 minutes, dosage of 2.5 gm, and pH of 10.45, the adsorption technique produced a remarkable color removal of 787.04% utilizing activated carbon made from sawdust.

Nasruddin et al (2018) made a study on the regeneration potential of activated carbon. The study discovered that employing 0.05 M HCl solution for 360 minutes at a flow rate of 1 mL/min is the ideal regeneration condition for used activated carbon. Methylene blue and iodine levels varied among the various forms of carbon, with BRAC (Batch Regenerated Activated Carbon) having the highest mesopore content and CRAC (Column Regenerated Activated Carbon) having the highest micropore concentration. Utilizing HCl solution for chemical regeneration, spent activated carbon was successfully cleaned of impurities, enhancing its ability to absorb substances. Utilizing activated carbon in industrial wastewater applications is made possible by this technique.

Al-Zawahreh et al. (2022) showed significant removal of textile dyes using pine bark compost in both batch and fixed bed column experiments. In both single and competitive settings, the ability of pine bark compost to remove the textile dyes BV10(Basic Violet) and DB151(Dark Blue) was evaluated. The dye removal efficiency in column studies ranged from 55% to 77% of batch equilibrium. Strong competition was seen when both colors were present, especially in dynamic/column settings, which decreased the compost's usage to 45%–61%. Without substantial bed depths, removing DB151 with BV10 under dynamic conditions might not be feasible. Ethanol column regeneration was successful, especially for preconcentrating textile dye streams.

Thuong et al. (2018) conducted a Fixed-Bed Column study for removing organic dyes from aqueous solution by pre-treated durian peel waste. Different bed heights (2 cm, 4 cm, 6 cm) and different flow rates were used in case of fixed bed column test. In a column mode, cationic dyes like methylene blue and crystal violet demonstrated great adsorption effectiveness on durian peel. Initial dye concentration, flow rate, and bed height were just a few of the variables that influenced removal effectiveness, breakthrough, and exhaustion times. The carbonyl and hydroxyl groups on the surface of the durian peel contributed to its efficacy. According to the study, durian peel could be used to filter harmful compounds out of water.

The study by Araújo in 2019 et al showed that employing graphene oxide (GO) for wastewater treatment results in the successful removal of color and turbidity. When compared to traditional treatments in textile mills, GO application showed considerable gains while requiring no pH modifications. By combining GO with centrifugation, turbidity was reduced by 90%, and color removal efficiency was increased by 76% in just one hour. Additionally, COD was reduced by GO therapy by more than 60%. Removal efficiency of 66% for color and 88% for turbidity were seen when GO was paired with sedimentation. To maximize GO surface alterations and investigate low-cost industrial production techniques, more study is required.

3. Methodology

3.1 Sample Collection

The sample water collection was carried out at Masco Concept Knitting Ltd., located in Gazipur. The collection process involved using clean, sterile containers with a 4-litre capacity, suitable for the intended analysis. During collection, the containers were carefully submerged at the designated sampling location, ensuring that the interior of the container or the water surface remained untouched. Filling these containers required careful attention to avoid introducing any air bubbles, and the containers were then filled to capacity. After filling, each container was securely sealed, properly labelled, and stored at room temperature, approximately 25 degrees Celsius, away from direct sunlight and chemical substances. The samples were transported by road using a CNG Autorickshaw to the laboratory for further analysis.

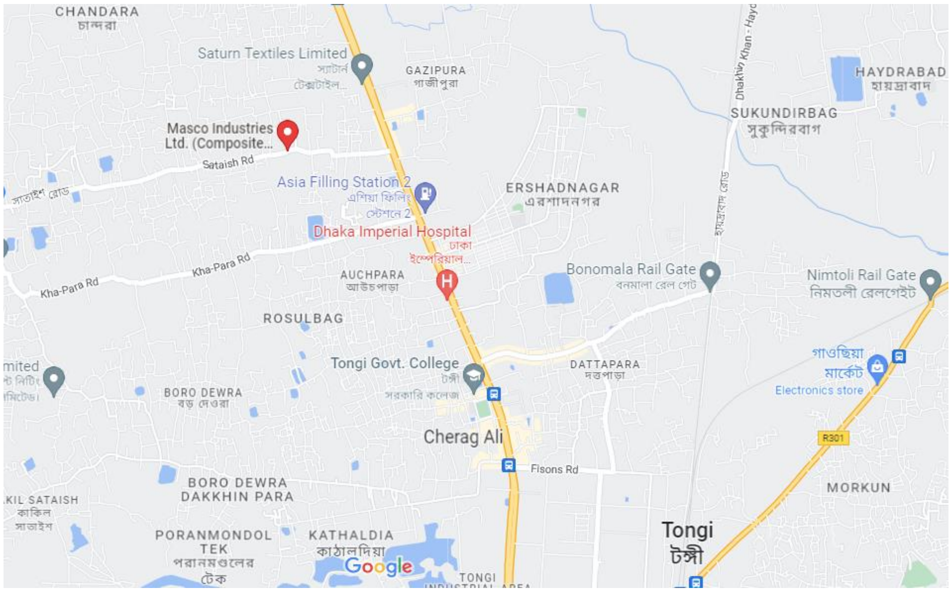


Figure 1 Location of Masco Concept Knitting Ltd.

The collected samples are from two different stages. One from the pit after going through the biological tank. And another from before going through any treatment process in the ETP.

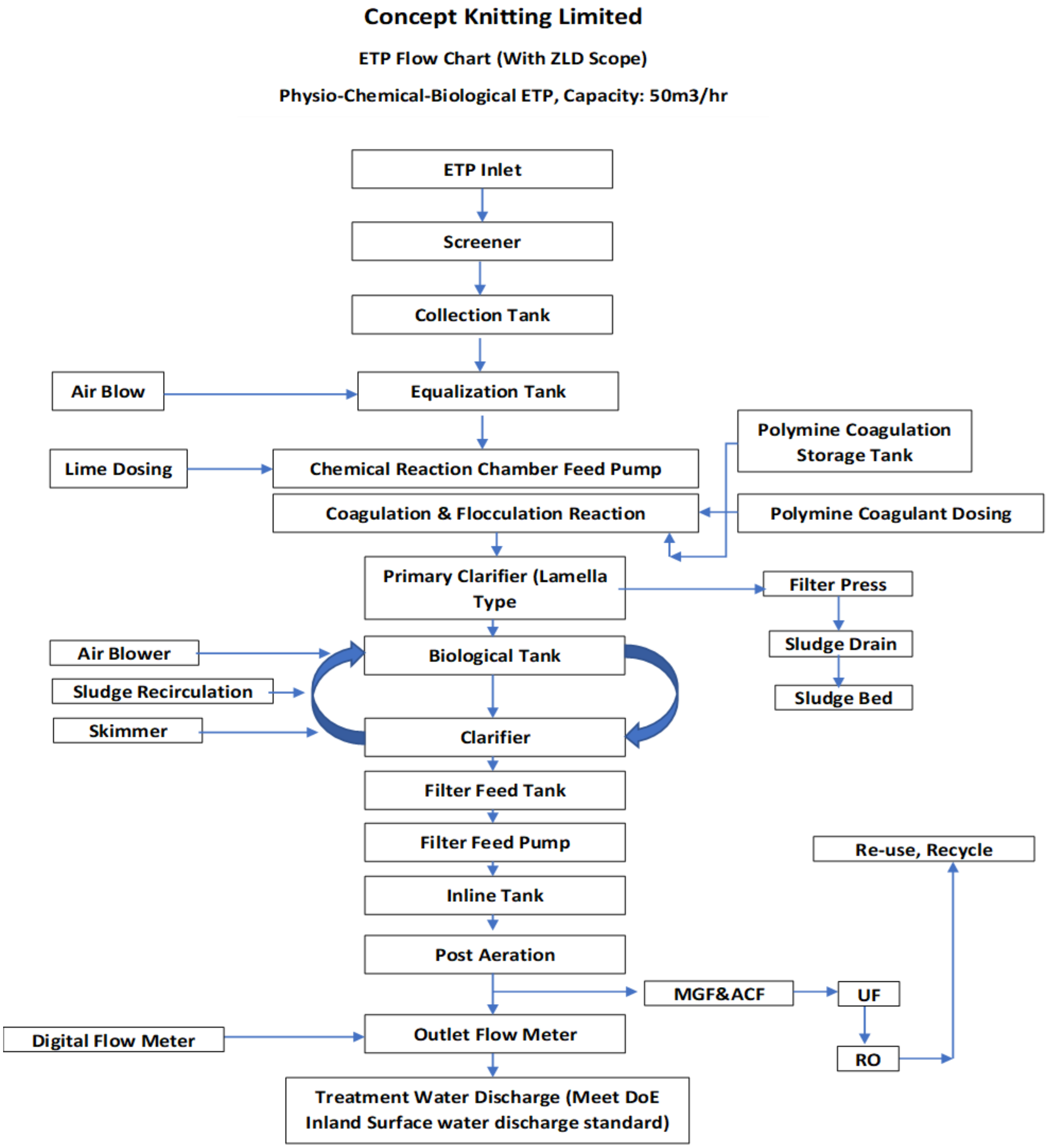


Figure 2 ETP Flow Chart

Figure 3 Sample Water

Table 1 Volumes of Water for Different Types of Uses in Masco Concept Knitting

Types of use	Volume (m^3)
Dying and washing	1400~2200
Miscellaneous (Washroom, bathroom, drinking water etc.)	200-800

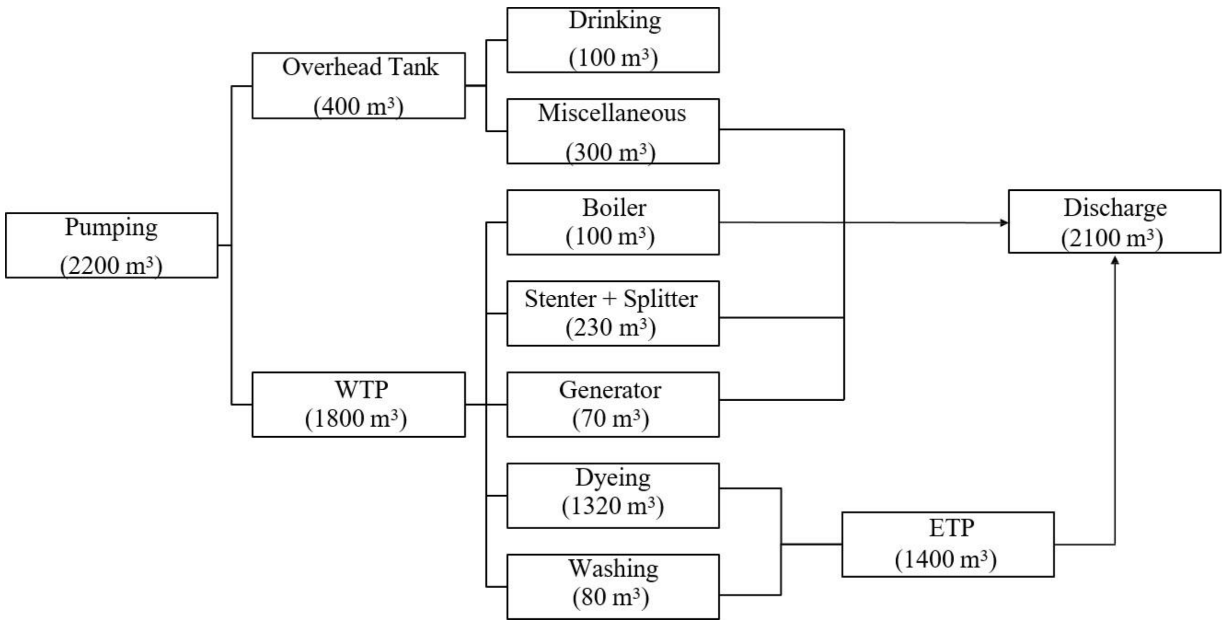


Figure 4 Direction of Water Flow in Masco Knitting

Each day, the apparel industry produces roughly 10 tonnes of clothing. The table indicates that each day, about 2400 m3 of wastewater is created.

3.2 Sample Parameter Test

Following sample collection, the sample was kept in the lab at room temperature. Both the sample testing and the jar testing were conducted on the day of collection. In order to identify the characteristics of the raw wastewater, we measured various water quality parameters using the instruments outlined in the accompanying table.

Table 2 Instruments used for Testing Different Physico-chemical Characteristics

Instruments / Process used	**Parameters**
Spectrophotometer	Color, TSS, COD, Fe, Mn,
Multimeter	pH, TDS
Titration	Chloride, Hardness
BOD Trak ii Chassis, Incubator	BOD
Turbidity meter	Turbidity

3.3 Jar Test

Six jars, each holding 500 ml of sample water, were used for the Jar Test. Each jar was treated with 1 mg (2 mg/L) of powdered Calcium Hydroxide. After the addition of Calcium Hydroxide, the jars were placed in a flocculator and stirred at 100 rpm for a minute. Then, each jar received a graduated addition of Powdered Activated Carbon, commencing with 0.5 mg (1 mg/L) in the first jar, 1 mg (2 mg/L) in the second jar, 1.5 mg (3 mg/L) in the third jar, and so on. The jars were then returned to the flocculator and mixed at a speed of 60 rpm for 10 minutes. Testing was carried out immediately after the settling period, and follow-up tests were conducted at intervals of 24 and 48 hours. Sperate tests were conducted both using filter paper and without the use of filter paper.

Figure 6 Jar Test (Raw Water)

Figure 5 Jar Test (24 hours after mixing PAC & Ca (OH)$_2$)

In this experiment, we used a glass column with a dimension of 6.5’’x6.5’’x12’’. The column was assembled using Granular Activated Carbon, and we conducted tests at bed heights of 3" and 6”. We began by adding a 2 mg/L dosage of Calcium Hydroxide to 1000 mL of the sample water. The sample was then subjected to flocculation for one minute at a rate of 100 rpm. The sample water solution was then introduced into the column, and we maintained control over the flow at the outflow at a rate of 50 ml/min. After passing through the column once, we tested the samples at varying time intervals (0 hour, 0.5 hour, 1 hour, 2 hours, 3 hours, 6 hours, and 24 hours) to evaluate different physicochemical characteristics.

Figure 7 Fixed Bed Column

3.4 Chemical used

Powdered Activated Carbon (PAC), Granular Activated Carbon (GAC), Lime ($Ca(OH)_2$)

3.4.1 Activated Carbon

Activated carbon is predominantly found in two forms:

1. Powdered Activated Carbon (PAC)
2. Granular Activated Carbon (GAC)

PAC is recognized for its superior absorption performance, cost-effectiveness, and finer particles. Activated carbon's increased adsorption capacity is due to its large surface area and well-developed micropores. According to Hu Zian (2018), The interaction of different forces, including as van der Waals forces and electrostatic action, is what essentially drives the adsorption property of AC. Because of its enormous, porous surface area and natural attraction force, AC may trap and hold a variety of substances on its surface. As a result, specific compounds are effectively eliminated from the wastewater. A study by Fares (2018) further substantiates this, claiming that the adsorption ability of AC powder increases the treatment's effectiveness.

3.4.2 Lime

Calcium hydroxide, also known as $Ca(OH)_2$ or lime, plays a crucial role in water treatment processes, primarily through increasing the pH level and precipitating ions responsible for water hardness. Apart from these functions, lime exhibits several advantages in conventional wastewater chemical treatment. It aids in pH regulation, oxidizable organic pollutant reduction, clarification, precipitation of dissolved pollutants, the flocculation of colloidal particles as well coagulation. Occasionally, lime serves as a supportive agent in processes such as coagulation, flocculation, and adsorption. Asadollahfardi's study in 2018 found lime to be a relatively superior coagulant in jar tests. Malakoutian (2010) discovered that how effectively color removal happens and with any increased use of lime. Primarily used as a softener, lime, when employed as an aid, binds with other particles, augmenting the mass of the flocs, and subsequently accelerating their settling speed in water.

3.4.3 Isotherm Method

The adsorption isotherm is a method for assessing a chemical material's capability for adsorption and establish the relationship between the amount of color removed and the amount of carbon required for color removal. To understand the thermodynamic phenomena of activated carbon adsorption, two isotherms are commonly employed. They are: Freundlich isotherm and the Langmuir isotherm. The primary distinction between these two is that the equation of Freundlich isotherm is based on empirical observations, while the Langmuir isotherm is more theoretically derived.

According to Ayawei (2015), the Freundlich isotherm is appropriate for modeling multilayer adsorption processes and is particularly applicable to adsorption that takes place on heterogeneous surfaces. It describes the surface's heterogeneity and the exponential distribution of each active site. (Ayawei, 2015). Adsorption process depends on the binding energy between adsorbed molecules and sorbent.

The Freundlich isotherm equation is stated in linear form by:

$$\ln\left(\frac{X}{M}\right) = \ln(k) + \frac{1}{n} lnC$$

here,

k = empirical constant (y -intercept)

n= slope-inverse constant

X = adsorbent actually adsorbed by Carbon (color difference)

M = carbon dose, mg/L
C = final color

In case of the Langmuir isotherm, it describes a monolayer adsorption process by explaining the coverage of surface by the balance between the rates of both adsorption and desorption, leading to a dynamic equilibrium. This model specifically applies to adsorption processes occurring on a homogeneous adsorbent surface. Plotting C/(X/M) against C or 1/(X/M) versus 1/C can be used to depict the Langmuir isotherm. The plot with a clear trend produces more precise constants.

Mathematically, the Langmuir isotherm can be expressed by the following formula:

$$\frac{1}{\frac{X}{M}} = \left(\frac{1}{ab}\right)\left(\frac{1}{C}\right) + (\frac{1}{a})$$

4. Data Analysis & Discussion on Results

Two sets of raw water were collected as mentioned before. The water quality of the two sets of raw water as follows:

Table 3 Water Quality of the Raw Sample Water

Characteristics	**Unit**	**Sample Value (ETP Treated)**	**Sample Value (Wastewater before being treated in ETP)**	**Instruments Used**
pH		7.73	9.76	pH meter
Turbidity	NTU	26.20	47.4	Turbidity Meter
Color	Pt-Co	640	2044	Spectrophotometer
TDS	g/L	2.54	3.30	Multimeter
Fe	mg/L	1.86	2.66	Spectrophotometer
Mn	mg/L	0.172	0.32	Spectrophotometer
COD	mg/L	7.00	124.63	COD Reactor and Test Tube Heater

For the standard value of different parameters of water to be used for maximum limit for the parameters of textile effluent and irrigation purpose, ECR 1997 and ECR 2023 guidelines were followed.

Table 4 Standard Water Quality

Parameters	**Units**	**Standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023)**	**Standard (for discharge in irrigated land)** **(Source: ECR 1997)**
pH		6-9	6-9
Turbidity	NTU	-	-
BOD	mg/L	30	-
COD	mg/L	200	400
SS	mg/L as $CaCO_3$	100	600
TDS	g/L	2.10	0.60
Color	Pt-Co	150	-
Fe	mg/L	0.10	2
Mn	mg/L	-	5

Compared to the ECR 1997 guidelines for discharge in irrigated land and ECR 2023 guidelines for maximum limit for the parameters of textile wastewater most of the values of the raw sample water do not comply with the standards.

4.1 Batch Reaction Results on ETP Treated Sample

Color

Table 5 Results of Color After 24 Hours

Sample	**PAC Dosage, g/L**	**Lime Dosage, g/L**	**Initial Value, NTU**	**After Addition of PAC and Lime (Without Filter), Pt-Co**	**After Addition of PAC and Lime (With Filter), Pt-Co**	**Standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023), Pt-Co**
Jar 1	1	2	640	75	13	150
Jar 2	2	2		33	12	
Jar 3	3	2		39	0	
Jar 4	4	2		35	5	
Jar 5	5	2		30	7	
Jar 6	6	2		29	2	

This Table represents changes in color at different time interval for different dosages. Powdered activated carbon of 1gm/L, 2gm/L, 3gm/L, 4gm/L, 5gm/L, 6gm/L was added to each jar respectively. Initially the color was 640 Pt-Co and it was decreased to 2 Pt-Co for 6gm/L of activated carbon after 24 hours.There is no noticeable difference in color change for 5 and 6 gm of activated carbon. This indicates that the adsorption of color was rapid in thefirst 12 hours for all six dosages. Thus, the equilibrium time for this sample is 12 hours and the optimum dose of powdered activated carbon is 5-6 gm. Data were also taken at different time interval after filtering.*Figure* shows that color has drastically changed after filtering for the first hour. It was almost the same for all intervals. Active sites can form stronger chemical bonds that release higher energyof adsorption.

The availability of active sites gradually decreases as time increases. As a result, the color removal was not significant after the equilibrium time. Adsorption rate typically increases with the increase in initial color concentration as increased color concentration increases the masstransfer driving force and hence the rate at which color induced molecules pass from the bulk solution to the particle surface (Rahman,2017).

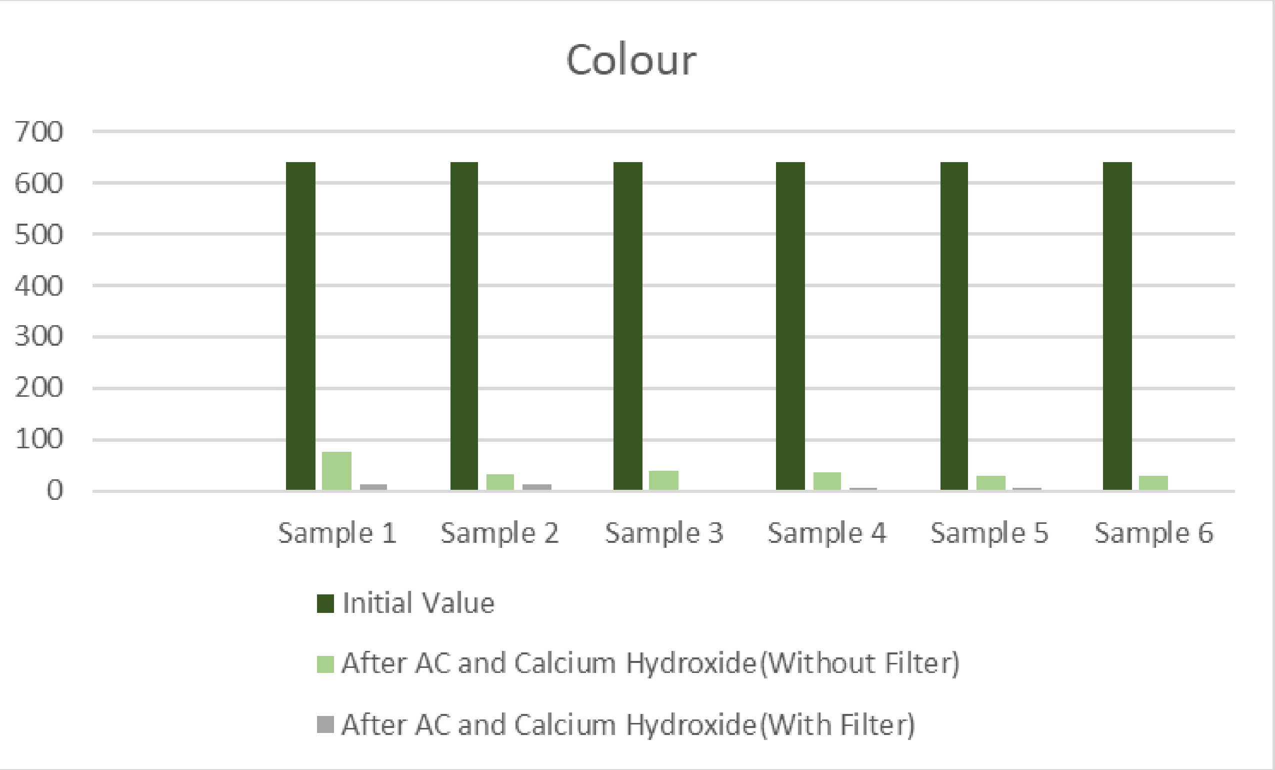


Figure 8 Reduction of Color in Jar Test (ETP Treated Sample)

pH

Table 6 Results of pH after 24 hours (ETP Treated Sample)

Sample	**PAC Dosage, g/L**	**Lime Dosage, g/L**	**Initial Value**	**After Addition of PAC and Lime (Without Filter)**	**After Addition of PAC and Lime (Without Filter)**	**Standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023)**
Jar 1	1	2	7.73	11.64	11.61	6-9
Jar 2	2	2		11.50	11.55	
Jar 3	3	2		11.54	11.59	
Jar 4	4	2		11.53	11.58	
Jar 5	5	2		11.62	11.62	
Jar 6	6	2		11.51	11.48	

This Table shows the value of pH increases in the treated water. It is because of the addition of Calcium Hydroxide. It is also noticed that the value of pH remains unchanged in the treated water for both filter and without filtered water.

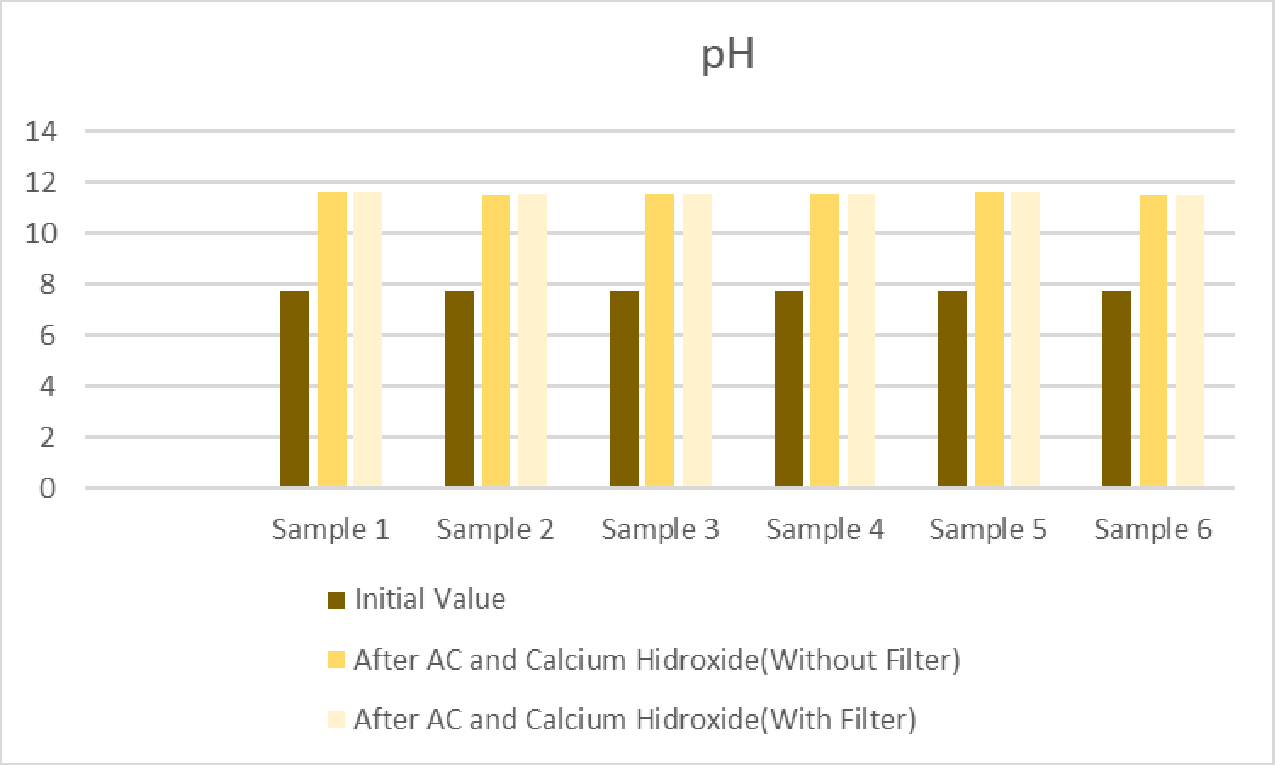


Figure 9 Change of pH in Jar Test (ETP Treated Sample)

Turbidity

Table 7 Results of Turbidity After 24 Hours (ETP Treated Sample)

Initial Value	**After AC and Calcium Hydroxide (Without Filtering)**	**After AC and Calcium Hydroxide (With Filtering)**
26.2	10.1	1.61
26.2	8.24	1.55
26.2	7.87	1.64
26.2	8.12	1.58
26.2	9.14	1.62
26.2	9.65	1.26

Turbidity in treated water has a significant decrease in value. The value seems to be even less after being filtered. There is no particular standard value for turbidity. However , it is evident the reduction of turbidity is possible in this way .

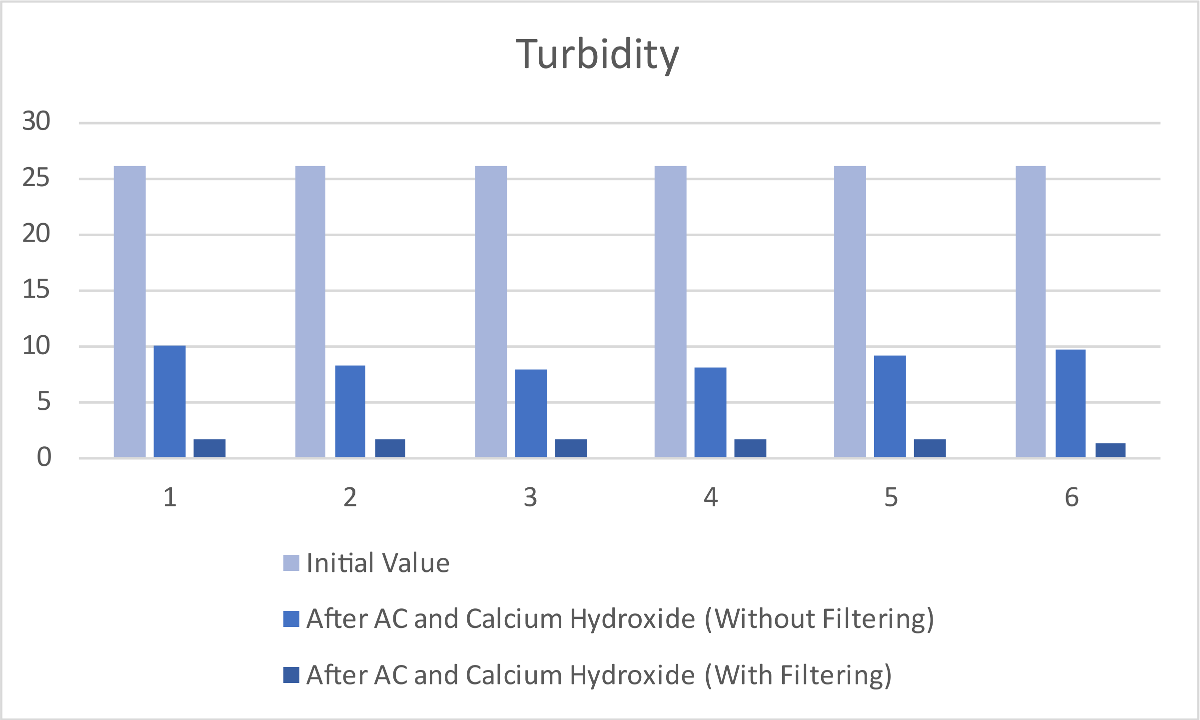


Figure 10 Reduction of Turbidity in Jar Test (ETP Treated Sample)

TDS

Table 8 Result of TDS after 24 Hours (ETP Treated Sample)

Initial Value	**After AC and Calcium Hydroxide (Without Filtering) (g/L)**	**After AC and Calcium Hydroxide (With Filtering) (g/L)**	**Standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023)**	**Standard (for discharge in irrigated land) (Source: ECR 1997)**
2.54	5.29	4.81	2.10	0.60
2.54	5.32	4.45		
2.54	5.14	4.59		
2.54	4.73	4.24		
2.54	5.00	4.22		
2.54	5.03	3.91		

In case of TDS, the standard value cannot be achieved for both irrigation purpose and standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023)

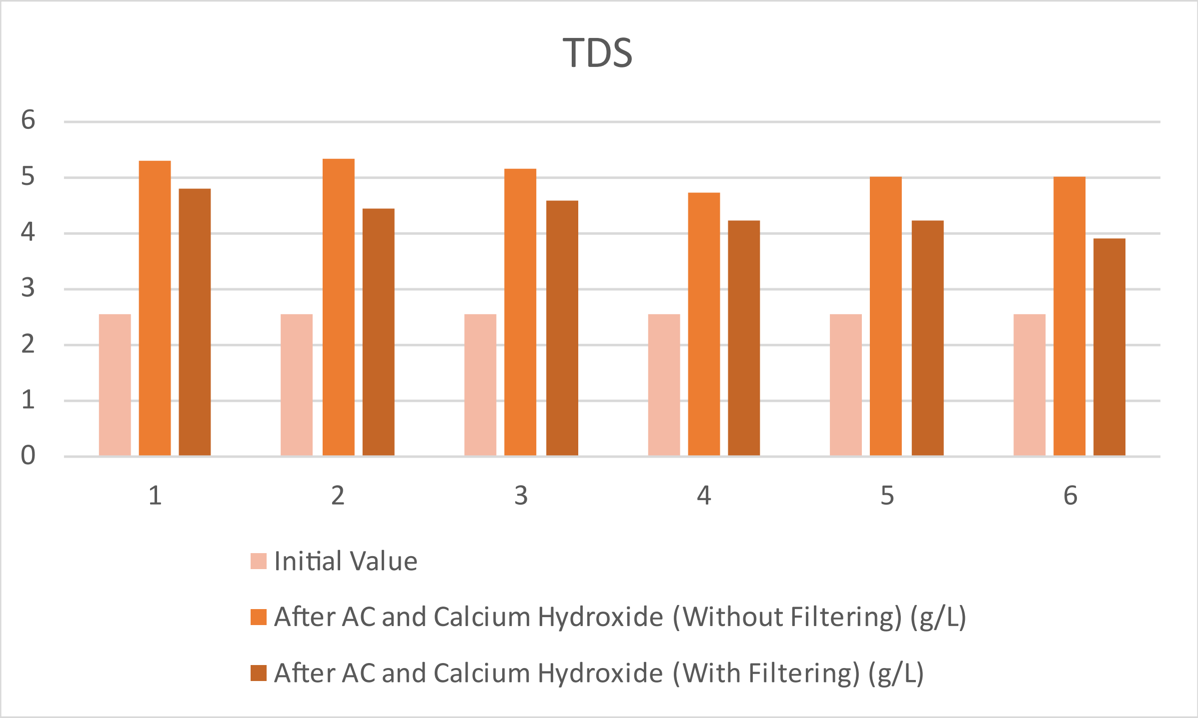


Figure 11 Change in TDS in Jar Test (ETP Treated Sample)

Further value for Fe, Mn and COD were also calculated. The summary table will be as follows:

Table 9 Jar Test Results After 24 Hours (ETP Treated Sample)

24 Hour	pH	Turbidity (NTU)	Color (Pt-Co)	TDS (g/L)	COD (mg/L)	Mn (mg/L)	Fe (mg/L)
Jar 1	11.61	1.61	13	4.81	<3	0.092	0
Jar 2	11.55	1.55	12	4.45	<3	0.095	0
Jar 3	11.59	1.64	0	4.59	<3	0.1	0
Jar 4	11.58	1.58	5	4.24	<3	0.097	0
Jar 5	11.62	1.62	7	4.22	<3	0.165	0
Jar 6	11.48	1.26	2	3.91	<3	0.189	0

Developing Isotherm on the result of color with ETP Treated Sample

The isotherm approach is mainly done to set all variables, except for the carbon dosages and removal rates. Once these constants are calculated, carbon dosage can be determined for any color.

For Freundlich isotherm, the trendline shows that no point acts as outlier and forms a strong correlation of parameters. The value of k and n is 1.625 and 0.60 respectively, calculated from the equation. The constant n provides information on intensity of adsorption. (i) If the values of ‘n’ are in the range $-0.1 < n < 0.5$, it indicates that good adsorption is possible, (ii) If $0.5 < n < 1$

moderate adsorption takes place, while *n* > 1 indicates it to be of weak adsorption (Ramesh,2017)

In case of Langmuir isotherm, a linear trend is difficult to produce in *Figure 1(b)*. It can be assumed that the parameters are 80-90% correlated as some of the points are scattered from the trendline. For one type of Langmuir isotherm, the value of a and b are 1666.67 and 0.007 respectively. Comparing to these two, Langmuir isotherm produces a clear trend that provides more accurate constants.

Table 10 Developing Isotherm (ETP Treated Sample)

M	C0	C	X	X/M	C/(X/M)	1/(X/M)	1/C	ln (X/M)	lnC
gm/L	Pt.Co	Pt.Co	Pt.Co	Pt.Co/(gm/L)	gm/L	(gm/L)/Pt.Co	1/Pt.Co		
1	2,520	62	2,458	2,458.00	0.03	0.000	0.016129	7.80710329	4.127134
2	2,520	56	2,464	1,232.00	0.05	0.001	0.0178571	7.116394144	4.025352
3	2,520	51	2,469	823.00	0.06	0.001	0.0196078	6.712956201	3.931826
4	2,520	37	2,483	620.75	0.06	0.002	0.027027	6.430928424	3.610918
5	2,520	31	2,489	497.80	0.06	0.002	0.0322581	6.21019839	3.433987
6	2,520	25	2,495	415.83	0.06	0.002	0.04	6.030284539	3.218876

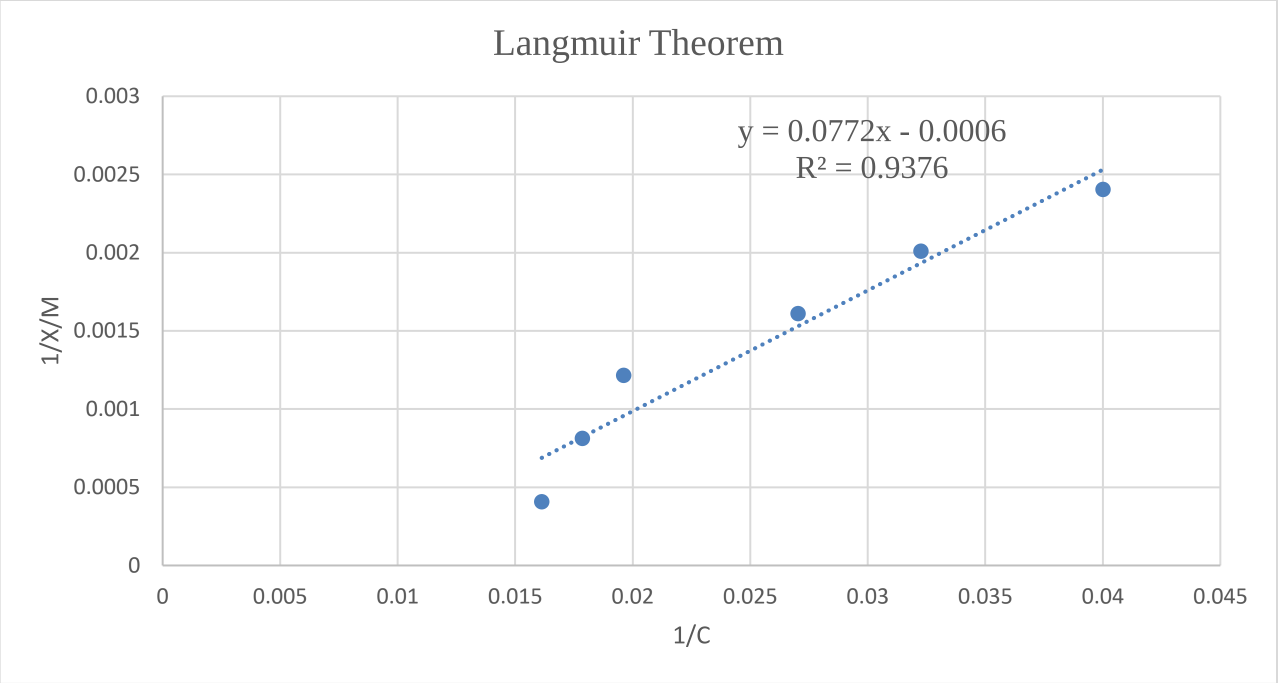


Figure 12 Langmuir Isotherm for Color Reduction (ETP Treated Sample)

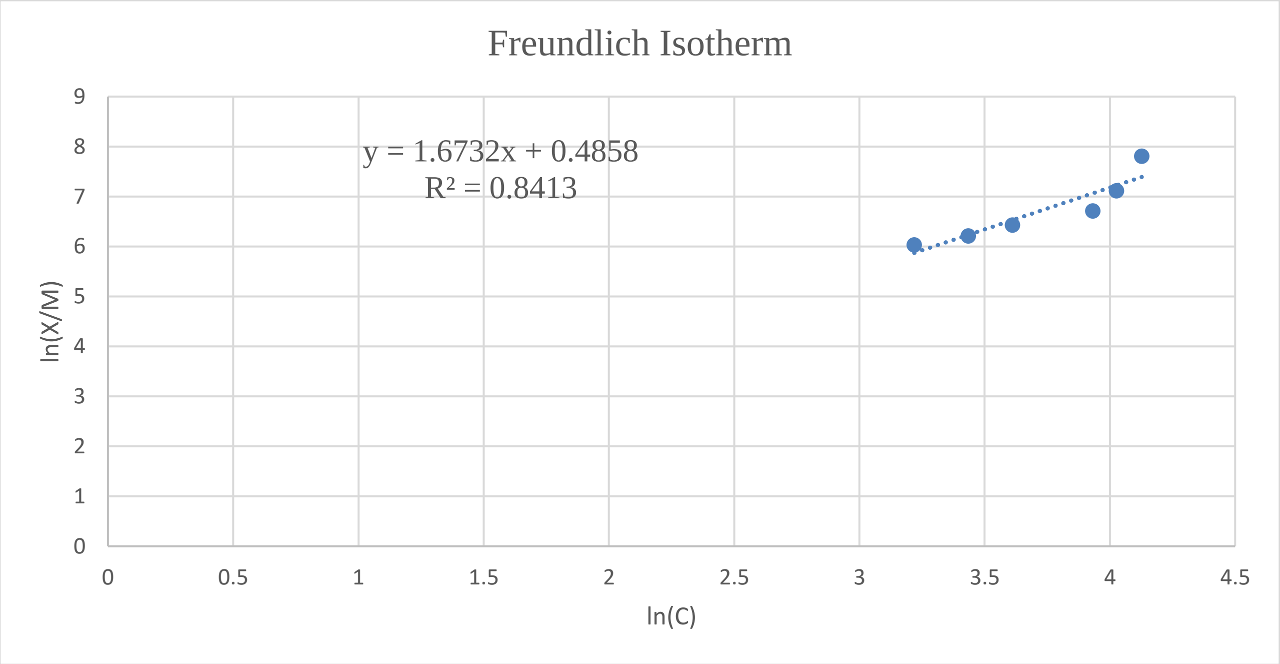


Figure 13 Freundlich Isotherm for Color Reduction (ETP Treated Sample)

4.2 Batch Reaction Results on Sample Water before being Treated in ETP

Color

Table 11 Results of Color After 0 Hour and 24 Hours (Before ETP)

Sample	**PAC Dosage, g/L**	**Lime Dosage, g/L**	**Initial Value, NTU**	**After Addition of PAC and Lime (After 0 Hour), Pt-Co**	**After Addition of PAC and Lime (After 24 Hour), Pt-Co**	**Standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023), Pt-Co**
Jar 1	1	2	2044	234	208	150
Jar 2	2	2		173	109	
Jar 3	3	2		155	104	
Jar 4	4	2		154	94	
Jar 5	5	2		140	88	
Jar 6	6	2		132	81	

This Table represents changes in color at different time interval for different dosages. Powdered activated carbon of 1gm/L, 2gm/L, 3gm/L, 4gm/L, 5gm/L, 6gm/L was added to each jar respectively. In case of waste water before being treated in ETP, the initial value is much more compared to wastewater after ETP. Though color reduction can also be achieved this way and dosage more than 5 mg/L of PAC can give us color value under the maximum limit for textile wastewater. After 24-

hour only 2 mg/L PAC dosage is enough.

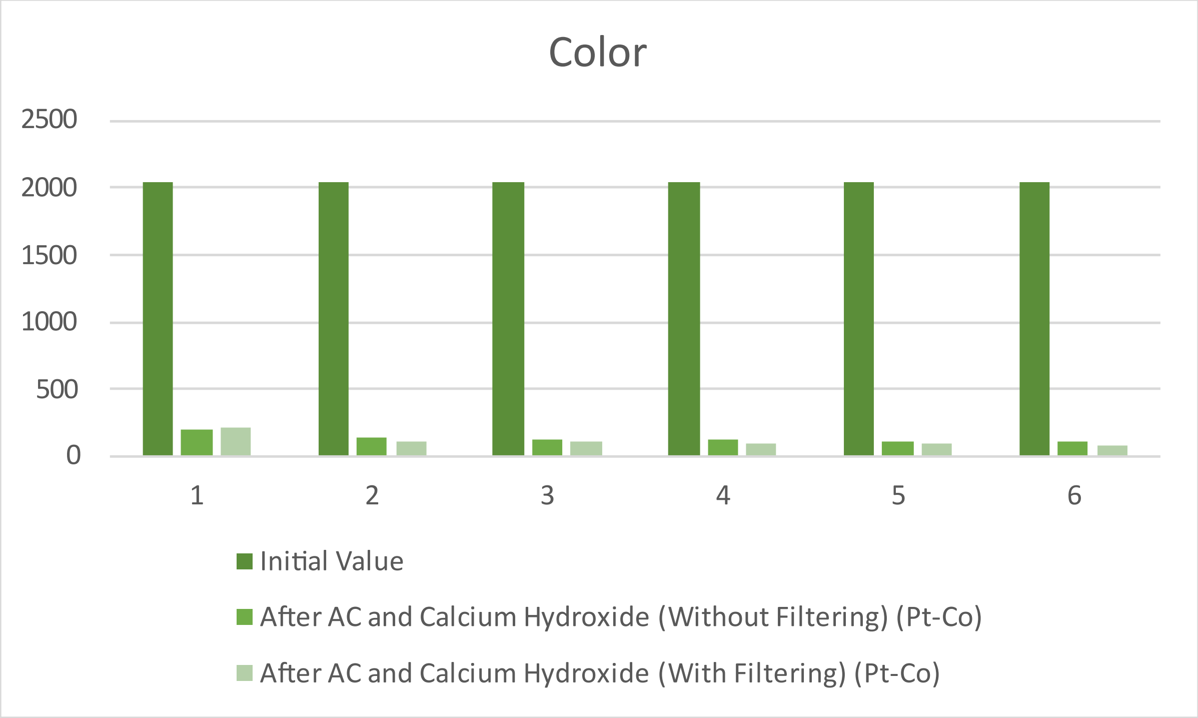


Figure 14 Reduction of Color in Jar Test (Before ETP Sample)

pH

Table 12 Results of pH After 0 Hour and 24 Hours (Before ETP)

Sample	**PAC Dosage, g/L**	**Lime Dosage, g/L**	**Initial Value**	**After Addition of PAC and Lime (0 Hour)**	**After Addition of PAC and Lime (Without Filter)**	**Standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023)**
Jar 1	1	2	9.76	12.06	11.90	6-9
Jar 2	2	2		12.01	11,86	
Jar 3	3	2		12.03	11.83	
Jar 4	4	2		12.00	11.78	
Jar 5	5	2		12.01	11.78	
Jar 6	6	2		12.00	11.80	

Optimal pH cannot be achieved. But after 24 hour a slight reduction of pH can be noticed. Still, the reduction do not fall into the standard value.

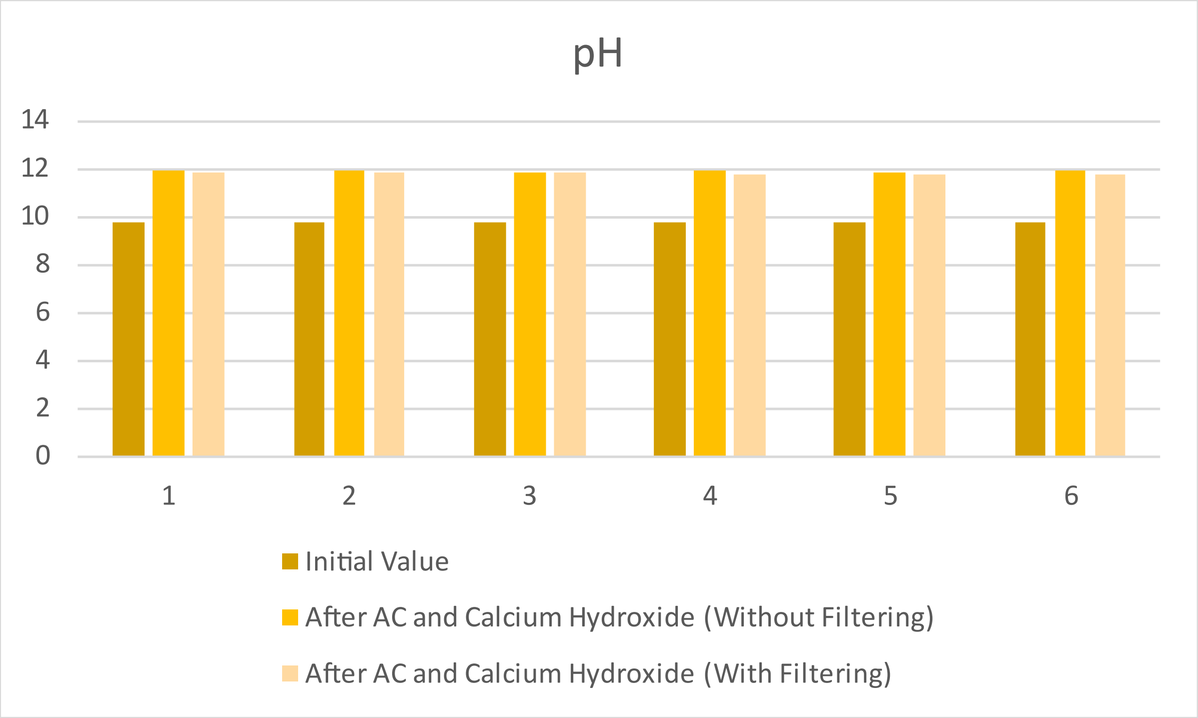


Figure 15 Change of pH in Jar Test (Before ETP Sample)

Turbidity

Table 13 Turbidity after 0 Hour and 24 Hour Before ETP

Initial Value	After AC and Calcium Hydroxide (0 Hour), NTU	After AC and Calcium Hydroxide (24 Hour), NTU
47.4	7.70	12.20
47.4	7.59	5.86
26.2	7.64	7.47
26.2	7.65	5.55
26.2	7.20	5.21
26.2	6.90	3.66

Turbidity in treated water has a significant decrease in value. The value seems to be even less after being filtered. There is no particular standard value for turbidity. However , it is evident the reduction of turbidity is possible in this way.

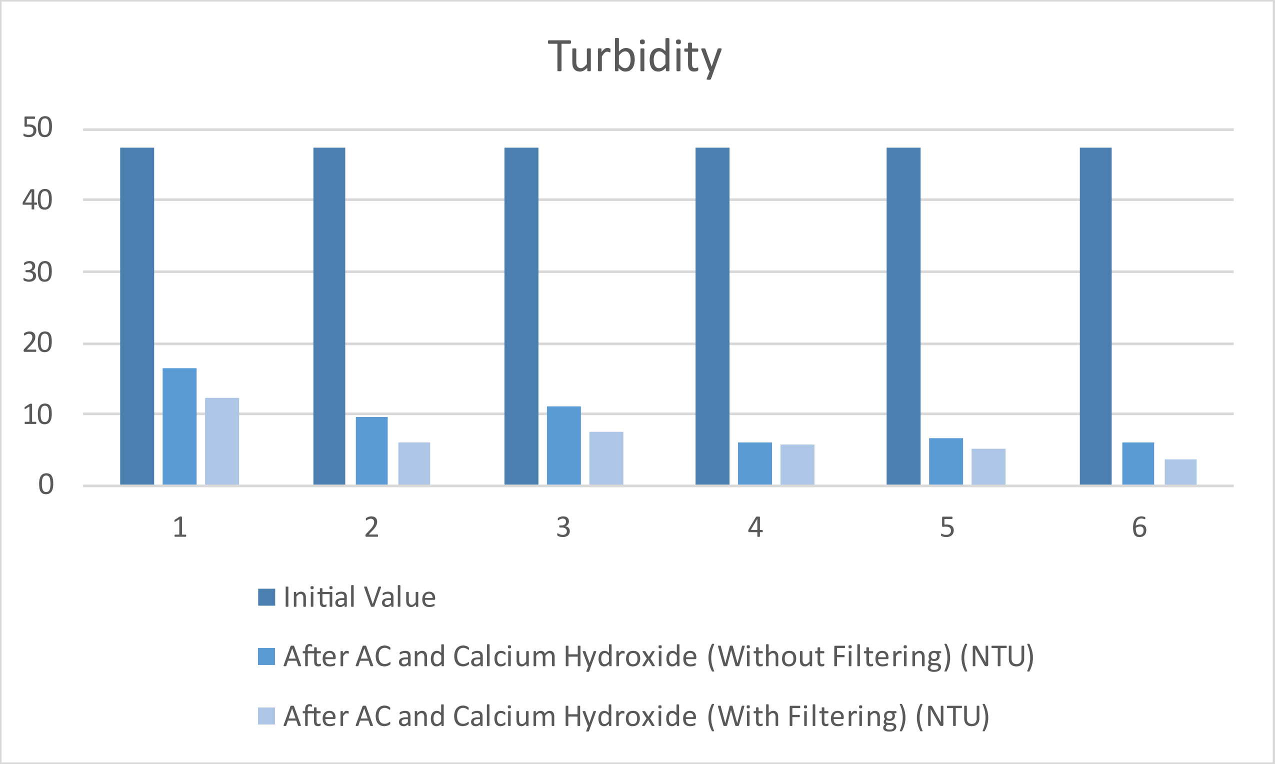


Figure 16 Reduction of Turbidity in Jar Test (Before ETP Sample)

TDS

Table 14 TDS after 0 Hour and 24 Hour before ETP

Initial Value	**After AC and Calcium Hydroxide (0 Hour) (g/L)**	**After AC and Calcium Hydroxide (24 Hour) (g/L)**	**Standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023)**	**Standard (for discharge in irrigated land) (Source: ECR 1997)**
2.54	5.76	4.71	2.10	0.60
2.54	5.35	4.68		
2.54	5.16	4.42		
2.54	5.29	4.40		
2.54	5.34	4.37		
2.54	5.47	3.39		

In case of TDS, the standard value cannot be achieved for both irrigation purpose and standard (Maximum Limit for the Parameters of Textile Wastewater, ECR 2023)

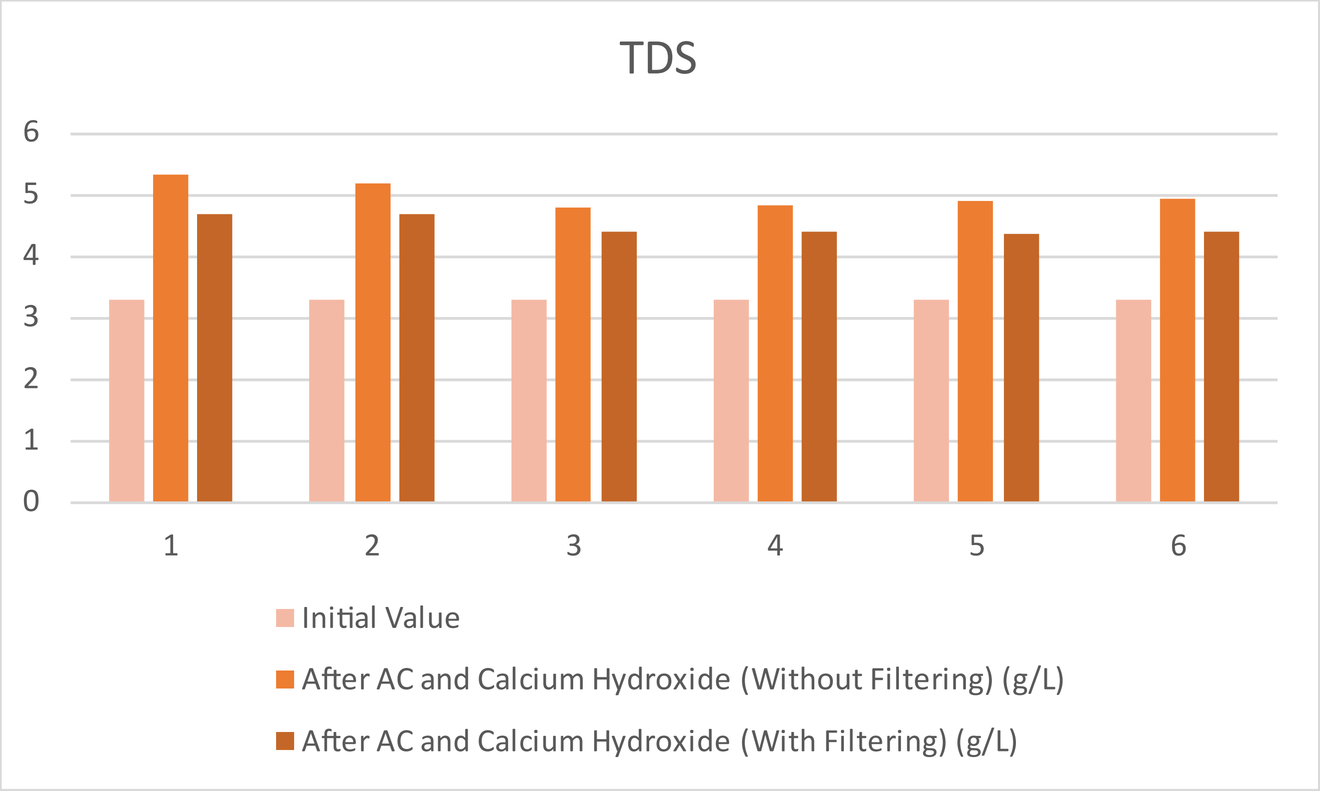


Figure 17 Change of TDS in Jar Test (Before ETP Sample)

Developing Isotherm on the result of color with ETP Treated Sample

Isotherm has also been developed for this sample's specific color reduction:

Table 15 Isotherm Table for Color Reduction of wastewater Before ETP

M	C0	C	X	X/M	C/(X/M)	1/(X/M)	1/C	ln (X/M)	lnC
gm/L	Pt.Co	Pt.Co	Pt.Co	Pt.Co/(gm/L)	gm/L	(gm/L)/Pt.Co	1/Pt.Co		
1	2,044	208	1,836	1,836.00	0.11	0.001	0.0048077	7.515344571	5.337538
2	2,044	109	1,935	967.50	0.11	0.001	0.0091743	6.874715425	4.691348
3	2,044	104	1,940	646.67	0.16	0.002	0.0096154	6.471830963	4.644391
4	2,044	94	1,950	487.50	0.19	0.002	0.0106383	6.18929029	4.543295
5	2,044	88	1,956	391.20	0.22	0.003	0.0113636	5.969218938	4.477337
6	2,044	81	1,963	327.17	0.25	0.003	0.0123457	5.790469725	4.394449

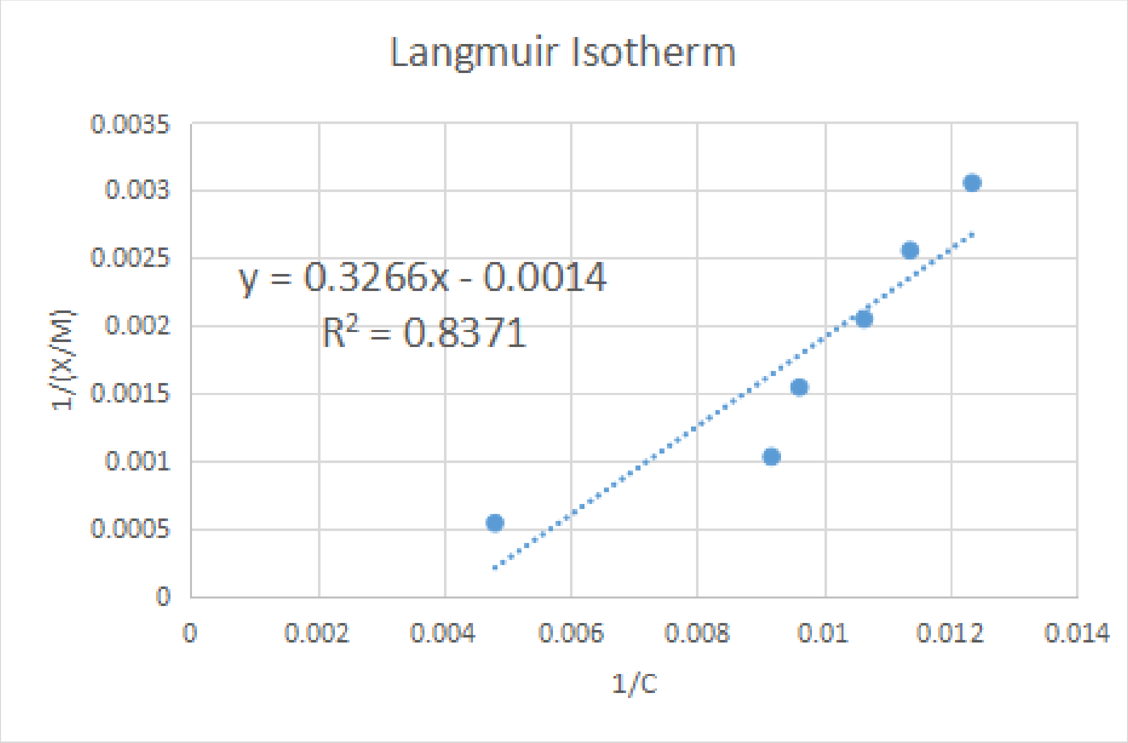


Figure 18 Langmuir Isotherm for Color Reduction (Before ETP Sample)

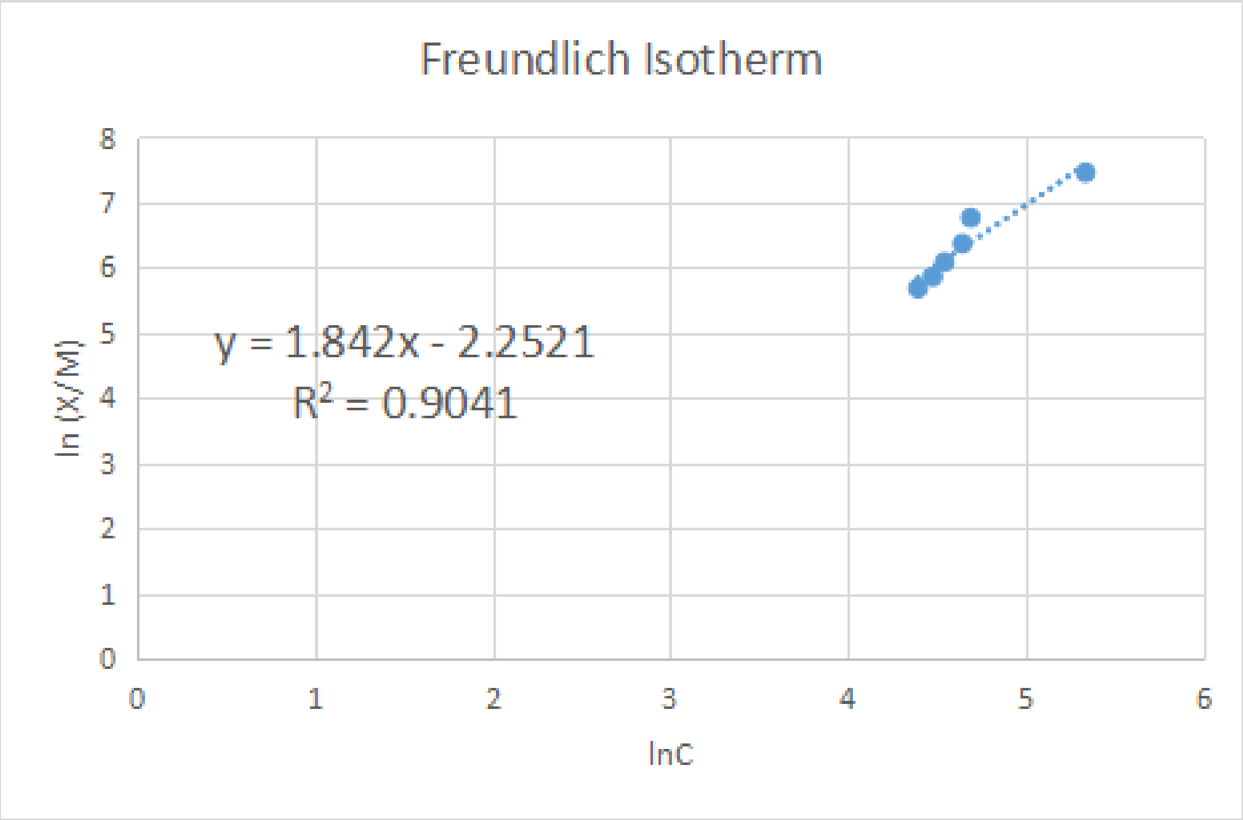


Figure 19 Freundlich Isotherm for Color Reduction (Before ETP Sample)

Freundlich theorem is more relevant for better value of correlation. Where, n=0.543 and k=0.105

Fixed Bed Column Test

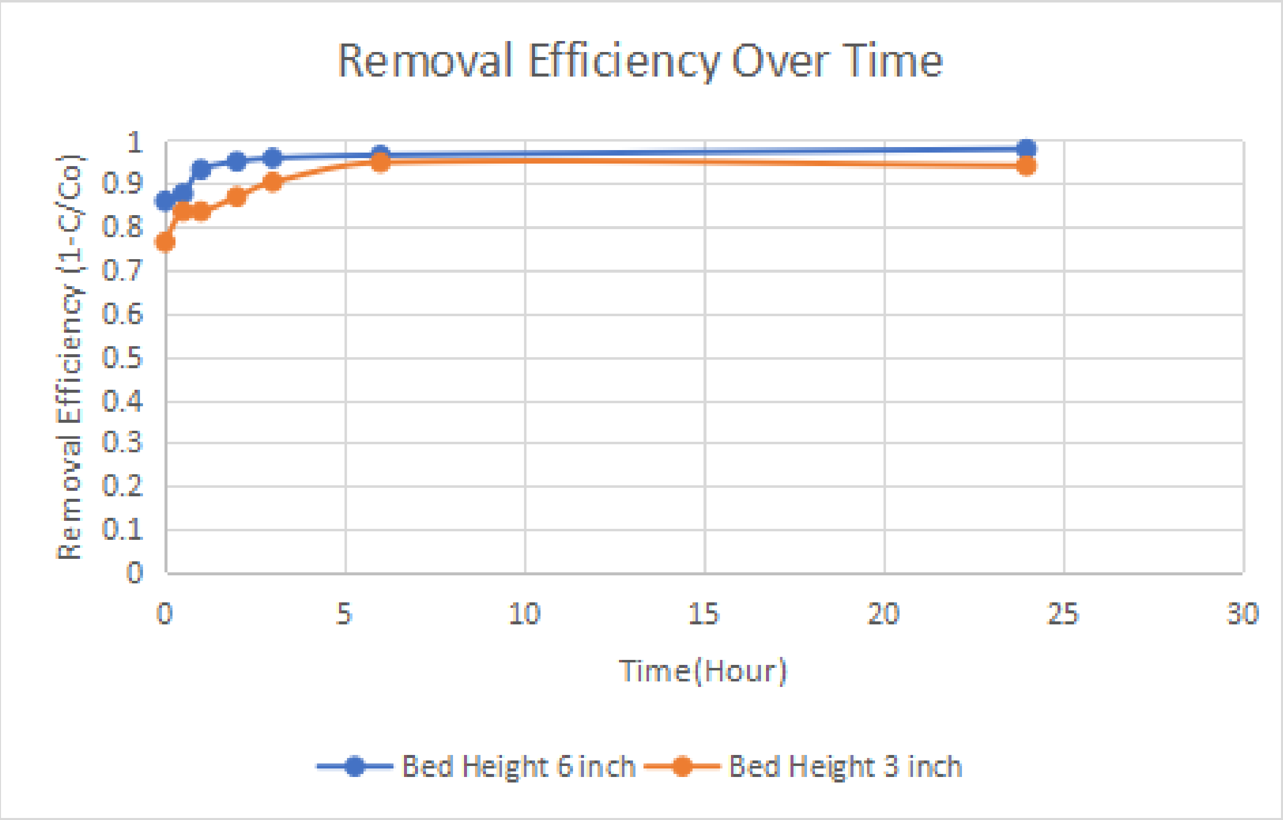
In case of fixed bed column test 2 bed heights were used and the tests were done for multiple time frame.

Color

Table 16 Column Test For Color Reduction

Time	**Initial Color, Pt-Co**	**3” Bed Height, Pt-Co**	**Removal Efficiency for 3”**	**6” Bed Height, Pt-Co**	**Removal Efficiency for 6”**	**Standard, Pt-Co**
0 Hour	2044	481	0.76	287	0.86	150
0.5 Hour		336	0.83	252	0.88	
1 Hour		336	0.83	138	0.93	
2 Hour		267	0.87	100	0.95	
3 Hour		197	0.90	84	0.96	
6 Hour		105	0.95	70	0.96	
24 Hour		120	0.94	41	0.98	

For a 6” bed height color removal is the most after 24 hours and the standard color can be achieved even for wastewater sample taken before ETP. This table shows, the comparison between the removal efficiency of color between 6in and 3in bed. A higher bed height shows higher removal efficiency. 98 percent removal efficiency can be seen in case of 6” bed height.



Turbidity

Table 17 Fixed Bed Column Test for Turbidity

Time	**Initial Color, NTU**	**3" Bed Height, NTU**	**Removal Efficiency for 3"**	**6" Bed Height, NTU**	**Removal Efficiency for 6"**
0 Hour	47.4	21.30	0.551	3.09	0.935
0.5 Hour		12.00	0.747	1.66	0.965
1 Hour		6.16	0.870	1.94	0.959
2 Hour		5.55	0.883	2.69	0.943
3 Hour		7.01	0.852	1.67	0.965
6 Hour		8.70	0.816	2.90	0.939
24 Hour		9.10	0.808	2.62	0.945

Removal efficiency for 6" for Turbidity Removal is much more compared to 3" bed height.

pH and TDS

Table 18 Column Test for pH and TDS

Time	3” Bed Height		6 “Bed Height	
	pH	TDS, g/L	pH	TDS, g/L
0 Hour	11.84	4.61	11.14	2.57
0.5 Hour	11.83	4.43	11.41	2.81
1 Hour	11.78	4.39	11.60	3.07
2 Hour	11.88	4.41	11.70	3.39
3 Hour	11.9	4.45	11.73	4.12
6 Hour	11.92	4.62	11.70	4.150
24 Hour	11.78	4.87	11.60	3.83

Both of pH and TDS show values which are much more than the required standard value.

Summary Comparison of Color:

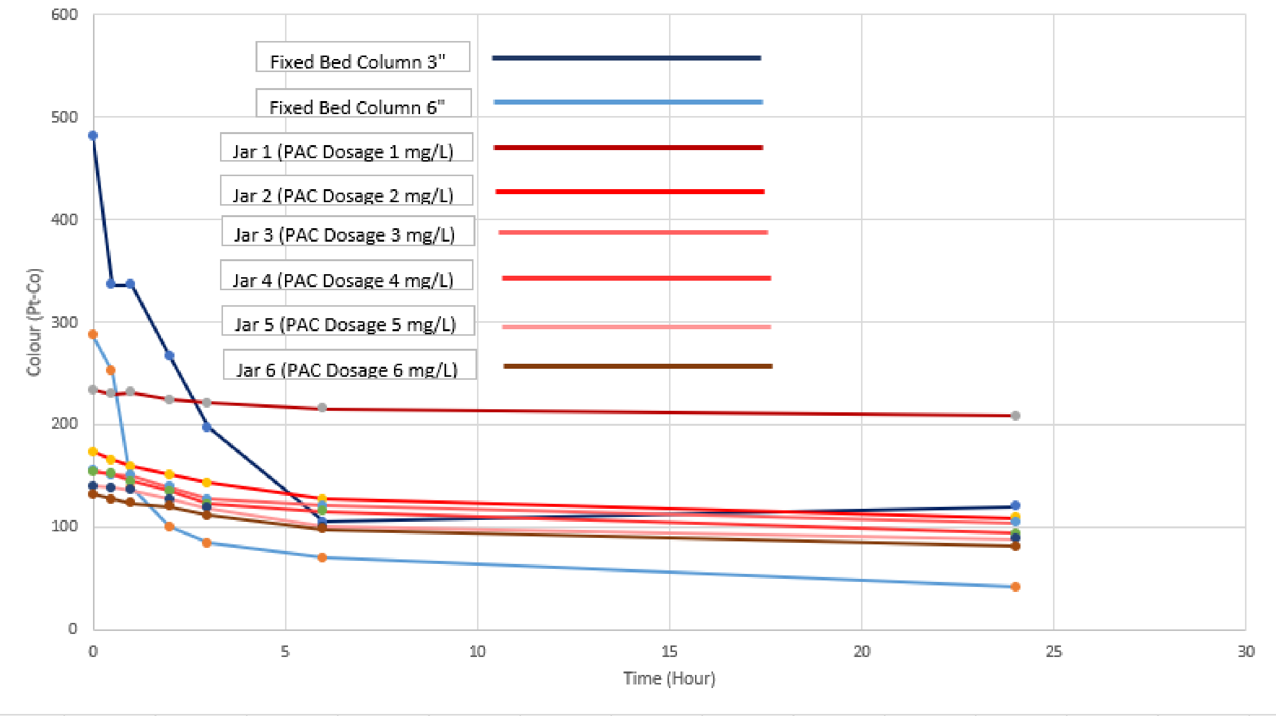


Figure 20 Summary Comparison of Color

This graph shows a comparison of color reduction with respect to time with both jar test and column test. We can see that the textile effluent standard has been achieved. Initially, the fixed bed column test does not show as much as color reduction as jar tests do. However, if we increase the retention time for fixed bed column for 24 hours, the color reduction is much higher than jar tests.

5. Conclusion

In the study conducted on textile wastewater treatment, it was found that both the Fixed Bed Column and Jar Reactions methods played a crucial role in achieving the desired standard color. However, the Fixed Bed Column exhibited a higher efficiency in reducing color compared to Jar Reactions within a specific time period. Interestingly, increasing the bed height in the Fixed Bed Column showed an even greater reduction in color, indicating the importance of bed design in optimizing treatment performance.

Furthermore, the results obtained from batch reactions showed that there was not a significant difference between the 24-hour and 48-hour settlement periods in terms of color removal. This suggests that the treatment process reached its optimal performance within the initial 24-hour period.

Significant improvements were observed in various water quality parameters. Notably, there was a substantial reduction in color, turbidity, Fe (iron), Mn (manganese), and COD (chemical oxygen demand). These findings highlight the effectiveness of the treatment methods in removing contaminants and improving water quality.

However, it is worth noting that there were certain changes in other parameters. Both pH and TDS (total dissolved solids) displayed an increase in their values after treatment. This indicates that the treatment process might have introduced certain alkaline components and dissolved solids into the water.

Regarding the determination of optimal carbon dosage for color removal, the Freundlich Isotherm was found to be more suitable than the Langmuir Isotherm. This suggests that the adsorption process in the treatment system followed a more complex and heterogeneous behavior, where the Freundlich model provided a better fit for predicting the optimal carbon dosage.

Overall, the findings of this study provide valuable insights into the effectiveness of different treatment methods and their impacts on various water quality parameters, which can be utilized for the efficient and sustainable treatment of textile wastewater.

6. Recommendations

Further study on the following issues can be conducted based on the findings of the study and the limitations discovered.

1. Conducting the fixed bed column study for multiple stages and analyze its efficiency
2. Adding Acids and run further tests to lower pH value
3. Find ways to achieve standard TDS through processes like filtration, reverse osmosis etc.
4. Further work can be done with additional water quality parameters

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