Wastewater Management Study for a Textile Processing Industry

Dissertation submitted in partial fulfillment of the requirement

for the award of the degree of

Master of Technology

in

Environmental Science & Technology

Submitted By:

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July 2013

CERTIFICATE

This is certified that the thesis entitled "**Wastewater Management Study for a Textile Processing Industry**" is an authentic record of my own work carried out as requirements for the award of the degree of M. Tech. (Environmental Science & Technology) at Thapar University, Patiala, under the guidance of **Dr. A. S. Reddy** (Associate Professor, SEE) during July 2012 to July 2013.

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DECLARATION

I hereby declare that the work presented in this dissertation entitled "**Wastewater Management Study for a Textile Processing Industry**" in partial fulfillment of requirement for the award of the **Master degree in Environmental science and technology** in the School of Energy And Environment, Thapar University, Patiala, on July 2013, is an authentic record of my own work carried out by me, under the guidance of Dr. A.S. Reddy, Head Of the Department, School of Energy And Environment , Thapar University, Patiala.

The matter embodied in this report has not been submitted in any other university or institute for the award of any degree.

(Arshdeep Kaur)

Date:

Place:

This is to certify that above declaration made by student concerned is correct to the best of my knowledge & belief.

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ABSTRACT

Textile processing is both water and energy intensive process. Core activities and support activities of the textile industrial unit involves the use water as process water and cooling water in large quantities with subsequent generation of large amount of wastewater. The effluents resulting from these processes differ greatly in composition, due to differences in processes, used fabrics and machinery. It is essential that control measures be implemented to minimize waste generation. Our study involved the development of wastewater management system for a textile industrial unit. This unit dealing with polyester and cotton dyeing and fabric washing. The industrial unit was surveyed for environmental analysis to identify the water consuming and wastewater generations activities, for the adequacy and capacity assessment of the effluent treatment plant. Measures for water conservation and waste minimization through source reduction/ recycling and reuse and for treatment of wastewater that are cost effective and compliance with the standards have been developed. Results shows that with implementing measures for source reduction, reuse and recycle at all feasible places have reduced water consumption, wastewater generation and steam consumption in the industrial unit.

Key words: Textile Waste water, Wastewater treatment, Wastewater management.

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CHAPTER 1

INTRODUCTION

'Save the Earth to save the future'. Right from the inception of urbanization and industrialization, it was gradually realized that growth cannot be considered to be a good thing if we ignore the environment in which we live. The textile chemical processing industry has importance of its own, being one of the basic needs of society and currently it is in the midst of a major restructuring and consolidation phase with the emphasis on product innovation, rebuilding and environmental friendliness. The textile industry has a major impact not only on the nation's economy but also on the economic and environmental quality of life in many communities.

The textile industry is one of the most complicated industries among manufacturing industries. Textile processing is both water and energy intensive process comprises pre-treatment, dyeing, printing and finishing operations. A detailed study of the textile processes will reveal that there are many complicated processes and series of steps in the industry. These processes involves the addition of water, chemicals, and dyes, heating to facilitate process reactions, cooling & washing, draining out the liquid and proceeding with the next step of processing . Textile dyeing industry consumes large quantities of energy and water and produces large volume of wastewater from different steps in the dyeing and finishing processes. Wasteful use of water, immense heating and cooling requirements, generation of immense quantities of wastewater has also been the problems associated with the textile processing industry. Small scale batch operations are also contributing to the problems being faced.

Effluents from the dyeing and finishing operations contains various chemical pollutants such as sizing agents, wetting agents, dyes, pigments, softening agents, stiffening agents, fluorocarbon, surfactants, oils, wax and many other additives which are used throughout the processes. These pollutants contributes to high suspended solids (SS), high dissolved solids, chemical oxygen demand (COD), biochemical oxygen demand (BOD), heat, color, acidity, alkalinity and other soluble substances.

Among all the effluents of textile processing, cotton textile dye bath dumps are the most polluted due to very rich in dyes and salt concentration (sodium sulfate or sodium chloride) is very high (2-8% salts in the dye bath). Untreated wastewater on disposal pollutes both surface and ground water resources and land if applied on land. Technologies are available for the textile wastewaters treatment proves very costly when used at the plant level for the total effluent and potential for water conservation through treated effluent recycling and reuse is relatively low.

Therefore waste management of wastewater becomes more & more necessary for water conservation and waste minimization. Source reduction of volume and strength of wastewater, recycling and reuse of wastewater, minimize the use of water and avoid the cost associated with its treatment are the approaches followed in wastewater management. Hierarchical order is important in wastewater management. Importance is given to wastewater generation, segregation of wastewater, pre-treatment and recycling and reuse to minimize wastewater generation, treatment and disposal of unavoidable wastewaters

Source reduction involves alternating input materials and process modifications eliminates wastewater generation and reduces the volume and strength of wastewaters. Wastewater generated from a process can be useful resource for some other process. Wastewater can be segregated and mixed with other water to enhance the reuse and recycling of wastewater and enhance treatability of the effluent.

Dye bath dumps waste streams can be segregated into two streams low level TDS and high level TDS. If segregated the low TDS wastewater can be easily treated and mostly reused in the processing. The high TDS water mostly generated in the cotton textile dye bath dumps is difficult to handle and management because of the residual dyes, high sodium sulphate/chlorides and BOD/COD.

Pretreatment is required to mix with other wastewater for further treatment and disposal. Wastewater pre-treatment and treatment removes undesirable contaminants and alters the quality to enhance recycling and reuse potential of wastewater, it can transform some of the containments of the wastewater into useful resources.

In the present study, wastewater management in the textile industry dealing with cotton, polyester dyeing has been planned wherein extra emphasis was given on waste minimization through source reduction and through recycling and reuse of wastes. Wastewater minimization and wastewater treatment with consistent and cost-effective compliance with the applicable effluent standards have been focused. In this study, a site visit was performed to investigating the processes of industries (core processes and support activities), and environmental concerns, to understand the points of wastewater generation and water consumption. Present waste water management practices of the industrial unit have been identified in the selected industry. Proposed wastewater management system was developed by suggesting the strategies for water reduction and wastewater generation and cost effective and consistent in compliance with prescribed standards.

1.2 Objectives of the study

1. To identify the environmental concerns in the textile industry

2. To suggest strategies for the wastewater management

1.3 Contents of the Thesis:

This M.Tech dissertation includes five chapters:

Chapter 1 is the introduction. It deals with objectives of the study. Overview of the report is also included in this chapter. Chapter 2 is the literature review**.** Review of literature has been carried out on Textile industry and processing, wastewater of textile industry, Treatment and disposal of textile industry, wastewater management of textile industry. Chapter 3 includes methodology for the present work. It includes the work involved carried out to achieve the objectives. Chapter 4 deals with results and discussion. Present and proposed wastewater management system have been summarized into this section. Chapter 5 The final chapter includes the overall findings of the study

CHAPTER 2
LITERATURE REVIEW

Review of literature has been carried out on following aspects for textile wastewaters:

1. Overview of textile industry and processes
2. Wastewater generation from textile industry
3. Treatment and disposal of textile wastewater
4. Wastewaster management of textile industry

2.1 Textile industry

Textile industries are one of most complicated manufacturing industries because of its fragmented and heterogeneous character. The textile industry uses a large quantity of chemicals, water and produces large volumes of wastewater from different processes occurs in textile industries.

Textile industry can be classified into three categories viz., cotton, woolen, and synthetic fibers (polyester, acrylics) depending upon the used raw materials. Cotton, which is the world's most widely used fiber, is also the substrate that requires the most water in its processing. The dyeing of one kilogram of cotton with reactive dyes demands 70 to 150 L water, 0.6 to 0.8 kg NaCl and anywhere from 30 to 60 g dyestuff **(Allegre, *et al*. 2006).**

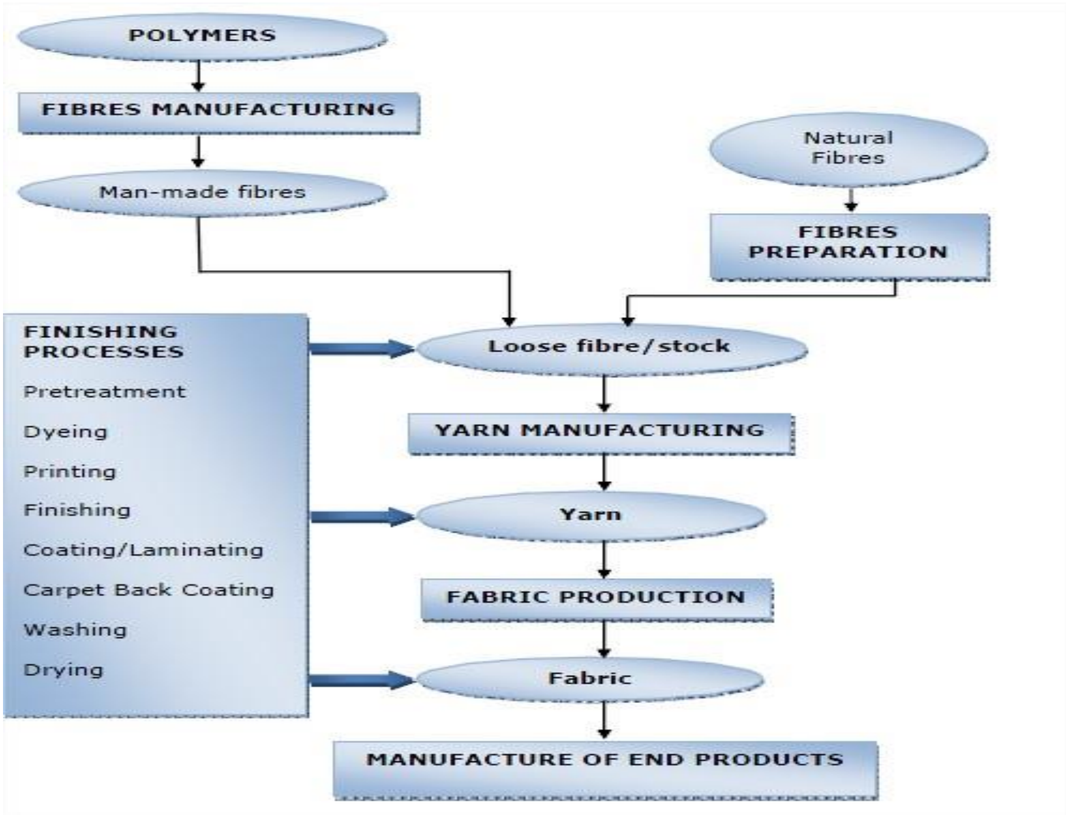
The textile industry consists of a number of processes employed for converting fibers of natural origin such as cotton, silk and wool, and of synthetic origin such as nylon; first into fabrics by weaving and knitting and then into the final products by applying wet processes. Fabric preparation includes Scouring, desizing, mercerizing, bleaching, and singeing, heat setting, etc. Dyeing, printing (Print paste preparation, printing, print fixing and drying, print washing, finishing (mechanical finishing chemical finishing) are the core activities of the industry.

Supporting activities and processes for wet processes includes Water pumping, storage and supply system, Soft water plant or RO water plant or DM water plant, Boiler and steam distribution system, Thermo Pac boiler and thermic fluid circulation system, Amenities (drinking water closets, wash basins and toilets), Electrical power system, DG sets Compressed air and instrumental air system are the supporting activities and processes also consumes water and require energy and generates wastewater have main impact on the environment.

Wastewater from printing and dyeing units is often rich in color, containing residues of reactive dyes and chemicals, such as complex components, many aerosols, various waste chemical pollutants such as sizing agents, wetting agents, complexing agents, dyes, pigments, softening agents, stiffening agents, fluorocarbon, surfactants, oils, wax and many other additives which are used throughout the processes. These pollutants contributes to high suspended solids (SS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), heat, color, acidity, alkalinity and other soluble substances.

Textile industries typically generate 200-500 L of wastewater per kg of finished product **(Marcucci, *et al.* 2001)**. Textile processing industries find treatment of its wastewaters in compliance with the applicable discharge standards, quite difficult and costly. Treatment especially for TDS removal and colour has become a major challenge to the industry. End of pipe treatment is widely used to overcome the pollution problem in textile industry for waste managment. This approach has not been very successful. Wastewater generation rate continues to remain high. Adopting an integrated multimedia approach for waste management though felt very essential has been rarely adopted in order to reduce water consumption.

Figure 1: Layout of processes in the textile industry is shown on next page:



Source: European Commission. (2003)

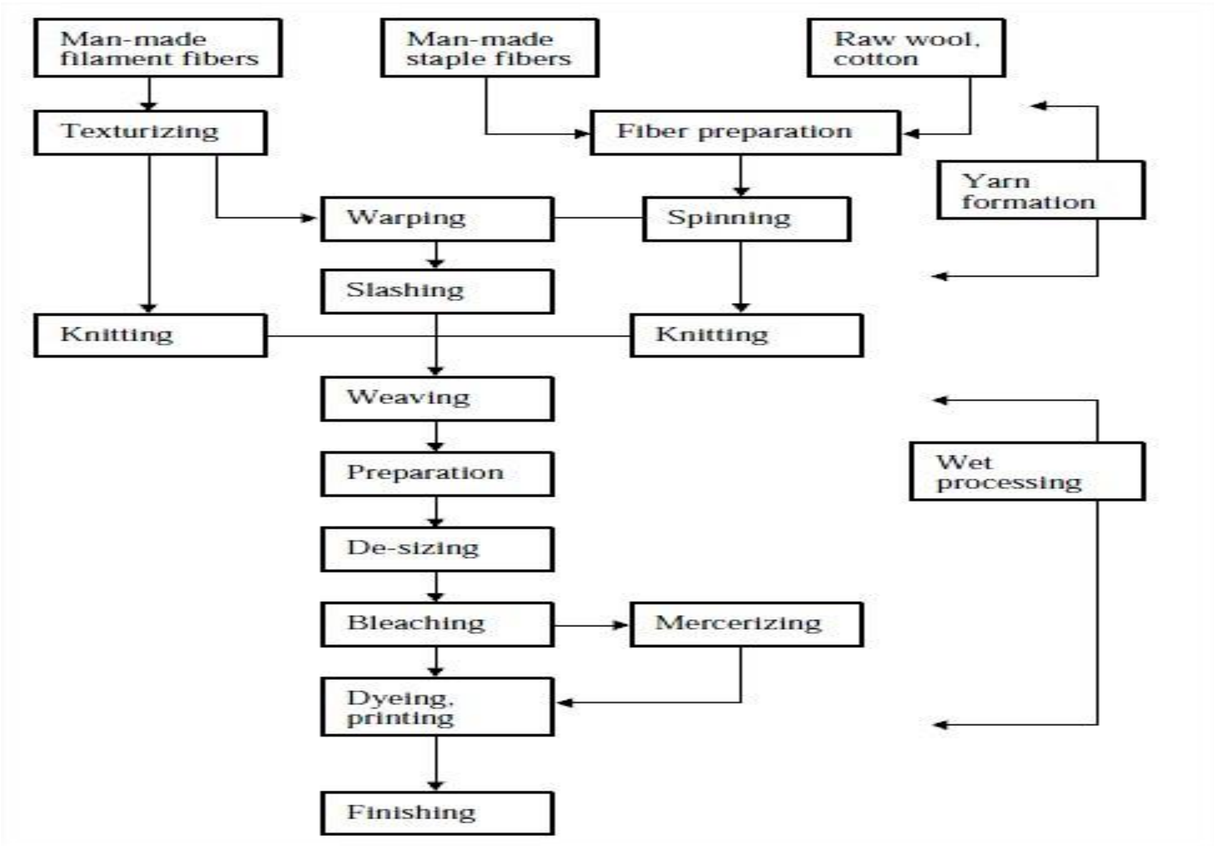
2.1.1 Overview of the Textile Processes

Textile industry is concerned with preparation of fiber and transformation into yarn/thread/web and conversion of yarn into fabric or related products and Garment manufacturing at various stage of production.

Textile processing industries including both (i) the mechanical processes such as carding, spinning, weaving, knitting or tufting and (ii) the physico-chemical process which mainly take place in aqueous media, such as the pre-treatment (desizing, scouring, bleaching, mercerizing, washing) drying, dyeing, printing and finishing processes. Different types of processes in textile processing industries are described below**:**

1. Desizing: Sizing applied to warp yarns prior to weaving or warp knitting by the slashing process must be removed prior to dyeing or finishing assuring even and uniform application of the dye or finish. Sizes can consist of starches, modified starches, and adhesives based on synthetic organic polymers. Starches and modified starches generally may be removed by dilute acid or enzyme treatment, whereas synthetic adhesive sizes can be removed by specialized short washing treatments.

Figure 2 shows various steps involved in processing textile in a cotton mill (Babu, et al 2007)



2. Bleaching

It involves elimination of unwanted color from textiles. These are three processes: sodium hypochlorite bleaching; hydrogen peroxide bleaching and sodium chlorite bleaching. Hypochlorite is one of the oldest industrial bleaching agents. For bleaching textiles are soaked with bleaching agents and then temperature is raised to recommended levels. Then textiles are thoroughly washed and dried.

3. Mercerization

It is carried out by treating cotton material with a strong solution of sodium hydroxide (about 18–24%) and washing-off the caustic after 1 to 3 min, while holding the material under tension. Cotton is known to undergo a longitudinal shrinkage upon impregnation with this solution. This process provides luster & strength to textiles

4. Dyeing

It is the treatment of fiber or fabric with chemical pigments/dyes to impart color. In this process, water is used to transfer dyes and in the form of steam to heat the treatment baths. Cotton, which is the world's most widely used fiber, is a substrate that requires a large amount of water for processing. The dyeing step in the textile production has the largest risk for the environment due to high concentrations of organic dyes, additives and salts used. Therefore, among the processes applied in the textile industry, dyeing process wastewater should be dealt with seriously. Most of the time, this process constitutes the major part of the water consumption and generates wastewaters distinguished by high chemical oxygen demand (COD), high dissolved and suspended solids, and high color contents (**Manu B. 2007).**

Dyeing Methods

Dyeing methods is main process cause of wastewater in textile industry, which can be divided in two types as follows.

1) Batch wise or discontinuous method that includes all dyeing processes wherein dyestuff is exhausted from a quantity of water relatively large in proportion to the material to be dyed. It varies according to method of dyeing. There are many types of the dyeing machines such as Jiggers, Winches, and Jet.

2) Continuous methods are mainly used in the dyeing of textile fibers when they are woven into cloth. The fabric is uniformly impregnated with the required amount of dyestuff and other

necessary chemicals by a process called "padding". This consists of a rapid passage of the fabric at full width through a solution or suspension of dyestuff, thus loosely applied to the fabric, is then fixed usually after intermediate drying, by passage through statement of hot air. It is at this stage the dye diffuses into the fabric interior.

Dyes and dye classification

Dyes as colored unsaturated organic molecules must have affinity for fibers to be effectively applied. It is generally applied in a solution that is aqueous. Dyes may also require a mordant to better the fastness of the dye on the material on which it is applied.

1. **Direct or Substantive Dyes direct**: These can be directly applied by immersing the cloth in a hot solution of the dye in water. They can be again classified into acid and basic dyes.Acid dyes are sodium salts of sulphonic acid and nitro phenols. They are used for dyeing animal fibers (wool and silk) but not vegetable fibers (cotton). The dye solution is acidified with sulphuric or acetic acid. Basic dyes are salts of color bases with hydrochloric acid or zinc chloride. They can directly dye animal fibers. They need a fixing agent called mordant (tannin) to dye vegetable fibers. These are used for dyeing silk and cotton.

2. Vat Dyes: Vat dyes are used in cotton dyeing where high wash & boil fastness required .Because of the high alkali concentration in the dye bath, pure vat dyes cannot be used on animal fibres, (wool, natural silk, & various hairs). These are water insoluble coloured compounds,

3. Reactive dyes: They react chemically with the fibre being dyed & if correctly applied, cannot be removed by washing or boiling. Cold water fibre reactive dyes, suitable for dyeing on cotton, silk, jute, rayon & hessian. These cannot be used on synthetics or fabric that has been coated with resin or drip-dry finish. These are very easy to use because the dye can be applied at room temperature.

4. Sulphur dyes: It dyes all cellulose fibres, but particularly linen & jute, to a lustrous & deep black with excellent wash & light fastness. Sulphur dyes are dyed from a dye bath containing Sodium Sulphide & common or Glaubers Salt, & are oxidized by airing or with some oxidizing agents (Sodium Bichromate or Hydrogen Peroxide) in a fresh bath. Sulfur Black 1 is the largest selling dye by volume. (**Burkinshaw, *et al*. 2005)**

5. Disperse dye: These are mostly used for polyester & acetate; can also be applied on nylon & Acrylic. In some cases, a dyeing temperature of 130 °C is required, and a pressurized dye bath is used.

According to the dyeing properties, the dye classes are; acid, basic, direct, disperse, mordant, reactive, sulfur and vat dyes. Each dye class is suitable to a specific type of fiber and hence the fixation rate of each class of dye is different

Table 2.1: Different dye classes with respective fibres

Dye class	**Fibres**
Acid	Wool and nylon
Azoic	Cotton and other cellulosic
Basic	Acrylic,
Direct	Cotton and other cellulosic
Disperse	Polyester, other synthetics
Reactive	Cotton and other cellulosics
Mordant	Natural fibres after pretreating with metals
Sulphur	Cotton and other cellulosic
Vat	Cotton and other cellulosic

Source : Pollution hand book

5. Drying

The purpose of drying process is to reduce or eliminate the water content of the, yarns or fabrics after wet processes applied in dyeing. In the selected mill, drying process is applied via contact driers at a temperature of 140^{o}C in order to reduce the water content of the rope from 68% to 7-8%.

6. Printing

It is generally defined as 'localized dyeing,' i.e. dyeing that is confirmed to a certain portion of the fabric that constitutes the design. It is form of dyeing in which the essential reactions involved are the same as those in dyeing. In dyeing, color is applied in the form of a solution, whereas in printing color is applied in the form of a thick paste of the dyes.

7. Finishing

Both natural and synthetic textiles are subjected to a variety of finishing processes. This is done to improve specific properties in the finished fabric and involves the use of a large number of finishing agents for softening, cross-linking, and waterproofing. All of the finishing processes contribute to water pollution. Among the products that are used in textile finishing, the most ecologically friendly ones are formaldehyde-based cross-linking agents that bestow desired properties, such as softness and stiffness that impart bulk and drape properties, smoothness, and handle, to cellulosic textiles.

2.1.2 Machinery and facilities used in textile processing

Textile processing encompasses different stages, and specialized machinery and equipment may be used at each of the stages. Dyeing can be done at any stage of the manufacturing process (at fibre, yarn, fabric and garment stages). Core facilities and support facilities used in the textile industry are explained below:

Yarn dyeing is mostly done by any of the following three methods: skein/hank (cabinet dyeing), package (top dyeing) and beam dyeing (**Ingamells. 1993**). For large, bulky or delicate yarns, skein/hank dyeing is preferred. For dense, small and highly twisted yarns, package dyeing machine is preferred. In package dyeing, the yarn is wound onto perforated tubes and stacked on perforated rods and placed in pressurized tanks. In beam dyeing, yarn in open width is rolled onto perforated beam and the dye liquor is allowed to circulate through the perforations in the beam.

Winch, jet and jig dyeing machines are used for the fabric. Woolen fabrics and occasionally cotton fabric are mostly dyed on winches. Many versions of jet dyeing machines (long tube and short tube jet dyeing machines, u-tube jet dyeing machines and soft-flow machines) are in use mostly for knitted polyester, polyester-cotton and cotton fabric dyeing. Jig dyeing machines are preferred for woven cotton fabric. Woven fabric is also dyed on continuous dyeing ranges.

Paddle dyeing machine is usually used for garment dyeing. The paddle circulates both the bath and garments in a perforated central island and the chemicals, water and steam for heat are added.

Dyeing machines can also classified into two types: rope dyeing and open width dyeing machines. In the rope dyeing machines (e.g. Jet and winch dyeing machines), the fabric is transported through the machine in a loosely collapsed rope like form. In open width dyeing machines (jigs, padding, and continuous processing and dyeing machines), the fabric is maintained, all the time, in a flat and open condition. **(Hickman. 2005)**

Hydro-extractor is used to reduce the moisture content of the wet processed fabric/yarn for ease of drying. Here fabric/yarn is loaded in a well and closed from top, then with the help of a motor the loaded well is spinned for the centrifugal separation of liquid from fabric/yarn. In case of woven fabric, the fabric is passed through press rolls and then dried on drying ranges. After hydro-dewatering, the fabric may be dried on a pole drier. In case of garments and yarn/fiber tumbler driers are used for drying. In case of the processed fiber cones drying is carried out in IR cone driers.

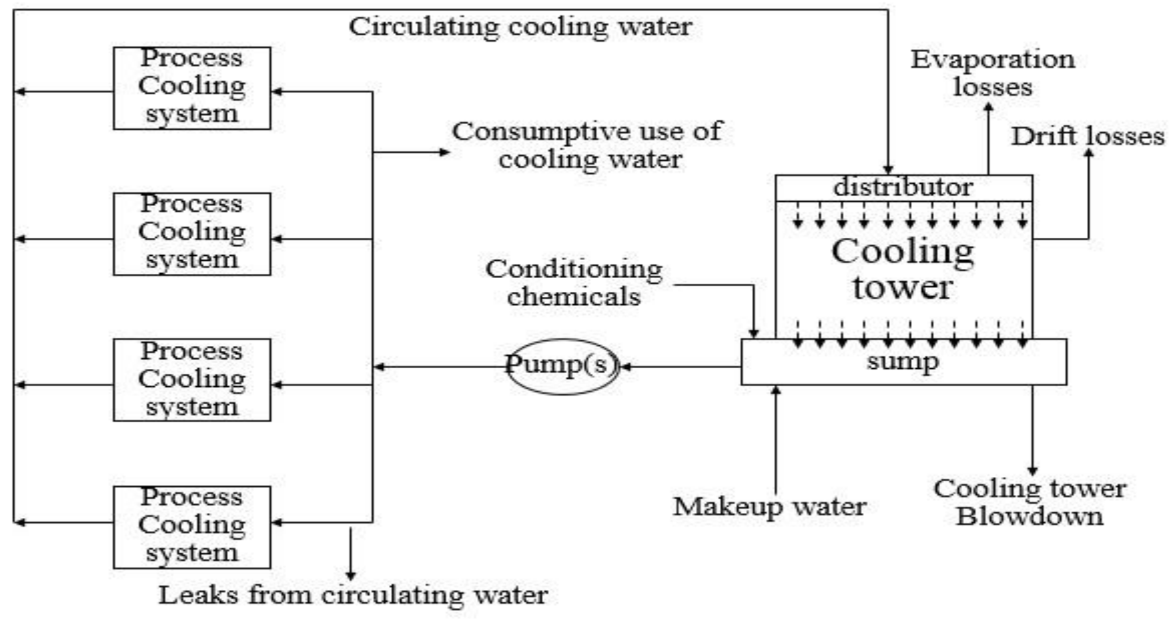
For supporting the core processing and providing the utilities and services the industrial unit have the machinery and facilities includes water supply system, soft water system/RO system, steam system, electrical system.

Water supply system is used where water is pumped from groundwater source, storage, and supply as both process water and as drinking water. The water is used in soft water, cooling tower, in dyeing machine. Soft water system produce process water from Ion-exchange process and Reverse osmosis process. Ion-exchange process based soft water plant includes Pressure filter, Activated carbon column, Salt for regenerating ion-exchange resin beds, Soft water storage and supply mostly as boiler feed water.

Water is consumed in the backing washing of ion exchange and regeneration of ion exchange Wastewater is generated from Backwashing of pressure filter, activated carbon column and ion-exchange resin bed and regeneration of the resin beds during chemical draw, slow rinsing and rapid rinsing resin beds .Reverse osmosis based soft water plant includes Chlorination, Iron removal column, Dechlorination , RO unit ,Soft water storage and supply (as boiler feed water).

Steam generating boiler are used to generate steam by combusting the fuel (coke, peat, wood). Steam is supplied for direct heating and indirect heating. Steam condensate is generated and recycled to boiler used as boiler feed water. Steam and thermopac boiler are mainly used for steam generation. In thermo pac boilers, Instead of boiler feed water, thermic fluid is forced to flow through the tubes (water tubes) for heating. The boiler system has a FD fan, furnace, three pass fire tube boiler, heat recovery unit (HRU), cyclone (APCD), ID fan and stack.

Circulating cooling water system is used usually includes Cooling tower (includes sump and fans) Pumps and piping for circulation between cooling towers and heat exchangers. It requires makeup water to compensate evaporation, drift and blow down losses; leaks and spills and consumptive uses. Scheme of cooling tower and circulating cooling system shown in figure 2.3



Cooling tower and circulating cooling water system

2.1.3 Water requirements for textile processes

The textiles industry has always been regarded as a water-intensive sector main processing stages that consume for its different wet processing operations, Water is the principal medium for removing impurities from raw materials, applying dyes and finishing agents, and for the generation of steam.

The used water from the industry comes as wastewater contains dyes, chemical and its characteristics depend upon the processing stages. Table2.2 indicates the water requirements of various machines used in dyeing. The Water Consumption and Effluent Generation in Different Wet Processing Stages in Textile Industries (Quantity Litre / 100 Kg.) are given in table 2.3.

Table 2.2 Water consumption in various dyeing machines

Dyeing machine	**Water consumption (**l kgl^{-1})
Beam	167
Beck	234
Jet	200
Jig	100
paddle	292
Skein	250
Stock	167
Pad batch	017

Package	184
Continuous	167
Indigo range	8 to 50

Source: Mathur, *et al.* (2003)

Table 2.3 Water Consumption and Effluent Generation in Different Wet Processing Stages in Textile Industries (Quantity Litre / 100 Kg.)

S. no	Activities	Water consumption		Effluent Variation
		Variation	Average	
01	Sizing/slashing	50-820	435	50-820
02	Desizing	250-2100	1175	250-2100
03	Kiering/scouring	2000-4500	3250	2000-4500
04	Bleaching			
	1. Yarn (Hypochlorite)	2400-4800	3600	2250-4600
	2. Yarn (Hydrogen peroxide)	2400-3200	2800	2250-3050
	3. Cloth (Hypochlorite)	2400-3200	2800	2250-3050
	4. Cloth (Hydrogen peroxide)	4000-4800	4400	3800-4600
05	Mercerizing	1700-3200	2450	1700-3200
06	Dyeing			
	1. Yarn (light and medium shades)	360017600	10600	3500-17500
	2. Yarn (Dark Shades)	3600-4800	4200	3500-4700
	3. Yarn (Very Dark Shades)	4800-6400	5600	4700-6300
	4. Cloth (Light and medium shades)	6600-8800 7800-9600	7700 8700	6500-8700 7700-9500
	5. Cloth (Dark Shade)	1040012800	11600	10300-12700
	6. Cloth (Very Dark Shades)	1430017600	15950	14200-17500

Source: ECAC. (2011).

2. Wastewater generation from textile industry

Sources of wastewater in the textile industry are generated from wet processes, which include sizing, desizing, scouring, bleaching, mercerizing, dyeing and printing. Each process produces a waste with different characteristics and varies in strength, flow, and composition. The processes and wastewater generated from them are given below Table 2.4. Among all the effluents of textile processing, cotton textile dye bath dumps are the most polluted due to very rich in dyes and salt concentration (sodium sulfate or sodium chloride) is very high (2-8% salts in the dye bath).The class of dye generates different type of pollutants are described in given table 2.5

Table 2.4 Wastewater constituents from textile processes

Various textile processes	**Constituents of Wastewaters generated**
Fiber preparation	Little or no wastewater generated.
Desizing	BOD from water-soluble sizes; synthetic size; lubricants; biocides; anti-static compounds
Scouring	Disinfectants and insecticide residues; NaOH; detergents; fats; oils; pectin; wax; knitting lubricants; spin finishes; spent solvents
Bleaching	Hydrogen peroxide, sodium silicate or organic stabilizer; high pH
Mercerising	High pH; NaOH.
Dyeing	Metals; salt; surfactants; toxics; organic processing assistance; cationic materials; color; BOD; sulfide; acidity/ alkalinity; spent solvents
Printing	Suspended solids; urea; solvents; color; metals; heat; BOD; foam
Finishing	BOD; COD; suspended solids; toxics; spent solvents
Product fabrication	Little or no wastewater generated.

Source : (Babu, *et al.* 2007)

Table 2.5 Dyes for Cotton Yarn Dyeing and the Compositions of the Wastewater

Type of dye	The compositions of the wastewater
Dyes	Composition of water
Reactive dye	Dye, caustic soda, soda ash, interfacial active agent, salt cake
Developed dye	Dye, sodium chloride, sodium nitrate, penetrant, sodium sulfide, chlorine or sulfate, developer (B-Naphthol), interfacial active agent, soap or sulfate soap or fatty alcohol.
Direct dye	Dye, sodium carbonate, salt or salt cake, interfacial active agent, Sodium sulfate.
Naphthol dye	Dye, caustic soda, interfacial active agent, alcohol, soap, soda ash, salt, bases, sodium acetic, sodium sulfide, sodium nitrate, sodium nitrite
Sulfide dye	Dye, sodium sulfide, sodium carbonate, salt
Vat dye	Dye, caustic soda, interfacial active agent, sodium hydrosulfite, potassium dichromate, perborate or hydrogen peroxide

Source : Honda and Vamamoto. (2000)

2.2 Water quality of textile industry

The effluents generated are heavily coloured, contain high concentrations of salts, and exhibit high biological oxygen demand/chemical oxygen demand (BOD/COD) values. **Sivaramakrishnan.(2004**) explained the characteristics of wastewater for textile chemical processing in table 2.6.

Table 2.6 Characteristics of wastewater

Property	Standard	Cotton	Synthetic	Wool
pH	5.5 – 9.0	8-12	7-9	3-10
BOD, mg/l, 5 days	30-350	150-750	150-200	5000 – 8000
COD, mg/l, day	250	200-2400	400-650	10,000 – 20,000
TDS, mg/l	2100	2100-7700	1060-1080	10,000 –13,000

Wahle, *et al.* (2002) noted that textile effluents are highly coloured and saline, contain non-biodegradable compounds, and are high in Biochemical and Chemical Oxygen Demand (BOD, COD). They reported that the presence of metals and other dye compounds inhibit microbial activity and some cases may cause failure of biological treatment system. Textile effluent from these six textile industries selected is collected and characterized for major pollution indicator parameters namely BOD, COD, TDS, sulphide, sulphate, chloride, hardness, alkalinity, calcium and magnesium. The concentration of total dissolved solid are observed to be higher than 5000 mg/L. The effluent also contains high concentration of sulphate, sulphide, chloride, calcium and magnesium, which are responsible for higher hardness of waste water were studied by **Paul, et *al*. (2012).** EPA (1974) reported that the pollution parameters in textile wastewater effluents are suspended solids, BOD, COD, nitrogen, phosphate, temperature, toxic chemicals (phenol), chromium and heavy metals, pH, alkalinity-acidity, oils and grease, sulphides, and coliform bacteria

Correia, *et al.* (1994) reported the characteristics of wastewaters generated from different textile wet processing steps. Table 2.4 represents the wastewater characteristics of each processing, and The some of the Parameters as Per the Standards of Central Pollution Control Board (CPCB) India, for the Requirements of Maximum Value to Discharge the Effluent Directly to the water given in table 2.5.

Table 2.7 Wastewater characteristics of each processes

Process	pH	BOD (mg/l)	TS (mg/l)
Desizing	---	1700-5200	16000-32000
Scouring	10-13	50-2900	7600-17400
Bleaching	8.5-9.6	90-1700	2300-14400
Mercerizing	5.5-9.5	45-65	600-1900
Dyeing	5-10	11-1800	500-14100

Source:Pollution hand book

Table 2.8 Discharge standards for effluent from textile industry

Parameter	Concentration not to exceed, milligram per litre(mg/l), except pH
pH	5.5-9.0
Total suspended solids	100
Bio-chemical oxygen demand (BOD)	30
Alkalinity	125-200
Total dissolved solids	50
Chemical oxygen demand(COD)	250
Total residual chlorine	1
Oil and grease	10
Total chromium as C	2
Sulphide as S	2
Phenolic compounds as C6H5OH	1

2.3 Treatment and disposal of textile wastewater

In the past several decades, many techniques have been developed to find an economic and efficient way to treat the textile dyeing wastewater, including physicochemical, biochemical, combined treatment processes and other technologies. In dyestuffs manufacturing industry, the membrane separation technology is applied in the improvement of conventional processes and treatment of wastewater for the purpose of waste minimization, energy and water saving **(Jia, *et al.* 2001)**.

Treatment of textile processing industry wastewaters includes preliminary treatment (screening, equalization, grit removal, oil separation, etc.), primary (physicochemical) treatment, secondary (biological) treatment and tertiary (physicochemical and biological) treatment.

2.3.1 Primary treatment: Primary treatment mostly includes neutralization, precipitation, coagulation, flocculation and settling. Suspended and colloidal solids concentrations are not very high in these waters. Primary treatment is most often concerned with the adjustment pH and with the removal of colour. The first step in the waste water treatment, is to mix and equalize the waste water streams that are discharged at different time, and different intervals from different stages in the processes. Some industries also prefer screening, oil trap prior to equalization for removal of solids and oil and grease. Equalization ensures that the effluent have uniform characteristics in terms of pollution load, pH and temperature.

Neutralisation: Normally, pH values of cotton finishing effluents are on the alkaline side. Hence, pH value of equalized effluent should be adjusted. Use of dilute sulphuric acid and boiler flue gas rich in carbon dioxide are not uncommon. Since most of the secondary biological treatments are effective in the pH 5 to 9, neutralisation step is an important process.

Coagulation flocculation: The coagulation/flocculation method is a wastewater treatment technique for the decolourization of residual dye bath effluents. Electro-coagulation is an efficient process, even at high pH, for the removal of color and total organic carbon. This is an economically feasible method of dye removal. etc. The main types of coagulant used for color removal are alum, ferrous sulfate and ferric chloride. A Selection of appropriate coagulants and doses of chemicals are determined on the basis of treatability study of effluent samples. The coagulation process effectively decolorized insoluble dyes, such as disperse dyes, but does not work well for soluble dyes.

Hao, *et al.* (2000) pointed out, a number of factors affect the efficiency of electrochemical coagulation. These include the intensity of the current, the engineering design of the equipment used, the types of electrodes used as well as their physical characteristics, the pH and temperature of the process, the solution characteristics and, not least, the properties of the dyes in the mixtures being treated themselves

Treatment of textile wastewaters by electrocoagulation using iron and of aluminum electrode materials has been investigated by **Kobya, *et al* (2003)**. He calculated the electrode and energy consumptions for each electrode. The results show that iron is superior to aluminum as sacrificial electrode material, from COD removal efficiency and energy consumption points. Lime and ferrous sulfate were used by **Georgiou, (2003)** for the colour removal. Lime alone when used removed color by 70–90% and COD by 50–60%. Treatment with ferrous sulfate and lime was found equally effective but at 9.0±0.5 pH (pH was adjusted with lime here).

Kim, *et al.* (2004) decolorized disperse and reactive dyes by electrocoagulation. Their study concentrated on examining the operating parameters such as current density, electrode number, electrolyte concentration, electrode gap, dyestuff concentration, and pH of the solution on the decolorization rates and efficiencies. **Gao, *et al.* (2007)** compared color removal from reactive and disperse dye wastewaters by different coagulants and found $MgCl_2/Ca(OH)_2$ as superior to $MgCl_2/NaOH$, $Al_2(SO_4)_3$, PAC and $FeSO_4/Ca(OH)_2$.

2.3.2 Secondary Treatment / biological treatment

Textile processing effluents are amenable for biological treatments .These processes may be aerobic or anaerobic. Secondary or biological treatment of textile wastewaters is meant mainly to remove biodegradable organic matter present in textile effluents and also colour. Bacteria, fungi and algae have been tried in the biological treatment of the wastewaters especially for the removal of colour ,oil and phenol. the dissolved and colloidal organic compounds.

Sequential system consisting of an anaerobic packed column and a conventional activated sludge unit, decolorisation efficiency of 85% and COD removal efficiency of 90% was obtained (**Kapdan,** ***et al*****. 2003)**. The combination of up-flow anaerobic sludge blanket (UASB) and sequencing batch reactor was chosen as an anaerobic and aerobic system, respectively, in the treatment of Orange II-containing wastewater. He studied that complete decolorization (>95%) was accomplished in UASB system when working at 0.3 g/l d of Orange II loading rate at 30 °C with hydraulic retention time of 24 hr. (**Soon an org ,** ***et al*** **2005).**

Kornaros and Lyberatos, (2006) used trickling filters (attached growth aerobic systems) for the treatment of textile wastewater and achieved 60 – 70 % COD removal efficiency. Granular Activated Carbon-Sequencing Batch Reactor (GAC-SBR) system was studied by **Sirianuntapiboon,** ***et al*****. (2007)** for the treatment of textile wastewater containing direct dyes and achieved 76%, 86%, 84% and 68% removal of color, COD, BOD and TKN respectively.

Goyal, ***et al*****. (2010)** studied performance of Rotating Biological Contactor (RBC) system for colour and COD removal from textile industry wastewater and reported up to 90±5% colour removal and 95±3% COD removal under optimum operating conditions. **Saeeda,** ***et al.*** **(2013)** used two lab-scale hybrid wetland systems treating a textile waste water and reported the pollutant removal efficiencies. In this study, the two systems had identical configurations, each consisting of a vertical flow (VF) and a horizontal flow (HF) wetland rremovals of BOD_5 (74–79%) and ammonia (59–66%) were obtained in the first stage VF wetlands and Second stage HF wetlands provided efficient color removal under predominantly anaerobic condition.

2.3.3Tertiary treatment/ advanced treatment

Textile wastewaters have been subjected to tertiary or advanced treatment processes mainly for the removal of residual colour, for reducing the dissolved salt levels and for the further polishing of the treated secondary effluents.It includes adsorption membrane technology, ion exchange, chemical oxidation, ozonation, advanced oxidation, photocatalysis,

1. Adsorption: Adsorption is the most used method in physicochemical wastewater treatment, which can mix the wastewater and the porous material powder or granules, such as activated carbon and clay, or let the wastewater through its filter bed composed of granular materials. Adsorption using Granular Activated Carbon (GAC) was tried by.

Various other types of adsorbents, such as, saw dust (**Batzias and Sidiras, 2007)**, coal fly ash **(Janos, *et al.* 2003)**, powdered waste sludge **(Ozmihci and kargi, 2006)**, waste red mud **(Namasivayam and Arasi, 1997)**, banana pith **(Namasivayam, *et al*. 1998)**, coir pith (**Kadirvelu, 1994)**, orange peel **(Sivaraj, *et al.* 2001)**, baggase **(Kaushik, *et al*. 2009)**, etc., have also been tried on textile wastewater for the decolorization by adsorption. **Hassani, *et al*. (2008)** to decolorize Acidic red, Direct red and Reactive red dyes and reported color reductions of 90%, 88% and 43% in 30, 60 and 120 min respectively

2. Oxidation methods:

Electrochemical: Electrochemical treatment also plays an important role in wastewater treatment. Ti/RuO2, Ti/Pt and Ti/Pt/Ir electrodes were investigated by **Naumcjyk, et al. (1996)** for the treatment of textile wastewater with high Cl- ion concentration. After 60 min. of electrolysis, at 6 A/dm2, 85–92% COD reduction was reported. Dimensionally stable anode (DSA) against steel cathode was investigated by **Vaghela, *et al*. (2005).** In a thin electrochemical flow reactor, at different current densities, flow rates and dilutions, 94-99% decolourization was achieved with azo dye effluents. **Miled et al., (2010).** studied the indirect electrochemical oxidation process for the textile wastewater treatment .Electrochemical degradation process was performed using graphite as anode and stainless Steel as cathode .The best removal of organic compounds contained in the waste has been obtained at pH 13, low electrolyte concentration and current density (0.1 M and 200 Ma, respectively. cod and colour removal were 75 % and 43 % respectively.

Advanced oxidation method: A Generation of hydroxyl radicals (•OH) is commonly accelerated by combining O3, H2O2, TiO2, UV radiation, electron-beam irradiation and ultrasound. Of these, O3/H2O2, O3/UV and H2O2/UV hold the greatest promise to oxidize textile wastewater. Combination of these oxidizing agents showed great promise to treat textile industry wastewater. (**Arslan, *et al.* 2000)**

Adel, *et al.* (2004) studied Advanced Oxidation Process (AOP) based on H_2O_2/UV system for the treatment of textile wastewater. In the study, UV intensity and dye concentration were varied and obtained 90.69% decolorization with H_2O_2 dose of 10cm^3 (3.9 wt %). **Al-Kdasi, *et al.* (2005)** carried out a study on treatment of textile wastewater by advanced oxidation processes. Conventional treatment such as biological treatment discharges will no longer be tolerated as 53% of 87% colours are identified as non-biodegradable. Advanced Oxidation Process represents a powerful treatment for refractory and toxic pollutants in textile wastewater.

Ozone treatment. Ozone can be employed to remove BOD, COD and color. Ozone (either singly or in combinations, such as O3-UV or O3-H2 O2) is now used in the treatment of industrial effluents **(Langlais, *et al*. 2001).** Ozonation leaves the effluent with no colour and low COD suitable for discharge into environmental waterways (**Robbison, *et al.* 2001).**

Decolorization and degradation of an anthraquinone dye (C.I. Reactive Blue 19) by ozonation was tried at laboratory scale in a cylindrical batch reactor **by Tehrani-Bagha, *et al*. (2010**). 55% COD and 17% TOC reductions were reported at 800 mg/L dye concentration for 90 min. ozonation.

Photo catalysis: In this process, photoactive catalyst illuminates with UV light, generates highly reactive radical, which can decompose organic compounds. A photo catalyst, methylene blue immobilized resin dowex-11, was tested by **Meena, *et al*., (2009)** for the degradation of model dyes, Ponceau S and Sudan IV, and observed 99% removal efficiency.

Patil, *et al*. (2010) tried photocatalysis with TiO_2 powder (anatase form) and ZnO as catalysts for the degradation of textile dyeing and printing wastewater. Catalytic performance of ZnO was found more effective.

Szpyrkowicz, *et al.* (2004) compared removal of disperse dyes from water by four oxidation methods – hypochlorite, ozone, electrochemical and Fenton's reagent. Since disperse dyes are highly insoluble, hypochlorite was the least effective of the methods. Ozone gave good colour removal (up to 90%) but low (10%) COD removal. Electrochemical oxidation was more efficient, particularly with the COD decrease (79%). Of the methods, the most satisfactory response was obtained with the Fenton process, where the effluent was turned colourless and the COD was decreased substantially.

3. Membrane Technology

Membrane technology are used for waste minimization and to remove dyes (colour), TDS with high removal efficiencies. It also allows reuse of water and recovery of some of the valuable waste constituents.

Microfiltration: MF refers to filtration processes that use porous membranes to separate suspended particles with diameters between 0.1 and 10 μm thus yielding a relatively higher flux than the other membrane separation technology. Thus, microfiltration membranes fall between UF membranes and conventional filters **(Baker, 2004).** MF membranes comprise the largest fraction of total membrane production due to their increasing usage in recent years (**Porter and Gomes, 2000).** MF has been gaining a wider acceptance for the pretreatment stage since it is economically more competitive than conventional methods such as coagulation, flocculation, sedimentation and filtration **(Vedavyasan, 2000)**.

Fersi, *et al.* (2009) investigated the parameters that determine the flux decline of textile waste water by membrane technologies where MF and UF processes were studied in order to be investigated as pretreatment for the NF process in the case of textile effluent treatment.

Ultrafiltration: It is primarily a size-exclusion based pressure-driven separation process through mesopores and are capable of retaining medium to large size dissolved molecules in the molecular weight range of 300 to 300000 Da. UF can be operated at 2 to 10 bar pressure**.** Ultrafiltration proved to be a suitable technology for the treatment and reuse of effluent and with dead-end filtration high permeate fluxes. The technical feasibility UF permeates have been accepted only for minor processes in textile industry when salinity is not a problem **(Bottino et al, 2000).** Dye rejection performances as high as 90-100% had been obtained in these studies, whereas UF performance was shown to be significantly variable, i.e., 34-93%%, for total waste streams from dye house (**Watters et al, 2001).** Therefore, further filtration by either NF or RO would be required in the case of water recovery **(Tang and Chen, 2002).**

In a UF study, textile wastewater was studied for reuse purpose and the proposed treatment scheme was the sequential application of cross flow UF and NF by **Barredo, *et al.* (2006).** It can be concluded from the study that UF is an appropriate technique as a pre-treatment of a NF/RO process to textile waste water reuse. In that study membrane selection and operating conditions were considered as important issues to optimize technically and economically the process. Nevertheless, these parameters were accepted as they of the reuse of effluent depends on the type of industry, the wastewater characteristics and the required permeate quality for reuse **(Roeleveld, *et al*. 2000).**

Nano filtration: NF also referred to as "loose RO". These membranes have typically pore sizes ranging from is 0.5-5 nm, and are capable of retaining monovalent salt ions in the molecular weight range of 300 Da . NF can be operated at 2 to 10 bar pressure. Nanofiltration membranes retain low molecular weight organic compounds, divalent ions, large monovalent ions, hydrolyzed reactive dyes, and dyeing auxiliaries. Harmful effects of high concentrations of dye and salts in dye house effluents have frequently been reported **(Tang andChen, 2002; Koyuncu, 2002;Jiraratananon et al.,2000; Erswellet al, 1988).**

2.3.4 Combinations of different techniques

Vander, *et al.* (2001) tested NF directly & sand filtration followed by NF with simulated dye bath & biologically treated effluent respectively. The author concluded that application of NF is efficient in textile wastewater recovery. Another investigation was performed with the biologically treated textile effluents by **BesPia, *et al*. (2004)**, where ozonation was further tested in the pre-treatment stage for NF. A COD removal efficiency of 43% was accomplished with low ozone doses at 60 min ozonation period, which in turn, resulted in an increase of NF membrane life.

Joonghwan, *et al*. (2007) used chemical coagulants such as HOC-100A, alum, and ferric chloride for pretreatment of the feed water of membrane processes were used. Under optimum conditions for all the coagulants used, about 90% of materials was removed from the solution when checked with the UV absorbance of the solution before and after treatment.

Amar, *et al*. (2009) investigated coupling of activated sludge treatment with either ultrafiltration-nanofiltration (NF) or reverse osmosis (RO) for the recycling and reuse of the wastewaters resulting from different baths of a denim fabric dyeing industry. NF allowed higher yield. At 9 bar, the TDS rejection reached 60% and hardness of the output water was <100 mg L^{-1} $CaCO_3$.

The combination of coagulation and adsorption (using alum and ferric chloride as coagulants and granular activated carbon (GAC) as adsorbent) was tried by **Guendy.(2010)** for the acid red dye removal. Application of coagulation before adsorption was found most effective in removing the color. Use of alum enhanced the removal from 71% to 97.7%, and use of $FeCl_3$

enhanced the removal from 53.7 % to 98.9%. **Park, *et al*. (2011)** investigated a combined process consisting of Moving-Bed Biofilm Reactors (MBBRs) of Polyurethane-Dyeing Sludge Carbonaceous Material (PU-DSCM) foam inoculated with white-rot fungus, Phanerochaete chrysosporium, and Chemical coagulation with $FeCl_2$ or alum for the dyeing wastewater treatment. MBB process removed COD and colour by 79% and 54% respectively. But, coagulation with alum followed by MBBR process increased the removal to 95.7% for COD and 73.4% for color

2.4 Wastewater management

The EPA has defined waste minimization to include source reduction and environmentally-sound recycling. Source reduction includes reducing the pollutant entering any waste stream or being released into the environment prior to recycling, treatment or disposal. It involves some combination of modifications of equipment or technology, process or procedure modifications, substitution of raw materials and improvements in training, and inventory control. The systematic representation of wastewater management technique is shown in figure 2.4.

Conventionally industrial wastewater management has been reactive, compliance based, end-of-the-pipe focused approach. It often involved treatment of one medium resulting in the contamination of another medium. This approach is considered unacceptable. Now it is clearer that end-of-the-pipe treatment alone cannot control the pollutant discharge. A market driven, proactive wastewater management approach is now replacing this conventional reactive approach. This new approach is based on a waste hierarchy that prioritizes solving of the problems of wastes as indicated in the following table (EPA 1978):

Table 2.9 Waste management hierarchy (ranked most favorable to least favorable).

Management options	Definition
Source reduction	Any practice that reduces the amount of any hazardous substance entering any waste stream before recycling, treatment, or disposal.
In-process recycle	Unreacted feedstock is separated and recycled to the process.

Onsite recycle	Waste from the initial process is converted into a commercial product in a second process performed onsite.
Offsite recycle	Waste from the initial process is collected and transferred to another facility, where it is converted into a commercial product.
Waste treatment	Waste is separated and treated to render it less hazardous.
Secure disposal	Waste is separated and sent to a secure site.
Direct release	Waste is separated from product and released to the environment.

In this new approach, waste-minimization is achieved through improving the plant operations, altering the process technologies, substituting the materials, reformulating products, and recycle, recover or reuse of wastes. Waste characterization is a baseline for any changes made to the production process.

Wang and Smith.(1994) presented four general approaches to wastewater minimization as follows:

1) Process change: Process changes can reduce the inherent demand for water. An example is the replacement of wet cooling towers by dry air coolers.

2) Water reuse: Wastewater can be reused directly in other water using operations when the level of previous contamination does not interfere with the water using operation. This reduces both freshwater and wastewater volumes but leave the mass load of contaminant essentially unchanged.

3) Regeneration reuse: Wastewater can be regenerated by partial or total treatment to remove the contaminants that would otherwise prevent reuse and then can be reused in

Other water using operations. The regeneration is any operation that removes the contaminants that prevent reuse and could be filtration, pH adjustment, carbon adsorption, and other processes. Regeneration reduces both freshwater and wastewater volumes and decreases the mass load of contaminant.

4) Regeneration recycle: Wastewater can be regenerated to remove contaminants and then the water recycled. In this case, regenerated water may enter the water using perations in which the water stream has already been used. Also, recycle can sometimes create a buildup of undesired contaminants not removed in the regeneration process.

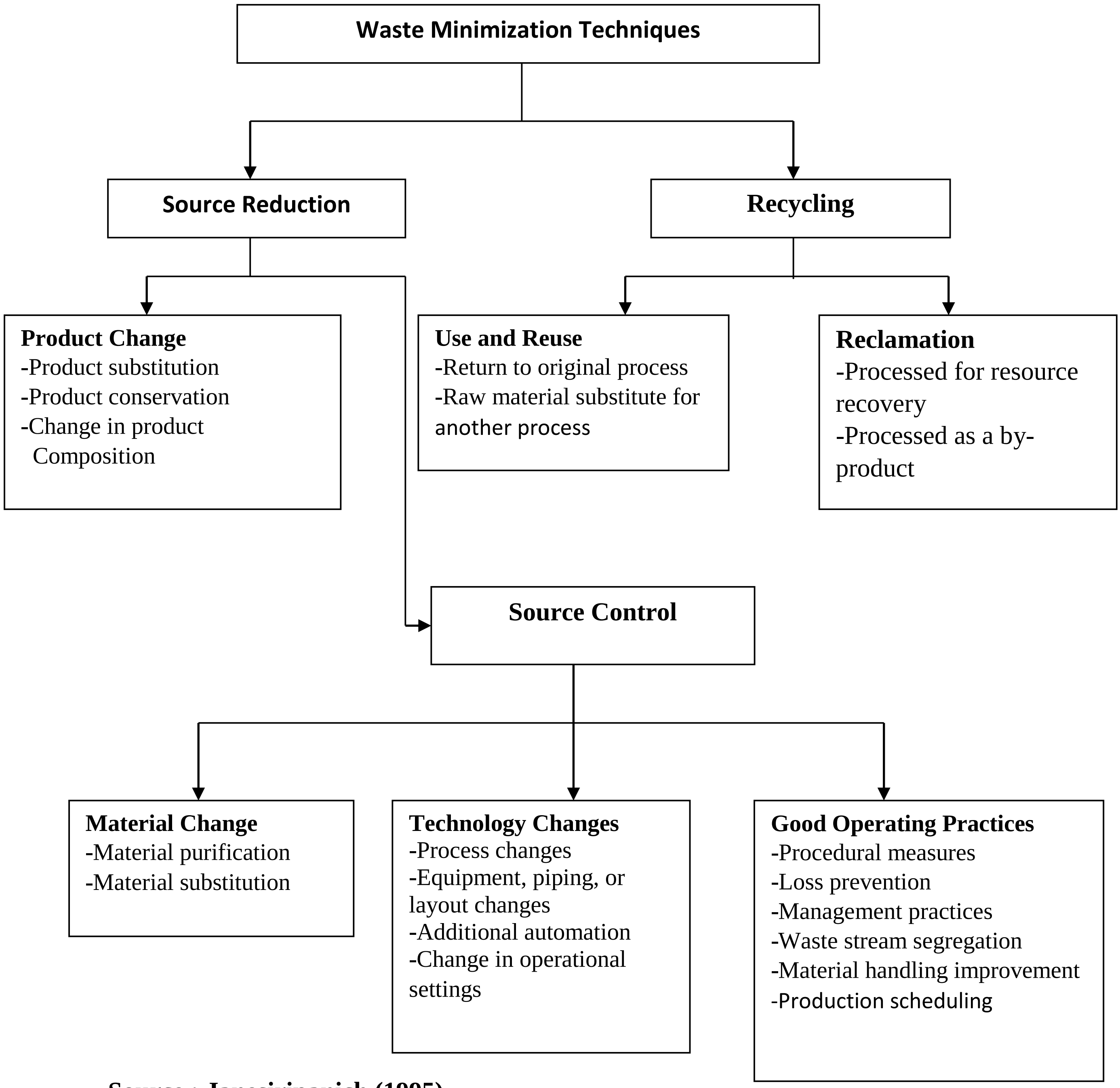
Visvanathan, *et al*. (2001) identified the industrial wastewater reuse into three ways asfollows:
1) Internal wastewaters recycle: Depending on the manufacturing process, water consumption can be cut down between 50% to 90% by adopting appropriate water recycling techniques. In Japan, 6.7% water recirculated in the textile industries.
2) Reuse of treated industrial wastewater.
3) Reuse of treated wastewater for other activities such as irrigation, fire protection, dual system etc.

Erdogan, et al. (2004) evaluated feasibility of wastewater minimization by water conservation and wastewater reuse for wool finishing textile mill. He based his evaluation upon a detailed analysis on water use, process profile and wastewater characterization. He indicated a potential for 34% reduction in water consumption and 23% of wastewater recovery for reuse. Stopping the shower rinsing at a point where COD of the segregated wastewaters reach under 50 mg/L, reuse of the wastewater streams having COD lower than 650 mg/l, etc., were suggested for the water conservation.

Babu, *et al*. (2007) suggested three ways to reduce pollution
1. Use of new, less polluting technologies;
2. Effective treatment of effluent so that it conforms to specified discharge requirements;
3. Recycling waste several times over before discharge which is considered the most practical solution.

Kocabus, *et al.* (2009) evaluated a few selected Best Available Techniques (BAT) in a denim manufacturing textile mill. Detailed mass balance calculations, installation of flow meters, counter-current rinsing, minimization of wash waters in the water softening plant, reuse of concentrate stream from reverse osmosis plant and compressor cooling waters, etc., provided 29.5% reduction in the total water consumption. In terms of Energy consumption, use of waste heat from wastewater streams (for heating up the wash water), heat insulation and maintenance etc., reduced energy consumption by 9%.

Figure 2.4: Waste minimization technique



Source : Janesiripanich (1995)

CHAPTER 3
METHODOLOGY

Background

This study involved development of wastewater management system for a textile processing industrial unit. The industry is involved in the dyeing of 9.0 tons/day of polyester fabric and 400 kg/day of polyester cotton dyeing, and 5.0 Tons/day of fabric washing. The plant uses soft water plant for boiler feed water and boiler to supply steam. This chapter describes the approach followed to the work on the following work elements that will lead to achieving the objectives.

1. **Environmental analysis of the industrial unit**
2. **Analysis of water and wastewater and waste treatment of the unit**
3. **Development of wastewater management strategies**
4. **Assessment of the influence of the measures suggested**

WE 1. Environmental analysis of industrial unit

The industrial unit was subjected to environmental analysis. Both core activities and support activities (including peripheral activities) consuming water and/or generating wastewater were identified and analysed. Each of the activities (processes/operations), infrastructural facilities (including the machinery and equipment), process conditions, and process/operation outputs (especially wastes) were analysed in detail. Process flow diagrams were developed for the following purposes:

- To understanding the points of water use and purposes of use
- Identifying the sources of wastewater and understanding the mechanism of generation of the all the wastewaters generated
- Getting an idea over the opportunities and options for the strength and volume reduction of the wastewater
- Knowing about the recycling and reuse potential of wastewaters and about the wastewaters collection, treatment and disposal.

WE 2. Analysis of water and wastewater and waste treatment of the unit

This work element is divided into two sections:

2.1 Water budget and inventory and characterization of wastewater

2.2 Study of existing wastewater treatment plant and wastewater treatment

2.1 Water budget and inventory and characterization of wastewater

An inventory of the water consumption and wastes generated by the textile processing unit was made for the characterization and quantification of wastewater generated. Material balance approach and actual calculations were used for the quantification of water and wastewater.

Wastewater from the selected streams (raw water, boiler feed water, application softener water, raw effluent, treated water) have been sampled nearest to their sources and analysed for the characterization. Parameters used for characterization included pH, alkalinity (total and phenolphthalein), acidity, TDS, chlorides, sulphate, colour, BOD, COD, turbidity and total suspended solids. The analytical technique used for the analysis of samples are given below in table 3.1.

Table 3.1 The analytical technique used for the analysis of sample are given below

S.No..	Parameter	Method	References
1	pH	Indicator method	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation.
3	Turbidity	HACH-Spectrophotometer	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation. Method no- 2130 B.
4	Alkalinity	Titration method	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation. Method No.- 2320 B.
5	COD	Open reflux method	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation. Method No.- 5220 B.
6	BOD	5 day BOD test	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation.

			Method No.- 5210 B.
7	TSS	Total suspended solids dried at 103°-105 °C	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation. Method No.- 2540 D
8	TDS	Total dissolved solids at 180 °C	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation. Method No.- 2540 C
10	Sulphate	Gravimetric method	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation. Method No.- 4500 C.
11	Chloride	Argentometric method	Standard methods for the examination of water and wastewater, 22nd Edn. APHA, Water environment federation. Method No.- 4500 B.

2.2 Study of existing wastewater treatment plant and wastewater treatment:

The industrial unit has an effluent treatment plant for the treatment of wastewater and compliance with the prescribed standards. The scheme of water treatment has been assessed for its suitability and sufficiency. Analysis of treated effluent and comparison with prescribed effluents standards were done to check whether or not, the treated effluent compile

WE 3. Development of wastewater management system

Environmental analysis of the selected industrial unit, information on the characteristics and quantities of different waste water, understanding on the textile processing and the wastewater management were used as the basis for executing this work element. The Wastewater management system developed might highlight following measures:

- Measures for wastewater minimization through source reduction/recycling and reuse
- Measures for cost-effective treatment and consistent compliance with the applicable effluent standards

Wastewater management strategies have been developed while giving due importance to source reduction (specially using alternate input materials and process modifications) and to wastewater recycling and reuse. Identification and working on the alternatives or options available for the wastewater management at all the four hierarchical waste management steps was tried for the industrial unit. Process modifications into the core processing of the industrial unit have been done especially for source reduction of wastewater.

It was found from characterization of wastewater, at present, the industrial unit is not in consistent compliance with the prescribed standards, specially, with BOD/COD and TDS. Necessary modification to ETP were suggested to improve the performance of existing ETP. In addition, alternate scheme of treatment of wastewaters that is cost-effective and consistent in compliance with the applicable effluent standards, has been proposed.

WE 4. Assessment of the influence of the measures suggested

Under this element, various measures and modifications suggested on water consumption, wastewater generated and on compliance with the prescribed standards was assessed

CHAPTER 4
RESULTS AND DISCUSSION

INTRODUCTION:

This chapter includes details on:

1. **Industrial units infrastructural facilities and activities and their water and wastewater**

    1.1 Overview of the infrastructure (including machinery equipment) of core processes

    1.2 Raw material being processed

    1.3 Core processing and environmental concerns

    1.4 Support processing and environmental concerns

2. **The water and the wastewater and the wastewater treatment**

    2.1 Water budget and inventory and characterization

    2.2 The existing wastewater plant and the wastewater treatment

3. **Wastewater management system developed highlighting the measures**

    3.1 For wastewater minimization generation through source reduction, recycling and reuse of water

    3.2 For cost effective treatment of wastewater and meeting the effluent prescribed standards

4. **Assessment of the influence of the measures suggested**

4.1 Industrial unit’s infrastructural facilities and activities

4.1.1 Overview of the infrastructure (including machinery equipment) of core processes

The industrial unit have the core facilities (machinery and equipment) given in **table-4.1** for the processing of Polyester and cotton and fabric washing. Sixteen soft flow machines are used dyeing. The liquor to fabric ratio used is 1:8. Two winche machines are used for job works mainly for softner application. Fabric liquid ratio employed in the winche machine is 1:20. Steam is injected directly into the winche machine for heating the contents. Hydro squeezers were used for the dewatering of died fabric. The dewatered fabric will be dried on the pole driers

Table 4.1: Machinery used in the processing of the fabric

S.no.	Description	Capacity	Number	Total capacity
1.	Long tube soft flow machine for dyeing	250 kg	1	250
2.	Cylindrical soft flow machines for dyeing	450 kg	3+1#	1350
		300 kg	2	900
		150 kg (1 ton)	1	150
		20 kg	1	20
3.	Cylindrical soft-flow machine for washing	450 (3 ton)	1	450
	Cylindrical soft-flow machine for cotton dyeing	300 (2 ton)	1	300
4.	Hydro squeezers	300	1	300
		200	1	200
		80	1	80
5.	Pole driers (20 poles with 10 radiator heaters as 4 units)	20 kg/pole/hour (cotton) 30 kg/pole (PC) 35-40 kg/pole (polyester)		
6.	Winch machines	650 kg	2	1300

4.1.2 Raw materials processed: Capacity of the unit is 9.0 tons/day of polyester dyeing and 400 kg/day of cotton dyeing, and 5.0 Tons/day of fabric washing. Quantity and type of fabric processed by the unit are given in table 4.2.

Table 4.2 Raw materials processed

Type	**Fibre**	**Production capacity (kg/day)**
Polyester (9 tons/day)	Light and medium shade (60%)	5400
	Dark shade (40%)	3600
Polyester Cotton (400kg/day)	Light and medium shade (60%)	240
	Dark shade (40%)	160
Total		9400

4.1.3 Core processing of the Industrial Unit

Dyeing of polyester (dark and light medium shades), cotton dyeing (dark and light medium shades) and fabric washing are the core activities of the industrial unit. Fabric dyeing and washing is done in soft flow machines. Steps of dyeing processing of polyester and polyester cotton in the industry are outlined as follows:

1. Dyeing of polyester (Dark shades)

Sequence of steps involved in the dyeing of dark shades of polyester fabric:

1. Fill machine with water, load fabric (fabric to water ratio is 1:10), raise temperature to 55C, dose dyes and chemicals (leveling agent 0.7%, green acid 0.7%, dispersing agent 0.5%, anticreasing agent 1%, and dyes 2-4%), raise temperature to 130C, cool to 80C and check. If fails in the check, further cool to 60C, dose chemicals and dyes, raise temperature to 130C, cool to 80C. If passes in the check, dose reduction cleaning chemical, raise temperature to 90C, cool to 80C, overflow cool to 60C, and drain.
2. Fill water, run the machine for cold wash and drain.
3. Fill water, dose cationic softner (2%) and acetic acid (0.2%), run the machine, and unload the fabric while draining out the liquid.
4. Load fabric to hydrosqueezer, squeeze dewater the fabric and unload the fabric.Load and unload a pole drier with the squeeze dewatered fabric for drying

2. **Polyester-Cotton dyeing (light shade)**

   Sequence of steps involved in the cotton fabric dyeing are:

   1. Fill machine with water, load fabric (fabric to water ratio is 1:10), raise temperature to 55C, dose dyes and chemicals (leveling agent 0.7%, green acid 0.7%, dispersing agent 0.5%, anticreasing agent 1%, and dyes 2-4%), raise temperature to 130C, cool to 80C and check. If fails in the check, further cool to 60C, dose chemicals and dyes, raise temperature to 130C, cool to 80C. If passes in the check, overflow cool to 60C, and drain. Fill water, run the machine for cold wash and drain.
   2. Fill water, dose cationic softner (2%) and acetic acid (0.2%), run the machine, and unload the fabric while draining out the liquid.
   3. Load fabric to hydrosqueezer, squeeze dewater the fabric and unload the fabric.
   4. Load and unload a pole drier with the squeeze dewatered fabric for drying.

3. Polyester-cotton (medium and dark shade) dyeing

Sequence of steps involved in the cotton fabric dyeing are

1. Fill water, load fabric, heat to 55C, dose chemicals (DFT, dispersing powder, green acid, dyes), heat to 130 (at the rate of 2C/min), run, cooling at the rate of 2C/min upto 80C, check sample, light shade overflow cooling, dark shade RC (80-90C) and overflow cooling upto 60-65C, and drain. In case failure of check cool to 60C, dose dyes, raise to 130 temperature.
2. Fill water, cold wash and drain.
3. Fill water, heat to 55C, dose chemicals (wetting agent, peroxide, caustic, and anticreasing agent), heat to 98C, hold for 45 min., cool to 80C, overflow cool to 65C, and drain
4. Fill water, heat to 55C, dose acetic acid and peroxide killer, run for 30 min., dose dyes and leveling agents, dose salt, soda and caustic, heat to 60C, hold for30 min, sample check, and drain. If the check fails, cool to 55C, dose dyes, heat to 60C, hold for 30 min, and check.
5. One cold wash
6. Fill water, dose acetic acid, run and drain.
7. Fill water, dose soap, heat to 70C, run, and drain.
8. Fill water, run for cold wash and drain.

9. Fill water, dose softner chemical and acetic acid, raise temperature to 40C, run for softner application and unload fabric while draining out the liquid.
10. Load the fabric to hydrosqueezer, squeeze dewater the fabric and unload the fabric. Load and unload a pole drier with the squeeze dewatered fabric for drying

4. Polyester-cotton (medium and dark shade) dyeing

1. Fill machine with water, load fabric (fabric to water ratio is 1:10), raise temperature to 55C, dose dyes and chemicals (leveling agent 0.7%, green acid 0.7%, dispersing agent 0.5%, anti-creasing agent 1%, and dyes 2-4%), raise temperature to 130C, cool to 80C and check. If fails in the check, further cool to 60C, dose chemicals and dyes, raise temperature to 130C, cool to 80C. If passes in the check, dose reduction cleaning chemical, raise temperature to 90C, cool to 80C, overflow cool to 60C, and drain.
2. Fill water, cold wash and drain.
3. Fill water, heat to 55C, dose chemicals (wetting agent, bioscaling agent, anticreasing agent, and acetic acid), run 45 min. run, dose dyes and leveling agent, dose salt, soda and caustic, heat to 60C, hold for 45 min, sample check, and drain. If the check fails, cool to 55C, dose dyes, heat to 60C, hold for 30 min, and check.
4. Cold wash-1 and Cold wash-2
5. Fill water, dose acetic acid, run and drain.
6. Fill water, dose soap, heat to 75C, run, and drain.
7. Cold washing 1 and cold washing 2.
8. Fill water, dose softner chemical and acetic acid, raise temperature to 40C, run for softner application and unload fabric while draining out the liquid.
9. Load the fabric to hydrosqueezer, squeeze dewater the fabric and unload the fabric.
10. Load and unload a pole drier with the squeeze dewatered fabric for drying\

4.1.4 Support processes and their environmental concerns

For supporting the core processing and providing the utilities and services, the industrial unit have the machinery and facilities indicated in table-4.3 environmental concerns associated with processes are summarized in table 4.4

1. Water supply

Ground water (raw water) is used in the industrial unit. The points of water use include soft water plant, dyeing machines, to amenities for domestic use

2. Soft water system

Ion exchange resin bed based soft water plant is used for producing the soft water (fed to the boiler as boiler feed water) from the raw water (groundwater). Regeneration is usually needed daily once and consumes salt.

3. Thermopac boiler and thermic fluid system

The thermo Pac boiler is of 10,00,000 kCal/hour heat supply capacity. It supplies heat through thermic fluid to the stenter and to some of the pole driers. Pet coke and/or wood is fired as fuel in the boiler furnace. Daily two tons of petcoke is burnt as fuel. Thermic fluid received from the stenter and the pole driers is heated in two steps (first in the economizer then in the boiler) and supplied back to the stenter and the pole driers. Exhaust gases of the boiler are passed first through the economizer, then through an air preheater (preheating of combustion air), then treated in a multiclone and a ventury scrubber and then discharged through a 80 feet height stack into the atmosphere. FD fan ahead of the air preheater and ID between the multiclone and the ventury scrubber help in pushing the combustion air into the boiler furnace and pulling out the boiler flue gases and discharging into the atmosphere.

4. Boiler and steam system

The steam boiler is of 5 ton/hour steam generation capacity. It is a fire tube boiler with water tubes embedded in the roof of the furnace. Soft water is used as boiler feed water and the generated steam is consumed in the soft flow machines, winch machines, pole driers and compactors. Condensate generated at the pole driers is recycled and reused as boiler feed water. Pet coke and/or wood are fired as fuel. The boiler has a heat recovery unit for preheating the boiler feed water to about 70C. Exhaust gases of the boiler are passed through the heat recovery unit, then treated in cyclone separators and a ventury scrubber, and then discharged through the 80 feet height stack (stack common to the thermopac boiler and the steam boiler) into the atmosphere. FD fan ahead of the boiler and ID between the cyclones and the ventury scrubber help in pushing the combustion air into the boiler furnace and pulling out the boiler flue gases and discharging into the atmosphere.

5. Amenities for the employees

The industrial unit is operated in two shifts (8 AM – 8 PM – 8 AM), and a total of 150-175 employees (100 in day shift and 50-75 in night shift) work in the industrial unit. Amenities provided for the employees include 6 urinals, 4 toilets and four wash basins

Table 4.3 Utilities and support activities related machinery/facilities of the industrial unit

S.no	Description	capacity	number	total
1.	Soft water plant(100 kg/2 days	60 cfm		
2.	Steam boiler	5 ton/hour	1	5 ton/hr
3.	Thermo pack boiler	10 lakh Kcal	1	10 Kcal
4.	Compressors			
5.	DG sets	300 + 250 KVA		

Table 4.4 shows the environmental concerns of the machinery used and supporting facilities

S. no	**Core/supporting facilities**	**Environmental Concerns associated**
1.	Soft flow machines	• Dumped dye baths, desize baths, scour baths, etc. • Wash water from jet washing of the fabric • Steam condensate generated at the external heat exchanger (can be contaminated by leaks in the heat exchanger) • Cooling water generated at the external heat exchanger (can be contaminated by leaks in the heat exchanger) • Packing material with residual chemical left behind after chemical use
2.	Hydro squeezers	• Centrifugally separated water comes out as wastewater • Electrical energy is needed for powering the drive
3.	Winch machines	• Dumped dye baths, desize baths, etc. Wastewater generation from the cooling and washing of the fabric • Vapours and heat loss from the liquid and fabric surface and generation of chemical waste and • Liquid/water spills and leaks

4.	Soft water plant	• Water consumption and wastewater generation for backwashing of ion-exchange resin beds, preparing the salt solution, regenerating ion-exchange resin beds during chemical draw, slow rinse and rapid rinse
5.	Steam system	• Fuel (lime in case of pet coke as fuel) • Boiler feed water (steam condensate + soft water or RO water) • Boiler feed water conditioning chemicals • Electrical energy for powering FD fan (primary air fan) and ID fan
6.	D G sets	• Exhaust gases discharged into atmosphere through stack (represent waste heat and air pollution) • Discarded engine oil, coolant oil, oil filters, etc. (hazardous wastes needing handling) • Noise pollution problems • Discarded batteries (statutory requirements applicable for disposal) • Leaks of oil and grease (housekeeping problem)
7.	Pole driers	• Electrical energy is required

4.2 The water and the wastewater and the wastewater treatment

4.2.1 Water budget and inventory and characterization of wastewater

4.2.1.1. Water requirements in the core processes: Places of water consumption in the industrial unit include soft flow machines for dyeing including overflow cooling and for cooling, winche machines for job works, amenities (urinals, toilets and wash basins), soft water plant for generating soft water and for the regeneration of ion exchange resin bed of the soft water plant. Water requirements by the core processes of the industrial unit are shown in table-4.7

Table 4.5: Water budge in the core processes

Fabric	Production capacity (kg/day)	Process water (m^3/day) (L/kg in parenthesis)	Cooling water (m^3/day) (L/kg in parenthesis)
Polyester –light and medium	5400	164.7(30.5)	105.3(19.5)
Polyester dark shade	3600	109.7(30.5)	83.8(23)
Polyester – cotton medium dark shade	240	17.3(72.2)	6.21(25.9)
Polyester cotton dark shade	160	11.8(74.1)	3.69(23.1)
Total	9400	303.5(32.2)	199.05(21.7)

4.2.1.2. Inventory of Chemicals: Chemicals and dyes are required for dyeing processes and effluent treatment. The industry is consuming around 32.2 kg/day of levelling agent, 37.8kg/day of green acids, 108kg/day of softner chemical and 12.7 kg/day of acetic acid. List of other chemicals consumed by the industrial unit are shown in table-4.6 .This list excludes the chemicals required in the effluent treatment.

Table 4. 6 List of Chemical and dyes consumed in the core processes

Cotton dyes
Polyester dyes
Common salt
Cationic softener
Anticreasing agent
Wetting agent
peroxide
caustic
soda
salts
dyes
Dispersing agent
Soap
Water softener
Peroxide killer

4.2.1.3 Inventory of wastewater generated: Wastewaters generated in the industrial unit include Steam condensate from the soft flow machine, cooling water from the soft flow machines, Wastewater drained from the fabric dyeing, boiler blow down water, regeneration wastewater from the soft water plant, wastewater from the amenities (goes directly into the municipal sewer). Inventory of the wastewater generated from the core process is given in table 4.8. Wastewaters generated from the utilities and services including amenities are shown in table 4.9.

Table 4.7 Inventory of wastewater generated from core processes

Fabric	Production capacity Kg/day	Steam condensate (m3/day)	Cooling water m3/day)	Wastewater Drained m3/day)	Total amount of waste generated (m3/day)
	(L/kg in parenthesis)				
Polyester –light and medium	5400	16.9 (3.13)	105.3(19.5)	163(30.2)	285.2(52.83)
Polyester dark shade	3600	3.30(11.8)	83.85(23)	108.7(30.2)	203.4(56.5)
Polyester – cotton medium dark shade	240	1.43(5.97)	6.21(25.9)	16.9(70.8)	24.6(102.6)
Polyester cotton dark shade	160	0.732(4.58)	3.69(23.1)	11.6(72.8)	16.07(100.48)
Total	9400	30.8(3.27)	199(21.68)	300.3(31.9)	529.27(56.2)

Table-4.8 Expected wastewater generation from the utilities and services

Utilities	Wastewater	Wastewater generated
Boilers	Boiler blow down	1.7 m3/day
Soft water plant	Regeneration water	3.2 m3/day
Amenities	Domestic water	6-7 m3/day

4.2.1.4. Characterization of wastewater

Characterisation of textile wastewater is very important to develop strategies for source reduction, water treatment and reuse and recycle. Characterization of raw water, boiler feed water, application softening water, raw effluent and treated water was done. Table 4.10 represents the characteristics of wastewater from different sources.

All of the results from analysis show that applicator softening water, raw and treated effluent produce higher concentration of wastewater in term of COD, TDS and BOD. Higher conc of TDS and COD in applicator softening water is due to chemicals used in the dyeing. The effluent characteristics of ETP 307.2 mg/L COD, 80mg/l TSS 34 pt. count colour and 900 mg/l TDS. It had been found that, at present the industrial unit is not in consistent compliance with the prescribed standards, specially, with BOD/COD and TDS.

Table 4.9 Characteristics of waste water of different samples

Parameters	Raw water	Boiler feed water	Applicator Softening water	Raw effluent	Treated water
p H	6.61	8.4	4.65	6.76	7.4
Turbidity (NTU)	32.5	23.8	301.6	527.3	51.5
TSS (mg/l)	30	40	150	190	80
TDS (mg/l)	50	80	1100	1290	900
COD (mg O2/l)	43.4	38.4	894	1094	307.2
Sulphate (mg/l)	0.5	4.66	164.2	148.1	127
Alkalinity (mg/l)	250	500	400	550	370
Chloride (mg/l)	49.65	76.4	449.7055	986.3	99.659
Colour (Pt. count)	4	6	23	182	34
Acidity (mg/l)	2	<1	26	3	2
BOD (mg/l)	22	17.3	489	566	153.6

4.2.2 The existing wastewater plant and the wastewater treatment

4.2.2.1. Existing effluent treatment plant and facilities of the ETP

Industrial unit have an effluent treatment plant for treating the wastewater and complying with the applicable effluent standards. The unit of the ETP includes reaction tank, flocculation tank, tube settler, pre filtration sump, pressure sand filter, activated carbon filter, sludge pits.

Table 4.10 Dimensions and capacity of facilities of unit

S.no.	Unit	Dimensions and capacities
1.	Raw effluent sumps	14 m x 4.25 m x 3.65 m 4.86 m x 3.65 m x 3.65 m (2 numbers) Effective volume: 285 m^3
2.	Raw effluent pumps	
3.	Reaction tank	Channel like metallic baffle tank
4.	Flocculation tank	1.2 m diameter and 2.45 m height cylindrical tank with hopper bottom
5.	Tube settlers	2 numbers each of 6 m2 area (2.45 m X 2.45 m)
6.	Pre-filtration sump	Ground level tank

		4.86 m x 3.65 m x 3.65 m Effective volume: 53 m^3
8.	Pressure sand filter	Two numbers (one in use) Diameter: 1.37 m Depth: 2.58 m Surface area: 1.47 m^2
9.	Activated carbon filter	Two numbers (one in use) Diameter: 1.37 m Depth: 2.58 m Surface area: 1.47 m^2
10.	Sludge pits	2 numbers each of 3.65 m length and 3.65 m width: 3.65 m Two additional pits each of 2 m width and 3 m length are associated with the sludge pits

4.2.2.2. Capacity assessment of the effluent treatment plant

Two Tube settler, numbers (2.45 m X 2.45 m**)** having surface areas 5.25 m^2 was considered to access the capacity of the effluent treatment plant. The capacity of treatment plant was estimated at 746 m3/day by assuming HRT of tube settlers is 30 mins.

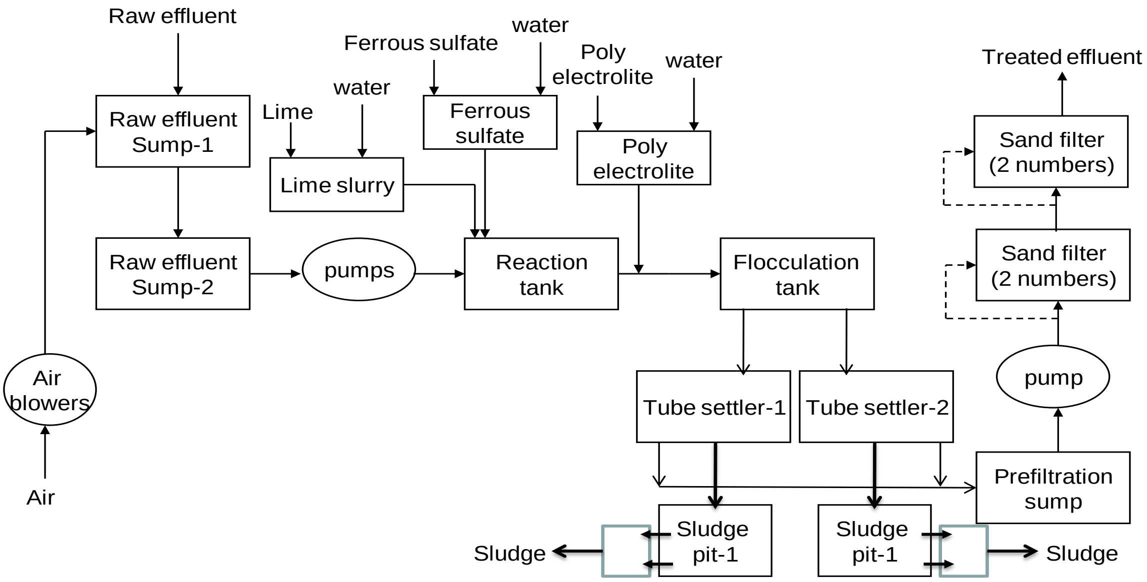
4.2.2.3 The wastewater treatment in existing ETP

All the generated wastewaters (including the wastewaters from the utilities like soft water plant, boiler, etc., the steam condensate and the cooling waters) are collected into the first compartment of the raw wastewater sump. There is a diffused aeration system in the first compartment. The first compartment of the sump is interconnected with the other two compartments. Wastewater from the second compartment is pumped and taken to the reaction tank. In the reaction tank, the wastewater is dosed with lime and ferrous sulfate and precipitation and flocculation are allowed to occur. Polyelectrolyte is dosed at the outlet end of the reactor into the effluent.

Wastewater from the reaction tank is allowed to flow under gravity into the two tube settlers through a flocculation tank for the clarification and removal of chemical flocs. The clarified effluent is collected into the pre-filtration tank. Settled sludge from the clarifiers is drained out into the sludge pits.

From the pre-filtration tank, the effluent is pumped and passed through a sand filter and then through an activated carbon filter, and disposed off as treated effluent into the municipal/public sewer. Both the sand filter and the activated carbon filter are backwashed at regular intervals with the effluent of the pre-filtration tank and the backwash water is taken back into the raw effluent sump.

Systematic representation of existing treatment plant is shown as below in figure 4.2



Existing Effluent Treatment Plant

4.3 Wastewater management system

Wastewater management system was developed highlighting the measures for minimization of the strength and /or volume of the wastewater generated through source reduction and through recycling and reuse of water and for cost effective treatment of wastewater and meeting the effluent standards prescribed.

4.3.1 Measures for wastewater minimization through source reduction and through recycling and reuse of water

1. Do not allow the cooling water into the effluent drain. Instead, provide a dedicated cooling tower and circulating cooling water system for supplying the cooling water to the soft flow machines.
2. Use of hot water in place process water in the dyeing machines
3. Segregate the steam condensate generated at the soft flow machines and recycle to the steam boiler for reuse as boiler feed water.
4. Avoid the overflow washing/cooling in the soft flow machines. This dramatically can

reduce water consumption and generation of wastewater from the dyeing process

4.3.1.1 Cooling tower and circulating cooling water system

Dedicated circulating cooling water system inclusive of cooling tower to supply cooling water to the dyeing machines will be satisfying the cooling water requirements. Hot water from circulating cooling water system will be pumped and stored in the overhead return head and will be used as hot water for the core processes in place of process water will reduce the water consumption and steam requirements.

Return Cooling water after use will be collected into cooling water sump through cooling water pit. From cooling water sump, water will be pumped into cooling tower for cooling and collected back into the sump. Cold water from the sump will be pumped supplied to the overhead cooling water tank and used in the machines when required.

Process water is used in the cooling water sump to make up with loses (evaporation losses, drift loses). **Figure 4.1 shows the scheme of circulating cooling water.** Process wise cooling water requirements have been estimated, when hot water coming out from circulating cooling system shown in the **Table-4.11.** In these estimations ΔT of the cooling water had been assumed as 30^0 C

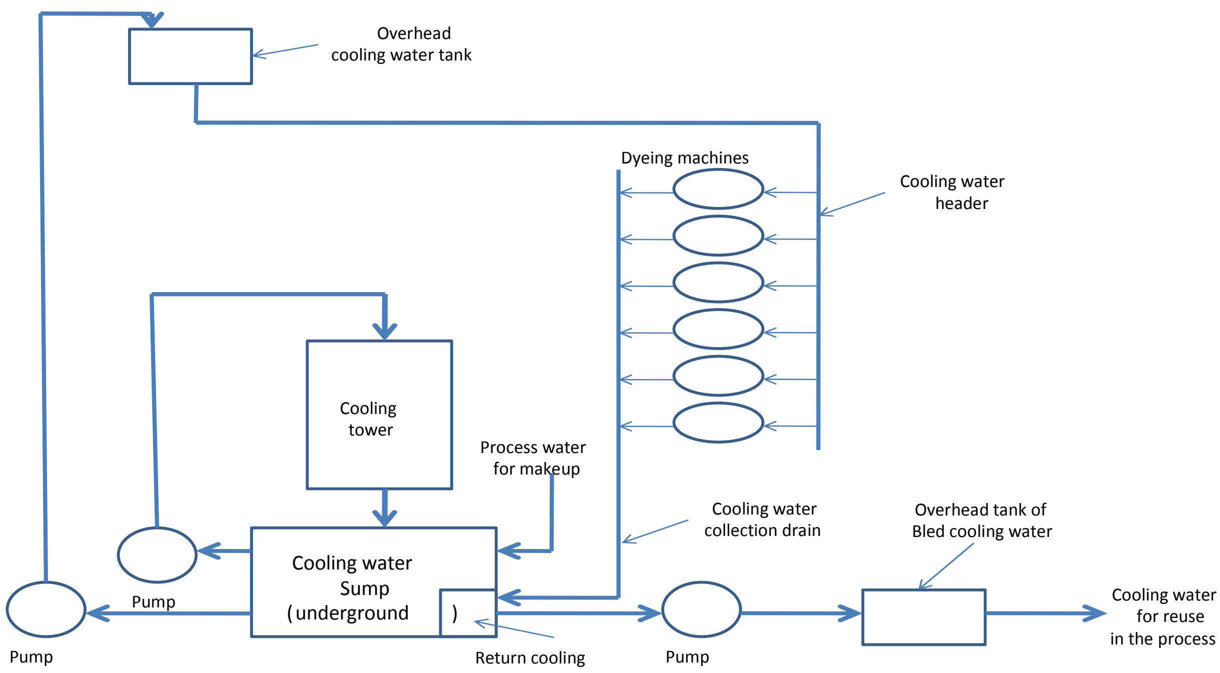


Figure 4.2 Scheme of circulating cooling system

Table 4.11 Cooling water requirements of the core processes

Fabric	Production capacity (kg/day)	Circulating cooling water requirement(m3/day)	Cooling water (m3/day)	Net Cooling water requiring cooling (m3/day)
Polyester –light and medium	5400	105.3	26.46	105.3-26.46= 78.84
	L/kg	19.5	4.9	14.6
Polyester dark shade	3600	83.85	21.9	61.6
	L/kg	23.3	6.1	17.2
Polyester – cotton medium dark shade	240	8.97	3.4	5.57
	L/kg	37.4	11.2	16.42
Polyester cotton dark shade	160	4.5	2.66	1.84
	L/kg	28.4	8.3	12.7
Total kg/day	9400	202.05	54.42	147.7
	L/kg	21.8	5.72	15.71

4.3.1.2 Use of hot water in place of process water: Steam requirements of the core processes are estimated at 30.8 tons/day, when the industrial unit is run at design capacity. Use of hot water from circulating system in place of process water, can bring down the steam consumption.

Table 4.12 shows the calculations of steam requirement when hot water is not used, and steam steam requirements after using hot water in place of process water. Here 95% steam was considered as dry, the useful energy of the dry steam as and 90% heat transfer efficiency at the dyeing machines**.** 0.02226 is taken as steam required for heating (Kcal/kg fabric/C). It has been calculated that, use of return cooling water effluent in place of process water at all feasible places will be reducing the steam requirements by 12 tons/day.

Table 4.12 Steam requirements in the core processes

Fabric	Production capacity (kg/day)	Steam requirements , (ton/day)	
		When hot water is not used	When hot water is used)
Polyester – light and medium	5400	16.9	10.4
	kg/kg	3.13	1.7
Polyester dark shade	3600	11.8	5.76
	kg/kg	3.3	1.6
Polyester – cotton medium dark shade	240	1.43	1.02
	kg/kg	5.97	4.1
Polyester cotton dark shade	160	.732	0.62
	kg/kg	4.58	3.9
Total	9400	30.86	17.9

4.3.1.3. Boiler and Segregated steam condensate system

Collection of all the steam condensate wherever generated and its reuse as boiler feed water will meet boiler feed requirement and will be reducing the boiler blow down wastewater generation and regeneration of soft water.

Assuming 30% energy losses in the steam distribution system, 95% steam was considered as dry, the steam generation requirements have been estimated at 46.9 tons/day**.**

If 5% is the boiler blow down losses. 48.8 m3/day water is required for steam generating 46.9 tonnes/day. Boiler feed water requirement for generating 26.9 tons/day of steam has been estimated at 28.08 m3/day. 63% of boiler feed requirements can be met from steam condensate.

Use of steam condensate will be reducing the soft water requirements from **28.08 m3/day to 10.8 m3/day.** Further, regeneration of soft water and boiler blow down wastewater generation will be reduced to **2.2 m3/day and 1.2 m3/day** respectively.

4.3.1.4. Eliminating overflow cooling/washing and reducing the number of scouring and dyeing steps: Avoid overflow cooling and washing, Instead cool in external heat exchanger with circulating cooling water to conserve water and minimize wastewater generation. These modifications will reduce water consumption and generation of wastewater from the dyeing process. (see table 4.14)

4.3.2 Measures for cost effective treatment of wastewater and meeting the effluent prescribed standards

4.3.2.1 Comparison with prescribed standards

The most important parameters in wastewater from textile industry are Chemical Oxygen Demand, Biological Oxygen Demand (BOD), pH value, Suspended solids, Total dissolved solid, colour. The effluent characteristics of ETP were analysed and compared with the standard prescribed by Central Pollution Control Board for treated effluent/discharge effluent. Comparison of discharge effluent from textile industry with standard prescribed by Central Pollution Control Board are given in table 4.13

Table 4.13 Comparison of discharge effluent with standard prescribed by CPCB

Parameter	Concentration not to exceed, milligram per litre(mg/l), except pH	Discharge effluent of ETP of industy
pH	5.5-9.0	7.4
Total suspended solids	100	80
(BOD)	30	153.6
Alkalinity	125-200	320
Total dissolved solids	50	546
Chemical oxygen demand(COD)	250	307

It has been found that values of COD and BOD, Total dissolved solid of textile effluent are 1095mg/l , 566 mg/l, 541mg/l respectively are higher than the standard prescribed by Central Pollution Control Board. So, at present the industrial unit is not in consistent compliance with the prescribed standards, specially, with BOD/COD and TDS. Additional treatment unit thus is needed to comply with the standards prescribed for discharge into land.

4.3.2.2 Problems identified in the existing ETP

1. It has been observed from the characteristics of untreated wastewater and treated wastewater, the industrial unit does not meet the prescribed standards for BOD/COD .
2. Coagulating agents used in the process, dosing of lime and ferrous sulfate is neither optimized nor sufficiently regulated.
3. There is unequally distribution of water in the both tube settlers used in the ETP.
4. Treated effluent comes as reddish brown color due to ferrous iron remain the treated effluent.
5. The existing filter press is suspectedly not having enough capacity to handle all the sludge generated
6. Filter backwashing is carried out by the effluent from the pre-filtration sump using the same pump which is being used for feeding the effluent to the filter.

4.3.2.3 Modifications/ suggestions for improving the performance of existing ETP

1. Turn the effluent treatment process into a batch treatment process. Create two or three raw wastewater sumps and alternatively use them for collecting the incoming wastewater. Once a sump is full, divert the incoming wastewater into the next sump and start treatment of the wastewater collected.
2. Regulate and control the chemical dose based on laboratory experimentation on the wastewater sample collected from the sump.
3. Provisions will be provided for mixing the dose in the raw water sump through diffused aeration system.
4. Division box will be provided between the flocculation tank and tube settlers tank to distribute equal amount of water between two tube settlers.
5. Create a biological (or secondary) treatment unit with diffused aeration system used in the aeration zone to ensure the treatment of BOD. Provisions will be made for removing the clarified effluent and disposing into the public sewer through a treated effluent sump. A biological system with aeration system will be downstream to the pressure sand filter.
6. Provisions will be made for handling and disposal of sludge from secondary effluent.

4.3.2.4 New effluent treatment plant proposed

New effluent treatment plant will have an additional biological unit for removal Of BOD and to meet with prescribed standards and treated effluent sump for handling the secondary clarified effluent**. Treatment Scheme of new treatment plant explained as follows:**

Two or three raw wastewater sumps will be created and alternatively use them for collecting the incoming wastewater. Once a sump is full, divert the incoming wastewater into the next sump and start treatment of the wastewater collected. The incoming wastewater of the industry collected into the raw water sump. There will be three raw sumps. These are alternatively used them for collecting the incoming wastewater. Once a sump is full, divert the incoming wastewater into the next sump and start treatment of the wastewater collected.

Dosing of lime, and ferrous sulfate chemicals for coagulation and flocculation to occur will be done into raw water sump with help of diffused aeration system. Bring about the coagulation and flocculation and also oxidation of ferrous iron into ferric iron within the raw wastewater sump with the help of the diffused aeration system.

After the chemical coagulation/precipitation-flocculation treatment, water will be pumped to to tube settlers through the flocculation tank. Clarified effluent will be collected into the pre-filtration tank. Laboratory experiments of the sample collected from sump will be done to control and regulate the dose of coagulant agents. When water from flocculation tank comes to tube settlers and provisions will be provided for the sludge produced from setters through sludge pit. Division box will be provided for equal distribution of water between two tube settlers.

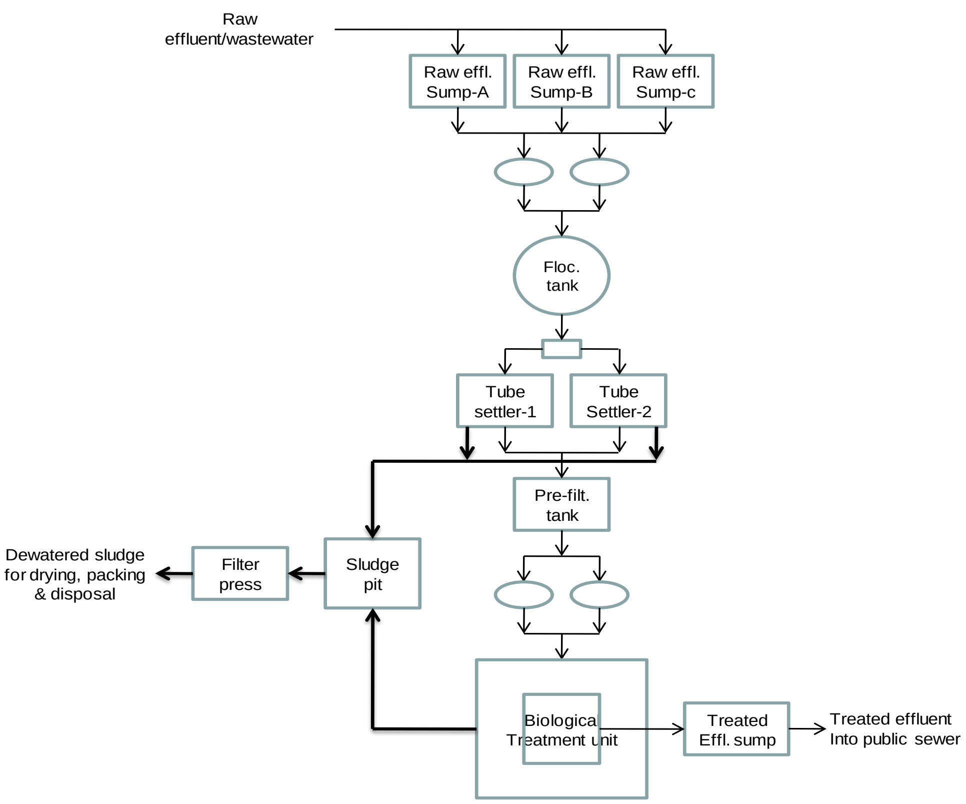
The biological unit will be created to meet the effluent standards for disposal and for the further treatment of the clarified effluent collected in the pre-filtration tank. This unit will have a peripheral aeration zone and a central settling zone. Diffused aeration system will be used in the aeration zone. Provisions will be made for collection and disposal secondary treated effluent and sludge produced from it. Clarified wastewater will collected from clarifier zone into treated effluent sump. This sump will have an overflow drain for draining out the excess treated secondary effluent for disposal on land.

Pump the clarified effluent, pass through a pressure sand filter and load into the aeration zone of the biological treatment unit. Collect the clarified waste water from the clarifier zone and drain into the treated effluent sump. From there allow the treated effluent to overflow into the municipal sewer.

Treated secondary effluent in the treated sump will be used for the preparation of the lime, and slurry, ferrous sulphate solution and polyelectrolyte solution and for the back washing of pressure sand filters. Then filter press is used for handling and dewatering of sludge produced from tube settles and sludge drained out from the biological unit. All the sludge generated is collected into a sludge pit. Sludge will be dewatered the in the filter press after addition of polyelectrolyte (for improving the dewatering properties).

The final effluent from the treated effluent sump will be used for the washing of the filter press. Filtrate generated from the sludge dewatering and wash water generated from the filter press washing may be taken back into the raw effluent sump for treatment along with other wastewaters. Dewatered sludge may be sun dried, packed in plastic bags, temporarily stored and finally transported to the Nimbua hazardous waste disposal site for disposal.

Schematic Representation of new effluent treatment plant proposed is shown in the following figure 4.3



4.4. Assessment of the influence of the measures suggested

Implementing modifications to the industrial unit i) dedicating circulating cooling system and cooling tower ii) avoiding overflow cooling and washing iii) use of hot water and in place of process water iv) Collecting the steam condensate, its use as boiler feed water, at all feasible places have been estimated to reduce water consumption in the core processes by 167m3/day, (shown in table 4.15), wastewater generation by 297 m3/day (shown in table 4.16)and steam consumption by 12 ton/day (and steam generation by 23 ton/day), represented in table 417. In addition, steam condensate will be limiting use of soft water limiting the use of soft water water just as a makeup boiler feed water are expected to reduce the RO water requirement by 63% and return steam condensate will reduce the boiler blow down waste generation.

Table 4.13 represents the input and output analysis of modified process after implementing the modification in the industrial activities.

Table 4.14 Modified process input and output analysis

Fabric	**Quantity processed**	**Process Water**	**Cooling water**	**Circ. Cooling Water**	**Steam**	**Condensate**	**WW**
Polyester – light and medium	per kg	14.7	8.8	21.5	1.7	1.7	23.37
	5400	79.38	47.9	116	10.4	10.4	126.1
Polyester – dark shade	per kg	14.7	8.8	25.1	1.6	1.6	23.3
	3600	52.9	31.9	90.36	5.76	5.76	83.7
Polyester – cotton Light medium	per kg	10.6	13.45	47.4	4.1	4.1	59.4
	240	2.5	3.2	11.3	1.02	1.06	14.2
Polyester - cotton Dark shade	per kg	9.14	12.3	33.4	3.9	3.9	53.1
	160	1.4	1.96	5.3	0.62	0.62	8.4
Total (m3/day)	**9400**	**136.7**	**84.96**	**223**	**17.9**	**17.9**	232

Table 4.15 Influence of the measures on water consumption in the core processes

Fibre	Production capacity(kg/day)	Without implementing modifications (m3/day)	With all modifications Suggested (m3/day)
		(L/kg in parentheses)	
Polyester –light and medium	5400	164.7(30.5)	79.38 (14.7)
Polyester –dark	3600	109.7 (30.5)	52.9(14.7)
Polyester Cotton – light and medium shade	240	17.2 (72)	2.5(10.6)
Polyester Cotton – dark shade	160	11.8 (74)	1.4(9.14)
Total	9400	303.45 (32.2)	136.7(14.5)

Table 4.16 Influence of the measures on wastewater generation in the core processes

Fibre	Production capacity(kg/day)	Without implementing modifications(m3/day)	With all modifications Suggested (m3/day)
		(L/kg) in parentheses	
Polyester –light and medium	5400	203.4(56.5)	126 (23.37)
Polyester –dark	3600	282.2(52.83)	83.7(23.3)
Polyester Cotton – light and medium shade	240	24.6(102.2)	14.2(59.4)
Polyester Cotton – dark shade	160	16.07 (100.48)	8.4 (53.1)
Total	9400	529.27 (55.95)	232(42.9)

Table 4.17 Influence of the measures on steam generation requirements

Fabric	Production capacity (kg/day)	Steam requirements , ton/day	
		When hot water is not used	When hot water is used
Polyester – light and medium	5400	16.9	10.4
	kg/kg	3.13	1.7
Polyester dark shade	3600	11.8	5.76
	kg/kg	3.3	1.6
Polyester – cotton medium dark shade	240	1.43	1.02
	kg/kg	5.97	4.1
Polyester cotton dark shade	160	0.732	0.62
	kg/kg	4.58	3.9
Total	9400	30.86	17.9

CHAPTER 5
CONCLUSION

The aim of the study was the development of wastewater management system for an industrial unit. The study was based on the environmental analysis of the unit to identify the water consumption and wastewater generation sources and analysis of existing effluent treatment plant of the unit to suggest the measures for wastewater minimization and for cost effective water treatment.

It has been found the industrial unit does not meet the effluents standards when compared with CPCB standards especially with BOD/ COD. After identifying the potential sources of water consumption and generation and wastewater treatment situation, Wastewater management strategies have been suggested through source reduction, recycling and reuse of water for water conversation and waste minimization. In addition, alternate schemes of cost effective treatment of wastewaters consistent compliance with the applicable effluent standards, have been proposed for wastewater management .It has been concluded that having a dedicated circulating system will meet the cooling water requirements and reducing the wastewater generation. Use of hot water (return cooling water) form circulating system in place of process water at all feasible places will reduce the water consumption by 46%. 30.8 tonnes/day of steam generation is required when industrial is run at design capacity. Use of hot water as process water will bring down the steam genera ration requirements to 17.9 tonnes/day. Collection of steam condensate and reuse it as boiler feed water will be limiting the use of soft water plant (supply water to boiler as feed water) and it will be reducing the boiler blown waste generation and regeneration of soft water. It has been estimated that about 60% of boiler feed water will be recovered from steam condensate.

Some parameters (energy losses in the steam distribution system, volume of boiler blow down, regeneration water of soft water plant, heat transfer efficiency during heating and cooling, delta temperature for cooling water) were assumed for the estimation of water requirements, waste generation, and steam generation in the core processes. These values may differ in the actual situations, hence calculations for waste generation, soft water requirements, and steam generations would be adjusted accordingly. Future work may involve use of flash tank in boiler blow down, efficiency improval of hot exchangers, recycling of treated effluent.

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