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APPLYING COAGULANTS TO IMPROVE THE EFFLUENT QUALITY OF ETP AND REDESIGNING APPROACHES

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DECLARATION OF CANDIDATES

We hereby declare that the project/thesis work under the supervision of Dr. Amimul Ahsan entitled "Applying Coagulants to Improve The Effluent Quality of ETP and Redesigning Approaches", has been performed by us and this work has not been submitted elsewhere for reward of any degree or diploma (except for publication).

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ABSTRACT

ETP plays a pivotal role in functioning a textile industry and ensuring environmental safety and sustainability. Various methods have been suggested over the years to enhance the effluent quality and ETP capacity. This study focuses on improving the quality of the effluent by applying Chemical Coagulant (*PAC* and *Cationic Polymer*) and Natural Coagulant (*Moringa oleifera*). COD, Turbidity and Color was removed for different amount of dosages for both coagulants, however, other parameters such as TSS, TDS, pH did not have a significant change.

The removal rate of PAC and Polymer combination for COD, Color and Turbidity was 34.89%, 22.35% and 42.53% respectively. On the other hand, *Moringa oleifera* had a removal rate of 12.77%, 21.83% and 18.6% for COD, Color and Turbidity respectively. Optimum dosages of PAC and Polymer for COD removal was 2% and 1.6%, while for Moringa oleifera the optimum dosage was 50 mg/L. For color and turbidity removal, the optimum dosages of PAC and Polymer was 4% and 3.2%, while for Moringa oleifera it was 20 mg/L. The study shows that the combination of PAC & Polymer had a better removal efficiency of Color, Turbidity and COD, as compared to the performance of *Moringa oleifera*.

It also offers a redesigning approach to enhance the capacity of the treatment plant by 20% to meet the criteria for future extension and compares the variation between existing design and the calculated design.

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CHAPTER I

INTRODUCTION

In this section, the background of the project which includes the present situation of current Effluent Treatment system, the problems faced, as well as the aim of the project. Along with the process, the areas that need improvement are also addressed.

1.1 About Ananta Casual Wear:

The ANANTA Group is one of the largest apparel exporters in Bangladesh. ANANTA group of the company started its journey in 1992 as ANANTA Apparels, later expanding its horizon by founding ANANTA Denim Technology Ltd in 2007, ANANTA Casualwear Ltd in 2009, ANANTA Huaxiang Ltd in 2010, Universal Menswear Ltd in 2011, DNV Clothing Ltd in 2012 and ZandZ Intimates Ltd in 2017. It is currently working with a workforce of 26000 people and an annual turnover of more than 300 million USD. It has some core concerns for environmental safety including raising energy efficiency, responsible packaging, efficient waste disposal, and carbon reduction, etc. ANANTA is recognized as a LEED Gold Certified factory by the U.S. Green Building Council (USBGC) in 2017. (Ananta: Our Story, n.d)

1.2 Problem Source:

Any type of textile production needs a lot of water in every step from the beginning to the end. According to a study, textile wastewater covers 20% of the total wastewater amount of the world and is the 2nd largest contributor to water pollution. (UN SDGs affect textile wastewater pollution research: Analysis, n.d). As a venture of ANANTA Group, ANANTA Casualwear produces some types of Ready-Made Garments which cause the effluent to have a heavy amount of chemical and microbial wastes. As a result, the BOD and COD of the water are very high at the beginning of the treatment process. Although the treatment plant has been working for a long period with the present process and design, with time the factory has increased its production and wastes are increasing accordingly. So as a renowned company, ANANTA Casual Wear wants to redesign and revise the strategy of effluent treatment before it exceeds the acceptable range as well as create a sustainable model for long-term usage.

1.3 Process Description:

The process flow diagram is shown in Fig: 1.1. here the major equipment for cleaning the influent water is the Sand Extractor Unit, Auto Screen Chamber, Coagulation Tank, Flocculation Tank, Primary Clarifier 1 and 2, Aeration Tank 1 and 2, Secondary Clarifier, and Post Aeration Tank. This process is discussed in detail later.

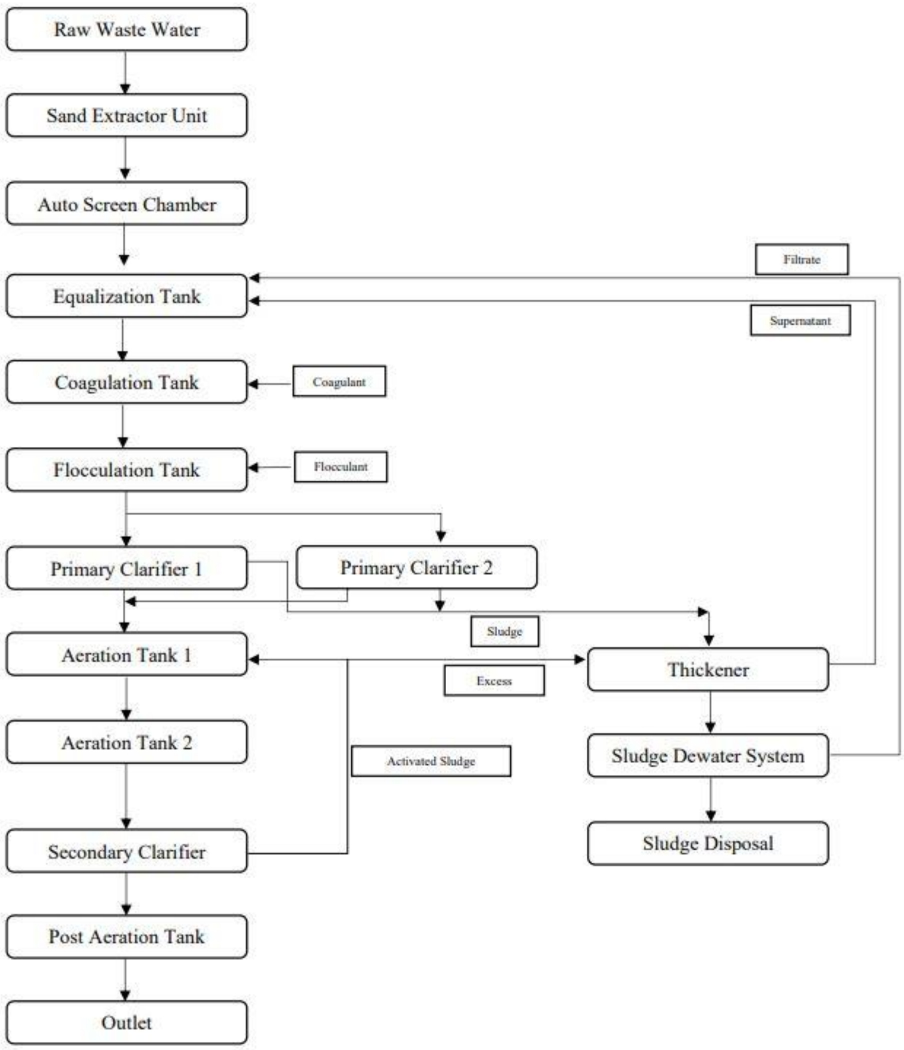

Figure 1.1 Process Flow Diagram of WWTP of ANANTA Casual Wear

Sand Extractor / Grit Removal Unit: All non-organic materials used in the pre-treatment of wastewater are collectively referred to as grit-sands, including not only silica sand but also all industrial byproducts and wastes. The wastewater (water plus sands or grit) enters the hopper by a flanged entrance, where the solid particles decant and settle to the tank's bottom. The separated material is transported to the discharge spout by a specific screw. And the hopper releases pure water.

Auto Screen Chamber / Mechanical Screen Chamber: The main purpose of screening is to remove solid materials that could cause damage to other process equipment, cause a reduction in the efficiency of the whole system, contaminate waterways, etc. Mechanical Screen is used for this purpose and with the variation of their design and mechanism they can be of various types.

Coagulation Tank: Colloidal suspended solids are filtered out of the water using coagulants. Coagulation can be done using a variety of coagulants. Electrical charges, typically negative charges, are carried by colloidal particles. To overcome the repulsive charge and destabilize the suspension, the opposite charges coagulant is introduced to the water.

Flocculation Tank: Flocculants are substances that support the aggregation of tiny particles in water, which results in a floc that floats to the surface or settles to the bottom. It is now simpler to eliminate these impurities from the water. Flocculants can be inorganic or organic and are in multiple forms, molecular weights, charge densities, and charges.

Primary Clarifier: The major function of the primary clarifier is to remove all settleable and floating solid waste which has a high oxygen demand – BOD. These are typically positioned downstream of the plant and have a circular form.

Aeration Tank: The aeration tank is where the wastewater undergoes biological treatment. Activated sludge is combined with the wastewater before it enters this tank. Numerous bacteria and other microbes can be found here that can degrade the colloidal, organic pollutants dissolved in the wastewater.

Secondary Clarifier: The secondary clarifiers are situated close to the biological treatment plant, close to filters or aeration basins. Here, processed wastewater from the earlier stage of treatment is removed using a clarifier. Clarification and thickening are two of the secondary clarifier's main functions.

Post-Aeration Tank: A higher level of disinfection of the effluent is provided in the post-aeration tanks.

1.4 Problem Definition:

As per the design of the Effluent Treatment Plant of ANANTA Casual Wear Ltd., the effluent has 28.5% residual impurities in the effluent, which is almost on the edge of the safety range. It can be an outcome of their rapid expansion and gradual increase in production, deterioration of equipment by age, and so on.

1.5 Objective:

The project aims to achieve a negligible trace of foreign matter in the effluent through a systematic approach.

- To redesign the ETP for textile industry for a higher capacity
- To apply coagulants to improve the effluent quality of ETP

CHAPTER II

LITERATURE REVIEW

The quality of the effluent and efficiency of the wastewater treatment plant can be improved through various ways. Several studies have been done on the subject and various methods have been proposed, such as correction of design, using various coagulants and other methods.

2.1 Identification and Correction of Design Deficiencies

The efficiency of a wastewater treatment plant depends on precision of design. Design deficiencies can lower the quality of the effluent. Mohammadi and Morhadhasseli (2012) showed in a research surveying twenty wastewater treatment plant of Iran that they had a number of design deficiencies such as inadequate process flexibility, insufficient oxygen transfer etc. which had an effect on the effluent quality and treatment efficiency. Therefore, identification and correction of design deficiencies is an important step to improve the quality of the effluent.

2.2 Usage of Coagulants

Coagulation is one of the important methods in improving the effluent quality in a wastewater treatment plant (WWTP). It is a water treatment process which removes solids from the water by electrical and chemical means. It introduces small and highly charged molecules into water to destabilize the charges on colloids, particles or oily materials in suspension (Bradley, 2022). By coagulation, destabilized particles start to collide and create small masses, which often are called “micro flocs”. Flocculation introduces a large molecule with electrostatically charged binding sites to attract oppositely charged “micro-flocs”. As a result, the “flocs” separate from the water.

Selection of Coagulant is one of the most important tasks for wastewater treatment. Different coagulants work better for different parameters and several studies have been done on selection of most appropriate coagulants for water treatment (Holt et al., 2002).

Primarily, two types of metal coagulants are used in the treatment of water- iron based coagulants and aluminum-based coagulants.

2.2.1 Chemical Coagulants

2.2.1.1 Iron-based Coagulants

Common iron-based coagulants include ferric sulfate, ferrous sulfate, and ferric chloride. Ferric salts can work as good coagulants in acidic conditions, but they are generally corrosive and not easier to dissolve. Its usage may lead to increasing the concentration of soluble iron in process effluents (Sahu and Chaudhari, 2013). For example, ferric Chloride is one of the cheapest and easiest coagulants to source, but it is the most corrosive of commonly used inorganic coagulants. Thus, ferric sulfate is usually preferred over ferric chloride because the chloride ions may increase the corrosivity of water (Brandt et. al, 2017). So the coagulant needs to be handled properly and extra cost may be required for corrosive protection.

2.2.1.2 Aluminum-based Coagulants

The coagulation mechanism here is controlled by the hydrolysis speciation (Dennet et al., 1996). Aluminum based coagulants include aluminum chloride, aluminum sulfate or alum and sodium aluminum. The most common and economically-friendly aluminum based-salt in the treatment of water is *alum* ($Al_2(SO_4)_nH_2O$). Using alum as the sole coagulant, significant organic removal can be achieved (Sahu and Chowdhury, 2013).

Mostofa and Peters (2016) showed that aluminum chloride ($AlCl_3$) is more effective than other iron-based common coagulants such as ferric sulfate, ferric chloride, and ferrous sulfate in wastewater treatment. It showed a higher efficiency in the removal of pollutants in lower dosages and more cost-effectiveness than other coagulants. To improve the efficiency of aluminum salts, poly-aluminum coagulants are developed.

2.2.1.2.1 Pre-polymerized Coagulants

Partial polymerization of aluminum salts is done as a process to improve the efficiency and effectiveness in water treatment. It resulted in production of a number of pre-polymerized aluminum solutions such as Poly-aluminum chloride (PAC), Pol-aluminum sulfates (PAS) or Poly Aluminum chloro-sulfates (PACS). Among these coagulants, Poly-aluminum chloride is one of the most efficient chemicals which is used in water treatment in the last few decades. It possesses several advantages over other popular coagulants like aluminum sulfate, such as, it performs better and faster in forming 'flocs', hydrolyses easily and possesses a lower dosage of aluminum which results in fewer aluminum residuals and sludge-waste (Chant, 2022). Farajnezhad and Ghabrani (2012) showed that PAC performs better in COD and Color removal than ferric chloride. Sabur et al. (2012) showed that PAC at a dose of 25 mg/L had 90.17, 74.09 and 93.47% reduction in COD, TDS and Turbidity in a textile Industry.

2.2.1.3 Polymer

Simple monomers polymerized into high-molecular-weight substances form polymers. In terms of charge, polymers can be cationic, anionic or non-ionic. As wastewater particles are usually changed negatively, cationic polymers or poly electrolytes can serve as a coagulant which reduces the negative charge off the particles, similarly as alum or ferric chloride. (Sahu and Chaudhari, 2013).

2.2.2 Natural Coagulants

Various natural coagulants are effective in quality-improvement of textile-based wastewater. *Moringa oleifera* powder removed 79% of COD according to a study (Muralimohan et al., 2014). Likewise, in various studies other coagulants such as

Chitosan had a COD removal efficiency of 73% (Ariffin et. Al, 2009), *Okra mucilage* had 85.69% (Wang et al., 2011), *Ocimum basilicum* had 61.6% , *S. Potatorum* had an efficiency of 72.7% (Dehghani and Alizadeh, 2016), Surjana seed had 74.11%, Maize seed had 68.82% and *P. ovata* had 89.3% (Ramavandi and Farjadfard, 2016) in various dosages.

2.3 Other Methods

There are other different methods of improving the effluent quality in wastewater treatment plants as suggested by researchers. Control strategies like controlling aeration system and sludge flow rate can improve the quality of the improvement (Rajaei and Nazif, 2022). Machine Learning Framework for quality control of effluent has been suggested (Wang et al., 2021). There also have been studies on the usage of new generation coagulation reagents (Tzoupanos and Zouboulis, 2008) to improve the quality of effluent in the treatment plant.

Thus, improvement of design and usage of proper coagulants is chosen in this study to improve the quality of the effluent. It is found from the above that Poly-Aluminum Chloride (PAC) is more effective among the chemical coagulants in the textile industry. Iron-based coagulants have some drawbacks, while cationic polymers can serve as a coagulant like alum or ferric chloride. For natural coagulants, *Moringa oleifera*, Okra mucilage and P. ovata had the best performance. Here *Moringa oleifera* was selected because of availability.

CHAPTER III

METHODOLOGY

3.1 Coagulation with PAC and Polymer

3.1.1 Sampling

Raw wastewater samples from the Ananta Casual Wear Ltd. ETP were collected. Wastewater was collected in plastic containers which has a capacity of 5 liters. After collecting wastewater samples, they were transported to the Environmental Laboratory of Islamic University of Technology, Gazipur. Wastewater was collected from three different stages of the treatment plant- inlet, before aeration tank (after primary treatment) and outlet.

Figure 2.1 Wastewater from different parts of the Ananta Casual Wear Ltd.- inlet, before aeration tank and outlet

We began the test of the wastewater samples on the same day of collection from the Ananta Casual Wear Ltd. ETP, to avoid microbiological decomposition of solids. Samples were analyzed for different parameters according to the DoE standards. The parameters were analyzed for BOD, COD, TDS, TS, pH, Turbidity (NTU), Color, and DO.

3.1.2 Mixing Coagulants

Coagulants were used in the experiment to improve the quality of the effluent. As discussed before, Poly-aluminum chloride (PAC) and Cationic Polymer were used as coagulants. The solution of PAC and Polymer were prepared and mixed with the second sample (the water taken coming from the inlet before going to the aeration tank) The sample was taken in six different jars and the coagulants were mixed in the following ratios in the first experiment:

Sample 1: Samples were taken from the water coming from the inlet before going to the Aeration tank.

Samples 2: 1% of PAC and 0.8% Polymer Solution with Sample 1

Sample 3: 2% of PAC and 1.6% Polymer Solution with Sample 1

Sample 4: 3% of PAC and 2.4% Polymer Solution with Sample 1

Sample 5: 4% of PAC and 3.2% Polymer Solution with Sample 1

Sample 6: 5% of PAC and 4% of Polymer Solution with Sample 1

The quantity of PAC and Polymer would be varied in the following experiments to find out the correct amount of dosage that improves the quality of our effluent.

3.1.3 Jar Test

After mixing of coagulants, Jar test was started. The jar test is a laboratory procedure which simulates coagulation/flocculation with differing chemical doses. The procedure aims to estimate the minimum coagulant dose required to achieve certain water quality goals. A conventional jar test apparatus was used in the experiment. The test was done as a batch test, accommodating a series of six beakers together with six-spindle steel paddles.

Figure 3.1 Jar Test (Flocculator Variable Speed, Bibbdy, United Kingdom)

3.1.4 Testing

After Jar Test, rest of the parameters were were tested. (BOD, COD, TDS, TS, pH, Turbidity (NTU), Color, DO). The parameters were tested for all samples, including the sample from inlet and outlet.

BOD: Measuring biochemical oxygen demand requires taking two measurements. One is measured immediately for dissolved oxygen (initial), and the second is incubated in the lab for 5 days and then tested for the amount of dissolved oxygen remaining (final). (Biochemical oxygen demand, n.d)

COD: An aliquot of the sample is digested for two hours at 150 °C in the presence of dichromate and sulfuric acid. The resulting solution is titrated to a colored endpoint with a ferroin indicator or read on a spectrophotometer at an appropriate. (Chemical oxygen demand, n.d)

TDS: TDS meter is a small hand-held device which is used to indicate the Total Dissolved Solids in a solution, usually in water. Since dissolved ionized solids, such as salts and minerals, increase the conductivity of a solution, a TDS meter measures the conductivity of the solution and estimates the TDS from that reading. (Total Dissolved Solids, n.d)

pH: pH meter is used to measure pH levels in the water. (pH, n.d)

Turbidity: To measure turbidity, a nephelometer also known as a turbidity meter was used. Turbidity meters utilize light and photodetector to measure light scatter, and read out in units of turbidity, such as nephelometric turbidity units (NTU). (Turbidity, n.d)

Color: Tintometer is a device to determine color in water. The unit of color measurement is TCU. 1 TCU is the color produced by 1 mg of platinum cobalt in the form of chloroplatinate ions dissolved in 1 liter of distilled water.

DO: Dissolved oxygen levels can be measured by a basic chemical analysis method (titration method), an electrochemical analysis method (diaphragm electrode method), and a photochemical analysis method (fluorescence method). (Dissolved Oxygen, n.d)

After testing, the results were plotted, and the change of variation and improvement of parameters were observed. According, the tests were repeated with a different dosage of coagulants to find out the best quality of effluents.

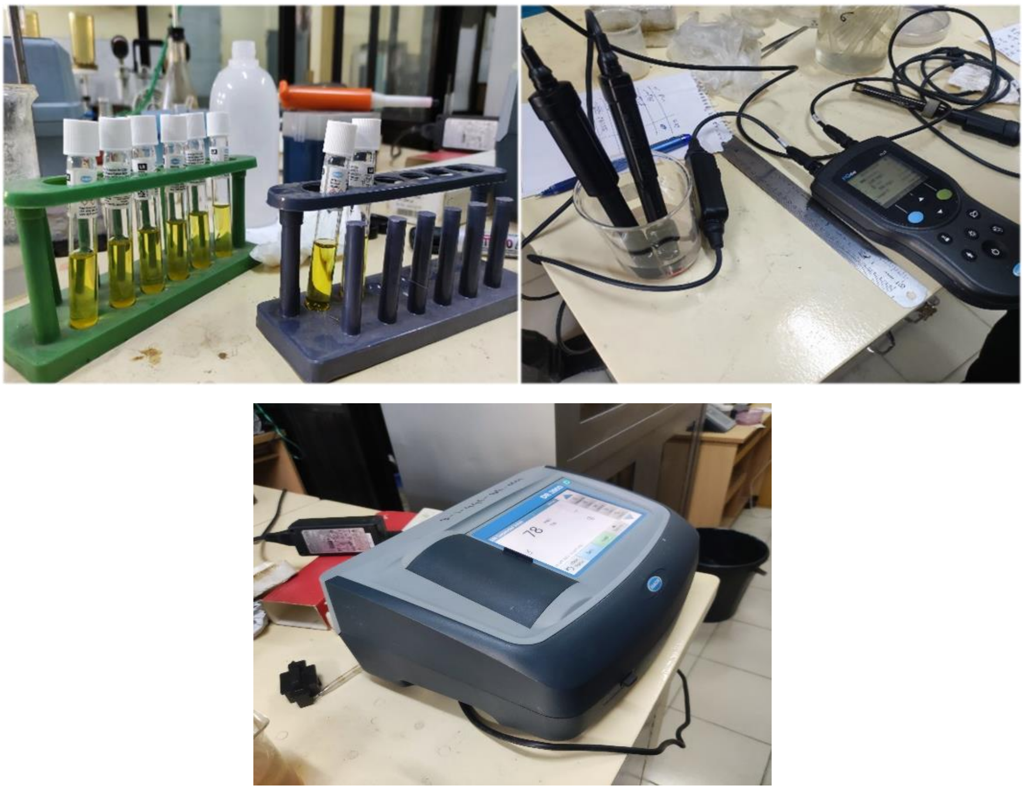

Figure 3.2 COD, pH and Color Testing in Laboratory

(Equipment: HACH, US)

3.2 Coagulation with *Moringa oleifera* (Natural Coagulant)

3.2.1 Sampling

As the wastewater could not be collected from Ananta Garments due to inconvenience, raw wastewater samples from the Apex Holdings Ltd. were used as an alternative for this test. Wastewater was collected in plastic containers which has a capacity of 5 liters. After collecting wastewater samples, they were transported to the Environmental Laboratory of Islamic University of Technology, Gazipur.

3.2.2 Preparation of *Moringa oleifera* Seeds Powder:

3.2.2.1 Collection of Moring Oleifera:

Ripe *Moringa oleifera* was collected from the local market. One kg of *Moringa oleifera* was taken and washed properly after the collection. After washing, seeds were extracted.

Figure 3.3 Collection of Moringa oleifera

3.2.2.2 Drying:

The seeds were dried in the sun heat for 5 days. It was ensured that no water remained in the seeds.

Figure 3.4 Drying of Moringa oleifera Seeds

3. Grinding:

Dried seeds were crushed in grinding stone. The crushing process continues until the seeds become fine powder. After completing the crushing procedure, the *Moringa oleifera* seeds powder were preserved it in an airtight jar. 100 g of *Moringa oleifera* seeds powder from initial sample of 1 kg.

Figure 3.5 Crushing of Moringa oleifera Seeds

3.2.2 Mixing Coagulants

Coagulant was used in the experiment to improve the quality of the effluent. As discussed before, *Moringa oleifera* Seeds powder was used. The sample was taken in seven different jars and the coagulants were mixed in the following ratios in the first experiment:

Sample 1: Samples were taken from the raw waste water of the plant before any treatment.

Sample 2: *Moringa oleifera* Seeds powder 20 mg/L Moringa with Sample 1

Sample 3: *Moringa oleifera* Seeds powder 50 mg/L Moringa with Sample 1

Sample 4: *Moringa oleifera* Seeds powder 100 mg/L Moringa with Sample 1

Sample 5: *Moringa oleifera* Seeds powder 140 mg/L Moringa with Sample 1

Sample 6: *Moringa oleifera* Seeds powder 180 mg/L Moringa with Sample 1

Sample 7: *Moringa oleifera* Seeds powder 230 mg/L Moringa with Sample 1

The quantity of *Moringa oleifera* Seeds powder would be varied in the following experiments to find out the correct amount of dosage that improves the quality of our effluent.

After mixing of coagulants, Jar test was started. The jar test is a laboratory procedure which simulates coagulation/flocculation with differing chemical doses. The procedure aims to estimate the minimum coagulant dose required to achieve certain water quality goals. A conventional jar test apparatus was used in the experiment. The test was done as a batch test, accommodating a series of six beakers together with six-spindle steel paddles.

3.2.3 Testing

Various parameter such as BOD, COD, Turbidity, TSS, DO etc. were tested in the same procedure as described before (PAC and Polymer).

3.3 Design Check

The design of the different parts of ETP of Ananta Casual Wear Ltd., such as the primary clarifier, aeration tank, secondary clarifier etc. was rechecked following the '*Fundamentals of Wastewater Treatment and Engineering*' authored by Rumana Riffat and '*Wastewater Engineering: Treatment and Reuse'* authored by Metcalf & Eddy. The input parameters were based on the considered value original design of the plant or assumed according to the general range of the value. The design flow is considered 20% higher (1900 m^3/day) than the original design (1584 m^3/day) to accommodate a higher capacity. The results were compared with the existing system and required improvements were suggested to improve the efficiency and quality of the ETP.

3.3.1 Design Procedure:

3.3.1.1 Coarse Screen Design

Coarse Screen was designed according to the book titled '*Wastewater Engineering: Treatment and Reuse* authored by Metcalf & Eddy (ex 5.1).

Input Parameters:

Coefficient of discharge Cd =0.70 *(0.7 for a clean screen and 0.6 for a clogged screen; Metcalf and Eddy p: 321)*

Velocity of flow through the openings of the bar screen V_S=0.90 m/s *(should not exceed 0.9 m/s; Metcalf and Eddy p: 321)*

Approach velocity in upstream channel v=0.50 m/s *(should be at least 0.45; Metcalf and Eddy p: 321)*

Acceleration due to gravity g=9.81 m/s^2

Output Parameters:

Head loss through the screen H_L=1/0.70*((0.90^2-0.50^2)/ (2*9.81)=0.041 m

Flow Q=1900 m^3/d=0.022 m^3/s

Bar Screen Channel cross section, Ac=0.022/0.5=0.044 m^2

Width=√(0.033/1.5) =0.171 m

Depth=0.171*1.5=0.257 m

Bar Screen Cross Section=0.044/0.866=0.051 m^2

3.3.1.2 Fine Screen Design

Fine screen was designed according to '*Wastewater Engineering: Treatment and Reuse* authored by Metcalf & Eddy (eq 5.2).

Input Parameters:

Coefficient of discharge C_d=0.70

Wastewater flow rate Q=1900 m3/d= 0.022m^3/s

Acceleration due to gravity g =9.81 m/s^2

Head loss through the screen H_L=0.150 m

Output Parameters:

Effective Open area of submerged screen, A =0.022/(0.70√(2*9.81*0.150))

=0.02 m^3 *(at least 0.05 m^2 for every 1000 m3 of daily flow; source: nestolwater.com)*

3.3.1.3 Grit Chamber Design (aerated)

Grit Chamber was designed according to '*Fundamentals of Wastewater Treatment and Engineering*' authored by Rumana Riffat (ex. 6.2).

Input Parameters:

Avg. Flow Rate=1900m^3/d

Peaking Factor=2.5

Air Supplied=0.35 m^3/min//m of length *(0.2-0.5; Metcalf and Eddy)*

Grit Collected =0.1 m^3/1000m^3

Number of Tank=2

Detention Time=5 min *(2-5 min; source: epa.gov)*

Output Parameters:

Peak Flow Rate=1900*2.5=4750 m^3/d

Flow in Each Tank=4750/2=2375 m^3/d *(considering 2 Tanks)*

Volume of Each Tank =2375*5/1440=8.24 m3

Depth=8.24/ (1+1.5+6)=0.97 m

Width=0. 97*1.5=1.45 m

Length =0.97*6=5.82 m

Tank Dimension= 0.97m x 1.45m x 5.82m

3.3.1.4 Equalization, Coagulation and Flocculation Tank Design

The Tanks were designed following the method of Mountain Empire Community College website (*https://water.mecc.edu/).*

Input Parameters

Design Flow =79.2 m^3/Hr

Number of Unit=2

Hydraulic Retention Time (Equalization Tank) =10 Hrs *(8-12 hour)*

Hydraulic Retention Time (Coagulation Tank)= 10 mins (1-10 mins)

Hydraulic Retention Time (Flocculation Tank)= 0.5 Hr (0.5-1hr)

Output Parameters:

Capacity of Equalization Tank =79.2*10=792 m3

Dimension:(approximate)

Length =14 m, Width=12 m, Height=5 m

Capacity of Flash Mixer (Coagulation Tank)=0.166666667*79.2=13.2 m^3

Dimension: (approximate)

Length=3 m, Width=2.5 m, Height=2 m

Capacity of Flocculation Tank =0.5*79.2=39.6 m^3

Dimension: (approximate)

Clear Length=8.5 m, Width=6 m. Depth=0.8 m

3.3.1.5 Primary Clarifier Design

Primary Clarifier was designed according to '*Fundamentals of Wastewater Treatment and Engineering*' authored by Rumana Riffat (ex. 7.4).

Input Parameters:

Tank type: Circular

Number of circular clarifiers used n=2

Average flow rate Q (avg)=1900 m^3/d

Flow in each clarifier Q=950 m^3/d

Surface overflow rate v_o=20 m^3/m^2-d=20/24 m^3/m^2-hr

=0.833333333 m^3/m^2-hr (range 0.1-1 m^3/m^2-hr)

Output Parameters:

Surface area of each clarifier A_s=Q/ v_o =1900/20=47.5 m^2

Diameter D (Upper Round) = $(4^* A_s/ \pi)^{1/2}$ =8 m

Surface area of each clarifier A_s (Design)=π/4*D2 = 50.27 m^2

3.3.1.6 Aeration Tank Design

Aeration Tank was designed according to '*Activated Sludge Calculations Spreadsheet: Aeration Tank Calculations*' by Harlan H. Bengtson.

Input Parameters:

Design ww Flow Rate, Q =1900 m3/d= 0.5 Mgd

Prim. Effl. TSS, X_o =157.5 mg/L

Waste/recycle activated sludge SS conc., Xw = 8,333 mg/L

Prim. Effl. BOD, S_o =120 mg/L

Aeration tank MLSS, X =1280 mg/L

Secondary Effl. TSS, X_e =71 mg/L

% volatile MLSS, %Vol =75%

Aeration Tank Sizing based on Volumetric Loading:

Design Volumetric Loading= 9

Aeration Tank Volume, V= 1000*8.34*WW Flow Rate* BODin / Vol. Loading

= 55600 ft^3 or 1574.4 m^3

Aeration Tank Sizing based on Hydraulic Retention Time:

Aeration tank HRT = 21 hr

Aeration tank vol. V_{MG} = WWFlowRateIn*21/24= 0.438 MG

Aeration tank volume, V = =.438*1000000/7.48= 58,489 ft^3 or 1656.2 m^3

Check on other design parameters:

Vol. Loading, VL =((8.34*BODIn*WWFlowRateIn)/40943)*1000

=8.6 lb BOD/day/1000 ft3

Aeration Tank F:M,

=8.34*WWFlowRateIn*BODIn / (8.34*PerCentVolatile*AerTankMLSS*.306)

= 0.143 lb BOD/day/lb MLVSS

Aeration Tank Sizing based on F:M Ratio:

Design Aer. tank F:M= 0.137(lb BOD/day/lb MLVSS)

Aeration tank vol. VMG =

=(BODIn*WWFlowRateIn)/(PerCentVolatile*AerTankMLSS*.137)

=0.456 MG

Aeration tank volume, V = .456*1000000/7.48 =60,990 ft3

= 60990/35.315=1,727 m3

Check on other design parameters:

Vol. Loading, VL

=((8.34*BODIn*WWFlowRateIn)/42693)*1000= 8.2 (lb BOD/day/1000 ft3)

= 8.2 lbBod/day/1000ft^3

Aeration tank HRT = 24*.319/WWFlowRateIn= 21.90 hr

Therefore, maximum volume of Aeration tank was 1727.03 m^3, which was designed based on F:M ratio.

3.3.1.7 Secondary Clarifier Design

Secondary Clarifier was designed according to '*Fundamentals of Wastewater Treatment and Engineering*' authored by Rumana Riffat (ex. 10.1).

Input Parameters:

Surface Overflow Rate=0.5 $m^3/m^2/hr$ (range: 0.1-0.5)

Weir Overflow Rate =2.5 $m^3/m/hr$ (range: 1-5)

Sludge Loading Rate=2 $Kg/m^2/hr$ (range: 2-3)

Hydraulic Retention Time=3 hr   (range: 2-3)

ETP Design Flow= 1583m3/d= 79.2 m^3/Hr

Part added from RAS Flow=14.5 m^3/Hr

MLSS=1.28 Kg/m3

Output Parameters:

Total ETP Flow=79.2+14.5=93.7 m^3/Hr

Peaking Factor=2

Total Design Flow=93.7*2=187.4 m^3/Hr

No. of Clarifier=2

Flow in Each Clarifier=93.7 m^3/Hr

Tank Volume=93.7*3=281.1 m^3

Total Tank Volume=281.1*2= 562.2 m^3

Weir Length=93.7/2.5=37.5 m

Surface Area (Based on SOR)=93.7/0.5=187.4 m^2

Surface Area (Based on SLR)=93.7*1.28/2=59.96 m^2

Diameter=√187.38*4/π=15.5 m

CHAPTER IV

RESULTS AND DISCUSSION

In this section, all the relevant findings for different coagulant dosages and design of treatment units have been discussed. COD, DO, TSS, TDS, pH, color and turbidity tests were conducted for both combinations of coagulants (for Poly-Aluminum Chloride and Cationic Polymer, and also for *Moringa oleifera* powder). Furthermore, the calculated values for different units of ETP have been analyzed and compared with the existing design. Finally, the treatment unit(s) which need to be improved have been demonstrated.

4.1 Results for Coagulants & Flocculants

4.1.1 Poly-Aluminum Chloride and Cationic Polymer

Various dosages of PAC & Polymer which were applied in the experiment are shown in Table 4.1.

Table 4.1 Dosage of PAC and Polymer

Sample	Volume of Solution (mL)	PAC Added (mg)	PAC (%)	Polymer Added (mg)	Polymer (%)
Raw WW	200	-	-	-	-
1		2	1	1.6	0.8
2		3	2	3.2	1.6
3		6	3	4.8	2.4
4		8	4	6.4	3.2
5		10	5	8	4

Here, 200 ml solution was made with respective amount of PAC and Polymer to form the desired solution. Applying these dosages, the obtained values are shown in Table 4.2.

Table 4.2 Results After Application of PAC & Polymer

Sample	**COD (mg/L)**	**TDS (mg/L)**	**TSS (mg/L)**	**pH**	**Turbidity (NTU)**	**Color (TCU)**	**DO (mg/L)**
Raw WW	129	777	11	6.92	5.76	179	0.69
1	84	798	10	6.98	3.66	165	0.89
2	84	822	11	6.94	3.49	172	0.38
3	90	843	8	6.94	3.35	154	0.73
4	-	875	8	6.88	3.31	139	1.3
5	109	901	11	6.81	3.55	174	0.27

The COD decreased in sample 1 and 2, Color and turbidity decreased up to sample 4. The lowest value for COD, Color and Turbidity was 84 mg/L, 139 TCU, 3.31 NTU respectively. However, the rest of the parameters such as TDS, TSS, pH, Turbidity, color did not have significant changes.

4.1.2 *Moringa oleifera* Powder

Various dosages for *Moringa oleifera* seed powder which were applied in the experiment is shown in Table 4.3.

Table 4.3 Dosage of Moringa oleifera Seed Powder

Sample	**Volume of WW mL**	***Moringa oleifera* added (mg)**	***Moringa oleifera* (mg/L)**
Raw WW		-	-
1		4	20
2		10	50

3	200	20	100
4		28	140
5		36	180
6		46	230

Here 200 ml water was taken and *Moringa oleifera* was added in their respective amounts. The changes in various parameters after applying the coagulant is demonstrated in Table 4.4.

Table 4.4 Results After Application of Moringa oleifera Seed Powder

Sample	**COD (mg/L)**	**TDS (mg/L)**	**TSS (mg/L)**	**pH**	**Turbidity (NTU)**	**Color (TCU)**	**DO (mg/L)**
Raw WW	376	549	78	7.69	114	852	1.59
1	-	568	77	8.08	92.8	666	2.70
2	328	566	88	8.03	97.2	680	1.06
3	-	563	80	7.93	93.50	788	1.23
4	384	566	83	7.94	93.80	856	1.84
5	376	567	80	8.01	94.10	840	2.48
6	-	575	83	8.03	94.70	822	3.06

Here the COD decreased in sample 2, Color and turbidity decreased in sample 1. The lowest value for COD, Color and Turbidity was 328 mg/L, 666 TCU, 92.8 NTU respectively. However, the rest of the parameters such as TDS, TSS, pH, Turbidity, color did not have significant changes.

4.1.3 Removal Rate and Optimum Values

Significant changes were found in COD, Color and Turbidity for both group of Coagulants, as demonstrated in the following graphs.

4.1.3.1 PAC and Polymer

The color removal rate for PAC & Polymer is shown in Figure 4.1

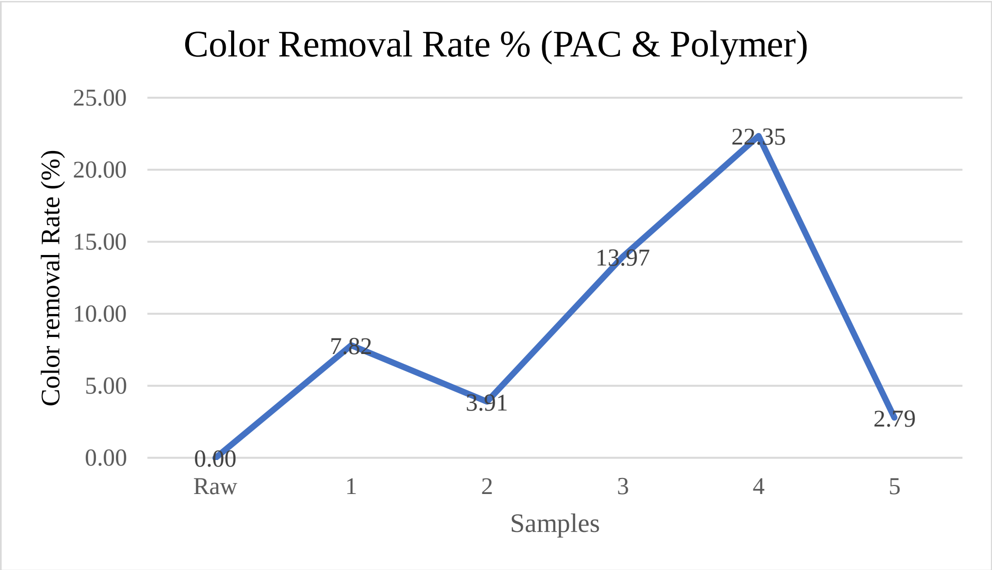

Figure 4.1 Color Removal Rate % (PAC & Polymer)

The highest removal percentage of color removal was obtained in 4th sample. The rate of removal was 22.35% and the dosage was 4% PAC and 3.2%.

The turbidity removal rate for PAC & Polymer is shown in Figure 4.2.

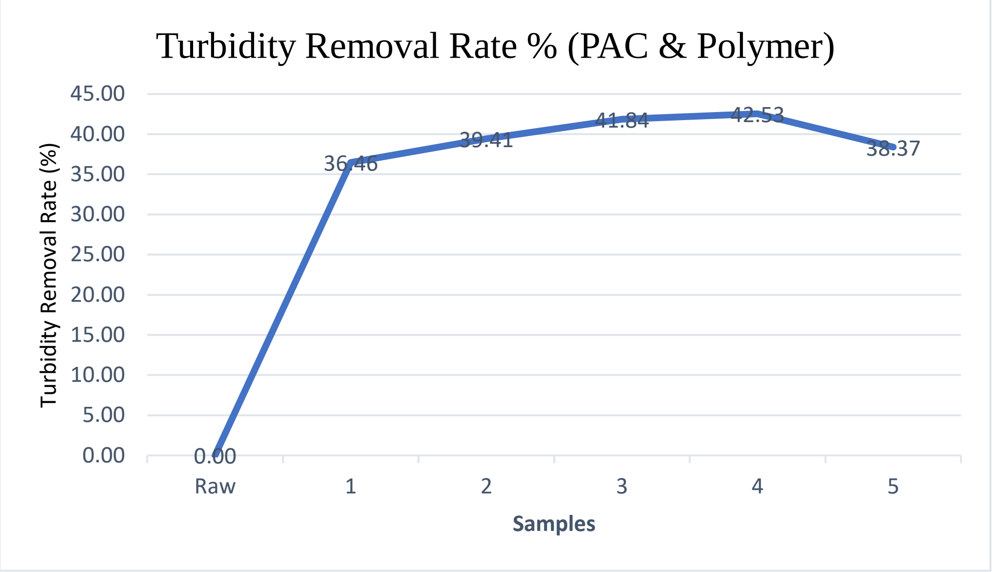

Figure 4.2 Turbidity Removal Rate % (PAC & Polymer)

The highest removal percentage of turbidity removal was obtained in 4th sample. The rate of removal was 42.53% and the dosage was 4% PAC and 3.2%.

The COD removal rate for PAC & Polymer is shown in Figure 4.3.

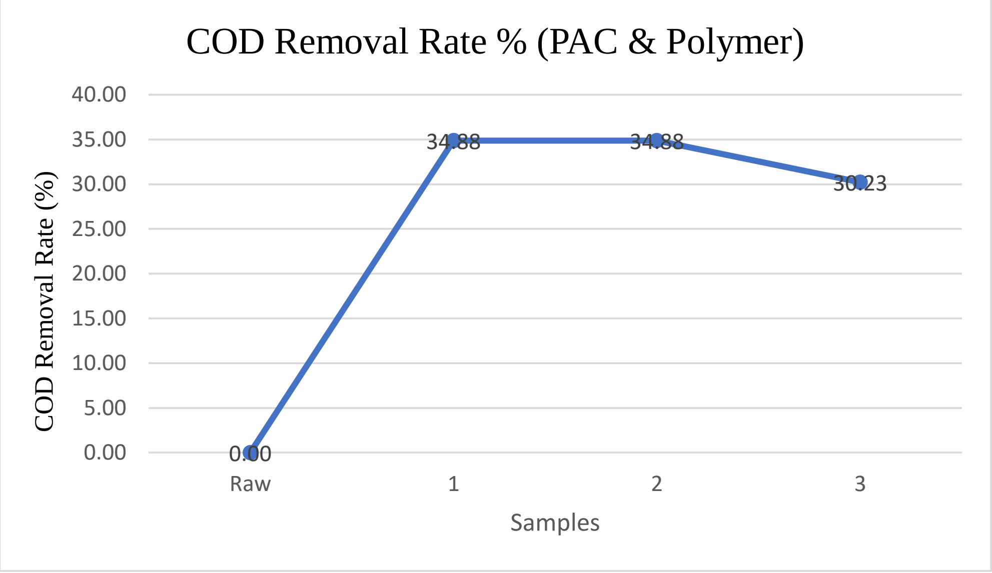

Figure 4.3 COD Removal Rate %, (PAC & Polymer)

The highest removal percentage of turbidity removal was obtained in 1st sample. The rate of removal was 34.88% and the dosage was 1% PAC and 0.8%.

4.1.3.2 Moringa oleifera

The color removal rate for *Moringa oleifera* is shown in Figure 4.4.

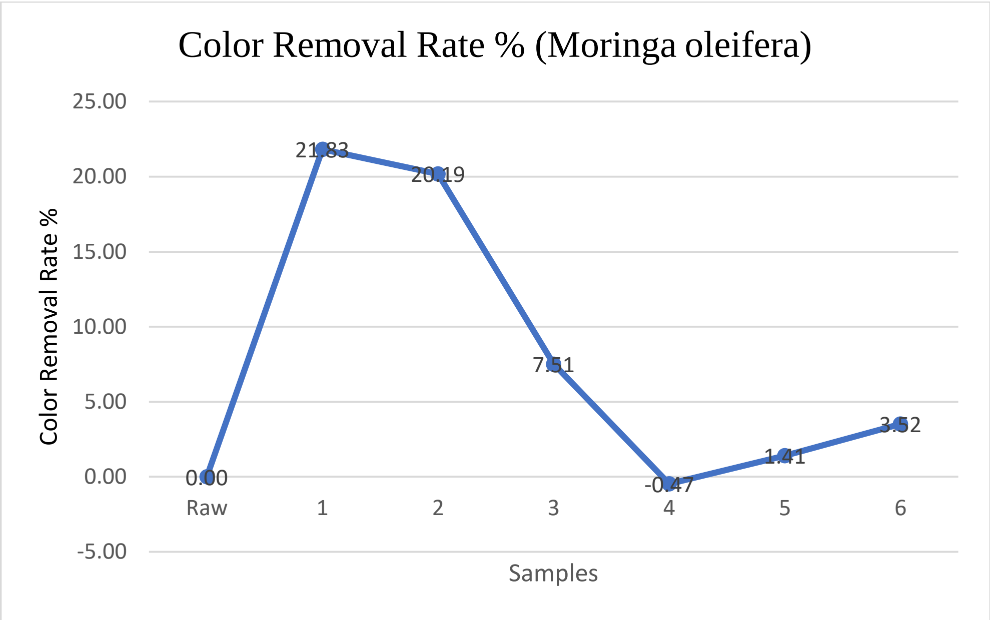

Figure 4.4 COD Removal Rate %, (Moringa oleifera)

The highest removal rate of color was obtained in 1st sample. The rate of removal was 23.83% and the dosage was 20 mg/L.

The turbidity removal rate for *Moringa oleifera* is shown in Figure 4.5.

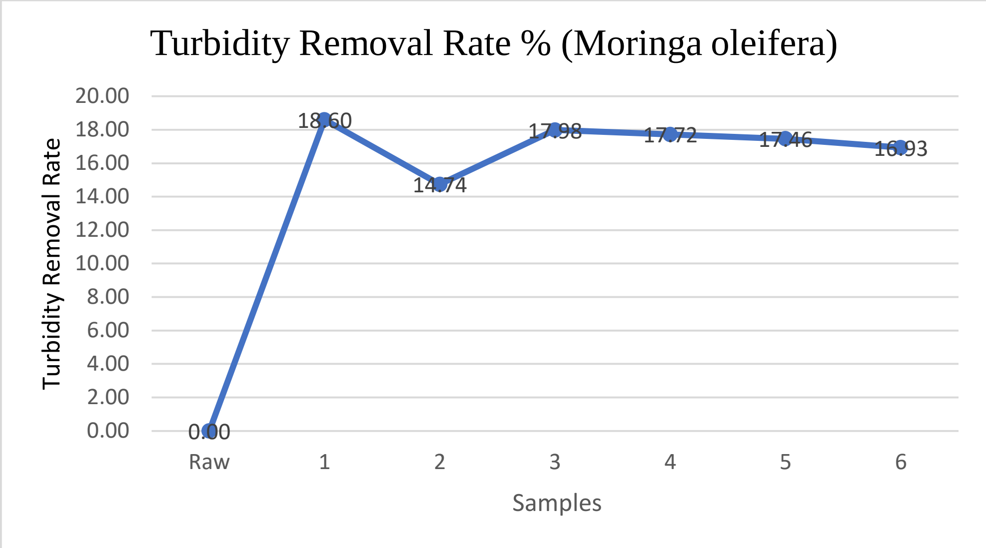

Figure 4.5 Turbidity Removal rate %, (Moringa oleifera)

The highest removal rate of turbidity removal was obtained in 1st sample. The rate of removal was 18.6% and the dosage was 20mglL.

The color removal rate for *Moringa oleifera* is shown in Figure 4.6.

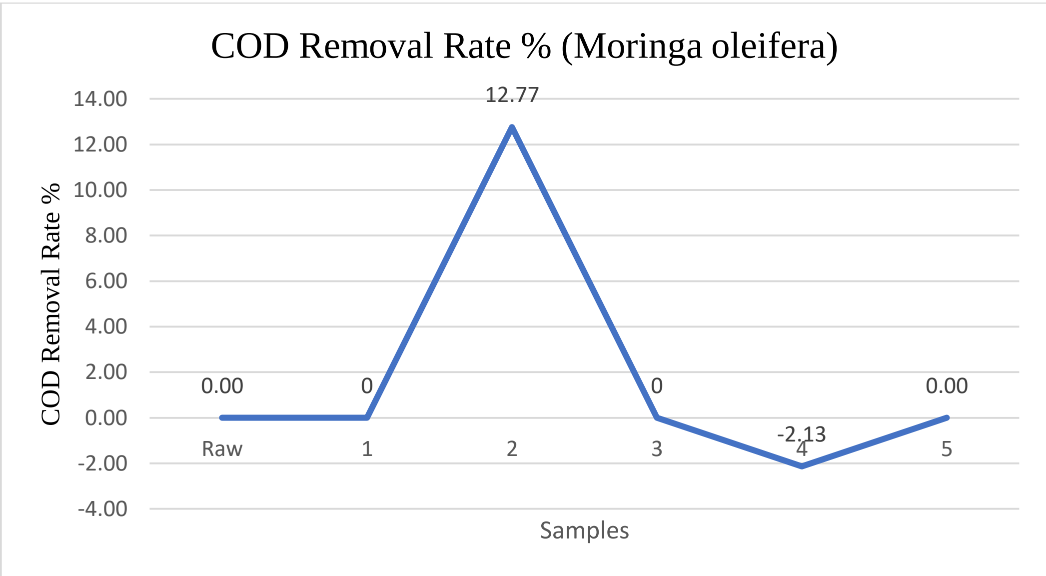

Figure 4.6 COD Removal Rate (Moringa oleifera)

The highest removal rate of color removal was obtained in 2nd sample. The rate of removal was 12.77% and the dosage was 50 mg/L.

Thus, the optimum dosages for these parameters for each Coagulant group is shown in the Table 4.5.

Table 4.5 Optimal Dosages of COD. Color and Turbidity Removals

Parameter	**PAC %**	**Polymer %**	***Moringa oleifera* (mg/L)**
COD	2	1.6	50
Color	4	3.2	20
Turbidity	4	3.2	20

The optimal dosages of color and turbidity removal were same for both coagulants (PAC & Polymer and *Moringa oleifera*). For COD removal, the optimal dosage was 2% & 1.6% for PAC and Polymer, while it was 50 mg/L for *Moringa oleifera*.

4.1.4 Efficiency Comparison

Here is a comparison of removal efficiency between two coagulant groups for COD, Color and Turbidity is shown in Table 4.6.

Table 4.6 Comparison of Removal Efficiency

Parameter	**PAC & Polymer**	***Moringa oleifera***
COD	34.89%	12.77%
Color	22.35%	21.83%
Turbidity	42.53%	18.60%

As per the removal efficiency for COD, Color and Turbidity of these coagulant groups, we found the Poly-Aluminum Chloride and Cationic Polymer is showing better result.

4.2 Design Comparison

A comparison between the existing design and our calculated design is shown in Table 4.7.

Table 4.6 Comparison Between Existing Design and Calculated Design

Units of ETP	Existing Design (m^3)	Calculated Design (m^3)	Remarks
Primary Clarifier	289.31	301.6	**Extension Required**
Secondary Clarifier	300.5	562.2	**Extension Required**
Aeration Tank	1336.2	1727.03	**Extension Required**
Equalization Tank	847.8	792	Extension Not Required
Coagulation Tank	11.07	13.2	**Extension Required**
Flocculation Tank	38.0	39.6	**Extension Required**

Here the comparison between the original design and calculated design (after enhancing the capacity) is shown. To accommodate 20% higher wastewater flow than existing design, the required volume of the primary clarifier is 301.6 $m^{3.}$ which needs extension of 12.29 m^3. In the case of the secondary clarifier the required volume is 562.2 m^3 and for aeration tank the calculated value is 1727.03 m^3. For equalization tank the calculated volume is 792 m^3 which does not need extension. As for coagulation tank and flocculation tank the calculated volume was 13.2 m^3 and 40.8 m^3, which require extension.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study shows that the combination of PAC & Polymer had a better removal efficiency of Color, Turbidity and COD, as compared to the performance of *Moringa oleifera*. The removal rate of PAC and Polymer combination was 34.89%, 22.35% and 42.53% for COD, Color and Turbidity respectively. On the other hand, Moringa oleifera had a removal rate of 12.77%, 21.83% and 18.6% for COD, Color and Turbidity respectively. Optimum dosages of PAC and Polymer for COD removal was 2% and 1.6%, and the optimal dosage of Moringa oleifera was 50mg/L. On the other hand, for color and turbidity removal, the optimum dosages of PAC and Polymer was 4% and 3.2%, while for Moringa oleifera it was 20 mg/L.

This study also shows the extension required in various units of ETP except equalization tank in order to enhance the treatment capacity by 20%.

5.2 Recommendations

The recommendations for future study on topics related to this-

- Dosages varied from a closer range should be observed for more accurate output of the optimal dosages.
- *Okra mucilage*, *P. ovata* and *Strychnos potatorum* can be used as natural coagulants for further research.
- Other effluent quality parameters should also be measured to analyze the effect of that coagulant on those parameters.
- Machine learning and control strategies can be utilized to improve efficiency of treatment plant.

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APPENDIX

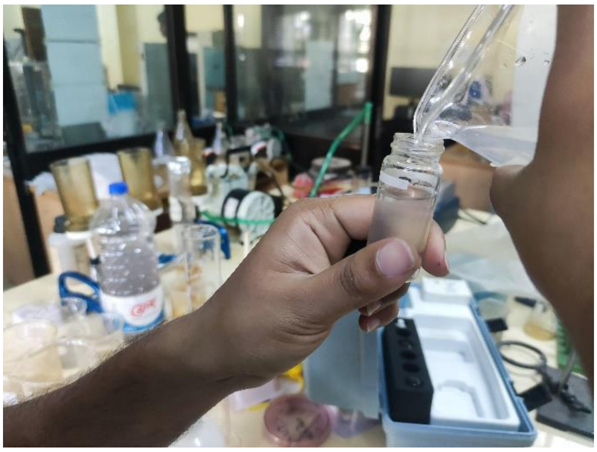

Fig. A1 Preparation of Solution

Fig. A2 Turbidity Test

Fig. A3 COD Test Result