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Performance Analysis of Textile Industry Wastewater Treatment Plant with Physicochemical Characterizations

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Abstract

In Ethiopia the rules of Ministry of Environment factories wastewater must treat before discharge as well as monitor the quality of their wastewater and stay within national discharge quality standard. Even there is stick rule and regulation some time due to in proper management or lack of technical expertise characteristics of the effluent cross the dischargeable limit. The aim of research work is to examine the performance of effluent treatment of Textile Industry and study the physicochemical parameter.

Keywords: Characteristics; Effluent; Management; Treatment; Wastewater

1 Introduction

The rapid but unplanned growth of industrial clusters, with several factories discharging large amounts of untreated or poorly treated wastewater, has led to serious localized water pollution. As a result, water bodies and agricultural land are displaying reduced productivity and the biological diversity of these ecosystems is threatened. The result is not only environmental degradation but also a reduction in the nutrition and incomes of families that traditionally depended on these resources; and they are not always the same people who get benefit from the jobs created by the factories. One solution is to ensure that all the effluent is properly treated before it is discharged [5]. The quality effluent treatment plants can be analyzed by their physico-chemical and biological analysis. Monitoring of the environmental parameters of the effluent would allow having, at any time, a precise idea on performance evaluation of ETP and if necessary, appropriate measures may be undertaken to prevent adverse impact on environment. The efficiency of individual units of an effluent treatment plants determines the overall performance of the plant and the final effluent quality. Textile industry is a water intense industry consumes large quantities of water and thus produces large volume of wastewater during its manufacturing steps like dyeing, mercerizing, bleaching, and finish process [5]. The waste water generated from different sources is shown in Table .1.

Bahir Dar Textile Share Company is working as a supplier of 100% cotton products. It was established in 1961 by the Italian government as war compensation. The factory is integrated mill consisting of spinning, weaving, dying/finishing and garment sections, has easily access to the main cotton growing regions called Humera and Metema. It is found near abay river Bahir Dar, Ethiopia. Factories have its own treatment plant and expected to treat effluents physically, chemically, electrochemically and biologically. Unfortunately the treated water from discharge points of ETP may not, most of the parameters, meet the standards. It is well understood that without treatment toxic dyeing effluents are harmful to environment and unfortunately treated effluent is also detrimental as because ETPs if are not well performed one. The efficiency evaluation is very much useful in identification and rectification of the existing treatment. Therefore, this research will be identifying whether or operational, technical/analytical, or managerial problems and it can be also utilized to establish methods for improved textile industry and plant waste minimization strategies [author].

The main objective of research work is to evaluate the efficiency of the existing waste water treatment plant in terms of physicochemical parameters and identify the potential of each unit operation.

2 Materials and Methods

2.1 Materials

The study has been carried out for textile waste water treatment plant located in Bahir Dar near Abay River. About 400-480 m^3/d water is required for manufacturing process, and the total generation of waste water from the textile process is about 360-400 m^3/d.

2.2 Description and plant process sequence

Basically, treatment plants have three methods, physical, chemical and biological; each may or may not contain three stages. These are primary treatment, secondary treatment and tertiary treatment [6]. Bahir Dar textile waste water

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treatment plant designed value, and model flow diagram of the plant shown in Fig. 1 and 2.

2.3 Sampling station

It was decide to collect the sample from four location raw influent, aeration tank, primary clarifier and finial discharge. The sample locations are mention on Table 2

Table.1: Effluent Characteristics from Textile Industry [4]

Process	Effluent composition	Nature
Sizing	Starch, waxes, carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA), wetting agents.	High in BOD,COD
Desizing	Starch, CMC, PVA, fats, waxes, pectins	High in BOD, COD, SS,DS
Bleaching	Sodium hypochlorite, Cl_2, phosphate, NaOH, H_2O_2, acids, sudfacts,$NaSiO_3$, short cotton fiber	High alkalinity ,high SS
Mercerizing	Sodium hydroxide, cotton wax	High pH, low BOD,TDS,
Dyeing	Dyestuffs urea, reducing agents, oxidizing agents, acetic acid, detergents, wetting agents.	Strongly colored, high BOD, TDS, low SS, heavy metals
Printing	Pastes,urea,starches,gums,oils,binders,acids,Thickeners,cross-linkers, reducing agents, alkali	Highly colored, high BOD, oily appearance, SS slightly alkaline, low BOD

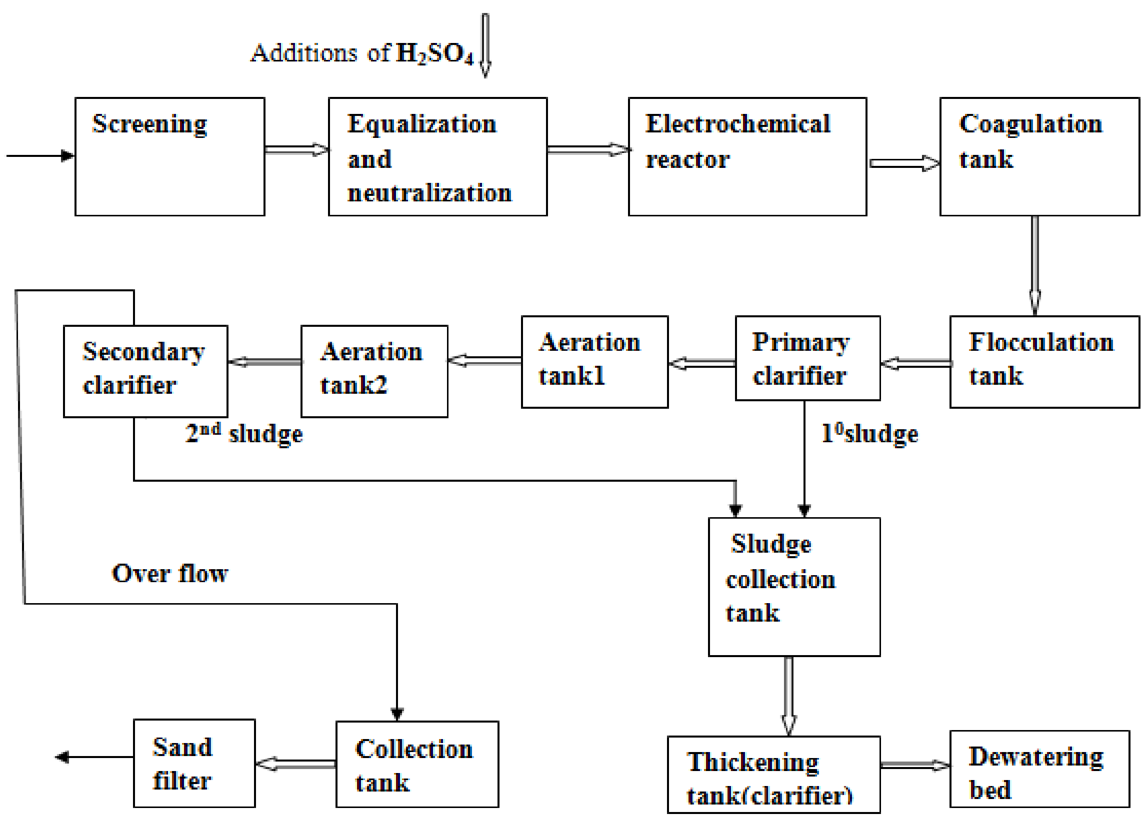

Fig. 1: Designed value Flow diagram of Bahir Dar textile waste water treatment plant [from plant]

Table 2: List of sampling location and objective of the sampling

Sampling unit	**Location of samples**	**Objective**
1	Raw Influent	To find out the effluent (untreated) water characteristics (before neutralization and equalization tank)
2	Aeration tank	To analyze the performance of Biological Reactor
3	Primary clarifier	To analyze the performance of Coagulation and Flocculation units
4	Final discharge (treated water)	To analyze the performance of secondary clarifier, and Sand Filter. Also to check whether the discharge water can meet the discharge standard or not.

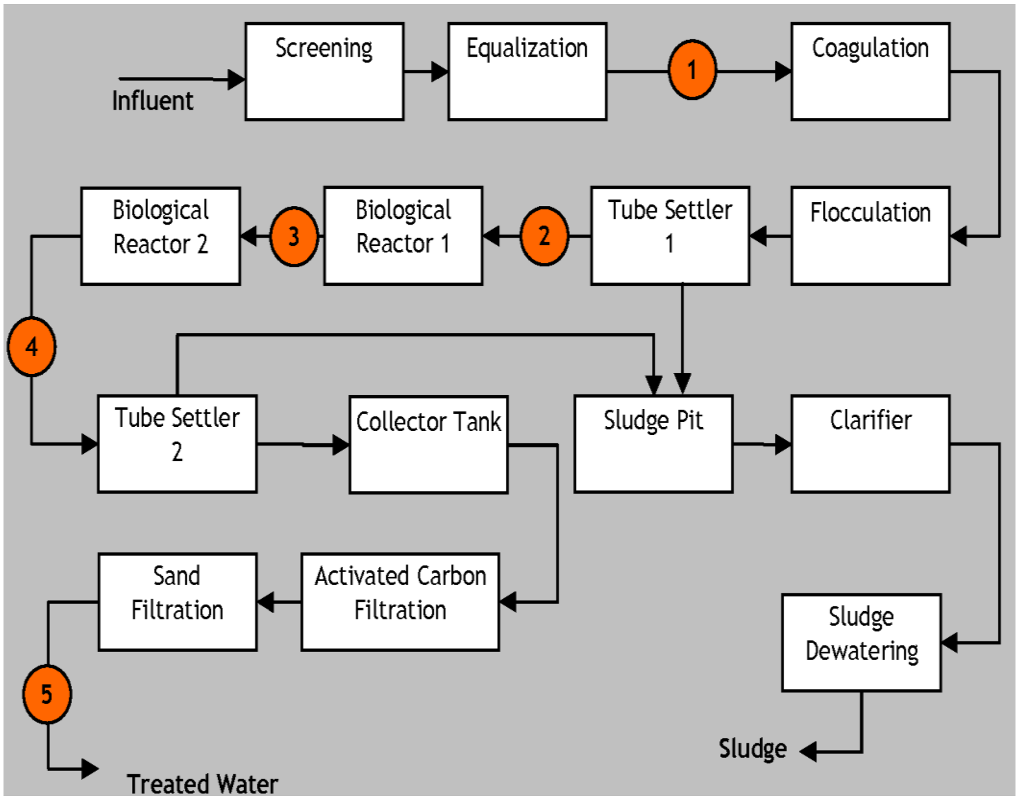

Fig. 2: Conventional commonly accepted model textile waste water treatment plant [3]

2.4 Preservation

Samples were collected in a plastic bottle, before collecting it was thoroughly cleaned with hydrochloric acid and washed with tap water to render free of acid. Until the analysis was over samples were preserved below 4°C [4].

2.5 Requirements

All the glassware, burette and pipettes were first cleaned with tap water thoroughly and finally with deionized water. The chemicals and reagents were used for analysis were analytical reagent grade. The procedure for analysis or calculating the different parameters were conducted in the laboratory [4].

2.6 Physico-chemical and biological analysis

The collected samples were analyzed for pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD).

I. **pH**: pH of the samples was determined using pH meter which has been initially standardized by using buffer solutions of known value before analysis.

II. **Total suspended solids (TSS):** Total suspended solids consist of silt, clay, fine particles of organic and inorganic matter. TSS was determined by filtering a known amount of sample through a pre-weighed filter paper. The filter paper will then dry at 103 - 105°C.

III. **Total Dissolved Solids (TDS):** The dissolved organic and inorganic matter will be determined. TDS was determined by using DDBJ-350 multifunctional conductivity meter.

IV. **Biochemical oxygen demand (BOD5):** Biochemical oxygen demand was determined by using BOD incubation method based on the initial and final DO value with OXI 45^+ DO meter [9].

$$BOD_n = \frac{V_{total}}{V_s} \cdot \left[BOD_{total} - \left(\frac{V_{total} - V_s}{V_{total}} \cdot BOD_{DW} \right) \right]$$

where BOD: Biochemical Oxygen Demand of the sample after n days [mg/l O], n: test duration in days (commonly5days), V_{total}: Total volume, consists of volume of sample water and volume of dilution water, Vs: Volume of sample water, BOD_{total}: Biochemical Oxygen Demand of the sample consists of sample water and dilution water, after n days, BOD_{dw}: Biochemical Oxygen Demand of the dilution water after n days.

V. **Chemical oxygen demand (COD):** The COD were determined by dichromate oxidation. Organic matter gets oxidized completely by potassium dichromate in the presence sulfuric acid solution at reflux temperature in the COD digester, Silver sulfate and mercury sulphate to produce CO2 and H2O. The was refluxed with a known amount of potassium dichromate in the sulfuric acid medium and The excess dichromate was titrated with standard ferrous ammonium sulfate, using ferroin as an indicator. The dichromate consumed by the sample is equivalent to the amount of O2 required to oxidize the organic matter [9].

$$COD\ (mg\ O_2\ /L) = \frac{[(A-B) \times M \times 8000))]}{V_{samlpe}}$$

.A = volume of FAS used for blank (mL)
B = volume of FAS used for sample (mL)
M = molarity of FAS
8000 = milli equivalent weight of oxygen (8) ×1000 mL/L.

3 Result and Discussion

3.1 Physicochemical wastewater treatment

Wastewater treatment is a mixture of unit processes, some physical, others chemical or biological in their action. A conventional treatment process is comprised of a series of individual unit processes, with the output (or effluent) of one process becoming the input (influent) of the next process. The first stage will usually be made up of physical processes. Physicochemical wastewater treatment has been widely used in the WW treatment plant which has a high removal of colloidal and suspended substances, while it has a low removal of COD [8].

3.1.1 Screening

This is adopted in WW treatment plant to remove relatively large solid wastes. Screens are very simple materials having iron bars in the form of square grids. Effluent is allowed to pass through the grid when large and coarse solid materials are arrested by it allowing smaller particles and effluent to pass through. In some several grids are use with diminishing grid sizes. Coarse suspended matters such as rags, pieces of fabric, fibers, yarns and lint are removed. Bar screens and mechanically cleaned fine screens remove most of the fiber [4].

3.1.2 Equalization and neutralization tank

Equalization tank is a large chamber having hydraulic retention time is generally about 12 hour. This means if the rate effluent is 30 cubic meter then the capacity of the equalization tank has to be 30 X 12 = 360 cubic meters. The equalization tank is specially built where air is blown around the clock on continuous basis. The purposes of equalization tank are [7]

(i) To supply oxygen so that DO level increases
(ii) To mix various type of effluents (homogenizations)
(iii) To reduce the temperature of the water.

Because of water highly polluted and quantity fluctuations, complex components, textile dyeing wastewater is generally required homogenization to ensure the treatment effect and stable operation [6]. In the Meantime to prevent the lint, cotton seed shell, and the slurry Settle to the bottom of the tank, it's usually mixed the wastewater with air or mechanical mixing equipment in the tank [8].The tank is then taken to the pH correction (neutralization) tank; where 98% H_2SO_4 acid is dosed for neutralizing the pH value around 6.5 to 8.5. It may be mentioned that different dyed effluent may generate different pH level. The pH correction tank is designed for hydraulic retention time of around 1 -2 minutes and is provided with slow speed agitator for thoroughly mixing of waste with acid to maintained pH value. Since most of the secondary biological treatments are effective in the pH 6.5 to 8, neutralization step is an important process [6].

3.1.3 Electrochemical reactor

The mechanism of the electrochemical process treating dyeing wastewater is making use of electrolytic oxidation, electrolytic reduction, and electro-coagulation destruct the structure or the existence state to make it bleached. It has the advantages of operation and management easily, higher COD removal rate and good bleaching effect, but the precipitation (iron containing sludge) and the consumption of electrode material is great, and the operating cost is high [13].

To remove dyeing wastewater, the most serious environmental problem, with biological methods cannot be effective to remove COD since many kinds of dyes have been developed showing resistance to biological decomposition (it is non-biodegradable). Thus this electrochemical reactor can degrade those which are non-degradable colored materials. As a result, the effluent becomes suitable for the next unit process (biological treatment and coagulation process) as well as can reduces the COD value [13].

3.1.4 Coagulation flocculation

Coagulation flocculation process is one of the most used methods, especially in the conventional treatment process. Active on suspended matter, colloidal type of very small size, their electrical charge give repulsion and prevent their aggregation. Adding in water electrolytic products such as aluminum sulphate, ferric sulphate, ferric chloride, giving hydrolysable metallic ions or organic hydrolysable polymers (polyelectrolyte) can eliminate the surface electrical charges of the colloids. Normally the colloids bring negative charges so the coagulants are usually inorganic or organic cationic coagulants (with positive charge in water) [14].

The metallic hydroxides and the organic polymers, besides giving the coagulation, can help the particle aggregation into flocs, thereby increasing the sedimentation [14].Finely divided suspended solids and colloidal particles cannot be efficiently removed by simple sedimentation by gravity. In such cases, mechanical flocculation or chemical coagulation is employed. In mechanical flocculation, the textile waste water is passed through a tank under gentle stirring; the finely divided suspended solids join together into larger particles and settle out. The degree of clarification obtained also depends on the quantity and quality of chemicals used. In this method, 80-90% of the total suspended matter, 40-70% of BOD, 5days, 30-60% of the COD and 80-90% of the bacteria can be removed. However, in simple sedimentation, only 50-70% of the total suspended matter and 30-40% of the organic matter settles out [11].

3.1.5 Sedimentation

Primary clarifier: From the flocculation tank the effluent is taken to the Primary Settling tank where the dyes and suspended particles are precipitated. The flocs formed are settled in the downstream Primary Settler by the help of tube settler media with gravity [7].The suspended matter in textile effluent can be removed efficiently and economically by sedimentation. This process is particularly useful for treatment of wastes containing high percentage of settable solids or when the waste is subjected to combined treatment with sewage. The sedimentation tanks are designed to enable smaller and lighter particles to settle under gravity. The most common equipment used includes horizontal flow sedimentation tanks and centre-feed circular clarifiers.

Finally the effluent is further flow by overflow system to the secondary settler tank where as the sludge is flow by downstream to the sludge outlet tank [8].

Secondary clarifier: From the primary settling tank the effluent taken to the secondary settling tank where the remaining suspended and colloidal particles are settled. The precipitates are settled in the downstream secondary settler with gravity. The effluent is flow by the overflow system to the sand filter where as the sludge is flow by downstream to the sludge outlet tank [3].

3.2 Biological wastewater treatment

The biological process removes dissolved matter in a way similar to the self-depuration but in a further and more efficient way than physico-chemical methods. The removal efficiency depends upon the ratio between organic load and the biomass present in the oxidation tank, its temperature, and oxygen concentration [10].The biomass concentration can increase by aeration but it is important not to reach a mixing energy that can destroy the flocs, because it can inhibit the following settling. Normally, the biomass concentration ranges between 2500-4500 mg/l, oxygen about 2 mg/l. With aeration time 24 hours the oxygen demand can be reduced to 99%.According to the different oxygen demand, biological treatment methods can be divided into aerobic and anaerobic treatment. Because of high efficiency and wide application of the aerobic biological treatment, it naturally becomes the mainstream of biological treatment. Bahir Dar textile waste water treatment plant is designed as aerobic biological treatment system, namely activated sludge process [15].

3.2.1 Aerobic biological treatment

According to the oxygen requirements of the different bacteria, the bacteria can be divided into aerobic bacteria, anaerobic bacteria and facultative bacteria. Aerobic biological treatment can purify the wastewater with the help of aerobic bacteria and facultative bacteria in the aerobic environment. Aerobic biological treatment can be divided into two major categories: activated sludge process and biofilm process [15].

Activated sludge process: Activated sludge is a kind of floc which is mainly comprised of many microorganisms, which has strong decomposition and adsorption of the organics, so it is called “activated sludge” [15].This is the most versatile biological oxidation method employed for the treatment of waste water containing dissolved solids, colloids and coarse solid organic matter. In this process, the waste water is aerated in a reaction tank in which some microbial floc is suspended. The aerobic bacterial flora bring about biological degradation of the waste into carbon dioxide and water molecule, while consuming some organic matter for synthesizing bacteria. The bacteria grow and remains suspended in the form of a floc, which is called “Activated Sludge”. The effluent from the reaction tank is separated from the sludge by settling and discharged. A part of the sludge is recycled to the same tank to provide an effective microbial population for a fresh treatment cycle. The surplus sludge is digested in a sludge digester, along with the primary sludge obtained from primary sedimentation. An efficient aeration for 5 to 24 hours is required for industrial wastes. BOD removal to the extent of 90-95% can be achieved in this process [10].

Biofilm process: The biofilm process is a kind of biological treatment that making the numerous microorganisms to attach to some fixed object surface, while letting the wastewater flow on its surface to purify it by contact. The main types of the biofilm process are biological contact oxidation, rotating biological contractors and trickling filter [15].

3.2.2 Anaerobic biological treatment

Anaerobic biological treatment process is methods that make use of the anaerobic bacteria decompose organic matter in anaerobic conditions. This method was first used for sludge digestion. In recent years it is gradually used in high concentration and low concentration organic wastewater treatment. In textile industry, there are many types of high concentration organic wastewater, such as wool washing sewage, textile printing and dyeing wastewater etc., which the organic matter content of it is as high as 1000 mg/L or more, the anaerobic wastewater treatment process can achieve good results. The anaerobic aerobic treatment process is usually adopted in actual project that is using anaerobic treatment to treat high concentration wastewater, and using aerobic treatment to treat low concentration wastewater [15].

Through making use of the anaerobic bacteria and facultative bacteria, the macromolecule, heterocyclic organic matter and other difficult biodegradable organic matter would be decomposed into small molecular organic matter, thereby enhancing the biodegradability of the wastewater and destructing the colored groups of dye molecules to remove part of the color in wastewater. More importantly, due to the molecular structure of the organic matter and colored material or the chromophore has been changed by the anaerobic bacteria, it's easy to decompose and decolor under the aerobic conditions, which improve the decolorization effect of the sewage. Currently, the anaerobic digestion process is an essential measure in the biological treatment of textile dyeing wastewater. In addition, there are many other processes used in textile dyeing wastewater treatment, such as upflow anaerobic sludge bed(UASB), upflow anaerobic fluidized bed (UABF), anaerobic baffled reactor (ABR) and anaerobic biological filter and so on [15].

3.3 Examine of physicochemical parameters in different sampling station

The physiochemical characteristic of sample collected from each station is shown in Fig.3.1 and removal efficiency is shown in Fig 3.2. The maximum TDS is 5012 mg/L in raw effluent (S1) followed by TSS 5996 mg /L ,COD 2838 mg/L ,BOD 476 mg/L. The reduction values of all parameters are observed in final effluent (S4).The maximum reduction 95.48% is observed in TSS followed by COD, BOD and then TDS which is 87.03 %, 78.36 % and 41.56 % respectively [12].It is observed from the Table 2 that primary clarifier having more reduction of TSS, but BOD in aeration tank. The industry had moderate removal efficiency in all parameter as expected from sampling location. The performance evaluation of textile industry found that BOD, COD and TSS reduced significantly whereas TDS reduction is very small.

pH: At the inflow, the pH is outside the limits required for bacterial growth (from aeration tank) which are between pH 4.0 and 9.5 with an optimal range of pH 6.5 - 7.5 [7]. Therefore, the desired pH will be reached after the neutralization from the equalization tank. Therefore, the value is 7.4 at the aeration tank have positive impact for biological activity.

TDS: The TDS value is somehow high and remained throughout the process. The weekly sampling and their two month average value decrease throughout the system except the primary clarifier (increase by 37.06%). This is due to the dissolved coagulants from the coagulation process. As a result the TDS value in the treated water is reduced to 41.56% from the standard value which is 2100mg/l [12].

BOD and COD: The trends observed for BOD and COD had sequential reduction. A significant reduction is observed in both parameters from the inflow to the outflow. But, specifically a high reduction of BOD was at the aeration tank and COD at the electrochemical process. However, the effluent quality still did not meet the standards of 50 mg/l for BOD and 200mg/l for COD.

A typical ETP consisting of physico-chemical and biological units can remove 90 percent or more of the BOD or COD present in the initial influent, when the ETP is operated efficiently [3]. After a series of treatment this ETP removed approximately 78.36 percent of the BOD load and 87.03 percent of the COD load which moderately good enough to the national and international standards [9].The overall performance of the ETP needs some improvement to meet exactly the national discharge quality standards and therefore requires immediate interventions to address the problems. Many of these may be management rather than structural and therefore not require any significant financial outlay by the factory, in fact better management of the plant could actually reduce costs. Total dissolved solids are a particular problem for textile dyeing industries because a large quantity of salt is required in the process, all of which is disposed of with the final effluent in addition to excess coagulants effects [6]. It would be expected that the equalization tank would lessen the variation, which suggests that the equalization tank may not be of sufficient capacity or have a long enough retention time. The TDS values also increased at some stages of the treatment process. These increases appear to be associated with chemical dosing to the treatment plant (in this case possibly coagulants in coagulation treatment unit) which implies that the ETP operator is adding excessive quantities of this chemicals [8]. It may be necessary to ensure that the biological reactors are adequately aerated and that the correct nutrient composition is being added to "feed" the bacteria, as textile effluent contains very little of the nutrients, including nitrogen and phosphorus, required fora healthy and active bacterial population.

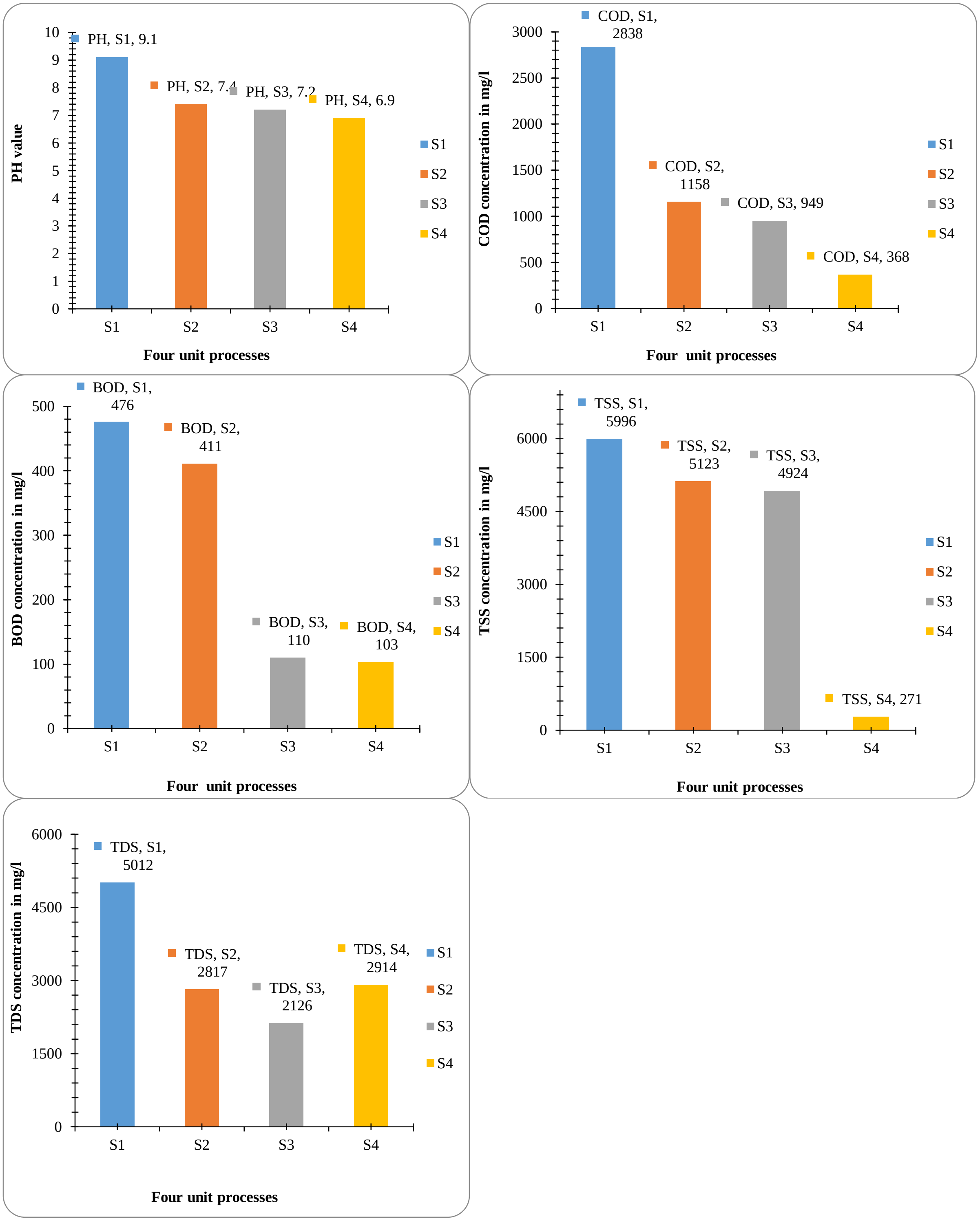

Fig 3.1 Characteristics pattern of PH, COD, BOD, TSS, TDS at different unit of ETP

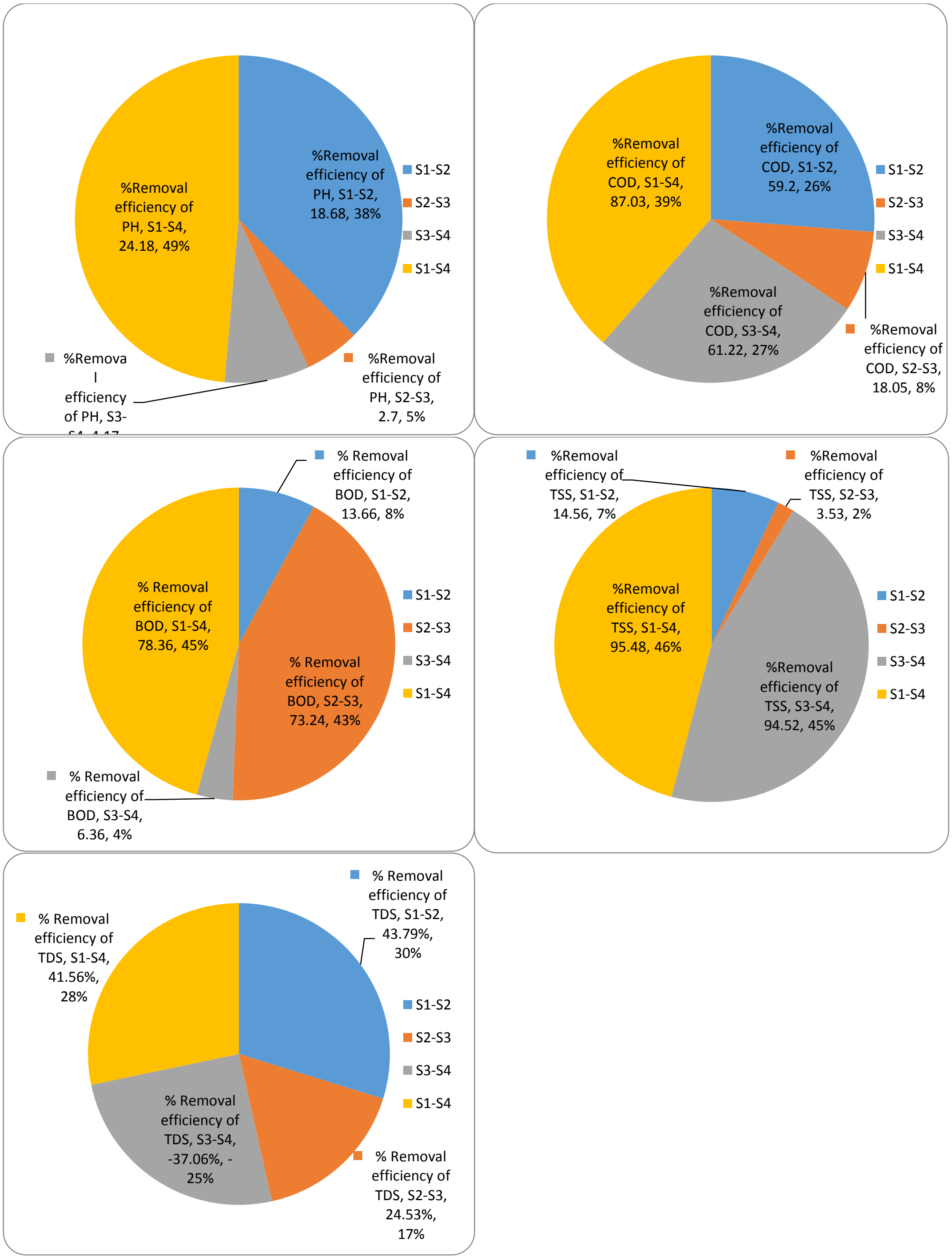

Figure 3.2 Percent removal efficiency of PH, COD.BOD, TSS and TDS at the four unit processes respectively

4 Conclusions

This study shows that through the process of simple monitoring of key parameters at strategic places in the treatment plant, the ETP manager would be able to optimize the treatment process further and potentially save money by reducing the chemicals and energy needed to run the system.

The main problems experienced by factories with ETPs are inadequate treatment due to incorrect dosing of chemicals required in the treatment process and inactivity and even death of necessary micro-organisms, due to insufficient oxygen or lack of nutrients. This is one of the difficulties for somehow below the standard discharge quality of the final effluent.

Based on the results obtained from this study, the following points are concluded: At present, effluent treatment plants of textile industry have moderate performances. The main reasons for plant failure are:

- Overloading to the existing treatment plant's capacity.
- Lack of skill for operation and maintenance for ETPs.
- The operating conditions are different from designed values.
- Lack of adequate equalization tank leads to fluctuations in quantities and quality of effluent in various treatment units of ETP, due to which the treatment unit may not perform as desired.

ETPs should regularly monitor the units in the plant where chemical dosing takes place so that they know their waste and can be more accurate in their dosing of chemicals. Further study should be taken on the nitrate, ammonium, and heavy metal content of the treated effluent to assure the performance of the ETP.

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