Performance of Conventional Wastewater Treatment systems in the Treatment of Textile Effluent at Hawassa Industrial Park

Gadisa Oljira Duressa

A thesis submitted to the Department of Applied Chemistry

School of Applied Natural Science

In partial fulfillment of the requirement for the degree of masters of Science in Applied Chemistry (Industrial Chemistry stream)

Office of Graduate Studies

Adama Science and Technology University

September, 2023

Adama, Ethiopia

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Declaration

I hereby declare that this Master's Thesis, entitled "**Performance of conventional wastewater treatment systems in the Treatment of Textile Effluent at Hawassa Industrial Park,**" is my original work. That is, it has not been submitted for the ward of any academic degree, diploma, or certificate at any other university. All sources of materials that were used for this thesis have been duly acknowledged through citation.

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Recommendation

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Performance of conventional wastewater treatment systems in the Treatment of Textile Effluent at Hawassa Industrial Park**" Prepared under my guidance by Gadisa Oljira and submitted in partial fulfillment of the requirements for the degree of Masters of Science in Industrial Chemistry.

Therefore, I recommend the submission of a revised version of the thesis to the department, following the applicable procedures.

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I, the advisor of the thesis entitled "**Performance of conventional wastewater Treatment systems in the Treatment of Textile Effluent at Hawassa Industrial Park''** and developed by Gadisa Oljira, hereby certify that the recommendation and suggestion made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, Members of the Board of Examiners of the thesis by Gadisa Oljira, have read and evaluated the thesis entitled "**Performance of conventional wastewater Treatment systems in the Treatment of Textile Effluent at Hawassa Industrial Park''** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Masters of Science in Industrial Chemistry.

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List of Abbreviations and Acronyms

APHA	American Public Health Association
BOD	Biological Oxygen Demand
CMC	Carboxyl Methyl Cellulose
COD	Chemical Oxygen Demand
COMESA	Common Market of Eastern and Southern Africa
CRGE	Climate Resilient Green Economy
CWST	Clear Water Storage Tank
DO	Dissolved Oxygen
EC	Electrical Conductivity
ETP	Effluent Treatment Plant
EPA	Environmental Protection Agency
FDRE	Federal Democratic Republic of Ethiopia
GHG	Green House Gas
HIP	Hawassa Industrial Park
HPLC	High Purity Laboratory Chemical
MLSS	Mixed Liquid suspended Solid
MLVSS	Mixed Liquid Volatile Suspended Solid
NTU	Nephelometric Turbidity Unit
NOM	Non-Organic Matter
PAC	Poly Aluminium Chloride
Pt-co	Platinum Cobalt unit

PVA	Poly Vinyl Alcohol
SVI	Sludge Volume Index
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
WAS	Waste Activated Sludge
ZLD	Zero Liquid Discharge

Abstract

The textile industry is one of the oldest industries in the world and is a high-income-generating industry for developing countries. There is a significant link between the environment and the textile industry. A great deal of damage can occur to the environment from the textile industry, and a major threat to the environment is the discharge of untreated toxic wastewater into the water bodies, which can cause several damages to aquatic ecosystems. Similar problem has been observed at HIP wastewater treatment plant, which high concentrations of toxic substances being discharged to Lake Hawassa after passing through treatment processes and affecting aquatic life .The main objectives of this research were to evaluate the performance of the textile wastewater treatment plant of Hawassa Industrial Park based on select physico-chemical parameters. The wastewater samples were collected from six units of the treatment process (receiving chamber, equalization tank, primary clarifier, aeration tank, secondary clarifier, and clear water storage tank) by grab sampling methods. Physico-chemical main parameters (pH, TSS, TDS, color, EC, turbidity, COD, BOD_5, total hardness, total alkalinity, heavy metals, oil and grease laboratory analysis were conducted for two months from February 25, 2023 to April 25, 2023 at the Hawassa Industrial Park wastewater treatment plant. Sample analysis methods employed were volumetric analysis and microanalysis according to the procedures of standard water and wastewater analysis. The overall performance of the treatment plant with respect to pH, EC, color, and TDS were found to be 16%, 20%, 69%, and 19.77%, respectively, and turbidity, TSS, COD, BOD, total alkalinity, total hardness, and oil and grease were found to be 94%, 84%, 81.8%, 83.9%, 75.56%, 34.79%, and 91.4%, respectively. The removal efficiency of the thirteen heavy metals examined is 10% (B), 52.85% (Zn), 34.21% (Cd), 13.74% (Hg), 90.38% (Fe), 95.84% (Mn), 7.62% (Se), 12.26% (Pb), and 0% (Cu, Co, Ni, Cr, and As). The results revealed that the wastewater treatment plant has good performance to reduce turbidity (94%), O&G (91.4%), TSS (84%), BOD (83.9%), COD (81.8%), and total alkalinity (75.56%), whereas poor removal performance observed in pH (16%), EC (20%), TDS (19.77%), total hardness (34.79%), and color (69%). Confirmed the need of improvement in the current performance of the treatment plant.

Keywords: - effluent, treatment, wastewater, performance, evaluation

CHAPTER ONE

1. INTRODUCTION

1.1. Back ground

The textile industry is one of the oldest industries in the world and is a high-income-generating industry for developing countries (A. Ahmed et al. 2019). Furthermore, the textile industry has the capability of strengthening local and international linkages, which in turn can upgrade the industrial and economic performance of the country (Wagaye et al. 2018). Ethiopia has prioritized the textile sector as a key area for boosting the industrialization process due to the comparative advantages that sector has, like job opportunities, local availability of raw materials, and different market opportunities like COMESA (the Common Market of Eastern and Southern Africa) (Lebenie et al., 2015). Since there is a significant link between the environment and the textile industry. Textile industries are the major source of pollutants because, they generate highly polluted organic and inorganic chemicals.

The main source of pollutants in textile manufacturing wet processing activities depends on variety of chemicals. Environmental pollution from the textile manufacturing is a big concern in Ethiopian, especially textile wastewater discharge before properly treated into water bodies affect aquatic life and human health (Terefe Gemeda et al., 2020). To regard this issue recent years have seen significant research on methods for treating wastewater and recovering resources from it.

The concept of zero-liquid discharge has altered the way waste water is treated in many different countries (Sankar & Rajesh, 2017). The ability of ZLD technology to enhance water recycling while concurrently reducing waste water volumes has stoked interest in the potential for resource recovery and reuse (Yaqub & Lee, 2019). The 3R approach integrates aspects of reduce, reuse, and recycle in various manufacturing phases through process optimization and modification and the adoption of more eco-friendly and environmentally friendly technology (Tong & Elimelech, 2016). To achieve the ZLD goal in the textile industry, a comprehensive and in-depth understanding of the overall textile wet process is necessary.

Currently textile factory in Ethiopia have installed zero liquid discharge treatment technology , nevertheless due to deficient availability of chemical and operational problems the treated water quality does not fulfill the required standard discharge (Terefe Gemeda et al., 2020). The Hawassa Textile Factor was established in 2016 by Ethiopian government and has its own wastewater treatment plant zero-liquid discharge. The capacity this plant treats per day 11million liter per day (11MLD). 8 MLD effluent treatment plant and 3MLD sewage treatment plant. The wastewater generated from each wetting process collected by a common wastewater pipe line towards the common effluent treatment plant. This plant was use physical, chemical and biological methods of treatment to reduce organic and inorganic pollutants and to acceptable level of discharge. However, there are still reports of high concentration of toxic substance discharged to lake Hawassa after passing through treatment processes (Bashaye, 2015). Difficult to maintain a water balance between the flow of raw incoming water and the volume treated water due to frequently clogged membrane hole of filtration system. This poses a question on the efficiency of the existing treatment system and evaluating the performance of this treatment plant has been needed. The main objective of this study was evaluating the performance of conventional wastewater treatment plant of Hawassa Industrial Park.

Performance evaluation of existing treatment plant is required for the following two reasons:

- To assess the existing effluent quality and check meet or not standard discharge.
- To know about the treatment plant where it is possible to handle higher hydraulic and organic load (Ramadan et al., 2017).

Generally, the environment and ecology will be significantly protected by identifying potential water quality issues, such as high oxygen-consuming pollutants, alkalinity, excess sediments, and undesirable compounds that can damage the receiving water bodies.

Knowing how well the entire system is performing in terms of effluent quality is crucial for optimizing a specific wastewater treatment plant system. To do thus, historical data from the plant and measured data from laboratory investigations on quality parameters can be utilized (Derseh, 2022).

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1.2. Statement of Problem

The Ethiopian government established the FDRE Ministry of Industry in 2013 EC with the aim of achieving lower middle-income status by 2025 EC through green technologies (an overview of industrialization from the Climate Resilient Green Economy (CRGE) agenda. Manufacturing industries thus occasionally expand in size. Since this industrial explosion, there has apparently been an increase in major contamination of surface and ground water sources, which has a negative effect on people's health and the environment.

Ethiopia's past wastewater treatment plant performance indicates that most of its textile sector fails to comply with national regulations for wastewater treatment parameters and that management or environmental compliance skills are lacking (Woldeyohannes et al., 2020). Similar problems have been observed at the textile wastewater treatment plant facility at Hawassa Industrial Park. The wastewater treatment plant facility for the Hawassa Industrial Park is located near Hawassa Town and connects Lake Hawassa to the main drainage system by the river TikurWuha. The plant uses physical, chemical, and biological treatment methods to reduce organic and inorganic pollutants in the effluent to an acceptable level before discharge, but there are still reports of high concentrations of toxic substances being discharged to Lake Hawassa after passing through treatment processes and affecting aquatic life (Toxicol et al., 2015). The second problem is that the RO plant of the Hawassa Industrial Park wastewater treatment plant frequently becomes clogged by scaling that forms on the membrane hole,and it is difficult to maintain a water balance between the flow of raw incoming water and the volume of treated water. Concerning those problems, this study was conducted to assess the performance of conventional effluent treatment plants' existing in HIP based on select physico-chemical and biological parameters and evaluate the operational process removal efficiency of each individual unit.

1.3. Objectives of the study

1.3.1. General Objective

The main objective of this research was to assess the performance of effluent treatment plant of Hawassa Industrial Park in terms of physico-chemical and biological parameters.

1.3.2. Specific Objectives

The specific objectives of this research were:

- To characterize the raw wastewater and treated effluents from each treatment units.
- To determine the removal efficiency in each treatment units and the combined system.
- To determine the heavy metal removal efficiency of raw wastewater and treated water.

1.4. Research Questions

- What are the physico-chemical characteristics of effluents in textile industry wastewater?
- How to evaluate the textile industry's wastewater treatment plant status performance?
- How significantly is the wastewater treatment plant's performance compatible with the discharge limit by EPA

1.5. Significance of the Study

This research will have paramount importance for Hawassa Industrial Park zero-liquid discharge wastewater treatment in assigning, identifying, and rectifying operational unit processes. Inputs to improve the wastewater treatment plant's efficiency are going to be drawn from the outcomes of this study.

1.6. Scope of the study

This research was carried out to assess the status of the performance efficiency of the effluent treatment plant at Hawassa Industrial Park based on data collected from each unit process. The parameters identified for the study were COD, BOD, TSS, TDS, EC, color, turbidity, oil and grease, hardness, alkalinity, heavy metals. The removal efficiency of the overall ETP in terms of inlet before treatment and outlet after treatment was determined. This study did not include the sludge and sewage treatment processes.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Over view of the Textile Industry in Ethiopia

The first textile industry was founded in 1939 in Dire Dawa. Ethiopia's government has placed a strong emphasis on the possibility of constructing a textile industry with government assistance, providing low-cost production and raw materials, and creating job opportunities for the young population (Woldeyohannes et al., 2020).

At the moment, Ethiopia is creating a number of industrial zones, some of which are designated for the manufacturing of textiles and apparel. As these zones were expanded, the employment contribution of the textile and apparel industries increased significantly (Amare, 2019). Since 2010, Ethiopia's government has worked to develop, support, and expand the textile industry so that it can serve the domestic market and compete internationally (Balchin et al., 2019). One of the largest textile industries in Ethiopia is Hawassa Industrial Park. Which is primarily intended for the textile and apparel industries, was officially opened in July 2016. The cost of building the Hawassa industrial park was the largest in Africa at 250 million USD. The government of Ethiopia has been earning an annual 1 billion USD from exports only from Hawassa Industrial Park.

2.2. Major Categories of Textile Production Processes

The overall processes of the textile industry can be categorized into two major classes, namely the dry and wet processes. Dry processes include spinning, knitting, and weaving. Spinning is the process that changes raw fiber into yarm or thread (Wagaye et al., 2018). The process is entirely dry, although some yarms may be dyed and finished. Knitting is the most common method of interfacing and manufacturing textile products. It requires a relatively fine, smooth, and strong yarm with good elastic recovery properties. The wet processes are sizing, scoring, bleaching, mercerizing, dying, printing, and finishing (Wang et al., 2022).

Sizing: In order to provide the warp thread, or yarm, with the tensile strength and smoothness required for weaving, the warp is sized by adding starch to it. Scaling is a process that gives cotton and some man-made yarms the requisite stiffness, strength, and fiber-breaking prevention properties before weaving. In 75% of the activities for size, starch or starch derivatives Polyacrylates, carboxymethylcellulose, and polyvinyl alcohol (PVA) are used.

Sizing liquid waste often occurs in tiny volumes but has significant COD,BOD, and suspended solids contents (T. Ahmed et al., 2021).

Desizing: Desizing is a method for removing the sizing components found in the gray cloth with the help of 0.5% H_2SO_4 or enzymes. After weaving, the waste materials must be eliminated before the cloth is subjected to further processing. By forming a layer inside the yarn, it prevents dyes and other chemicals from penetrating the fabric. Depending on the size, alkalis, acids, enzymes, or surfactants are used (Assefa et al., 2016). After desizing, the fabric is rinsed before being cleaned. Wastewater contains total solids, or BOD, and the load from textile wastewater can be substantial.

When starch is employed as a size in the woven fabric process, up to 50 -55% of the total BOD may be created during the de-sizing step.

Scouring: Natural or organic impurities like grease, waxes, oils, fats, pollutants, dust clouds, etc. can be removed by boiling with NaOH, sodium silicate, Na_2O_2, and a tiny amount of detergent. The ecology of aquatic species is harmed by higher pH, BOD, and COD levels in the waste water produced by the scouring processes (Tadesse et al., 2018).

Bleaching: By bleaching the fabric, the natural color has been eliminated. These include H_2O_2, Na_2O_2, and alkaline hypochlorite. To remove any traces of alkali or Cl_2 residues before bleaching, it is common practice to first wash with water and then scrub with sodium bisulfate.

The bleaching effluent contains a variety of substances, including chlorine, hypochlorite, peroxides, alkalis, chromium, phenolics, oils, and waxes (Yaseen et al., 2019).

Mercerizing: Boiling a fabric in a 20% caustic soda solution and washing it in water is mercerization. The requisite characteristics, including strength, shine, absorbency, and color affinity for cotton fibers, are added to the fabric through mercerizing. The fibers expand and transform from an oval shape to one with a circular cross-section when a cold sodium hydroxide solution is applied. Waste water produced by mercerizing typically has low BOD and dissolved solids levels (Bashaye, 2015).

Dyeing: Dyeing is a method used to color various textile fabrics. Various auxiliary materials and dyes or pigments are used to color textiles in this process. It releases most of the wastewater that blocks sunlight from entering the water, inhibiting photosynthesis. Additionally, a number of colors are exceedingly toxic and harmful, as are the byproducts of their decomposition (Yaseen et al. 2019).

Printing: printing is the process of creating attractive designs on textile material by applying print paste to the fabric. In general, dyes and auxiliaries used in printing are quite similar to those used in fabric dyeing, with the exception that the color is only applied to specific sections of the garment (Woldeyohannes et al., 2020).

Finishing: Typically, finishing requirements impart several important characteristics that enhance clothing appearance, boost fabric strength, and also add weight to the fabric. They can alter the stiffness or softness of textiles. Numerous chemicals and auxiliary compounds, such as flame-retardant finishers and dirt-release finishers, are used in the finishing of textiles. Chemicals, some of which are organic molecules like phenol and organic solvents, are frequently used. Sulfate is a chemical that is present in sulfate nitrogen, to put it briefly, and it explains how textiles contribute significantly to the environmental load on the planet. At every stage of the textile production process, environmental consequences can be recognized, including fiber production owing to agricultural and industrial synthesis through a variety of processes such as spinning, weaving, and sewing (Uddin, 2018).

2.2. 1. The source of Wastewater in the textile industry

Water used for cleaning, preparation, dyeing, finishing, and other processes is often the main source of effluent. Depending on the mill, process, and materials produced, the industry has a wide range of waste usage. Every textile process uses a significant amount of water, which ultimately becomes waste water (Ananthashankar et al., 2013). The dyeing and printing procedures used in the textile industry use a lot of water, which results in effluent that is very contaminated after each step. The waste water produced by various textile manufacturing processes typically has a high pH, suspended and dissolved solids, and hazardous and non-biodegradable matter. Generally, the main pollutants in textile effluents can be classified into three main categories: floating matter, suspended matter, and dissolved matter, as shown in Figure 1.

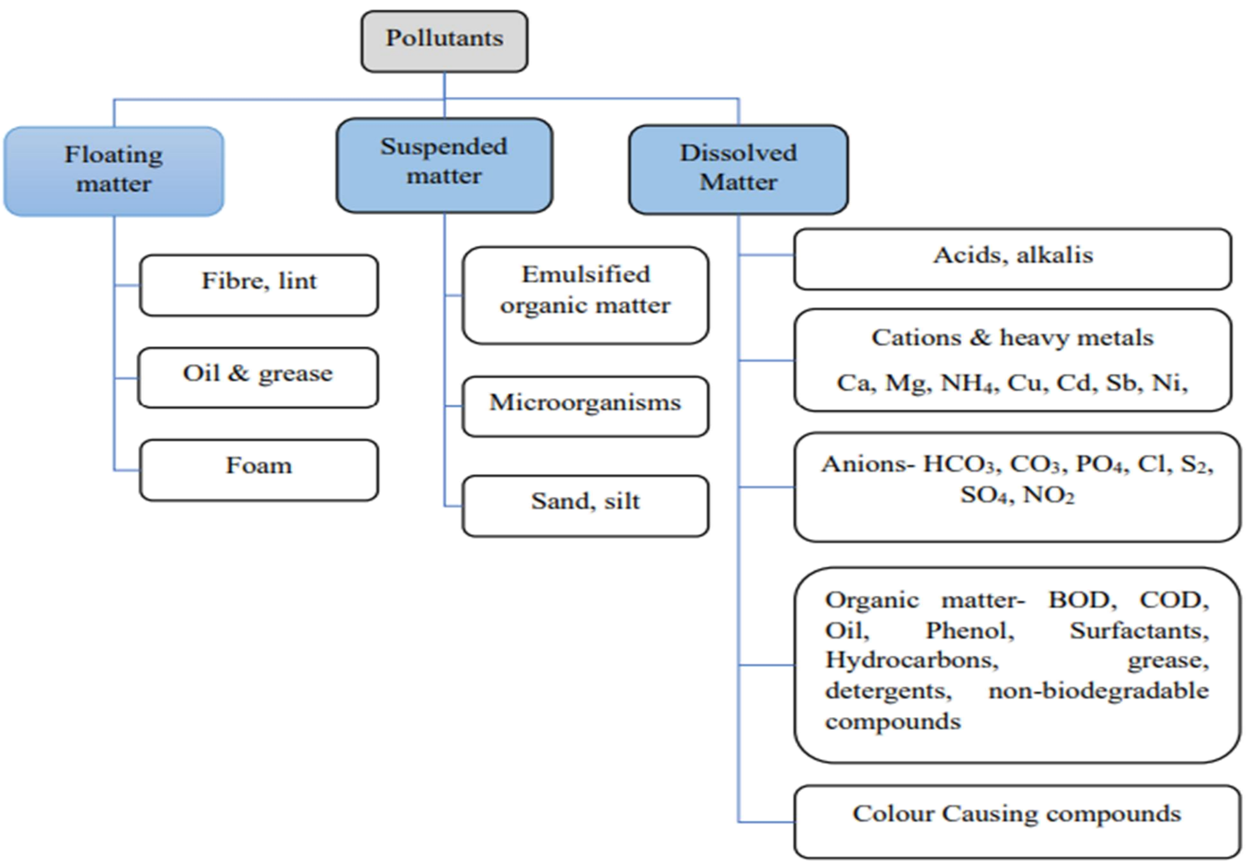

Figure 1 . Sources of waste water in the textile industry at different stages of the manufacturing process(Smarzewska et al., 2021).

2.2.2. Textile Wastewater Characteristics

The production of fibers, manufacturing, distribution, consumer use, and final disposal of the clothing all require significant amounts of natural resources, including water, land, and other resources. As a result, textile industries are major contributors to environmental pollution by discharging significant amounts of waste water (Uddin, 2018). Discharge from these industries is a significant problem that requires attention for the following reasons:

Wastewater from the textile industry is enormous and contains harmful pollutants, and the effluents are highly colored and saline, as well as containing non-biodegradable compounds that have the potential to result in biological and chemical oxygen demand. The production of textiles uses large amounts of water and chemicals, which results in waste water (Alam et al., 2017). The many steps of textile manufacture and processing result in the production of enormous amounts of complex chemical substances by the textile industry as waste materials, including dyes. Approximately 200 liters of water are used to make 1kg of cloth. According to the Yasen report, color, biological oxygen demands (COD), toxic heavy metals like chrome, arsenic, copper, zinc, lead, and mercury, as well as residual chlorine, total dissolved solids (TDS), total suspended solids (TSS), and non-biodegradable organics referred to as refractory materials, are among the pollutants present in a typical textile waste effluent. (Yaseen et al., 2019). The toxins found in wastewater harm both the ecosystem and human health. They interfere with photosynthesis, increase the need for biological oxygen, prevent sunlight from passing through the water, and have an impact on aquatic life (Stone et al., 2019).

The effluents generated by the various phases of textile processing differ from one another in terms of their contents and characteristics. The selection of treatment techniques, the dosage of treatment chemicals, the level of waste pollution, and the quality of the standard limit parameters depend greatly on the characterization of the various phases of the textile process (Wang et al., 2022). Table 1 shows the characteristics of effluent from different textile wet processing stages (S.M. Imtiazuddin et al., 2012).

Table 1. Characteristics of textile industry wastewater from different wet processes (Smarzewska & Morawska, 2021).

Parameter	Sizing	De-sizing	Scouring	Bleaching	Mercerizing	Dyeing	Printing
pH	7-9.5	5.8-8	10-13	6- 11.6	5.5- 14	5-12.5	4-9
COD (mg/L)	_	4600-15000	147-8000	1149-13500	100-2688	1100-4600	785-49170
BOD (mg/L)	600-2500	4400-5060	100-2900	50-1700	20-300	10-1800	400-1800
TDS (mg/L)	_	8700-10200	6323	2400-22000	5000-12000	35000	2000
TSS (mg/L)	_	400-4000	_	288	105	499	125-9500
Chromium (mg/L)	_	_	_	_	_	0.39-1.23	_
Copper (mg/L)	_	_	_	_	_	0.38-0.43	_
H_2S (mg/L)	_	_	_	5.44	1.31	1.62	_

The fabric being processed, the chemicals being used, the technology being employed, and the operational procedures all affect how much and what kind of waste is produced (Yaseen et al. 2019). The composition of textile effluent during manufacturing processes is shown in Table 2.

Table 2. Composition of textile wastewater during, the manufacturing process

Process	wastewater Composition	Nature
Sizing	Starch, waxes, carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA), and wetting agents	High BOD, COD
Desizing	Starch, CMC, PVA, fats, waxes, and pectins	High BOD, COD, and TSS
Bleaching	Sodium hypochlorite, chlorine, NaOH, H_2O_2, acids, $NaSiO_3$, sodium phosphate, and cotton fiber	Highly alkalinity, highly TSS
Mercerizing	Sodium hydroxide, and cotton wax	High pH, low BOD, high TDS
Dyeing	Dyestuffs, urea, reducing agents, oxidizing agents, acetic acids, detergents, and wetting agents.	Strongly colored, highly BOD, TDS, low TSS, and heavy metals.
Printing	Pastes, urea, starches, gums, oils, binders, acids, thickeners, cross-linkers, reducing agents, and alkali.	Highly colored, highly BOD, oily appearance, TSS, and slightly alkaline.
Finishing	Inorganic salts, formaldehyde, resins, waxes, softeners, solvents, PVA, and hydrocarbon.	Low BOD and high pH,

2.3. Environmental and human health impacts of Textile Industry Wastewater

When untreated effluents from various stages of the textile manufacturing process, which are characterized by a high consumption of water and a variety of chemicals like sulfur, COD, BOD, and heavy metals, are released into the water body, they usually cause environmental pollution (Wang et al., 2022). Wastewater from the textile industry is more colored and contains oil, which gives the water an unpleasant look and smell. When this waste is discharged into fresh water, it blocks sunlight from penetrating, which is critical for aquatic plants to perform photosynthesis (Alanezi, 2018). These effluents clog soil pores when they are used to water agricultural fields, which reduces the productivity of the land (Al-Tohamy et al., 2022). According to Islam (2020), the presence of sulfur, nitrates, acetic acid, chromium, copper, arsenic, lead, cadmium, mercury, nickel, cobalt, and other organic and inorganic chemicals in effluents constitutes hazardous toxic waste (Islam, 2020). The negative effects of textile wastewater are described in Table 3.

Table 3. Textile wastewater pollutants and their negative effects (Uddin, 2018)

Pollutants	Symbol	Main negative effects
Chromium	Cr	Its toxic to aquatic life, humans, and crops at high temperatures because it oxidizes to chromium Vi, which is extremely toxic.
Total Dissolved Solids	TDS	Harmful to plants, high salinity causes osmotic pressure, reducing water availability and retarding plant growth.
Oil &Grease	O & G	Forms surface films on water and is deposited, which leads to environmental degradation and interferes with biological processes.
Total suspended Solids	TSS	Can form deposits and create anaerobic conditions that pose danger to aquatic life.

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According to Ethiopia's guidelines for the Ministry of the Environment, factories must treat their waste water before discharging it, keep a check on its quality, and adhere to national discharge quality standards (EPA FDRE, 2003). Even if there are regulations and rules in place, sometimes, due to poor management or a lack of technical knowledge, the characteristics of the effluent exceed the allowable discharge limit, which causes an imbalance in the ecosystem (Terefe Gemeda et al., 2020). Therefore, in order to effectively treat textile waste water before it is discharged into rivers, numerous treatment techniques, including chemical, biological, physical, and hybrid treatment processes, have been devised (Yacout et al. 2016). Therefore, the textile companies must regulate their discharges and have effluent treatment facilities.

2.4. Textile Wastewater Treatment Methods

The methods of treatment of wastewater vary a lot, and it mainly depends on the characteristics of the effluent, the level of effluent, the level of toxicity to be removed, and the type of environment to receive the effluent. Physico-chemical and biological processes are treatment processes that have been adopted for the effluent treatment plant (Brahmbhatt et al., 2015). The physico-chemical process consists of screening, coagulation, flocculation, and sedimentation, and the biological treatment process is responsible for the removal of BOD and COD effluent. The treatment plant involves step-wise treatment systems. The conventional techniques adopted to treat the waste water are physical, chemical, and biological (Assefa et al. 2016). However, individually, these methods are not enough to remove all the pollutants from textile wastewater. In real-world applications, a combination of methods is efficient in treating textile wastewater, and the process of treating wastewater from textiles typically consists of varying stages: preliminary treatment, primary treatment, secondary treatment, and tertiary treatment. Throughout each of these processes of treatment, various impurities are eliminated (Patel et al., 2015). Preliminary, primary, secondary, and tertiary treatments are the steps commonly used for conventional industrial wastewater treatment applications.

Those steps are described in Figure 2.

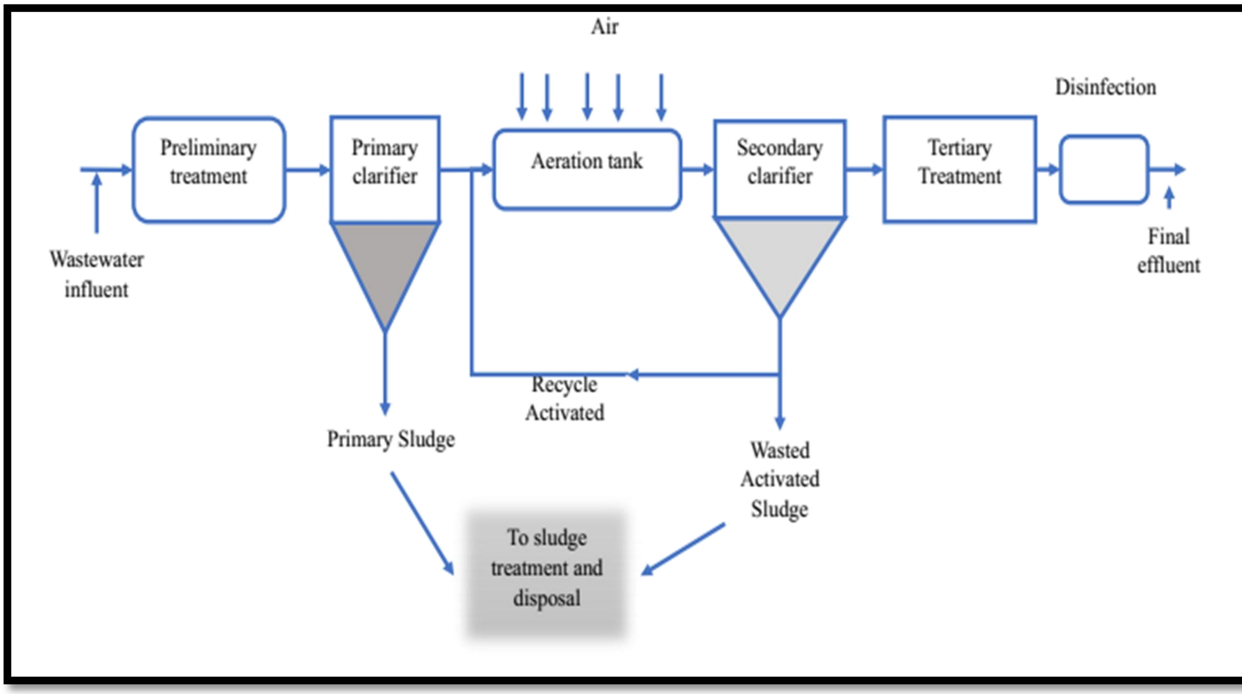

Figure 2. The flow diagram of Conventional treatment unit process

2.5. Preliminary Treatments

The first stages of the treatment process main part of these treatments are screen and grit removal processes.

i, **Screen:** The initial process of waste water treatment facilities is to remove large floating objects such as rags, cans, bottles, wood, and debris to reduce clogging in the subsequent operations. A coarse screen removes floating solids in waste water that have a size between 6 to 20 mm and are cleaned either manually or mechanically, while a fine screen removes small rags, lint, and plastic materials that have a size of 0.5 to 6mm (Smarzewska et al., 2021).

ii**, Grit Removal**

The raw wastewater passes the screening, and next to pretreatment is grit removal. Grit removal systems are commonly found where material that has a greater specific gravity in wastewater settles under the bottom of the grit removal tank and is finally removed from the tank by common pipe grit removal. Grit includes heavy sand, gravel, and other particulate materials that have a specific gravity of 2.65 or higher. Grit removal is a crucial pre-treatment to protect mechanical equipment and pumps from abrasive wear and to avoid pipe blockage due to grit deposition.

Equalization Tank

The goal of the equalization tank is to properly mix and balance wastewater from various textile streams in order to generate homogenized materials that can be handled consistently. By collecting and storing the wastewater, allowing it to mix, and making sure that its composition is less irregular before being pumped to the treatment units at a steady rate. The equalization tank has a design volume of 2500 m^3 and a retention time of 7 hours.

According to the Assefa report (2016), the objective of equalization for industrial treatment plants is

- To a minimize treatment systems' flow disruptions.
- To aid in sufficient pH regulation or to reduce the amount of chemicals needed for neutralization.
- To prevent high concentrations of harmful elements from entering the biological treatment plant, mixing ensures appropriate equalization and inhibits the buildup of settleable solids in the tank. Additionally, mixing and aeration may cause the reduction of hydrogen sulfide or the oxidation of reduced chemicals that are already present in the waste stream (Assefa et al., 2016).

2.5.1. Primary Clarifier (Chemical Treatments)

The second stage of wastewater treatment, known as primary treatment, is responsible for separating grease, total suspended solids, and other items that escaped from the first stage.

The primary treatment is chemical treatment methods, which are coagulation and flocculation units designed to reduce the pollution load by removing total suspended solids (TSS), reducing COD, and also BOD (Al-Asheh et al., 2017). According to the Asefa report (2022), primary treatment removes 30-60% of income COD and total suspended solids (80-90%) (Characterizations, 2022). Coagulation is a comprehensive process that involves adding coagulants (iron or aluminum salts) such as aluminum sulfates ($Al_2 (SO_4)_3$, iron sulfate ($FeSO_4$), iron chloride ($Fecl_3$), or poly aluminum chloride (PAC). These substances are known as coagulants and are positively charged. The coagulants' positive charge neutralizes suspended materials in wastewater, which have negative charges. It serves to reduce total suspended solids (Aragaw et al., 2023).

The types of coagulants are chemical and natural plant coagulants, animal coagulants, and microorganism-based coagulants). The definition of flocculation states that it is related to water treatment procedures that mix or coagulate microscopic particles that decant out of the water. Polyelectrolytes are used to improve the settling characteristics of floc produced by coagulants. The dosing rate of chemical flocculants and coagulants is relative to the pollution load, with higher loads requiring higher dosing rates. To improve the coagulation and appropriate chemical reaction through mixing, particle destabilization and the development of early-stage flocs take place during rapid mixing in the coagulation process for coagulant and raw wastewater, and neutralization of the electrostatic charges on colloidal particles occurs during these processes.

Coagulation Mechanism

Most solids or suspended particles are smaller and carry negative charges in an aqueous medium, and to facilitate the sedimentation process, particles must be clumped together to form larger flocs. Therefore, it takes longer to settle and requires destabilizing the particles using coagulants (El-taweel et al., 2023). The destabilization mechanism was followed by steps after the addition of a coagulant agent (Ghernaout et al., 2020).

Electrostatic double-layer: the interaction between the surface of a colloidal particle and ions that are present in wastewater in which colloidal particles are dispersed.

Neutralization of the charge: Charge neutralization is referred to as the direct interaction of a charged Al (III) hydrolysis product, such as Al (OH) $^{2+}$ or Al^{3+} with a negatively charged colloid.

Adsorption: the metal hydroxide forms a precipitate (floc), then the floc adsorbs particles (turbidity) in the water.

Sedimentation

According to Derseh's report, sedimentation is the way for the smallest things in suspension to be drawn out of the suspension liquid during coagulation-flocculation in the clarifier tank (Derseh, 2022). In addition to causing coagulation, the metallic hydroxides and organic polymers can aid in particle aggregation into flocs. Those colloidal particles and finely scattered suspended solids can be effectively removed by sedimentation. Specific gravity causes suspended particles like clay or silt that are present in effluent to settle at the bottom of the clarifier, where they are slowly passed through. This process is a chemical treatment method that uses coagulant and flocculant agents on the primary clarifier unit. The steps of coagulation, flocculation, and sedimentation in chemical treatments are shown in Figure 3.

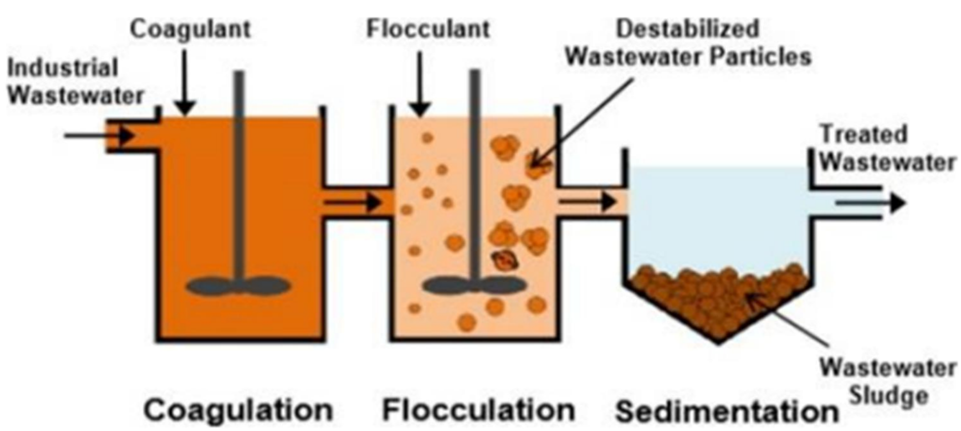

Figure 3. Steps of the coagulation, flocculation, and sedimentation processes.

2.5.2. Biological Treatment Methods

2.5.3. Aeration Tank

Aeration is required in biological treatment processes to provide oxygen to the microorganisms that breakdown the organic waste. In order to eliminate organic loads and inorganic compounds, industrial wastewater undergoes biological treatment.

The biological treatment methods are all centered on microorganisms, especially bacteria (K. M. F. Hasan, 2016). The main goal at the aeration stage is to further minimize the amount of organics (expressed as BOD and COD) and other substances still present in the effluent after the chemical treatment and thereby satisfy the standards and limits for discharge into surface waters (Chen et al., 2020). In the aeration tank, aerobic bacteria are cultivated using dissolved oxygen provided by a common air blower. The residual organic matter in the clarifier wastewater is biodegraded by aerobic microorganisms to the point where the quality of the treated effluent is within acceptable bounds.

In order to make sure there is enough oxygen available for successful treatment, dissolved oxygen (DO) is a crucial parameter in effluent treatment in the aeration unit. For organic matter to decompose, dissolved oxygen is necessary, and the average dissolved oxygen ranges from 1.5 to 4 in an aeration tank. For the proper functioning of the biological unit, the biomass in the reactor needs to be monitored regularly. For the active sludge plant (ASP), this monitoring is usually done by the mixed liquid suspended solids (MLSS) test. Mixed liquid suspended solids are materials undergoing aeration that consist of activated sludge and effluent being treated. It is also related to the food-microorganism ratio, which is in turn related to all aspects of sludge properties. MLSS represents the total solids, including bacteria, dead biomass, and higher life forms, irrespective of biological activity. The organic portion of MLSS is represented by mixed liquid volatile suspended solids (MLVSS), which represents biomass. MLVSS can be obtained by multiplying MLSS by 0.75. MLSS is controlled by the sludge waste rate, and the conventional activated sludge MLSS value ranges from 3000-5000 mg/L and for membrane bioreactors to 6000 to 10,000 mg/L.

2.5.4. Secondary Clarifier

The application of bioprocesses in the treatment can partially stabilize the compounds in the aeration tank that are biodegradable in nature.

In secondary clarifiers, where solid-liquid separation occurs, the overflow from the aeration tank is directed to the secondary clarifier, and biological solid sludge is settled under the bottom of the secondary clarifier. A portion of active sludge returns to the aeration tank through sludge pumps and is mixed with wastewater in the aeration tank to maintain the desired MLSS level, and the remainder is waste active sludge (WAS), which is transported to the sludge collection tank for additional treatments. The efficiency of the secondary clarifier was in removing total suspended solids (TSS), color, and turbidity. The condition of the activated sludge and the proper operation of the secondary clarifier are the major factors determining this process's efficiency (Chen et al., 2020). The plant consists of tertiary treatments, which are disinfection systems. This unit was not functional at time the of the study, and the effluent water from the secondary clarifier goes to the clear water storage tank by pass.

2.6. Clear water storage tank (CWST)

Treated effluent water was overflowing from the secondary clarifier to a clean storage tank. The disinfectant chemicals, like sodium hypochlorite solution, were added to further treat the microorganisms present in the treated water. The treated water's physico-chemical parameters were then examined and compared to be within acceptable limits.

2.7. Comparison conventional with advanced wastewater treatment plant

Conventional wastewater treatment plant typically consists of primary and secondary clarifier unit operation. The conventional design wastewater treatment plant include rapid mix, coagulation-flocculation and sedimentation (Koivunen, 2007). Primary clarifier chemical treatment by coagulation-flocculation process and suspended solid removed settle at the bottom of clarifier by sedimentation. In many cases, Dissolved Air Flotation (DAF) is an excellent choice for treatment process.

In the DAF process, raw water particles are flocculated and separated out of the water by floating to the surface rather than settle to the bottom of a basin. This hydroxide floc is formed when coagulants are added to enhance turbidity, color and organics removal(Wong et al., 2020). In the secondary treatment step, the conventional activated sludge process (CAS); organic material is degraded by microorganisms in aerated basinets. The microorganisms accumulate into flocs, which are suspended in the wastewater. After the treatment step, the flocs are then removed from the liquid in a secondary settler. However, this process depends on easily settle-able flocs and can be disturbed by variations in wastewater volumes or composition. MBR can replace biological treatment and gravitational settling or clarifier, because they can handle larger concentrations of solids than CAS systems, which are limited by the sedimentation rate(Wong et al., 2020).

2.8. Performance evaluation of textile wastewater treatment plant

In order to find and address issues with the current treatment facility, the efficiency study is quite essential for the plant's overall performance and its ability to fulfill standard discharge depends on how well each of its various operational units operates (Assefa et al., 2016). Wastewater quality parameters based on present-day standards and guides are presented to assist in the establishment of discharged system performance goals for any plant (Khan et al., 2009). Industrial wastewater standards may vary among countries and regions. There is no single approach that is universally applicable. It is essential that within the development and implementation of government, consideration is taken regarding water, health, and native help in setting discharge systems. Performance targets for any facility, wastewater quality measures based on current standards and recommendations are offered. For each parameter, ranks were assigned based on the corresponding testing values and the textile effluent discharge to water regulations outlined by environmental standards for industrial pollution control in Ethiopia (Derseh, 2022). The evaluation of wastewater treatment facilities' quality often involves physico-chemical and biological analysis (Mehta et al., 2021).

During the performance evaluation, the basic elements that are analyzed at the wastewater treatment plants are:

- Plant performance of each unit operation
- Operational problems
- Laboratory facilities

Monitoring environmental effluent parameters and the efficiency of each individual unit helps assess the overall performance of effluent treatment plants (N. Hasan et al., 2023).

Generally, plant performance evaluation depends on the type of treatment plant, the treatment capacity design, unit operations, and parameter design (Derseh, 2022). Each unit's performance was evaluated and compared with the national standard for wastewater textile discharge.

2. 8.1 Wastewater treatment plant Performance indicators

A performance indicator helps to assess, monitor and evaluate the effectiveness of service.

Performance indicators categories into environmental, physical, operational and quality treated wastewater. Those indicators used to evaluate the wastewater treatment plant performance (Thesis, 2011).

2.8.2 Operational Performance of effluent treatment Plant

Wastewater performance evaluation is complex task that consists of evaluating many units process, which is not achievable through straight forward procedures.

Wastewater performance evaluation is a function a very large numbers factors that affect the overall performance of a wastewater treatment plant. The key factors are called wastewater treatment plant performance limiting factors. Those factors are: operational, design, maintenance and administration practice (Derseh, 2022). Generally,the environment and ecology will be significantly protected by identifying potential water quality issues, such as high oxygen-consuming pollutants, alkalinity, excess sediments, and undesirable compounds that can damage the receiving water bodies.

Knowing how well the entire system is performing in terms of effluent quality is crucial for optimizing a specific wastewater treatment plant system. To do thus, historical data from the plant and measured data from laboratory quality can be utilized to (Derseh, 2022).

The Ethiopian textile industry effluent standard discharges are listed in Table 4.

Table 4. The textile industry wastewater limit value for discharges (EPA FDRE, 2003).

Parameters	EPA (2003)	World Bank (2007)
pH	6 to 9	6 to 9
BOD	50	30
COD	150	160
TSS	30	50
Oil and grease	20	10
Nickel (Ni)	1	0.5
Cobalt (Co)	1	0.5
Lead (Pb)	0.5	0.5
Antimony (Sb)	2	-
Chromium (as total Cr)	1	0.1
Arsenic (As)	0.25	-
Cadmium (Cd)	1	0.5
Zinc (Zn)	5	2
Copper (Cu)	2	0.5
Boron (B)	5	-

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of Study Area

3.1.1 Geographical location

Hawassa Industrial Park is located at the heart of Hawassa City, the capital city of Sidama, located 275km south of Addis Ababa. It has a latitude and longitude of $7^{0}3'N$, $38^{0}28'E$, respectively, and an elevation of 1708 meters above sea level. Hawassa Industrial Park is the first sustainable textile and apparel park in Africa. It was founded in July 2016. Constructed on 340 hectares, it has 52 sheds. Consistent with the Ethiopian government's commitment to a green economy. Hawassa Industrial Park (HIP) is designed, constructed, and operated as an eco-friendly park. It has a wastewater treatment plant with zero liquid discharge (ZLD), which uses the latest technology for treating and recycling about 90% of the water used in the park. The wastewater treatment plant is located in Chaffe Oda Kebele, in Addis Ketema sub-city in, the southeast part of Hawassa city in the Hawassa Industrial Park compound. It is between Hawassa University and the Tabor Ceramic Factory. Figure 4 shows the location of Hawassa Industrial Park.

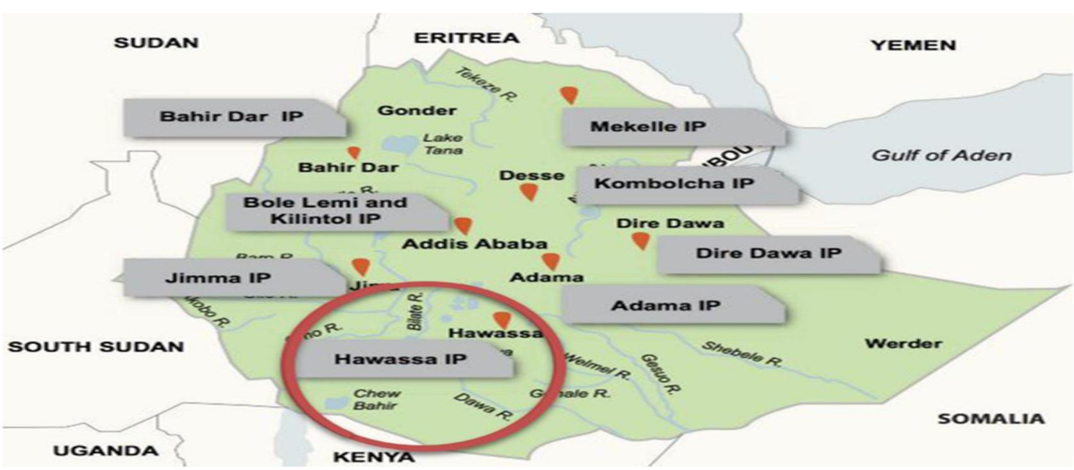

Figure 4. Hawassa Industrial Park location (source goggle map).

3.1.2. Wastewater treatment facility of Hawassa Industrial Park

The study was conducted at Hawassa Industrial Park's zero liquid discharge common wastewater treatment plant. The capacity of the proposed wastewater treatment plant is 11 million liters per day (11 MLD), or 11000 m³/day. 8 MLD for effluent treatment plant and 3 MLD for sewage treatment plant. The textile wastewater comes from companies such as PVH (Philip Van Heusen) American clothing company, Raymond, Silver Spark Apparel Ltd., Wuxi Jinmao Co., Ltd., TAL Apparel, Arvind Ltd., Hirdaramani Garment Plc., Busana Apparel Group, Indochine International, Isabella and Sarasavi Export (Pvt) Ltd., EPIC Group, Hela Clothing Group, Ontex Group NV, Everest Textile, Chargeurs Fashion Technologies, Quadrant Apparel Group Plc., Jiangsu Golden Island Group, Best Corporation Private Ltd., FCI Talisman (FCI Group), etc. The ZLD facilities have been constructed, and more than 1.5km of effluent line, 13km of recycle water line, and more than 20km of integrated drainage line have been constructed. This plant treatment system has been conventional for primary and secondary clarifier-based sedimentation. Plant design limit of each unit process shown in Table 5.

Table 5 Plant design limit of unit process

	Unit process					
	Receiving chamber	Equalization	Primary clarifier	Aeration	Secondary clarifier	CWST
	Plant design	Plant design	Plant design	Plant design	Plant design	Plant design
Parameters						
PH	11	7.0 - 8.5	7.0 - 8.0	7.5 - 9.0	7.0 - 8.0	7.0 - 8.0
TSS	138	-	< 50	-	< 30	< 20
Turbidity	-	-	15	-	< 15	< 10
TDS	2387	-	-	-	-	-
EC	-	-	-	-	-	-
Color	775	-	-	-	-	-
COD	996	-	-	-	-	-
BOD	151	-	-	-	-	-
Total alkalinity	-	-	-	-	-	-
Total hardness	-	-	-	-	-	-
Oil & grease	< 3.6	-	-	-	-	-

3.2. Instruments

The pH, total dissolved solids (TDS), and conductivity (EC) of the samples were measured by HANNA (Model HI 5521, USA). Color, total suspended solids (TSS), and chemical oxygen demand (COD) were measured by a HACH spectrophotometer (Model: DR/3900, HACH, USA), and turbidity was measured by a turbid meter (Model: HI 98703, Manufacturer: HANNA, USA). COD digestor (DRB 200, PATEL,China). Dissolved oxygen (DO) was measured by a DO meter (Model: I98193, Manufacturer: HANNA, USA). BOD was tested by a BOD incubator (manufacturer: PATEL Sci. Inst. Pvt.Ltd., Gujarat, India). Aeration settling was measured by a graduate cylinder (capacity: 1000 ml, manufacturer: Tarson Pvt.Ltd., Kolkata, India). Muffle furnace (Model: PSI, Manufacturer: PATEL Sci. Inst. Pvt. Gujrat, India). Analytical balance capable of weighing up to 200g (Model: CY 223, Manufacturer: Mumbai, India). Evaporating dishes of 100 ml capacity, a water bath, a desiccator, petridiches, Whatman filter paper, a Gouch crucible, a separator funnel, an Elemnery flask, BOD bottles with a capacity of 300 ml, pipettes, burettes, and beakers (manufacturer: HANNA, USA), and a drying oven (PSI, Gujarat, India) were used during sample analysis. All instruments were checked and calibrated according to the manufacturer's specifications. The pH meter was calibrated using buffer solutions of pH 4, 7, and 10 supply by (HANNA, Smithfield, USA). The electro-conductivity meter was calibrated using the potassium chloride solution provided by the manufacturer (HACH, Loveland, USA, 1997). A blank sample (deionized water) was used between every measurement of effluent samples to check for any eventual contamination.

3.3. Chemicals and Reagents

Chemicals and reagents that were used during the analysis are:
Hydrochloric acid (HCl) purity 36%, sulfuric acid (H_2SO_4) purity 98%, manganese sulfate purity 98%, Sodium thiosulfate (99%), and the manufacturer, HPLC (Higher Purity Laboratory Chemicals) Pvt. Ltd., Mumbai, India. Standard buffer solution of pH7.0, standard buffer solution of pH4.0, standard buffer solution of pH10.0 (HANNA, Smithfield, USA), $K_2Cr_2O_7$ reagent (purity 99.5%), EDTA (Ethylenediamine tetra aceticacid), (purity 98%), Erochromo black T sodium salt, ammonia solution (purity 25%), phenolphthalein indicator.

n-hexane (purity 99%), and sodium sulfate anhydrous (purity 99%) were used for this study, and the supplied by HPLC Pvt.Ltd., Mumbai, India.

3.4. Sampling Design

Sampling and testing were performed to investigate the wastewater quality from each treatment unit. The sampling method, the location of sampling points, and the analyses of particular treatments were determined for the purpose of evaluating the performance.

A quantitative analysis of wastewater generated from the textile factory of Hawassa Industrial Park was performed in the laboratory of Hawassa Industrial Park. Wastewater sample analyses were conducted for two months (from February 25, 2023 to April 25, 2023). Samples were collected using the grab sampling method from the effluent treatment plant's (ETP) six-unit operational processes (receiving chamber, equalization tank, primary clarifier, aeration tank, secondary clarifier, and clear water storage tank). The sampling was conducted every day from 9:00 to 11:00 a.m and after noon from 2:00 to 4:00 p.m for 60 days, or 8 weeks. Samples were collected diligently in 1L polyethene bottles and filled to the total volume to avoid any air space inside the bottle, then capped. Bottles were first washed with HCl and again washed with distilled water, and they were thoroughly rinsed with the wastewater at sites before collecting the samples, and then the bottles were labeled accurately (Duncan et al., 2007). To prevent surface contamination of the sample by grease or floating particles during the sampling, taken the sample at a depth of 50 cm to 80cm. Table 6 shows the point of sample collection from the six-unit operational process.

Table 6 Sampling point of the unit treatment process

Sampling unit	Location of the sample	Objective of Sampling
1	Receiving chamber	To find out the untreated water characteristics before neutralization and equalization tanks.
2	Equalization tank	To analyze the pH neutralizing and homogenizing different streams of textile wastewater.

3	Primary clarifier	To analyze the performance of coagulation and flocculation units.
4	Aeration tank	To analyze the performance of biological parameters.
5	Secondary clarifier	To analyze the performance of secondary clarifier physico-chemical parameters.
6	Clean storage tank	To analyze whether the performance of the final treated water of ETP meets the standard or not.

3.5. Methods of Analysis

The methods of analysis employed are mostly the procedures described in the standard methods for water and waste water analysis (APHA (American Public Health Association), 2012). Performance has been assessed by comparing the pollution concentration at the treatment unit's inlet and outlet (Firew et al., 2018). To investigate the performance of treatment sequence it is very important to identify the key unit process treatment and select sampling location. Samples were collected at each treatment unit's inlet and outlet points, and they were then examined in accordance with the standards for testing water and waste water (APHA (American Public Health Association), 2012).

Volumetric analysis: This method depends on the measurement of volumes of reagents of known strength. The normality of standard solutions is chosen so that the titer value directly gives the value that represents the quantity of substance in water pollution, such that alkalinity and hardness are analyzed by using this method.

Microanalysis: In this method, modern instrument-based techniques are used. Techniques like spectrophotometry based on color intensity measurements are useful to analyze color, COD, and heavy metals.

3.6. Laboratory Analysis Procedures

During the study period, samples from different stages of treatment units of ETP were collected and analyzed for evaluation. The collected samples were analyzed for:

Physico-chemical parameters such as pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Oil and Grease (O&G), Electrical Conductivity (EC), Turbidity, Hardness, Alkalinity, and Heavy Metals (Hussain et al., 2004).

All experiments were carried out at a temperature of 25^0C. Characterization of waste water for selected physico-chemical parameters (pH, EC, TDS, TSS, turbidity, and color) was done three times per day for two months (total sample =180) for each parameter, and COD, oil, and grease were measured once per day for two months (total sample =60) for each parameter.

Total alkalinity and total hardness were measured once per 10 days for two months (total sample =6), respectively. BOD was tested once per 5 days for two months (N total sample =12). Heavy metals were analyzed once per 60 days for the two-unit operation (receiving and clean water storage tanks). Determinations of the parameters were done according to the analytical methods described in standard methods for the examination of water and wastewater (APHA (American Public Health Association), 2012).

pH: The basic principle of electronic pH measurement is the determination of the activity of hydrogen ions by potentiometer measurement using a standard sensing electrode (glass electrode) and a reference electrode (calomel electrode).

When a glass electrode is immersed in a solution, a potential difference develops between the solution in the glass bulb and the sample solution, and the pH of the samples is measured. The pH of the sample's measurements was carried out using a pH meter model (HANNA HI 5521). Before starting the analysis, calibration of the pH of the meter using buffer solutions of 4.0, 7.0, and 10.0 pH was done.

Color: Color in water may result from the presence of natural metallic ions (iron and manganese), humus and peat materials, plankton, weeds, and industrial wastes. The term color is used in two ways: true color, from which the color of water turbidity has been removed. Apparent color, which includes not only the color of water but also suspended matter, color was measured at 340nm wavelength by a spectrophotometer model (DR/3900). The respective sample was taken in a clean sample cell up to 10 mL, and then the cell was capped. After that, the cell was wiped with a soft cloth and then pressed ON/OFF on the power of the instrument. The sample cell was inserted into the instruments, and the lid was closed. The last "READ" key was pressed, and it displays the result of the sample by pt/co unit.

Electrical conductivity (EC): EC is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions in wastewater. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Generally, the EC of waste water is actually a measure of salinity. Therefore, EC is related to total dissolved solids (TDS). Conductivity (µS/cm) x 2/3 = TDS (mg/L). The samples were taken in a clean beaker up to 250 mL, and the conductivity cell was dipped into the sample-containing beaker. Initially, the mode was pressed, and then the electrical conductivity measurement was selected. The direct value of electrical conductivity is displayed in the desired unit as µS/cm.

Total dissolved solids (TDS): Dissolved solids are the major concern in wastewater pollution. The TDS determinations and electrical conductivity measurements are of great interest. Discharges of highly mineralized wastewater may cause changes in density; for this purpose, the total dissolved solids test can be used to good advantage to detect such changes. Select TDS measurement mode and press. The direct value of TDS in the desired unit, as mg/L, is displayed.

Total Suspended Solids (TSS): Total suspended solids consist of silt and fine particles of organic and inorganic matter in wastewaters and wastewaters, as measured by a DR/3900 spectrophotometer. The respective sample was taken in a clean sample cell up to the 10 mL mark, then capped. After that, the cell was wiped with a soft cloth. Then press ON/OFF to turn on the power of the instrument. The sample cell was inserted in the instrument cell compartment. The lid was closed, and lastly, pressed the "READ" key to display the TSS value in mg/L.

Turbidity: To determine the turbidity of wastewater, a turbidity meter (HANNA model HI 98703) was used. The method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the intensity of scattered light, the higher the turbidity. The turbidity is specified in a range of 0 to 750 nephelometric transparency units (NTU).

Chemical oxygen demand (COD): COD is defined as the amount of oxygen used while oxidizing the organic matter content of a sample with a strong chemical oxidant under acidic conditions. In COD determination, the organic matter (both biologically and chemically oxidizable) is completely oxidized to CO_2 and H_2O.

COD was also measured by the DR/3900 spectrophotometer. The determination of COD has been carried out using $K_2Cr_2O_7$ as the most suitable oxidizing agent, which is capable of oxidizing a wide variety of organic matter to CO_2 and H_2O. The procedures were to first turn on the reactor and preheat it to 150^0C. Then homogenize 100 mL of sample for 1 minute in a blender. Carefully pipette 2.0 ml of sample into the vial cap and clean the outside of the vial. Invert gently several times to mix, and when the sample becomes very hot during mixing, placed the vial in the preheater reactor for two hours. Turn the reactor off and wait for 20 minutes to cool the vial to 120^0C. Select COD ranges (low range or high range). Insert the blank up to 16mm of cuvette cell into the instrument cell holder. Then insert the vial samples and directly display the COD value in the desired unit in mg/L.

Biological Oxygen Demand (BOD): BOD is defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions.

The term decomposable means the organic matter can serve as food for the bacteria, and energy is derived from its oxidation.

BOD is used to determine the relative oxygen requirements of wastewater and polluted waters. The method consists of filling the sample to overflow in an airtight bottle of 300 mL and incubating it at 27^0C for 5 days. Dissolved oxygen (DO) is measured initially and after incubation, and the BOD is determined from the difference between the initial DO and the final DO. The BOD is calculated using Equation 1.

BOD_5 in mg/L $= \frac{\text{D1}-\text{D2}(\text{B1}-\text{B2})\,\text{f}}{p} x1000$ ----------- (1)

Where $D_{1:}$ is the initial DO of the sample before incubation in mg/L.

$D_{2:}$ DO of the sample after incubation in mg/L.

B_1: DO of the seed control before incubation in mg/L.

B_2: DO of the seed control after incubation in mg/L.

f - Ratio of seed diluted sample to seed control.

p - Sample volume.

Total hardness: Total hardness is defined as the sum of calcium and magnesium concentrations, both expressed as calcium carbonate in mg/L. This method involves the use of ethylenediaminetetraacetic acid (EDTA) or its sodium salt as the titrating agent. In alkaline solution conditions, EDTA reacts with calcium and magnesium to form a soluble chelated complex. This chelated complex gives a color change in the presence of an indicator. Eriochrome black T (EBT) is used as an indicator. Total hardness is calculated using Equation 2.

Total hardness (mg $CaCO_3$mg/L) $= \frac{\text{A}\times\text{B}\times 1000}{\text{Sample volume}}$ --------- (2)

Where A- is the amount of EDTA in mL titrated for the sample.

B- 1mL EDTA titrant equivalent to mg $CaCO_3$.

Total Alkalinity: Alkalinity is a measure of the capacity of water to neutralize acids.

The alkalinity of water is primarily due to the presence of bicarbonate, carbonate, and hydroxide ions. The alkalinity of water is the capacity of that water to accept protons.

It may be defined as the quantitative capacity of an aqueous medium to react with hydrogen ions to pH 8.3 (phenolphthalein alkalinity) and then to pH 3.7 (total alkalinity).

Alkalinity is calculated using Equation 3.

Total alkalinity (as mg/L $CaCO_3$) $= \frac{(A+B)\times N\times 50{,}000}{V}$---------------- (3)

Where A is mL of the standard sulfuric acid used to titrate to pH 8.3.

B is mL of the standard sulfuric acid used to titrate from pH 8.3 to pH3.7

N is the normality of acid used.

V is volume of the sample taken for test in mL

Oil and Grease: Oil and grease are useful to determine treatment plant efficiencies and to overcome difficulties during treatment. The source of oil and grease is the natural raw materials used in the process, such as the lubricants applied to machines. The oil and grease contain hydrocarbons, lipids, fatty acids, soaps, and waxes (Chaudhari et al., 2021). It should be removed by solvent extraction. Oil, grease, and other extractable matter are dissolved in a suitable solvent and extracted from the aqueous phase. The solvent layer is then evaporated, and the residue is weighted as oil and grease. The concentration of oil and grease is calculated using Equation 4. Oil & grease (mg/L) = $\frac{(W2 - W1)\times 1000}{V}$ ----------- (4)

Where W_2 - weight of oil and grease + weight of dish

W_1- is the weight of the empty evaporated dish.

V- denotes the volume of the sample taken.

Heavy metals analysis

The study of trace metals in wet and dry processes has increased in recent decades because trace metals have adverse environmental and human health effects (Astuti et al., 2023). Heavy metals such as chromium, lead, mercury, cadmium, antimony, and arsenic are extremely toxic, even in very small amounts (Barakat, 2011). Heavy metals were analyzed at the Bishoftu laboratory of Horti coop (Horticulture) Ethiopian PLC. The samples were preserved by acidifying them with concentrated HNO_3 to a pH of 2.0 or less and stored at approximately 4^0C to prevent changes in volume due to evaporation. All heavy metal measurements were performed using an optical emission spectrometer optimized with a small volume and 32 linear CCD detectors. The wave length ranges between 130 and 770 nm simultaneously. The sample is nebulized into the argon gas field plasma, and the energy excitement is measured in single spectra and expressed in intensity, which is directly proportional to concentration. The concentration is calculated on the linear graph of the standard concentration and the corresponding intensity.

However, the measurement was done once the samples arrived at room temperature (Koesmawati et al., 2021). The estimation of the concentration of the different heavy metals was performed based on the calibration curves of each metal (Appendix 2).

Mixed liquor suspended solids: MLSS testing measures the total concentration of mixed liquid suspended (non-soluble) solids in the aeration basin. Determination of MLSS: take 25mL of mixed aeration sample in a graduate cylinder and weight the Whatman filter paper. Filter the sample by using Whatman filter paper, remove the filter from the filtering system with care, put it in a petri dish, and dry it for one hour in an oven set to 103 to 105 degrees Celsius. Then, cool it in a desiccator for 20 minutes, and weight the filter after dehydration, and take note. Equations 5 and 6 are used for calculating MLSS and MLVSS.

$$\text{MLSS (mg/L)} = \frac{(\text{AXB}) \times 10e^{6}}{\text{Sample size in mL}} \text{ --------- } (5)$$

Where A - the weight of dried residue + dish before ignition in gm.

B - The weight of dried residue + dish after ignition in gm.

$$\text{MLVSS} = \frac{\text{MLSS x 10 } e^{6}}{\text{Sample size in mL}} \text{ --------------- (6)}$$

Sludge Volume Index (SVI): Measuring sludge settleability is fundamental to the operation and control of the biological system. It is defined as the volume in milliliters occupied by 1g of the suspended solids following 30 minutes of unstirred settling of the aeration basin MLSS.

The most significant deficiency of the SVI as a measure of sludge settleability is its dependency on mixed liquor concentration. The critical MLSS concentration is low, and SVI provides a poor characterization of sludge settleability. Equation 7 is used to calculate SVI.

$$\text{SVI} = \frac{\text{Settled sludge volume x 100}}{\text{MLSS}} \text{-------------- (7)}$$

3.7. Data Analysis

Primary data were measured in laboratory direct sampling (for the inlet flow and outlet flow of each treatment plant unit) from the wastewater treatment site. The study used the quantitative data presentation analysis method, and all water quality data were analyzed using Microsoft Excel 2016 and single-factor ANOVA. The obtained results for different parameters are expressed as the mean ± standard deviation of triplicate measurements. Significant differences between consecutive operational units and the inlet and outlet of the treatment plant were tested by the student's t-test. According to Khumalo waste water treatment plant performance was measured through the percentage removal of physico-chemical parameters (Khumalo et al., 2023). Removal efficiency, after determining the value of each parameter at each sampling point, was calculated according to Equation 8.

Removal Efficiency (%) = $\left(\frac{\mathrm{Ci} - \mathrm{Ce}}{\mathrm{Ci}}\right) x100$----------- (8)

Where Ci is the concentration of the pollutants in the influent (before treatment), Ce is the concentration of the pollutants in the effluent (after treatment).

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Raw wastewater characteristics

Raw wastewater, which has irregular characteristics an organic or inorganic load from different streams of the textile industry.is collected in the receiving chamber.

Table 7 physico-chemical characteristics of raw wastewater

Parameters	Unit	Mean	Std.Deviation	Min	Max	Range	Plant design limit
PH	-	9.2	0.54	8	10.4	8.4	11
TSS	mg/L	137.3	37	66.3	227	160.7	138
Tur	NTU	70	23.9	31.6	133	101.4	
TDS	mg/L	2483.4	439.2	1356.6	3769	2412.4	2387
EC	µs/cm	3832.1	735.8	2087	5798	3711	3672
Color	pt/co	1262	398.5	518.6	3545.6	3027	775
COD	mg/L	1026.8	353.9	568	1724	1156	966
BOD5	mg/L	510	168.5	336	855	519	151
T.H	mg/L	218.7	21	204	264	60	
T.A	mg/L	488.5	24	522	558	36	
O & G	mg/L	2.84	0.34	1.2	4.6	3.4	

The observed value of raw wastewater from table 6 parameters were pH, TSS, Tur, TDS, EC, color, COD, BOD, T.A, T.H, and O&G range from 8 to 10.4, 66.3 to 227mg/L, 31.6 to 133 NTU, 1356.6 to 3769 mg/L, 2087 to 5798 µs/cm, 518.6 to 3545.6 pt-co, 568 to 1724 mg/L, 336 to 855 mg/L, 204 to 265 mg/L, 522 to 558 mg/L, and 1.2 to 4.6 mg/L respectively.

In generally, it observed value of inlet some parameters (TDS, color, COD, BOD) were above the plant design limit, which was affect on the performance of the plant.

Equalization tank: removal efficiency of equalization tank laboratory analysis parameters pH, TSS, TDS, color, EC, turbidity, and total hardness are 7.7%, -12.46%, 2.32%, 7.87%, 2.87%, -1.54%, and 20.24%, respectively. When different types of textile wastewater are homogenized by air in the equalization tank, more suspended particles are created, which causes TSS and turbidity to rise during operation.

Primary Clarifier: the removal pollutant efficiency of primary clarifier parameters pH, TSS, color, EC, turbidity, TDS, total hardness, COD, and O&G are 10.78%, 78.2%, 21.27%, 5.4%, 80.84%, 5.91%, 12.78%, 34.51%, and 79.51%, respectively. According to primary performance characterizations reported in 2022 (Characterizations, 2022), primary clarifiers reduce 80-90% of TSS and 30 - 60% COD. However, the current performance of primary TSS reduction is poor; it is only 78.2%, and the COD performance is 34.51%, which is also very low.

Aeration tank: According to the different oxygen demands, biological treatment methods can be divided into aerobic and anaerobic treatments. Because of their high efficiency and wide application, aerobic biological treatments are mostly selected. A kind of floc in an aeration tank that is mainly comprised of many microorganisms is known as activated sludge, which has strong decomposition and adsorption of organic matter in wastewater. This is the most versatile biological oxidation method employed for the treatment of wastewater containing dissolved, colloidal, and solid organic matter. In this process, the wastewater is aerated in an aeration tank, resulting in the biological degradation of the waste organic matter into carbon dioxide and water molecules while consuming some organic matter for synthesizing bacteria. The removal efficiency of aeration tank parameters for pH, TDS, and BOD is -3.87%, 4.06%, and 56.47%, respectively. According to the Asefa performance characterization of the aeration process (characterizations, 2022), the expected value of BOD removal efficiency at the aeration tank unit operational process is 90-95%. But the actual result of performance is 56.47%, which is poor performance.

Secondary clarifier: In this clarifier, due to the scraper agitator, total suspended solids (in the form of return activated sludge and waste activated sludge) settled under the bottom of the secondary clarifier, and the treated water overflow on the top of the clarifier flowed to the clean water storage tank.

The main objectives of a secondary clarifier are to reduce total suspended solids (TSS) and turbidity. The removal efficiency of secondary clarifier parameters pH, TSS, color, EC, turbidity, TDS, total hardness, COD, and BOD is 0.66%, 25.94%, 48.5%, 15.62%, 64.86%, 4.83%, 1.81%, 43.96%, and 20.04%, respectively. It is observed that turbidity is showing a significant decrease, which is also the main purpose of the secondary clarifier. The TSS removal is not considerable as per the purpose of the unit.

Clear Water Storage Tank: The final treated water was stored in this tank, and all physico-chemical parameters were analyzed. The pollutant removal efficiency of CWST parameters pH, TSS, color, EC, turbidity, TDS, total alkalinity, total hardness, COD, BOD, and oil and grease are 0.77%, 13.64%, 16.77%, -3.07%, 16.42%, 4.42%, 75.5%, 4.53%, 50.46%, 53.7%, and 33.9%, respectively. The mean and range value of physico-chemical data analysis of different unit process is shown in Table 8.

Table 8 mean and range value of different unit process

Parameters		Unit process					
		Receiving	Equalization	Primary clarifier	Aeration	Secondary clarifier	Clear water storage tank
pH	Mean value of two months of data	9.2±0.54	8.473±0.4	7.53±0.2	7.82±0.1	7.77±1.8	7.71±0.2
	Range	2.4	1.64	0.86	0.6	0.8	0.5
TSS (mg/L)	Mean value of two months of data	137.29±37	154.4±16.4	33.65±16.4	-	24.92±5.9	24.92±5.9
	Range	160.7	241.7	79.34	-	26	25
Color (pt/co)	Mean value of two months of data	1261.99±398.5	1162.59±273	915.26±259.8	-	471.27±114.6	392.2±177.6
	Range	3027	1204	1208.7	-	645	1080
EC (μs/cm)	Mean values of two months of data	3832.13±735.8	3721.99±614.9	3520.97±241.9	-	2970.93±526.4	3062.17±776
	Range	3711	3009.6	2813	-	2957	3779
Turbidity (NTU)	Mean values of two months of data	70.06±23.9	71.14±28.3	13.88±8.6	-	4.877±5.6	4.076±1.5
	Range	101.4	190	47.56	-	6.9	6.1
TDS(mg/L)	Mean values of two months of	2483.45±439	2425.9±394.7	2282.56±408.4	2189.9±404.2	2084.12±47	1991.95±505.8
	Range	2412.4	1534	1829	2082	2265	2456
Total hardness(mg/L)	Mean values of two months of data	218.71±21	174.43±36.6	152.14±28.6	-	149.387±63.5	142.61±55.3
	Range	36	92	72		52	167
COD (mg/L)	Mean values of two months of data	1026.82±353.9	-	672.45±258.9	-	376.83±182.9	186.68±110
	Range	1156		1019		771	522
BOD (mg/L)	Mean values of two months of data	510±168.5	-	-	222±241.9	177.5±83.9	82.05±51.3
	Range	519		-	339	284	151.5
O&G (mg/L)	Mean values of two months of data	2.841±0.34	-	0.582±0.3		-	0.243±0.2
	Range	3.4		1.2			0.52

In conjunction with the main objectives of each unit's operational process, from Table 8, the removal efficiency of the TSS inlet to primary clarifier is 75.48%, and on the secondary clarifier (from inlet to secondary clarifier), it is 81.84%. The TSS was reduced from receiving to primary by 75.48%, from primary to secondary by 6.36%, and from secondary to CWST by 2.56%. COD was reduced from receiving to primary clarifier by 34.51% and receiving to secondary clarifier by 63.3% and from primary to secondary by 28.79% and secondary to CWST by 18.5%. BOD removal efficiency from inlet to aeration was 56.47% and from inlet to secondary was 65.2%. The data were analysis variance one-way ANOVA to compare concentration of different unit process (Haile & Mohammed, 2019). The significance analysis of all physico-chemical at a 95% confidence level interval or at P = 0.05(Appendix 3).

The removal efficiency of different unit process is shown by figure 5.

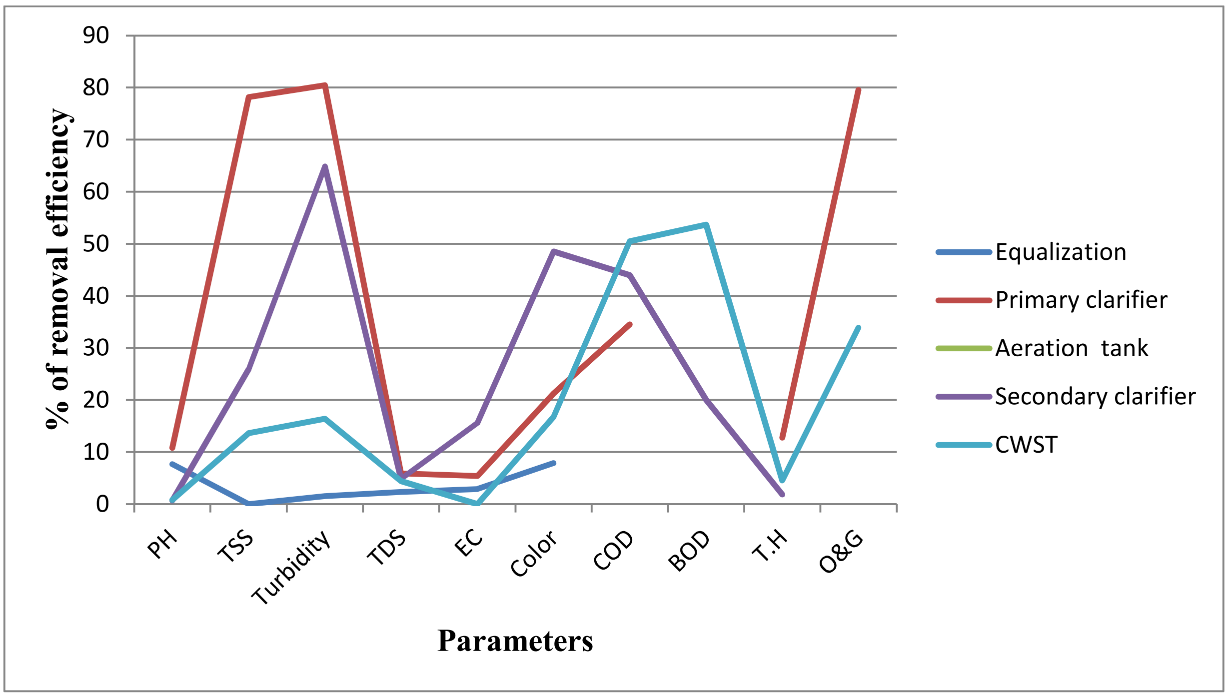

Figure 5 removal efficiency of different unit process

4.2. Physico-chemical characteristics of different parameters

4.2.1. pH

From the laboratory analysis of textile waste water characteristics, the pH of the inlet ETP ranged from 8 to 10.4 with a mean value of 9.18 ± 0.536, and the outlet ETP (treated) of textile waste water ranged from 7.53 to 8.03 with a mean value of 7.71 ± 0.159. This shows that the pH of textile effluent was in a wide range, from slightly alkaline to strongly alkaline, because in most of the mercerizing processes, caustic and other detergents of an alkaline nature are used in large quantities.

4.2.2. Electrical conductivity (EC)

The EC of the inlet was observed to be 2087 µs/cm and 5798µs/cm as minimum and maximum, respectively, with a mean of 3832µs/cm ± 753.79µs/cm, and the outlet was 756µs/cm and 4535µs/cm as minimum and maximum, respectively, with a mean of 3062µs/cm±776µs/cm. Conductivity in water was affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Therefore, TDS determination and specific conductance measurements are of great interest (Rebello et al., 2020).

4.2.3. Total dissolved solids (TDS)

The total dissolved solids inlet of ETP from our data was observed at 1356.667 mg/L and 3769 mg/L as minimum and maximum, respectively, with a mean of 2483 mg/L±439.2 mg/L. The outlet was 491.33 mg/L and 2947.667 mg/L as minimum and maximum, respectively, with a mean of 1992±505.87 mg/L. The higher TDS mean values (1992±505.87 mg/L) were seen in our data, which exceeded the guideline limit value (1200 mg/L). Due to the higher presence of dissolved ions (salinity), such as sodium, magnesium, and calcium ions, in textile wastewater and the high values of TDS associated with excessive scaling in pipes or membranes, which may cause corrosion and settleability of suspended solids, this affects the treated water quality.

4.2.4. Color

The color of the inlet effluent was observed at 206 pt-co and 1286 pt-co as minimum and maximum, respectively, with a mean of 1262 pt-co±398.47 pt-co, and the outlet was 32 pt-co and 133 pt-co as minimum and maximum, respectively, with a mean of 70±24 pt-co. From this data result, it is shown that the inlet to ETP was colored mostly due to dyes present in textile wastewater. At the primary clarifier unit, the coagulation-flocculation and sedimentation processes worked well. At this stage, chemical treatment is used, such as PAC as a coagulant, polyelectrolyte as a flocculant, and decolorized agents as a color removal agent. Those combinations of chemical treatments removed dyes and, hence, decreased color at the outlet of the ETP.

4.2.5. Turbidity

Turbidity measurement was observed in the inlet range of 32 to 133 NTU as minimum and maximum, with a mean of 70±24 NTU, and the outlet range was 2 to 8.1 NTU as minimum and maximum, with a mean of 4.076±1.54 NTU. From this data observed, at the inlet of ETP, a higher value of turbidity was observed due to polluted raw textile wastewater by suspended and dissolved materials, and on the primary clarifier, those suspended solids were removed by the coagulation-flocculation process, and turbidity decreased significantly at the outlet of ETP.

4.2.6. Total suspended solid (TSS)

Total suspended solids for the inlet of ETP were observed at 66.33 mg/L and 227 mg/L as minimum and maximum, respectively, with a mean of 137.3±37.014 mg/L. The outlet of ETP was 11 mg/L and 36.667 mg/L as minimum and maximum, respectively, with a mean of 21.52±5.89 mg/L. From the above observed data, at the inlet of the ETP, the highest value of TSS was observed due to the coming of more fine suspended matter from textile wastewater into the receiving chamber. At the outlet of the ETP (clean water storage tank), after wastewater from textiles was treated by different unit processes, especially the primary clarifier coagulation-flocculation process, TSS significantly decreased, reaching an acceptable value compared with the standard textile effluent discharge value of 30 mg/L. But the plant design limit is ≤ 20 mg/L.

4.2.7. Chemical Oxygen Demand (COD)

The chemical oxygen demand value of the inlet ETP textile wastewater was observed to range from 568 mg/L to 1724 mg/L, with a mean value of 1026.82±353.93 mg/L. The outlet was observed to range from 51 mg/L to 573 mg/L, with a mean value of 186.68±110.11 mg/L. At the inlet of ETP, a higher COD value was observed because, in the wet process of textile manufacture, sizing liquid waste was usually small in quantity but had very high levels of chemical oxygen demand (COD) and suspended solids. At the outlet of ETP after being treated by different units, the process COD value decreased, but it was above the guideline-limited value of EPA 150 mg/L. The higher chemical oxygen demand of the wastewater is due to the presence of ox-disable compounds, which are used in various steps of the textile process, and to impurities from chemicals used in the textile industry.

4.2.8. Biological Oxygen Demand (BOD)

From our data, the BOD_5 of the inlet ETP measurement was 336 mg/L and 855 mg/L as minimum and maximum, respectively, with a mean of 510±168.52 mg/L. The outlet was 28.5 mg/L and 180 mg/L as minimum and maximum, respectively, with a mean value of 82.05±51.26 mg/L. This result shows the highest BOD value at the inlet of ETP because raw textile wastewater contains cotton fiber cellulose. To remove this cotton in the sizing and desizing steps, the cloth must be treated with starch, gum, and enzymes. These wastewaters have a high BOD value. From above, our data analysis result shows that the treated water BOD mean values are 82.05±51.26 mg/L, which is higher than the guideline limit of 50 mg/L.

Higher values of BOD are an indication of contamination and could indicate that there is less oxygen available for living organisms in wastewater to decompose organic matter.

4.2.9 Total alkalinity

The alkalinity values showed that the inlet range was 522 mg/L to 558 mg/L as minimum and maximum, respectively, with a mean of 488.57±24.05 mg/L, and the outlet range was 90 mg/L to 132 mg/L as minimum and maximum, respectively, with a mean value of 119.43±14.95 mg/L. This result shows a higher value of total alkalinity in treated water at CWST, but the guideline did not restrict the value of discharge.

4.2.10 Total hardness

The total hardness result from the data collection of inlets was 204 mg/L to 264 mg/L as minimum and maximum, respectively, with a mean of 218.71±1.66 mg/L. The outlet range was 96 to 263 mg/L as minimum and maximum, with a mean of 142.61±55.34 mg/L. The textile effluent discharge limit value of total hardness is not restricted by the EPA.

4.2.11. Oil and grease: the oil and grease values were observed in the inlet range of 1.2 mg/L to 4.6 mg/L as minimum and maximum, respectively, with a mean of 2.84±0.34 mg/L. The outlet range was observed to be 0 to 0.52 mg/L, with a mean of 0.243±0.165 mg/L. The oil and grease of treated water mean value is 0.243±0.165 mg/L, which is below the guideline limit value of textile effluent discharge of 10 mg/L.

4.2.12. Heavy metals

The heavy metals sample analysis results show that the Boron (B) mean values of the inlet and outlet were 0.58 mg/L and 0.52 mg/L, respectively. Zinc (Zn) had mean ±Sd values of 0.07±0.01 mg/L and 0.033±0.006 mg/L, inlet and outlet, respectively.

The mean ± sd concentration values of Cd and Hg were 0.076±0.0321 mg/L and 0.553±0.032 mg/L at the inlet, 0.05±0.0173 mg/L and 0.52±0.045 mg/L at the outlet, respectively. At the inlet and outlet, the mean concentrations of Cu, Co, Ni, Cr, and as showed the same values of 0.032, 0.119, 0.001, 0.001, and 0.001 mg/L, respectively. The mean ± Sd concentrations of Fe, Mn, Se, and Pb were 1.33±0.0351 mg/L, 0.32±0.01 mg/L, 0.306±0.0404 mg/L, and 1.06±0.096 mg/L at the inlet, 0.133±0.0208 mg/L, 0.0133±0.005 mg/L, 0.283±0.0152 mg/L, and 0.93±0.0173 mg/L at the outlet, respectively.

4.3. Removal efficiency of major physico-chemical parameters

The overall plant physico-chemical characteristics of Hawassa Industry Park textile wastewater treatment plants and their removal efficiency are shown in Table 9.

Table 9 Variation of major physico-chemical parameters before and after treatment

Parameters		Number of samples size	Minimum	Maximum	Mean ± SD	% removal efficiency
PH	Inlet	180	8	10.4	9.18 ± 0.536	
	Outlet	180	7.53	8.03	7.71 ± 0.159	16
EC (μ/cm)	Inlet	180	2087	5798	3832± 753.79	
	Outlet	180	756	4535	3062 ± 776	20
TDS (mg/L	Inlet	180	1356.67	3769	2483 ± 439.2	
	Outlet	180	491.33	2947.67	1992 ± 505.87	19.77
Color (Pt-Co)	Inlet	180	518.667	3545.67	1262 ± 398.47	
	Outlet	180	206	1286	392 ± 177.68	69
Turbidity (NTU)	Inlet	180	32	133	70 ± 24	
	Outlet	180	2	8.1	4.076 ± 1.54	94
TSS (mg/L)	Inlet	180	66.33	227	137.3± 37.014	
	Outlet	180	11	36.667	21.52 ± 5.89	84
BOD (mg/L)	Inlet	12	336	855	510± 168.52	
	Outlet	12	28.5	180	82.05 ± 51.26	83.9
Total alkalinity (mg/L)	Inlet	6	522	558	488.57± 24.05	-
	Outlet	6	90	132	119.43 ±14.95	75.56
Total Hardness(mg/L)	Inlet	6	204	264	218.71±21.66	-
	Outlet	6	96	263	142.61 ±55.34	34.79
O & G(mg/L)	Inlet	60	1.2	4.6	2.84 ±0.34	
	Outlet	60	0	0.52	0.243±0.165	91.4
COD (mg/L)	Inlet	60	568	1724	1026.82± 353.93	
	Outlet	60	51	573	186.68 ± 110.11	81.8

From the table 9 pollutant removal overall efficiency of main physico-chemical parameters pH, EC, color, and TDS were 16%, 20%, 69%, and 19.77%, respectively.

Turbidity, TSS, COD, BOD, total alkalinity, total hardness, and oil and grease were 94%, 84%, 81.8%, 83.9%, 75.56%, 34.79%, and 91.4%, respectively. The significance between the inlet and outlet of all physico-chemical parameters was tested by the student's test at P = 0.05 and the results are shown in Appendix 1.

Heavy metal characteristics of laboratory analysis results and removal efficiency are shown in

Table 10 all values are mean ±SD expressed in mg/L.

Table 10 characterization of heavy metals for raw wastewater and treated water

Metals	Raw wastewater	Treated water	Standard limit value by EPA (2003)	% removal efficiency
	Mean ±SD	Mean ± SD		
B(mg/L)	0.58 ± 0	0.52 ± 0	-	10
Zn(mg/L)	0.07 ± 0.01	0.033 ± 0.005	5	52.85
Cd(mg/L)	0.076 ± 0.032	0.05 ± 0.0173	1	34.21
Hg(mg/L)	0.553 ± 0.0321	0.52 ± 0.045	-	13.74
Cu(mg/L)	0.032 ± 0	0.032 ± 0	2	0
Co(mg/L)	0.119 ± 0	0.119 ± 0	1	0
Ni(mg/L)	0.001 ± 0	0.001 ± 0	1	0
Fe(mg/L)	1.33 ± 0.0351	0.133 ± 0.0208	-	90.38
Mn(mg/L)	0.32 ± 0.01	0.0133 ±	-	95.84
Cr(mg/L)	0.001 ± 0	0.001± 0	1	0
Se(mg/L)	0.306 ± 0.0404	0.2833 ±	-	7.62
Pb (mg/L)	1.06 ± 0.096	0.93 ± 0.0173	0.5	12.26
As(mg/L)	0.001 ± 0	0.001 ± 0	-	0

The order of concentration heavy metals analysis result show pb >Hg>Se>Fe>Co>Cd> Zn>Cu>Ni.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The objective of this study was to evaluate the efficiency of wastewater treatment plant for textile wastewater at Hawassa Industrial Park. The results confirmed that, the wastewater treatment plant has good performance to reduce turbidity (94%), O&G (91.4%), TSS (84%), BOD (83.9%), COD (81.8%), and total alkalinity (75.56%). Whereas the performance with respect to EC (20%), TDS (19.77%), and color (69%) has poor performance and the parameter values are not within the limit set by the EPA. The heavy metal removal efficiency was also good when compared with the Ethiopian standard discharge. The overall performance of the conventional textile wastewater treatment plant at Hawassa Industrial Park needs some improvements to meet exactly the national discharge quality standards, and therefore, it requires immediate interventions to address the problems.

5.2. Recommendations

To improve the performance of textile wastewater treatment plants:

- The raw water coming from different streams to the receiving chamber parameters are greater than the plant design limit, and it will require action to relate to the plant design.
- The ETP facilities should balance the water at the inlet and outlet of the existing wastewater treatment plants by applying an appropriate design.
- Better pH correction and chemical dosing systems will improve with jar testing.
- To improve operational and maintenance problems at the treatment plant, monitor and control system devices and equipment properly during the plant's operational time.
- The government must support the establishment of an internationally accredited laboratory to test waste water and treated water quality in the textile industry.

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APPENDIX 1

Significance difference test by t-test paired the inlet and outlet mean of all parameters.

t-Test: Paired Two Sample for Means

pH	*Inlet*	*Outlet*
Mean	9.175399422	7.70504
Variance	0.28799667	0.025357978
Observations	60	60
Pearson Correlation	-0.376156916	
Hypothesized Mean Difference	0	
Df	59	
t Stat	18.53347685	
P(T<=t) one-tail	1.4019E-26	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	2.8038E-26	
t Critical two-tail	2.000995378	

t-Test: Paired Two Sample for Means EC

EC	*Inlet*	*Outlet*
Mean	3817.14955	3062.1685
Variance	451697.9654	602554.7617
Observations	60	60
Pearson Correlation	0.566862394	
Hypothesized Mean Difference	0	
Df	59	
t Stat	8.596493673	
P(T<=t) one-tail	2.70237E-12	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	5.40475E-12	
t Critical two-tail	2.000995378	

t-Test: Paired Two Sample for Means color

Color	*Inlet*	*Outlet*
Mean	1261.993711	392.2047167
Variance	158783.024	31573.06745
Observations	60	60
Pearson Correlation	0.142068042	
Hypothesized Mean Difference	0	
df	59	
t Stat	16.32906363	
P(T<=t) one-tail	7.41183E-24	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	1.48237E-23	
t Critical two-tail	2.000995378	

t-Test: Paired Two Sample for Means turbidity

Turbidity	*Inlet*	*Outlet*
Mean	70.064395	4.075816667
Variance	575.5828219	2.380987168
Observations	60	60
Pearson Correlation	0.340477189	
Hypothesized Mean Difference	0	
df	59	
t Stat	21.74092484	
P(T<=t) one-tail	3.73289E-30	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	7.46578E-30	
t Critical two-tail	2.000995378	

t-Test: Paired Two Sample for Means TSS

TSS	*Inlet*	*Outlet*
Mean	137.2932233	21.51792333
Variance	1370.080246	34.7049929
Observations	60	60
Pearson Correlation	-0.103700714	
Hypothesized Mean Difference	0	
df	59	
t Stat	23.5508167	
P(T<=t) one-tail	5.38892E-32	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	1.07778E-31	
t Critical two-tail	2.000995378	

t-Test: Paired Two Sample for Means TDS

TDS	*Inlet*	*Outlet*
Mean	2483.448407	1991.9518
Variance	192899.1466	255909.296
Observations	60	60
Pearson Correlation	0.573096058	
Hypothesized Mean Difference	0	
df	59	
t Stat	8.640370898	
P(T<=t) one-tail	2.28097E-12	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	4.56193E-12	
t Critical two-tail	2.000995378	

t-Test: Paired Two Sample for Means

Total Alkalinity	*Inlet*	*Outlet*
Mean	488.5714286	119.4285714
Variance	578.6190476	223.6190476
Observations	7	7
Pearson Correlation	-0.566993421	
Hypothesized Mean Difference	0	
df	6	
t Stat	28.07534931	
P(T<=t) one-tail	6.7558E-08	
t Critical one-tail	1.943180281	
P(T<=t) two-tail	1.35116E-07	
t Critical two-tail	2.446911851	

t-Test: Paired Two Sample for Means Total hardnes

Total hardness	*Inlet*	*Outlet*
Mean	218.7142857	142.6142857
Variance	447.9047619	3063.441429
Observations	7	7
Pearson Correlation	0.056845876	
Hypothesized Mean Difference	0	
df	6	
t Stat	3.464119988	
P(T<=t) one-tail	0.006699832	
t Critical one-tail	1.943180281	
P(T<=t) two-tail	0.013399664	
t Critical two-tail	2.446911851	

t-Test: Paired Two Sample for Means COD

COD	*Inlet*	*Outlet*
Mean	1026.816667	186.6833333
Variance	125273.1692	12124.42345
Observations	60	60
Pearson Correlation	0.770052398	
Hypothesized Mean Difference	0	
Df	59	
t Stat	23.3949225	
P(T<=t) one-tail	7.68224E-32	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	1.53645E-31	
t Critical two-tail	2.000995378	

t-Test: Paired Two Sample for Means BOD

BOD	*Inlet*	*Outlet*
Mean	510.1	82.05
Variance	28401.65556	2627.802778
Observations	10	10
Pearson Correlation	-0.165025659	
Hypothesized Mean Difference	0	
df	9	
t Stat	7.353898907	
P(T<=t) one-tail	2.15468E-05	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	4.30936E-05	
t Critical two-tail	2.262157163	

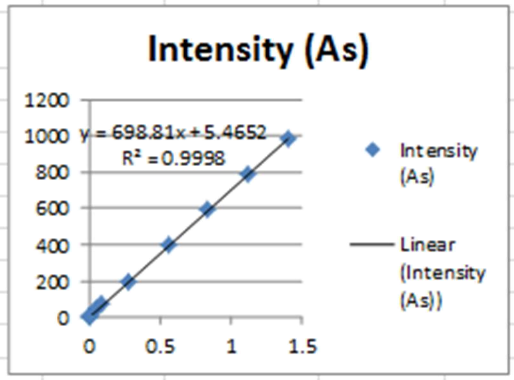
t-Test: Paired Two Sample for Means oil and grease

Oil & grease	*Inlet*	*Outlet*
Mean	2.841666667	0.236516667
Variance	0.745522599	0.027448051
Observations	60	60
Pearson Correlation	0.57300426	
Hypothesized Mean Difference	0	
Df	59	
t Stat	25.85754651	
P(T<=t) one-tail	3.51121E-34	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	7.02242E-34	
t Critical two-tail	2.000995378	

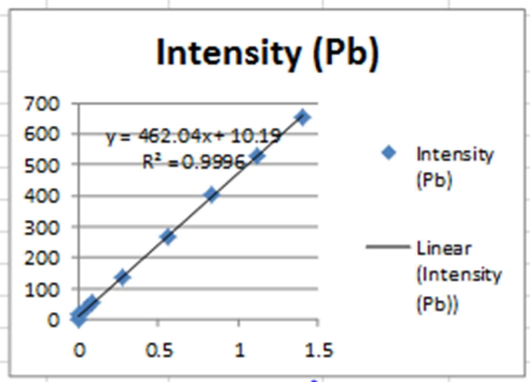
APPENDIX 2

Heavy metals Standard Concentration and intensity with their graph

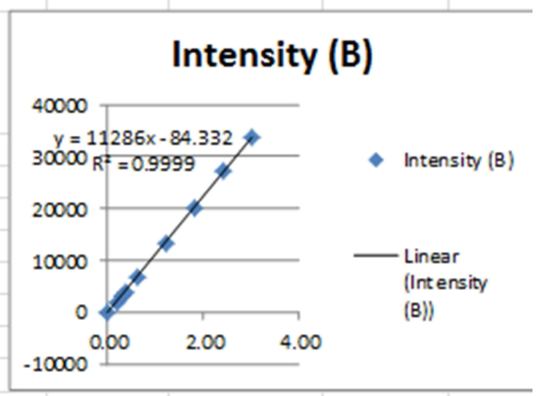
STD	Con/n (As) mg/l	Intensity (As)
STD 0	0	0
STD 1	0.007	14.404
STD 2	0.056	43.377
STD 3	0.084	72.825
STD 4	0.28	193.356
STD 5	0.56	395.091
STD 6	0.84	594.43
STD 7	1.12	792.793
STD 8	1.4	980.643



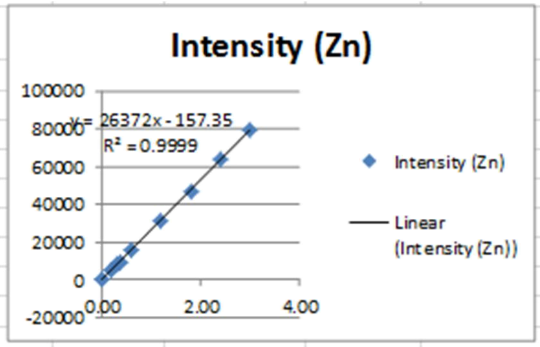
STD	Con/n (Pb) mg/l	Intensity (Pb)
STD 0	0	0
STD 1	0.007	16.865
STD 2	0.056	41.376
STD 3	0.084	54.129
STD 4	0.28	136.682
STD 5	0.56	265.552
STD 6	0.84	401.514
STD 7	1.12	527.116
STD 8	1.4	656.943



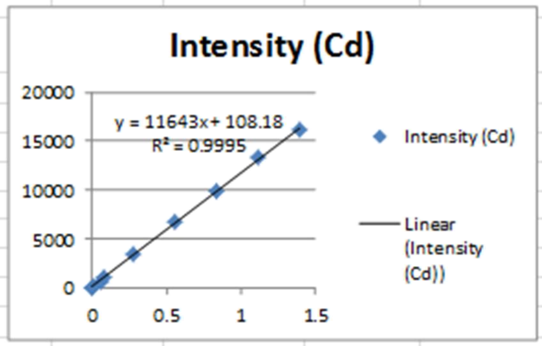
STD	Con/n (B) mg/l	Intensity (B)
STD 0	0.00	0
STD 1	0.18	1969.46
STD 2	0.30	3333.1
STD 3	0.36	3973.35
STD 4	0.60	6670.16
STD 5	1.20	13222.85
STD 6	1.80	20180.35
STD 7	2.40	27229.65
STD 8	3.00	33714.15



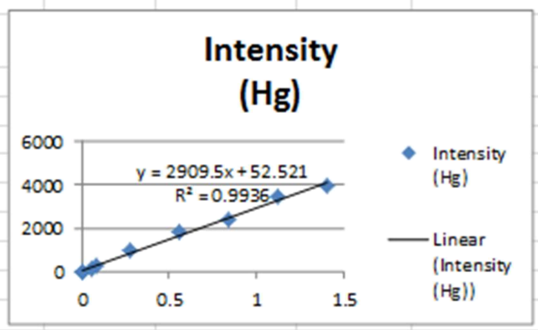
STD	Con/n (Zn) mg/l	Intensity (Zn)
STD 0	0.00	0
STD 1	0.18	4688.332
STD 2	0.30	8100.312
STD 3	0.36	9171.132
STD 4	0.60	15249.132
STD 5	1.20	31452.832
STD 6	1.80	47022.332
STD 7	2.40	63406.432
STD 8	3.00	78991.132



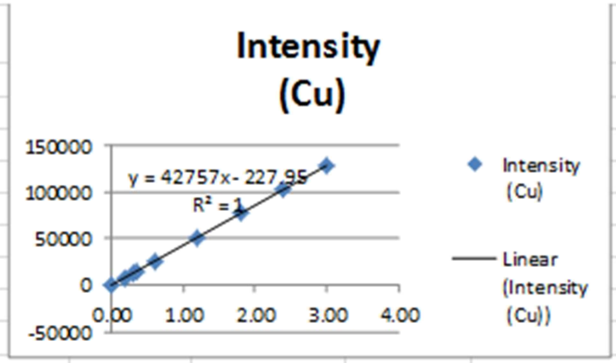
STD	Con/n (Cd)	Intensity (Cd)
STD 0	0	0
STD 1	0.007	124.719
STD 2	0.056	677.425
STD 3	0.084	1148.545
STD 4	0.28	3441.535
STD 5	0.56	6817.145
STD 6	0.84	9859.465
STD 7	1.12	13312.165
STD 8	1.4	16203.165



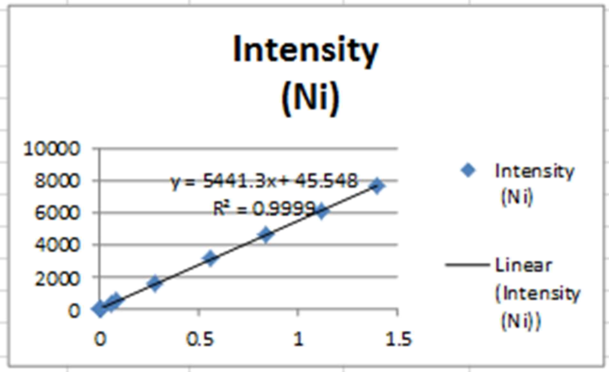
STD	Con/n (Hg)	Intensity (Hg)
STD 0	0	0
STD 1	0.007	20.27
STD 2	0.056	112.672
STD 3	0.084	265.748
STD 4	0.28	1026.36
STD 5	0.56	1856.26
STD 6	0.84	2432.296
STD 7	1.12	3443.546
STD 8	1.4	3962.936



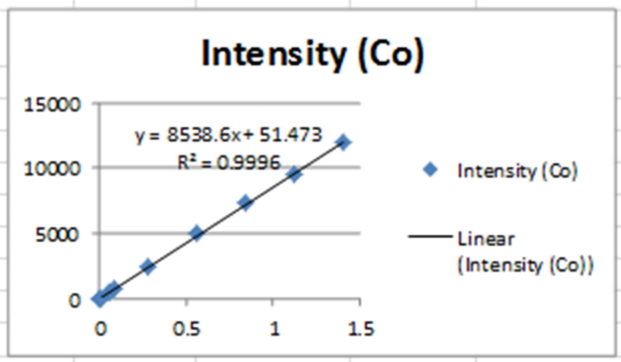
STD	Con/n (Cu)	Intensity (Cu)
STD 0	0.00	0
STD 1	0.18	7449
STD 2	0.30	12530.2
STD 3	0.36	14884.1
STD 4	0.60	25192.2
STD 5	1.20	51218.7
STD 6	1.80	77414.3
STD 7	2.40	102045.7
STD 8	3.00	127942.7



STD	Con/n (Ni)	Intensity (Ni)
STD 0	0	0
STD 1	0.007	62.77
STD 2	0.056	356.58
STD 3	0.084	530.71
STD 4	0.28	1584.51
STD 5	0.56	3126.98
STD 6	0.84	4620.24
STD 7	1.12	6136.18
STD 8	1.4	7645.08



STD	Con/n (Co) mg/l	Intensity (Co)
STD 0	0	0
STD 1	0.007	58.78
STD 2	0.056	492.09
STD 3	0.084	816.05
STD 4	0.28	2427.36
STD 5	0.56	4993.55
STD 6	0.84	7311.29
STD 7	1.12	9494.08
STD 8	1.4	11987.18



Appendix 3

Anova: Single Factor

SUMMARY

pH	*Count*	*Sum*	*Average*	*Variance*
Receiving	60	550.524	9.175399	0.287997
Equalization	60	508.4298	8.47383	0.118218

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.76599	1	14.76599	72.70038	5.88E-14	3.921478181
Within Groups	23.96668	118	0.203107			
Total	38.73267	119				

Anova: Single Factor

SUMMARY

pH	*Count*	*Sum*	*Average*	*Variance*
Equalization	60	508.4298	8.47383	0.118218
Primary clarifier	60	451.6561333	7.527602222	0.041345

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	26.86041022	1	26.86041022	336.6752	2.32E-36	3.921478
Within Groups	9.414202039	118	0.079781373			
Total	36.27461226	119				

Anova: Single Factor

SUMMARY

TSS	Count	Sum	Average	Variance
Receiving	60	8237.5934	137.2932233	1370.08
Primary Clarifier	60	2019.2034	33.65339	268.3283

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	322236.4516	1	322236.4516	393.353	2.23E-39	3.921478
Within Groups	96666.10422	118	819.204273			
Total	418902.5558	119				

Anova: Single Factor

SUMMARY

TSS	Count	Sum	Average	Variance
Primary Clarifier	60	2019.2034	33.65339	268.3283
CWST	60	1291.0754	21.51792333	34.70499

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4418.086537	1	4418.086537	29.15908	3.5E-07	3.921478
Within Groups	17878.96431	118	151.5166467			
Total	22297.05084	119				

Anova: Single Factor

SUMMARY

COD	Count	Sum	Average	Variance
Receiving	60	61609	1026.816667	125273.2
Primary Clarifier	60	40347	672.45	67066.59

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3767272.033	1	3767272.033	39.1731	6.47E-09	3.921478
Within Groups	11348045.83	118	96169.87994			
Total	15115317.8	119				

Anova: Single Factor

SUMMARY

COD	*Count*	*Sum*	*Average*	*Variance*
Secondary Clarifier	60	22607	376.783333	33450.47768
CWST	60	11201	186.683333	12124.42345

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1084140.3	1	1084140.3	47.57619976	2.8E-10	3.921478
Within Groups	2688919.17	118	22787.4506			
Total	3773059.47	119				

Anova: Single Factor

SUMMARY

BOD	*Count*	*Sum*	*Average*	*Variance*
Aeration	10	2108	210.8	14380.84
Secondary Clarifier	10	1628	162.8	8806.178

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11520	1	11520	0.993659	0.332062	4.413873
Within Groups	208683.2	18	11593.51111			
Total	220203.2	19				

SUMMARY

Oil & Grease	Count	Sum	Average	Variance
Receiving	60	170.5	2.841666667	0.745522599
Primary clarifier	60	34.96	0.582666667	0.104911412

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	153.09243	1	153.09243	360.0336486	1.2E-37	3.921478
Within Groups	50.17560667	118	0.425217006			
Total	203.2680367	119				

Anova: Single Factor

SUMMARY

COLOR	Count	Sum	Average	Variance
Receiving	60	75719.62267	1261.993711	158783.024
Primary Clarifier	60	54915.962	915.2660333	58555.52656

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3606602.476	1	3606602.476	33.18879662	6.79E-08	3.921478
Within Groups	12822974.48	118	108669.2753			
Total	16429576.96	119				

Anova: Single Factor						
SUMMARY						
Turbidity	*Count*	*Sum*	*Average*	*Variance*		
Primary clarifier 24.833	60	808.5256	13.70382373	74.1200287		
Secondary clarifier 3.3667	60	289.3111	4.903577966	3.263525418		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2284.607602	1	2284.607602	59.04633427	5.41361E-12	3.922879362
Within Groups	4488.246139	116	38.69177706			
Total	6772.853741	117				

Anova: Single Factor

SUMMARY

Turbidity	*Count*	*Sum*	*Average*	*Variance*
Secondary clarifier 3.3667	60	289.3111	4.903577966	3.263525418
CWST 3.5667	60	240.9823	4.084445763	2.417493964

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	19.7938382	1	19.79383822	6.968410732	0.00943717	3.92287936
Within Groups	329.499124	116	2.840509691			
Total	349.292962	117				

Appendix 4 Photographic Representation of laboratory work

a) Photographic representation while oil and grease analysis

b) COD reagent **c)** HACH Spectrophotometer (model DR 3900)