Re-use of Textile Effluent - An Experimental Study of Color Removal

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PROJECT REPORT APPROVAL

It is hereby certified that the thesis entitled "Re-use of Textile Effluent - An Experimental Study of Color Removal" submitted by Bushra Rahman and Tasnim Ara Baten has been found as satisfactory and fulfilling the requirements for the Bachelor of Science Degree in Civil & Environmental Engineering.

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DECLARATION OF CANDIDATE

We hereby declare that the undergraduate research work reported in this thesis has been performed by us under the supervision of Professor Dr. Md. Rezaul Karim and this work has not been submitted elsewhere for any purpose (except for publication).

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DEDICATION

We dedicate this thesis to our parents who gave significant time, money and effort for us to become who we are now. We also want to thank Professor Dr. Md. Rezaul Karim, our esteemed supervisor.

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

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Abstract

Textile wastewater treatment is a great concern worldwide. Due to its uneven water quality parameter, it is difficult to handle using tradition treatment methods. Besides, huge amount of water usage plays a vital role on depleting ground water level. Rainwater harvesting system does not show any significance contribution in this purpose. Thereby comes the necessity of reusing of effluent after proper treatment. In Bangladesh's textile industry, ensuring proper and effective wastewater treatment has become a difficult task. Adsorption is one of the most common and effective methods for dye removal. In this experimental work, the study shows how well Powdered Activated Carbon (PAC) as adsorbent with Lime or $Ca(OH)_2$ as an aid works for removal of color, TDS (Total Dissolved Solid), turbidity and pH. Freundlich and Langmuir are two common models of adsorption to achieve the particular carbon dosage for maintaining any particular range of color. In this study, between Freundlich and Langmuir type of isotherm Freundlich shows a clear trend with determining parameters. After collecting the samples, jar test procedure was followed to achieve the optimum dosage. Jar test method is a laboratory process for estimating the dosage to achieve certain water quality goals. The optimum dosage of PAC was obtained 5-6 gm with adding 1.5 gm $Ca(OH)_2$ and the equilibrium time was 12 hours for color removal. The removal efficiency obtained from the test was 99.3% for color, 99.87% for TDS and 97.8% for turbidity. The results suggest that the combined use of PAC and $Ca(OH)_2$ can be useful as dye removal from textile wastewater. A feasibility study can help to check economic perspective of effectiveness of implementing this process in industry.

Key words: Textile effluent, color removal, turbidity removal, optimum dosage, powdered activated carbon (PAC), $Ca(OH)_2$, isotherm

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1. Introduction

1.1 Background

The textile industry focuses on the development, manufacture, and distribution of yarn, cloth, and garments. Economy of Bangladesh is mostly centered on the ready-made garment industry, making it the world's second-largest exporter of clothes behind China (Islam *et al.,* 2013). According to the estimation of Berg *et al.* (2021), Bangladesh accounts for 84% of the country's overall export. These industries employ about 4.2 million people and contribute significantly to the GDP, with women playing an important role (Natasha & Jeny, 2018). Industry contributes significantly to national economic development, but it also has an impact on the environment and human health. According to Sharma & Imran (2011) several chemicals can cause allergic dermatitis, skin irritation, and kidney, liver, brain, reproductive, and central nervous system problems. Exposure to chemicals, dust, and noise causes a variety of health concerns, including colorectal cancer, thyroid tumors, nasal malignancy, skin disease, asthma, and hearing impairments (Kumar & Krishnamoorthy, 2018). Because of their genotoxicity and non-biodegradability, the widespread use of synthetic dyes discharged by the dyeing and textile industries harms the whole ecological systems (Asouhidou *et al*., 2009).

Textile industries not only poses a public health risk, but also consume high volumes of water per unit fabric for processing that causes depletion of ground water levels at a high rate (Hossain & Sarker, 2018). According to Water and Clothing (2019), the textile manufacturer requires about 93 billion cubic meters of water per year, accounting for 4% of global freshwater drawdown. Groundwater level is decreasing by 2-3 meters every year and this study predicts that the groundwater table will go down to about 110 to 115 meters by 2050 (Anwar Zahid, 2011).

One of the primary sources of water pollution is untreated effluent created by different departments of textile industries. Several studies estimated that more than 10000 types of pigments and dyes are used and 7×10^5 tons of dyes are produced annually all over the world. (Zollinger, 1987; Robinson at el., 2001; Ogugbue and Sawidis, 2013). According to researchers, more than 100,000 commercially available dyes are identified each year (Menaka & Rana, 2017).Textile effluents exhibit high BOD, COD, total dissolved solids, total suspended solids, and low dissolved oxygen (DO) values, in addition to being highly colored (World Bank, 2010). The textile industry ranks first in terms of dye use (Islam and Mostafa, 2018). Due to the presence of several chemicals and dyes, degradation in different water quality parameters occurs from the standard one. Dyes can be of different types such as fiber tractive, all purpose dyes, natural dyes, disperse dyes, azoic dyes, direct dyes, vat dyes (Gordon, 1990; Textile Infomedia, 2021). The water quality parameters of wastewater- color, turbidity, TDS, pH, COD, BOD, total organic carbon (TOC), *arsenic*, *sulfur*, *manganese* etc. can be adjusted to the standard values through different physical, chemical and biological processes.

1.2 Research Significance

1.2.1 Dye 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 apparent color 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 of solid 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 in removing 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 processes generally has their effect on removing various parameters.

1.2.2 Adsorption Process

Adsorption is a separation procedure of specific fluid phase components attracted to the surface of a solid adsorbent by forming physical or chemical interactions. Thereby removing the component from 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 adsorbent for 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 depending on the type of carbon the characteristics of the wastewater, activated carbon adsorption treatment has 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 activated carbon for recycling effluent. The primary goal of this research is to use the jar test method for determining the optimum dosage for removing color, turbidity, TDS, and pH utilizing PAC and $Ca(OH)_2$.

1.3 Objectives

The objective of the present study following jar test

1. Assessment of color removal by Powdered Activated Carbon (PAC) with $Ca(OH)_2$
2. Assessment of reduction in turbidity, TDS and pH following the same process
3. Analysis of Freundlich and Langmuir isotherm based on experimental data

1.4 Organizations of the Thesis

The entire research effort is organized into chapters to achieve the stated objectives and to make the evolution of the work more understandable. The rest part of the thesis contents of each chapter are briefly described below.

Chapter 2: Literature Review- This chapter covers previous work on similar studies and provides guidance on the scope of work

Chapter 3: Methodology- This chapter describes the approach used to conduct the research starting from scratch

Chapter 4: Result and discussion- This chapter deals with findings from the experiment and analysis of the collected data

Chapter 5: Conclusions and Recommendations- This chapter summarizes the contributions and effectiveness of the study and provides recommendations for future work

2. Literature Review

This chapter focuses on the relevant studies of reduction in several water quality parameter following different methods. Some of the processes are also performed in several textile industries in Bangladesh. But every study shows its own constraints. Now in our study, we tried to overcome these confines and to develop a more effective and useful method.

There are various common treatment methods are in practice. These processes can be classified into four types-

1. Physico-chemical method: Coagulation-flocculation, ion exchange, adsorption, membrane seperation are some mentionable physico-chemical methods. These methods separate color physically.
2. Chemical method: Chemical oxidation and ozonation are two commonly used methods. These procedures eliminate color by decomposing the dye and destroying the color-producing chromophore.
3. Biological method: Aerobic treatment, anaerobic treatment, anaerobic-aerobic treatment are the common biological methods. In these methods, decolorization occurs due to dye adsorption on activated sludge or biological breakdown of dye molecules.
4. Electrochemical method: Electrodialysis or ion oxidation is the generally followed method. This method combines the electrolytic oxidation of the dye and other pollutants with the physical chemical precipitation of the sludge.

For conducting the experiment we collected our sample wastewater from Masco Concept Knitting Ltd. playing a leading role in exporting knitted clothing since July, 2001. It is a vertical net composite plant with complete internal equipment and modern machinery to provide the best possible service. Over 2000m^3 of water is utilized for dyeing and washing every day and thereby wastewater contains numerous dyes and chemicals. After analyzing the water quality, it results notable variations to acceptable range and neither reusable nor environmentally friendly for discharging into water bodies. ETP plant of this textile follows biological process for treatment purpose of effluent which does not perform up to the mark. Color removal, turbidity reduction, and TDS are the key goals of our study in order to acquire the optimum dosage of commercial Powdered Activated Carbon with lime.

A study by Harrelkas *et al.* (2018) discussed about the combined process of basic physicochemical process with membrane processes. In this study, the inefficiency of coagulation-flocculation (CF) was intended to reduce by combining with microfiltration (MF), ultrafiltration (UF) and powdered activated carbon (PAC). Color reduction was found to be 65%, 74% and 50% respectively by The

CF/MF, CF/UF and CF/PAC. But removal of turbidity showed a negative response and the quality of water treated by CF/PAC or coagulation/UF is still insufficient for reuse in industry.

According to Iwuozor (2019) *Aluminium Sulphate, Aluminum Chloride, Polyaluminium Chloride, Sodium Aluminate, Chlorinated Ferrous Sulphate, Ferric Chloride, Ferric Sulphate, Ferrous Sulphate* are used for coagulation and flocculation by following jar test method. Some merits and demerits then discussed of this coagulation and flocculation process. More research on selection of high efficiency flocculants that can be used in industries are recommended in this study.

Malakootian & Fatehizadeh (2010) conducted a study where they used jar equipment, lime, and NaOH as softening agents and to raise the pH of the process. To increase the size of flocs in varying pH and color removal from water, alum and ferric chloride coagulants were utilized. The original color, pH, and coagulant and lime dosages were all investigated along with residual ones. The study found the process removed about 75% of color using 40mg/L of alum and ferric. But the electrical conductivity of water increased during the treatment. In terms of reducing the amount of color to less than 15 units, this study contradicts the findings of Coro & Laha (2001). By adding high amounts of ferric chloride coagulants, organic polymers, and activated silica to the water, the researchers were able to reduce the color to less than 15 units. Coagulation and fluctuation, rather than improved softening, appear to be the main mechanisms in color loss in this scenario.

The goal of the study conducted by Islam & Mostafa (2018) was evaluating efficiency of *polyaluminium chloride* and *ferric chloride* ($FeCl_3.6H2O$) for removal of color from synthetic wastewater containing drimarene reactive red dye considering pH, coagulant dosages, initial concentration, temperature, and mixing speed. The color removal efficiency of *polyaluminium chloride* was shown to be better than that of $FeCl_3$ following coagulation method. In this study, the efficiency of the coagulants was found to be strongly influenced by operational parameters, which required to be optimized before being applied to an industrial process otherwise it can have an adverse effect on other water quality parameters like turbidity.

The purpose of the study conducted by Mohamed *et al.* (2014) to focus on the effect of PH, coagulant dosage and settling time for obtaining optimum condition of reactive dye removing. Using three types of coagulants, almost 90% of dye removal on average were seen by *aluminum sulphate* (alum) at pH 2.4, $MgCl_2$ at pH 10.4 and *polyaluminium chloride* at pH 4.1 with Koaret PA 3230 as coagulant aid three optimum dosage was achieved. But high amount of chemical usage is noticeable here.

Karim (2006) conducted a study on four carbonaceous materials Segun sawdust, water hyacinth, rice husk, and jute stick were used to create porous activated carbon using ZnCl2 activation process after carbonization in tube furnance. Though this study found Segun sawdust and water hyacinth demonstrated significant ability of removing coloring compounds from effluents but the effect of jute stick and rice husk on effluent decolorization is insignificant. Different chemical usage in various steps of color removal process is also another drawback of this study.

An experiment was done by Bari & Sultana (2016) using four different materials: wooden charcoal, banana leaves ash, and rice husk ash (black and white) to remove color from methylene blue aqueous solution using the one-factor-at-a-time (OFAT) method with five varying particle size of each. Result showed banana leaves ash could be a viable adsorbent for removing color from industrial colored effluent. In this study, though mixing time was considered to be fixed but it can varied and during preparation phase, banana leaves are burned to obtain ash in the presence of oxygen that can have vital impact on environment.

Agarwal *et al.* (2017) conducted a study with the purpose to determine the efficiency of removing four different parameters- BOD, COD, pH and turbidity from wastewater exposed to Activated Carbon (AC). 4% AC gives the efficient result for treatment after 14 days for removal of the aforementioned parameter. Though it suggested to be a modern technique but exact methodology was not mentioned as well as different chemical usage was also notable.

A research by Jiang *et al.* (2019) focuses on the structure, adsorption mechanism, modified activated carbon, microbial and microwave bound activated carbon, and future research directions for activated carbon. Hu (2018) described activated carbon is an excellent adsorbent in water treatment and is a non-polluting material. Porosity and large specific surface area make it a good purifier. But the use of activated carbon is insufficient which clearly indicating that there is still a long way to go. To optimize the adsorption capacity of activated carbon in water treatment, improved water treatment service, cost savings, energy consumption minimization, and efficiency improvement have all become basic research criteria.

A study by Saeed *et al.* (2015) conducted on removal of dye by activated carbon produced from rice husk using adsorption method. Two dyes Congo red and magenta was removed 69.3% at 0.9g dosage and 95.3% at 1g dosage respectively. However, effects of this process on other water quality parameter and removal of other dyes using same method are not mentioned in this study.

3. Methodology

3.1 Sample Collection

A textile industry was selected to collect sample wastewater named as Masco Concept Knitting Industry. It is situated in Cherag Ali, Boardbazar, Gazipur, Bangladesh. It is a vertical knit composite plant with all in-house equipment and advanced machines to offer the finest possible services, operated by diverse manpower.

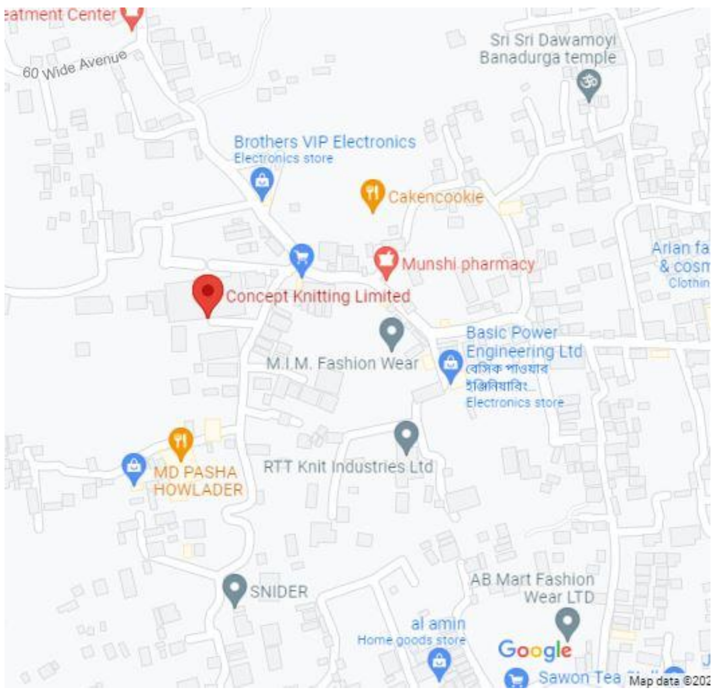


Figure 1: Location of the Industry

Table 1:Volume of water for different types of uses

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

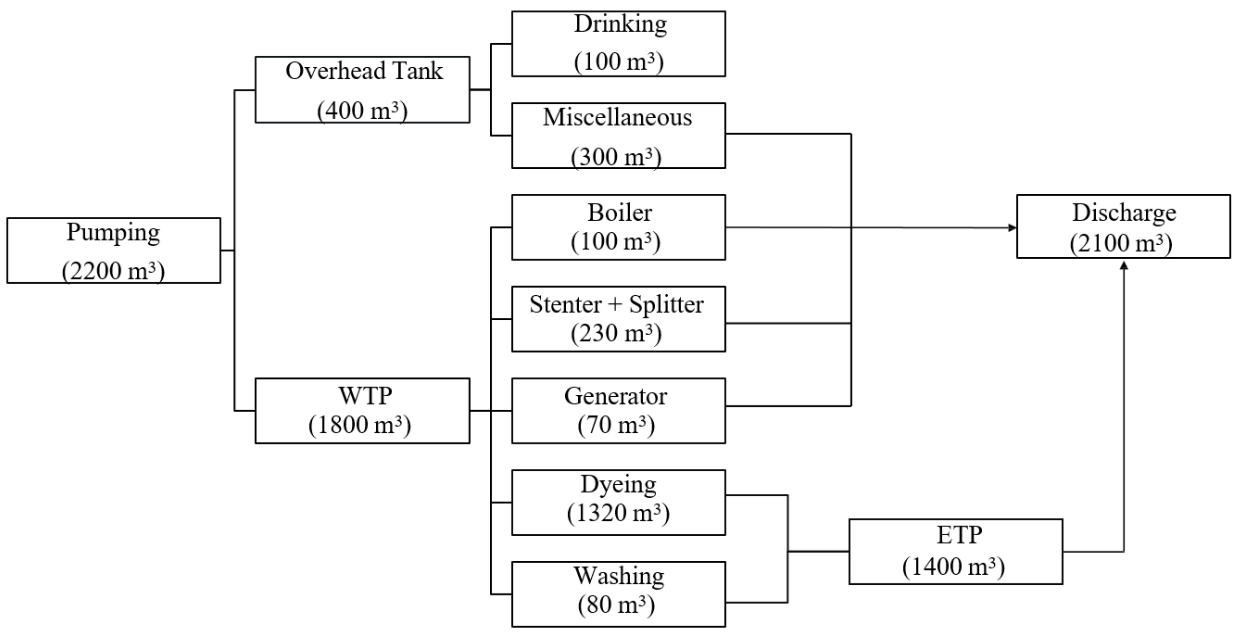


Figure 2: Direction of water flow in Masco Concept Knitting

In this industry, about 10 tonnes of clothes are produced each day. The figure shows around 2400 m^3 wastewater is produced everyday. The distance between the laboratory and the industry is 11Km.Sample were delivered to the lab on the day of collection. It was collected in five liter plastic bottle and was kept in room temperature after sampling.

3.2 Sample Parameter Test

After collection of sample, it was kept in room temperature in the laboratory. Both sample test and jar test were done on the day of the collection. To characterize the raw wastewater, we have determined these water quality parameters using these instruments given in the table below.

Table 2: Sample Treatment Process

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

3.3 Jar Test

Jar test identifies the optimum dosage of the chemical aimed at removing suspended matter for wastewater treatment. It includes six jars, each having 500mL of sample wastewater. Powdered Activated Carbon was added to each jar chronologically starting from 1 gm. It was then stirred for 1 min at 100 rpm and after that for 20 mins at 30 rpm. It was kept for settling for another 20 minutes. At this point, some of the water quality parameters were tested again. After that,1.5 gm of Lime ($Ca\ (OH)_2$) was added to each jar and it was stirred the way as previously done. Later on color, turbidity, TDS, pH - these parameters were tested at different time interval.

Figure 3: Final Result after Addition of Ca(OH)$_2$

3.4 Chemical used

Powdered Activated Carbon, Lime ($Ca(OH)_2$)

3.4.1 Activated Carbon

Activated carbon is commonly available as powdered activated carbon (PAC) and granular activated carbon (GAC). Powdered Activated Carbon (PAC) is known as high performance absorbent. It is less expensive and has finer particle. Activated Carbon has great adsorption capacity because of its larger surface area and developed micropores. Hu Zian (2018) found that interaction between many forces such as van der Waals' force, electrostatic action etc. causes adsorption of activated carbon. Activated carbon's large and porous surface area, combined with attraction force, capture and hold various types of materials onto its surface. Thus, specific compounds are removed from the wastewater. According to a study by Fares (2018), activated carbon powder enhances the treatment efficiency by its adsorption capacity.

3.4.2 Lime

Calcium hydroxide ($Ca(OH)_2$) or lime is mainly used in water treatment to increase its pH level and precipitate the ions that cause hardness. Besides this**,** it has several advantages in conventional chemical treatment of wastewater. It helps in controlling pH, reducing oxidizable organic pollutants, clarification, precipitation of dissolved pollutants as well as flocculation and coagulation of colloidal particles. Sometimes, lime is used as an aid in coagulation, flocculation and adsorption. According to a study by Asadollahfardi (2018), lime was the most suitable coagulant comparatively in the jar test. Malakoutian (2010) found out that color removal efficiency increases with increase of lime. Lime is mostly used as a softener but when it is used as an aid, it bonds with the other particles and increases the mass of the flocs. It is then increases the speed with which they settle out of the water.

3.4.3 Isotherm Method

The adsorption isotherm is a method to determine the adsorption capacity of a chemical material. It also helps to find out the relationship between the amount of color removed and the amount of carbon required for color removal. In order to understand the thermodynamic phenomena of activated carbon adsorption, two isotherms were used to fit the experimental data**,**Freundlich isotherm and Langmuir isotherm. The main difference between these two isotherms is that the Freundlich isotherm equation is an empirical approach. It is considered as the ideal one whereas Langmuir isotherm is more theoretical.

Freundlich isotherm can describe multilayer adsorption process. It is only applicable to such adsorption process that occurs on heterogenous surface (Ayawei 2015). Freundlich isotherm thus defines the heterogeneity and the exponential distribution of all individual active sites(Ayawei 2015). The mechanism of the adsorption process depends on binding energy between adsorbed molecules and sorbent.

The linear isotherm according to Freundlich is as follows:

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

where,

X = adsorbent actually adsorbed by Carbon (color difference)

M = carbon dose, mg/L

C = final color

k = empirical constant (y -intercept)

n= slope-inverse constant

Langmuir isotherm describes monolayer adsorption process. It explains the surface coverage by balancing the relative rates of adsorption and desorption (dynamic equilibrium). This model describes adsorption process over a homogeneous adsorbent surface. The Langmuir isotherm can be plotted in terms of C/(X/M) versus C or of 1/(X/M) versus 1/C. The plot that produces a clear trend provides the more accurate constants.

The Langmuir isotherm is defined by the following equation

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

Where,

a = maximum number of moles adsorbed per mass of adsorbent at monolayer saturation

b = empirical constant

4. Data Analysis & Discussion on Results

Most of the values are in range with the standard value. But there are some elements with alarming amounts such as color, TDS, turbidity, COD, sulphate etc. These are the parameters that actively determines the quality of water on dyeing purposes that means treatment procedures have to be conducted to get the value of these parameters within range.

Table 3: Standard Values of Parameters

Parameters	Units	Standard Value	Sample
Color	Pt-co	5	1843
pH	-	6.5-7.5	7.93
TDS	mg/L	300	2185
TSS	mg/L	0	67.63
Total Hardness	mg/L as CaCO3	30	51.25
COD	mg/L	0	124.63
BOD	mg/L	40	20.18
Turbidity	NTU	0	66.2
Mn	mg/L	0.05	0.32
Fe	mg/L	0.01	2.66
Cl	mg/L	150	185.91
SO_4	mg/L	150	362.50
NO_3	mg/L	0	0.10

4.1 Results on Color

Table 4 represents changes in color at different time interval for different dosages. Powdered activated carbon of 1gm,2gm,3gm,4gm,5gm,6gm was added to each jar respectively. Initially the color was 1843 Pt-Co and it was decreased to 13 Pt-Co for 6gm of activated carbon after 24 hours. There is no noticeable difference in color change for 5 and 6 gm of activated carbon. Most of the color was removed in the first 12 hours. This indicates that the adsorption of color was rapid in the first 12 hours for all six dosages. After this12 hours, the amount of color absorbed was insignificant. 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 4* 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 energy of 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 mass transfer driving force and hence the rate at which color induced molecules pass from the bulk solution to the particle surface(Rahman,2017).

Table 4: Color Change in Different Time Interval (Before Filtering)

Time Interval	S-01	S-02	S-03	S-04	S-05	S-06
1	52	50	44	42	29	18
2	54	45	39	43	33	29
3	52	48	38	41	31	27
4	48	40	36	38	29	27
6	39	35	33	32	28	30
8	48	45	40	42	26	25
10	44	39	38	40	20	21
12	36	34	36	36	18	23
14	50	30	38	45	35	34
24	59	32	14	31	14	13

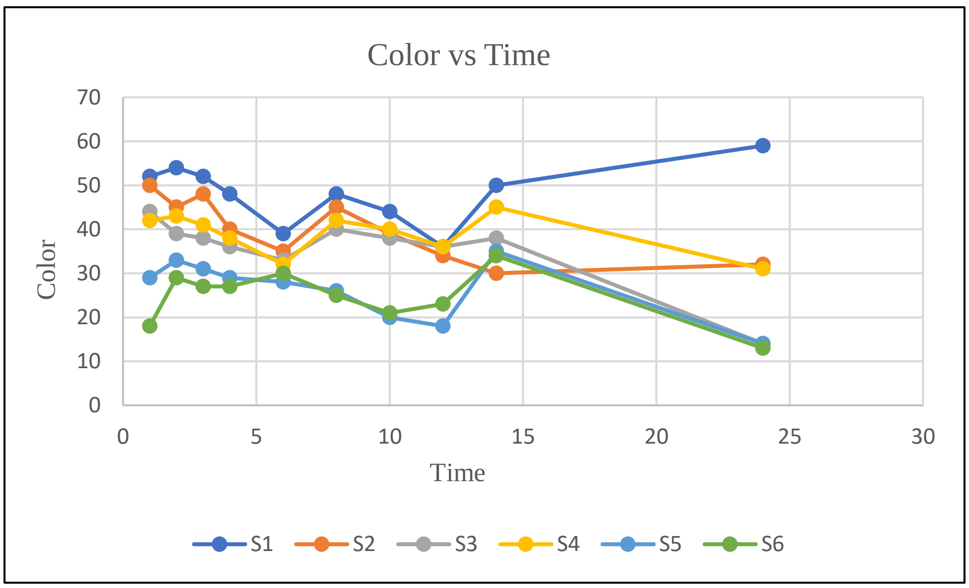


Figure 4: Color vs Time (Before Filtering)

Table 5: Color Change in Different Time Interval (After Filtering)

Time interval	S-01	S-02	S-03	S-04	S-05	S-06
1 hr	20	23	6	4	3	2
2hr	16	8	4	3	4	3
3 hr	19	6	5	7	4	3
4 hr	17	10	6	8	4	2
6 hr	14	8	7	6	3	3
8 hr	9	5	7	3	4	4
10 hr	4	7	10	2	5	5
12 hr	7	3	9	3	3	4
14 hr	5	2	6	4	4	5
24 hr	11	9	10	10	5	4

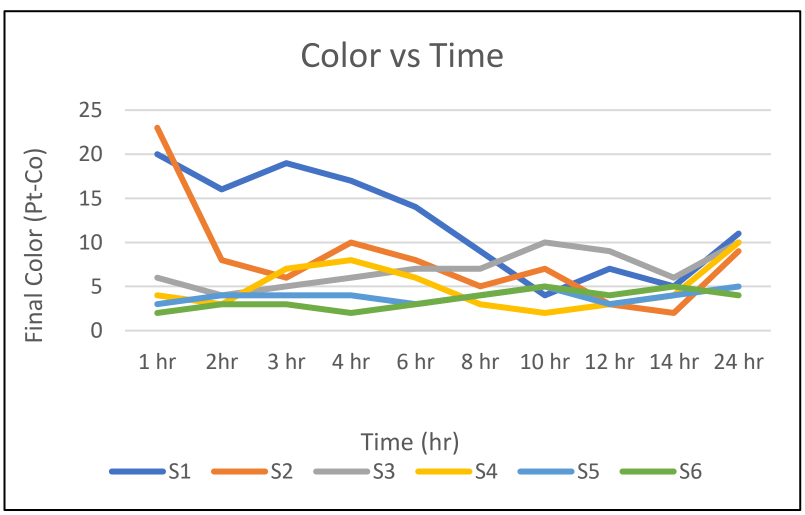


Figure 5: Color vs Time (After Filtering)

4.2 Results on pH, TDS, and Turbidity

Figure 6 shows effect of lime on color removal. Only 44.7% color is removed by activated carbon alone. After adding lime, color removal has increased to 99%. Lime bonds with the other particles and increases the mass of the flocs .It is then increases the speed with which they settle out of the water.

Similarly, turbidity and TDS have been removed at quite a greater percentage.For the raw wastewater ,turbidity was 66.2 NTU. *Figure 8* shows that 97.8% turbidity was removed during this experiment. Initially, the raw water contained 2185 gm of TDS. It has been reduced to 2.46gm.

Table 6: Data on pH after addition of AC

	S-01	**S-02**	**S-03**	**S-04**	**S-05**	**S-06**
Initial Color	1843	1843	1843	1843	1843	1843
AC	1019	988	954	800	735	785
AC + $Ca(OH)_2$	52	50	44	42	29	18

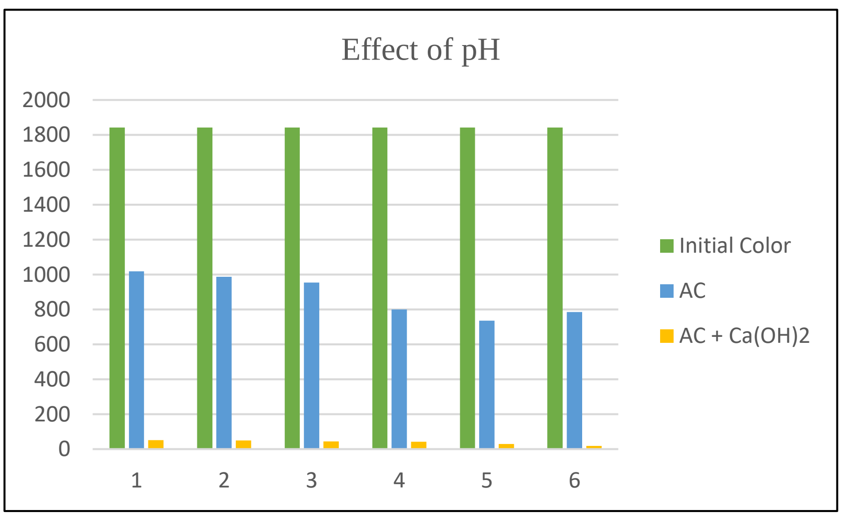


Figure 6: Effect of pH

Table 7: pH change with different time interval

Time	S-01	S-02	S-03	S-04	S-05	S-06
0	7.93	7.93	7.93	7.93	7.93	7.93
1	11.28	11.3	11.35	11.24	11.25	11.25
8	11.26	11.28	11.31	11.24	11.21	11.2
14	11.3	11.3	11.3	11.23	11.08	11.14
24	11.65	11.64	11.66	11.56	11.5	11.56

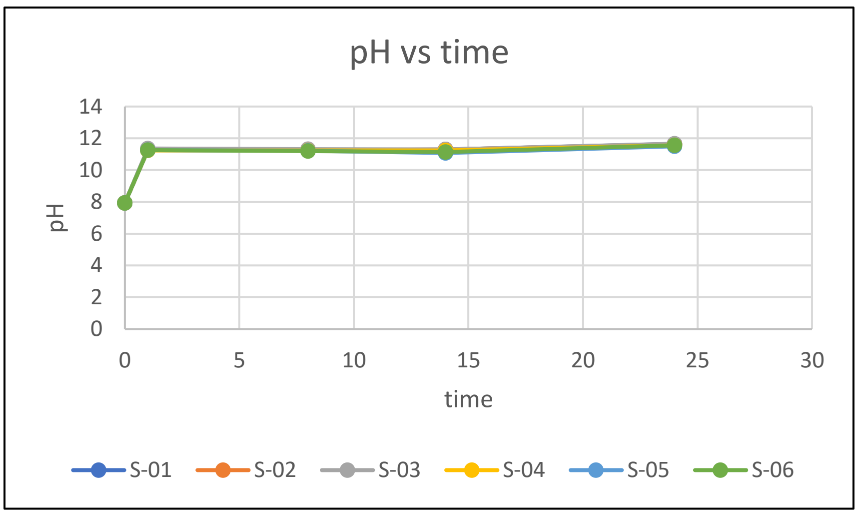


Figure 7: pH vs Time

Table 8: Change of turbidity with time

Time	S-01	S-02	S-03	S-04	S-05	S-06
0	66.2	66.2	66.2	66.2	66.2	66.2
1	4.34	5.35	6.14	4.49	3.66	2.67
8	4.64	4.59	4.55	4.03	3.65	2.79
14	4.1	4.2	4.3	3.2	2.4	2.5
24	3.9	2.09	1.86	1.86	1.68	1.45

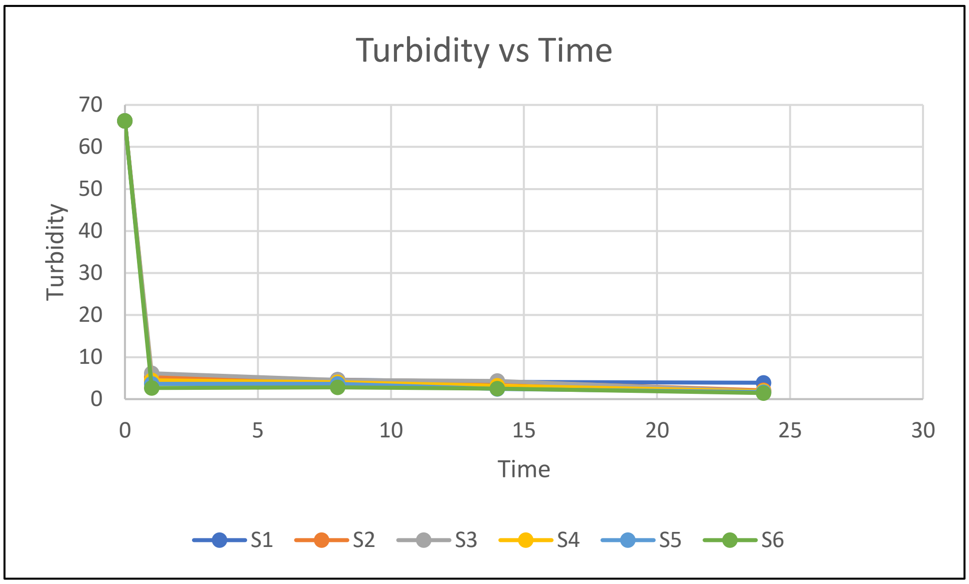


Figure 8: Turbidity vs Time

Table 9: Change of TDS with time

Time	S-01	S-02	S-03	S-04	S-05	S-06
0	2185	2185	2185	2185	2185	2185
1	2.79	2.81	2.86	2.72	2.75	2.78
8	2.85	2.83	2.93	2.8	2.79	2.84
14	2.84	2.73	2.7	2.76	2.46	2.55
24	2.81	2.8	2.92	2.84	2.75	2.85

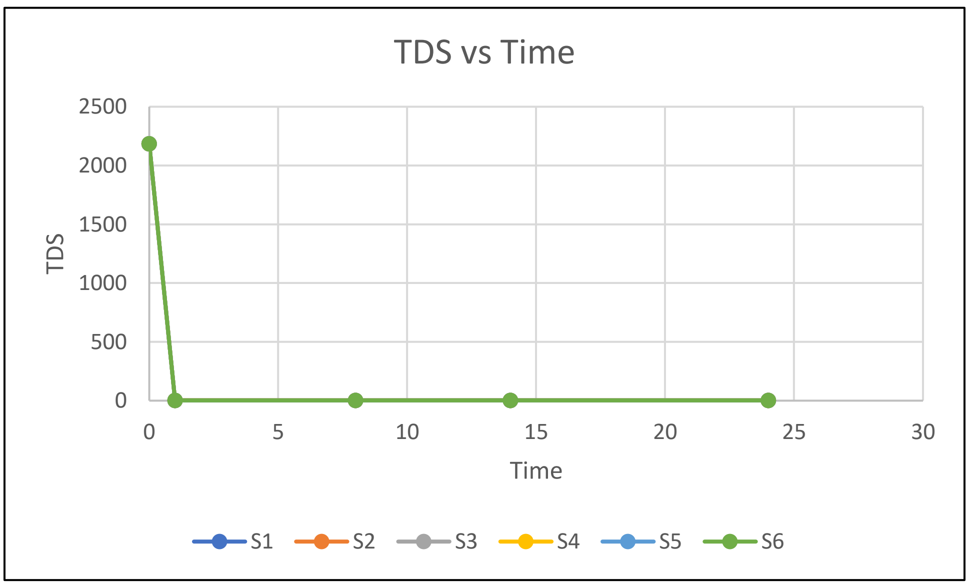


Figure 9: TDS vs Time

4.3 Modelling Adsorption Isotherm

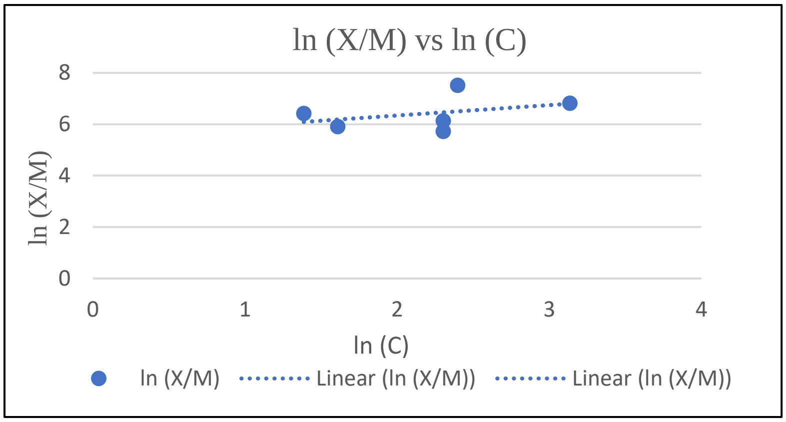
The isotherm approach is mainly done to set all variables ,except for the carbon dosages and removal rates. Once these constants are calculated, carbon dosage can be determined for any color.

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 252.52 and 2.47 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)

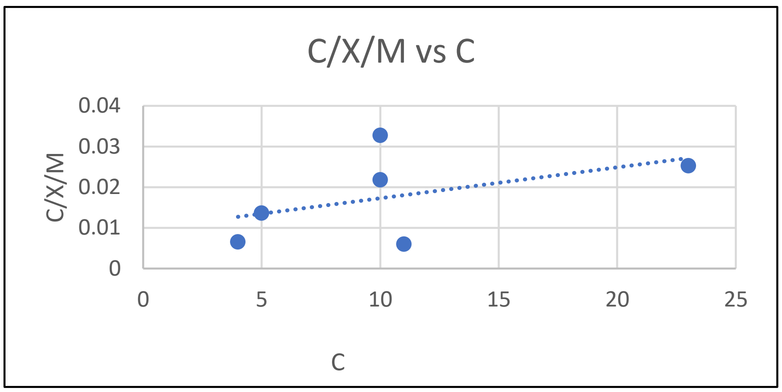
In case of Langmuir isotherm,a linear trend is difficult to produce in *Figure 1(b)* .It can be assumed that the parameters are 60-70% correlated as some of the points are scattered from the trendline. For one type of Langmuir isotherm, the value of a and b are 1250 and 0.082 respectively, For another type, these values are 312.5 and 2.13. Comparing to these two, Freundlich isotherm produces a clear trend that provides more accurate constants.

Table 10: Data calculation for Isotherm Plotting

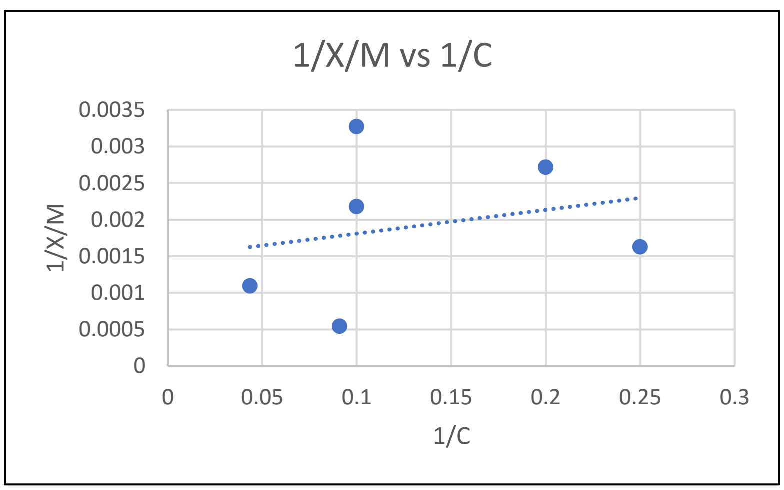
M,g/mL	Initial color,Co	Final Color,C	X	X/M	C/X/M	1/X/M	1/C	ln (X/M)	lnC
1	1843	11	1832	1832	0.006	0.000546	0.0909	7.513	2.398
2	1843	23	1820	910	0.0253	0.00109	0.0435	6.813	3.1354
3	1843	4	1839	613	0.00653	0.00163	0.25	6.418	1.3863
4	1843	10	1833	458.25	0.0218	0.00218	0.1	6.1274	2.303
5	1843	5	1838	367.6	0.0136	0.00272	0.2	5.9069	1.609
6	1843	10	1833	305.5	0.0327	0.00327	0.1	5.7219	2.302



(a)



(b)



(c)

Figure 10: a) Freundlich Isotherm, b) Langmuir Isotherm (1), c) Langmuir Isotherm (2)

5. Conclusion

The textile industry can effectively recover water from wastewater for reuse in production processes by properly selecting and applying individual or combinations of advanced treatment methods. Several studies were conducted to evaluate the removal efficiency of different water quality parameters following these treatment methods.

The main objective of this study was to find out the efficiency of removing color, turbidity, pH and TDS. For this purpose, adsorption process was followed by using Powdered Activated Carbon (PAC) as an adsorbent with Lime or $Ca(OH)_2$ as an aid. Adsorption process considered to be an effective dye removal depending on the adsorbent used.

The removal efficiency obtained from the test was 99.3% for color, 99.87% for TDS and 97.8% for turbidity. The optimum PAC dosage determined from the jar test was 5-6 gm with 1.5 gm $Ca(OH)_2$, and equilibrium time for color removal was 12 hours. Two commonly used adsorption model- Freundlich and Langmuir was compared to obtain the specific carbon dosage to maintain particular range of color. In this case, Freundlich isotherm determines parameter better than Langmuir showing a cleared trend. Thereby this process can be effective one for adjusting parameters of effluent.

6. Recommendations

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

1. In this study, in batch experiment, removal efficiency of color, turbidity and TDS are evaluated. Further studies can be done with other water quality parameters specially COD and BOD.
2. In this study, economic perspective of this newly addressed method is not mentioned. Additional economic analysis as well as feasibility study of this method can be done.

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