CHAPTER I

INTRODUCTION

1.1 GENERAL INTRODUCTION

Textile industry in India is on a resurgent path since last couple of years. This growth started with the termination of the multi fibre agreement (MFA) which ended on 31^{st} December 2004. The textile industry had sensed this opportunity and had started gearing up for the same. The industry has gradually increased its capacity and modernized manufacturing facilities. The textile exports have grown at a phenomenal rate of 20% during the first year after the closure of MFA. Though the growth has a bit slowed down in the subsequent year, the opportunities for growth to the industry are encouraging and are acting as stimulant for investments. There has been a total investment of about Rs. 65,000 crores in the industry between 2004 – 2007. This had gone up to 150,000 crores by 2013.

India grows all the four cultivated species of cotton, namely, Gossypium arboretum, G. herbaceum, G. hirsutum and G. barbadense. India is the leading producer of cotton in the world accounting for one-fourth of the world output covering 36% of the area under global cotton cultivation. The area under cotton cultivation crossed 11.0 million hectors with over 350 lakh bales of cotton in the year 2016 – 2017. Besides, india is the largest consumer of cotton in the world with a robust cotton value chain. However, in this conventional value chain, there are several week links and also missing links. The crucial unit operation involved in the value chain namely ginning ie. conversation of seed cotton in to lint, is still considerd to be one of the weakest links characterized by excessive use of energy, low productivity, absence of cleaning and lack of facilities for quality assessment of the lint that this sector produces. Although, the spinning industry in India is considered as one of the most modern sectors with standards that are comparable to rest of the progressive countries, the same cannot be said about the weaving/ knitting sectors as far as quality of the end product is concerned. Further, in the down stream processing such as preparatory

chemical treatments like scouring and bleaching of yarns or fabrics, ecofriendliness, energy use efficiency, effluent generation and its treatment are factors that need immediate attention.
In the small scale sector as well as in handloom industry, non-availability of quality raw material and use of highly carcinogenic synthetic dyes causing untold miseries in terms of health problems among workers/ artisans handling these chemicals/ pigments are issues that remain unresolved.

Grey fabric as it comes out of loom contains natural and added impurities. These non-cellulosic materials in the fabric make the dyeing and printing process non-uniform. Hence, grey fabric is given some pretreatment before they are sent for the dyeing / printing and finishing. Unless the fabric is dyed or printed it cannot become attractive and in turn saleable in the market. Therefore pretreatment is carried out in certain sequence and all the fabrics have to be passed through the following sequences. The sequences are: Singeing, Desizing, Scouring, Bleaching and Mercerization.

Above mentioned preprocessing steps at each stage has their individual objective. Among these **"Scouring"** plays an important and critical part for the subsequent treatments. Boiling in Sodium Hydroxide (NaOH) is the conventional scouring process used by the textile industry to improve the wetting and the penetration of aqueous dyeing and finishing solution. Uniform wetting strongly depends on the scouring conditions and the structure of the cotton products, i.e. yarns and fabrics. The scouring process involves large quantities of water and energy and requires special handling of the sodium hydroxide effluents.

Scouring consists of the hot alkaline liquor containing a detergent through a regularly packed column of desized cloth usually under pressure for a prolonged period of normally up to 4 hours to 6 hours, and at room temperature up to 24 hours. This is done in a boiler, also called a **Kier**.

Textile industries use various chemical agents in their different processes like desizing, cotton softening, denim washing, silk degumming etc. These chemicals after their use cause pollution in the effluents and some of them are corrosive which could damage equipment and the fabric itself. However with the introduction of the "enzymatic process in textiles", the scenario has changed in recent times ensuring eco-friendly production and are successfully used in various textile process like pretreatment, dyeing and finishing.

Commercial enzymes for scouring is an effective way to scour cotton and cotton blended fabrics for a natural look or to prepare fabric for dyeing. The process is known as "bio-preparation" or "bioscouring" because it's a biological alternative treatment to that of harsh chemicals. "Whereas, the **"Microbiological scouring"** process is carried out by employing a group of microorganisms producing enzymes in the absence of air in an aqueous system. Fabric can be subjected to anaerobic treatment for 12-24 hours followed by boiling in 0.1% alkali at 100°C for 15 mins. The results have indicated that such anaerobically treated yarns and fabrics followed by bleaching and dyeing indicated deep shades than their conventional dyed counter parts. This indicates that quantity of dyes required may be slightly less which could bring down the cost of the finished fabrics.

There are several advantages in bioscouring: Smoother dyeing, Dye stuff saving, Safer and easier handling, Water savings, Softer feel and the cotton fibre is the least damaged in the process. It works well not only on cotton fabrics, but also on blended ones.

The present study is carried out on 100% cotton as well as on polyester/cotton blended fabrics. Hence it is important to understand the fibre structure of both the fabrics.

1.2 COTTON FIBRES

1.2.1 History[4]:

Cotton is the oldest and the most important of the textile fibres. The cotton plant belongs to the natural order of the Malvaceae. There are four species of cotton viz; *Gossypium herbaceum, G. arboreum, G. hirsutum and G.*

barbadense which are under commercial cultivation. No matter where the spinning and weaving of cotton may have been developed first, there is no doubt that India was the true cradle of the cotton industry.

1.2.2 Formation & Structure[9]:

When the boll opens, the moisture evaporates from the fibres. Until this happens, the fibres maintain their tube-like appearance, with a circular cross-section. When the boll bursts and the fibres dry out in the air, they twist length wise, forming convolutions which are characteristic of the fibre. These twists take place in both directions in the fibre; some are left handed and others are right handed, with an almost equal number of each in any individual fibre. The mature fibre can be recognized by the twist or **convolutions** which are a characteristic to cotton. Typical Indian cottons will have about 150– convolutions per inch.

The wall of the fibres varies in thickness. It consists of two main sections, the **Primary wall** or cuticle forming the outer layer and the **Secondary wall** forming the inner layer.

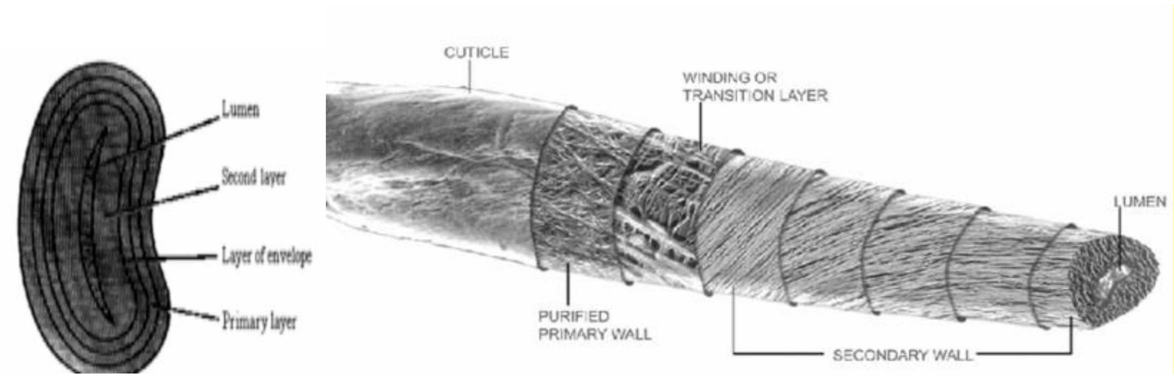

Fig: 1. Structure of Cotton Fibre

The **Primary wall** is a tough, protective layer that formed the shell of the fibre during its early days of growth inside the boll. Seen under the microscope at high magnification, the surface of the cotton fibre is wrinkled like a prune. These surface wrinkles are caused by shrinkage as the fibre has dried.

The **Secondary wall** or the inner layer of cellulose forms the bulk of the cotton fibre. This is the cellulose that is laid down during the second stage of fibre growth, after the fibre has attained its full length. The fibrils of the secondary wall are packed together in a near parallel arrangement. The secondary wall is the pure cellulose and represents about 90 per cent of the total fibre weight.

As the fibre dies and collapses, the liquid disappears leaving an almost empty channel running length wise through the centre of the fibre. This central canal is the **Lumen**. Cottons have been grown experimentally in which the lumen contains brown or green pigments which act as natural “dyes.

1.2.3 Constituents of Raw Cotton[33]:

Raw cotton contains, in addition to cellulose, the usual constituents of a vegetable cell. These are oils and waxes, pectoses and pectins, proteins and simpler related nitrogen compounds, organic acids, mineral matter and natural colouring matter. The approximate composition of raw cotton is as follows:

Table: 1. Composition of raw cotton

Composition	(%)
Cellulose	85.5 %
Oil and waxes	0.5%
Proteins, pectoses and the colouring matter	5.0%
Mineral matter	1.0%
Moisture	8.0%

1.2.4 Types of Cotton[4]:

The length of cotton varies from few mm to 45 mm and grouped as short staple, medium staple, long staple and extra long staple cottons. Staple length beyond 25mm with good strength goes for spinning purpose.

1.2.5 Processing of Cotton fibres[33]:

After the cotton is cultivated and cotton fibre is obtained from the field by manual or mechanical picking process, it does go through lots of processing in the mill to obtain yarns and then fabric out of this cotton fibre. The stages of processing of cotton fibre in the mill are as follows:

1.2.5.1 **Ginning:** After picking, the cotton fibre has to be separated from the seeds, a process carried out mechanically by the cotton gin.

1.2.5.2 **Preliminary process of spinning:** Before the actual spinning of the cotton is carried out, the fibres are subjected to several preliminary processes namely, carding, drawing and combing.

1.3 POLYESTER FIBRES[8, 21]:

Polyester made in America (Dacron) is synthesized by polymerizing terepthalic acid with ethylene glycol at a high temperature; whereas the polyester made in UK (Terylene) is produced by polymerizing DMT and ethylene glycol at high temperature. In both these reactions the end product is the same, the only difference being in Terylene, the end group is an ester where as in Dacron the end group is carboxyl group. All over the world DMT is prepared instead of a terepthalic acid because it is easy to purify Dimethylterepthalate than Terepthalic acid by distillation at low temperature. The polymerized substances extruded in the form of a ribbon from the autoclave on to a moving wheel where the ribbons solidify. This is then cut into small chips and dried to remove the moisture. These chips are then passed in to the melt hopper for melting. The melt polymer is then extruded through the spinneret. The filaments solidify instantly when they come in contact with the air. These filaments are then wound on bobbins. These bobbins are further taken to draw twist machine where the filaments are hot stretched to about 5 times its original length. This twisted yarn is wound on cones and bobbins are supplied to mills to make fabrics.

Table: 2. Summary of Textile Properties of Polyester and Cotton

Properties → / Fibre ↓	Mechanical Properties	Water Absorption	Dyeability	Aesthetic Property	Abrasion	Creasing	Crease Retention	Bulk of Staple	Static	Pilling	Softening point
Cotton	B– A	B-A	A	B	B	C	C	C-B	A	A	A
Polyester	A	C	C	A	B	A	A	B	C	C	B

Above Polyester and Cotton fibre properties are explained through a rating between A, B & C; Where; **“A”** – Excellent, **“B”** – Average & **“C”** – Poor**.**

It can be seen from above mentioned table that none of the two fibres has “Excellent” recorded for every property. Each fibre has a balance of good points and bad points. By proper blending, the deficiencies of one material can be corrected by the advantage of other.

1.3.1 Importance of Blending[12,13,19]:

The term “Blending” is used by the yarn manufacturer to describe specifically the sequence of processes required to convert two or more kinds of staple fibres in to single yarn composed of an intimate mixture of the component fibres. This may be necessary to obtain a uniform yarn from different varieties of the same fibrous polymer. Any blend must have acceptable properties for the spinner. Important factors include the relative diameter, staple length and the extensibilities of the fibres present. Woven staple 67:33 and 50:50 polyester/cotton blends in numerous constructions form the well established basis of this field and many of these fabrics are produced in sufficient quantities to justify continuous dyeing.

1.3.2 Properties of Polyester/Cotton Blended fabric[12]:

Fibre blending can be regarded as a contribution to fabric engineering. By using fibres that differ in absorbency, fabrics with specific moisture regain values can be created. Polyester/Cotton blends represents the most successful compromise between the contrasting physical properties of synthetic and natural fibres are as follows -

1.3.2.1 In blends of polyester fibre with cotton, the synthetic component provides crease recovery, dimensional stability, tensile strength, abrasion resistance and easy care properties, whilst the cellulosic fibre contributes moisture absorption, antistatic characteristics and reduced pilling.

1.3.2.2 Earlier fabrics were unable to retain creases once they had been made into garments. Later the polyester/cotton blends was adopted, where the durability and crease resistance of the polyester made an impressive contribution to the garments.

1.3.2.3 A valuable advantage for polyester in blends with cotton is its outstanding resistance to severe preparation necessary for raw cotton before dyeing. Cotton is usually the minor component in a polyester/cotton blend so that alkaline scouring, peroxide bleaching and mercerizing usually provide adequate preparation.

1.3.2.4 Cold mercerizing after bleaching improves absorbency, luster and dimensional stability of polyester/cotton and improves the colour yield of reactive dyeing.

1.3.2.5 Crease recovery, dimensional stability and pilling resistance are all improved by stenter setting of polyester/cotton fabrics. This is normally carried out at 180 - 200°C on a stenter either before or after dyeing.

1.3.2.6 Singeing at both side of the fabric is essential for polyester/cellulosic staple blends, but this treatment should be carried out after batch-wise dyeing. The microscopic beads of fused polymer formed on the tips of the projecting polyester fibres take up dye more readily which produce an unacceptable skitter or speckled appearance, especially after batch wise dyeing.

1.4 PREPARATORY PROCESSES:

1.4.1 Introduction[23]:

For perfect colouration of the substrate, it is necessary that all the impurities be removed from the surface so that the colourants can penetrate inside the substrate as required by the particular system. Textile materials possess natural as well as added impurities. Raw cotton beside cellulose contains other natural impurities such as waxes, fats and pectic substances. Some materials are occasionally contaminated by accidental impurities acquired while handling of the materials. For example; some chemicals may be added purposefully for better spinning or weaving process. These impurities make the cotton fibre more or less water repellent and prevent it from wetting out easily when placed in water. This results in poor dyeing operation as the dye stuff solution will not penetrate within the fabric perfectly and evenly. All such impurities are to be removed before actual dyeing or printing processes. The steps by which the impurities are removed are called Preparatory process or Pretreatment process.

1.4.2 Aim & Stages of Preparatory processes [5,18,20,26]:

The aim of preparatory wet processing is to treat the goods by standard procedures so that they are brought to a state in which they can be dyed, printed or finished without showing any fault or damage on the material.

The prepared material should have the following properties:

1. Uniform power of absorption for dyes and chemical in subsequent processes.
2. Removal of all types of impurities including broken seeds etc.
3. Minimum damage of the material.
4. Absence of creases and wrinkles.

5. High whiteness value.

Different textile material possesses different inherent impurities. The preparatory processes, therefore, vary for textile substrate. However they can be generalized into following sequence:

SINGEING ⇒ **DESIZING** ⇒ **SCOURING** ⇒ **BLEACHING** ⇒ **MERCERIZIN**

Fig. 2: Sequence of preparatory process

1.4.2.1 Singeing: When yarn is made from short staple fibres, the two ends of the fibre may not be embedded inside the yarn and are projected due to the twist imparted during spinning. The aim of singeing is to burn off the protruding fibres and hairs from the fabric surface without scorching or damaging the body of the fabric.

1.4.2.2 Desizing: Desizing is the process in which the size applied to the warp yarn before weaving is removed to facilitate the penetration of dyes and chemicals in the subsequent wet processing operations. The presence of size makes the fabric stiff and the dyeing process difficult. Therefore, one of the initial steps in wet processing is the elimination of size, the operation being called Desizing. In desizing, the starches and polymers that applied are insoluble and converted into water soluble compound to ease their removal. This is accomplished by transferring the starch into their simple sugars or simple water soluble polymers. Solubility of starch may be promoted by the action of acids, oxidizers, alkalis and enzymes.

1.4.2.3 Scouring: It is the most important wet process applied to textile materials before dyeing or printing. The Scouring process is also known as Kiering & Kier Boiling. The objective of scouring is to reduce the amount of impurities sufficiently to obtain uniform results in dyeing and finishing operations. When the impurities are removed, the cotton becomes absorbent. In fact, the success of a scouring process is judged by the improvement in wettability of the scoured material. The appropriate type of scouring agent generally depends on the kind of fibre; fabric type i.e. Woven or Knitted, thick or thin; texturised or non-texturised and the extent of impurities present in the fibre. Scouring agents can be generally classified into different groups.[23]

Scouring Agent

- **Alkaline Agents**: NaOH, KOH, Na_2CO_3, Liquid NH_3 (Sodium metasilicate, Trisodium Phosphate, Tetrasodium Phosphate, Sodium tri-polyphosphate, Borax etc.)
- **Surfactants**: Anionic activator, Non-ionic activator
- **Emulsion Scouring**
- **Organic Solvent**
  - **Chlorine System**: Carbontetrachloride, Trichloroethylene, Perchloroethylene, Methylchloroform, Trichloromethane, Fluorine.
  - **Hydrocarbon system**: Benzene, Industrial Gasoline, White spirit, Solvent naphtha

Fig. 3: Classification of Textile Scouring Agent

The impurities which must be removed are natural oils and waxes, proteins, pectic substances, natural colouring matter and adventitious dirt. Vigorous scouring is desirable since the cotton goods are opt to contain cotton seeds, husk and leaves which interfere in dyeing and subsequent processing. Efficient boiling is essential for good bleaching in accordance with saying – **"Well boiled half bleached".** The changes caused by the treatment with boiling alkali have been summarized as follows:

1. Hemicelluloses as well as cellulose fractions with a low DP are dissolved.
2. Saponifiable oils and fats are converted into soaps.
3. Unsaponifiable oils and waxes are melted at the scouring temperature and are emulsified by the soap formed during saponification.
4. Pectins and pectoses are converted into soluble salts of pectic acid and metapectic acid.
5. Proteins are hydrolysed with the formation of soluble sodium salts of amino acids or ammonia.
6. Water soluble mineral substances are dissolved.
7. Insoluble dirt is removed and retained in suspension.

8. Sizing and other added impurities, if presents are broken into soluble products.

Kier boiling may be carried out either at atmospheric pressure in an open kier or under pressure in a closed kier. In the latter case, the pressure is often taken as measure of the temperature – this is true only if no air is present in the kier. For example, 20, 30 and 40 pounds per square inch (psi) (1.4, 2.1 and 2.8kg/cm^2 respectively) pressure are equivalent to temperature of 125°C, 134°C and 141°C respectively. Caustic alkalinity at the time of draining should not be less than 10% of the starting concentration in order to maintain the impurities in the suspended form. Lighter fabrics are usually handled in rope form, but heavier materials show creases marks if processes in rope form, therefore the fabric are placed in the open-width form in the specially designed kier for such purpose.

1.4.2.4 Bleaching: After desizing and scouring processes, the textile materials are in very absorbent form and can be dyed without much problem. But the materials are still yellowish or brownish in colour, which may affect the tone and brightness of the shade obtained by dyeing, particularly for light shades. The removal of natural colouring matter requires a special step of preparatory process called **Bleaching**. For white goods, the degree of whiteness required is much more stringent. One must be careful while choosing the bleaching agent; the fabric should not undergo chemical damage or degradation during bleaching. Bleaching Agents are of two types:[20]

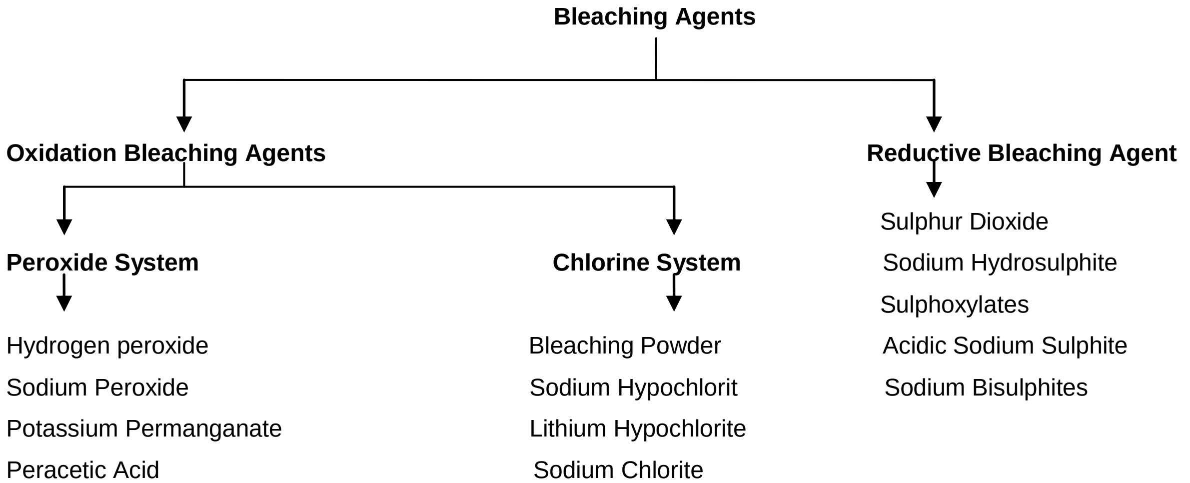

Fig. 4: General classifications of bleaching agents

a. Oxidative Bleaching Agent: The medial process of bleaching was to lay the material out in a field for exposure to sunlight and air. In ancient days this slow process was the only method for the bleaching of cotton and linen goods. Slow atmospheric oxidation is not commercially viable. The most important oxidative bleaching processes are: **Hypochlorite Bleaching, Hydrogen Peroxide Bleaching and Sodium Chlorite Bleaching**. But hydrogen peroxide has several advantages, these are:

1. It is a universal bleaching agent and can bleach most of the textile fibres without damaging the materials.
2. It is eco-friendly and bleaching can be safely carried out in an open vessel.
3. As peroxide bleaching is done under alkaline conditions at or near boil, both scouring and bleaching can be combined..
4. The cloth appearance after bleaching is much better and fuller than hypochlorite bleached material.
5. There is less risk of tendering due to over bleaching.
6. No other after treatment is required after peroxide bleaching.

1.4.2.5 Mercerization: Mercerization was discovered by John Mercer in England in 1850 and the process is named after him. It is defined as the treatment of cotton textiles with a concentrated solution of alkali solution around 31% to 35% at a temperature of 15 - 18°C. When cellulose immersed in the solution of caustic soda of mercerizing strength, water and alkali diffuses in and the material swells**.** The fibre hairs quickly commence, untwist from its twisted ribbon like form and tend to become cylindrical rod like surface due to deconvolution. The cross-section of the fibre diminishes and the diameter of the fibre becomes more round. Mercerization increases the **tensile strength, lustre, absorbs more water, shows increased depth of shade and increased rate of dyeing and also improves the dimensional stability of cotton fibres**. Mercerization also gives moderate improvement in crease recovery of cotton fabrics.

1.5 INTRODUCTION TO ENZYMES

1.5.1 History[1]:

Bacterial enzymes are produced by growing cultures of certain **micro-organism** in sterilized wort, providing an excellent supply of enzymes. Large population of microbial cells can be grown under controlled conditions and in a relatively short time to provide a uniform and inexpensive raw material for enzyme manufacture.[22] Amylases, proteases, esterases, cellulases are well known to be elaborated by micro-organisms. These enzymes are known to work at specific pH and temperature.

1.5.2 Use of Enzymes in Textile Processing[6]:

Enzymes commonly used in textile processing are discussed below.

a. Amylases: Amylases are widely used as desizing agents to remove starch from fabrics after weaving. Starch is a polysaccharide composed of glucose. Depending on the number of branches, two types of polymer, amylose and amylopectin, are distinguished. Since amylases' have been naturally designed to act on an insoluble substrate, most amylases have an extra substrate binding domain. The substrate binding domain brings the catalytic domain into the close vicinity of the target substrate, enhancing the catalytic performance of the enzyme. Most commercial amylases used are crude mixtures of thermostable enzymes of bacterial origin.

b. Cellulases: Cellulases are used in textile processing mainly for depilling and to obtain stone washing effects. Cellulases are also used as part of detergent formulations to enhance detergency, to improve brightness and to remove microfibrils. Like amylases, cellulases have a catalytic domain and a substrate binding domain.

c. Pectinolytic enzymes: Pectin degrading enzymes have received much interest for their use in the pretreatment of textiles fabrics ("bioscouring") prior to dyeing. The removal of pectin components from the cotton cell wall is claimed to improve fibre hydrophilicity, to facilitate dye penetration and to contribute to substantial water savings when compared to traditional alkaline scouring process. It should be noted that at pH values higher than 7, pectin can be hydrolysed.

d. Esterases: Esterases have been suggested as useful components of detergent formulation to remove lipid-based stains from textiles while some esterases have been claimed to hydrolyse polyester. Esterases hydrolyse ester bonds and their classification is based on the type of ester bond hydrolysed. The latter enzymes are better known as Lipases, many esterases are multifunctional enzymes and they can work as carboxylesterases, lipases and others.

e. Proteases: Proteases are important components of detergent formulations for removing protein stains (egg, blood etc.) from textiles. Additionally, proteases have useful potential in silk and wool processing. Protease or, more correctly, peptidases hydrolyse peptide bonds in soluble and insoluble peptides and form the group of Hydrolases.

f. Catalases & Peroxidases: Catalases can be used in textiles processing for removal of residual hydrogen peroxide after bleaching while peroxidases have a potential for dye decolourization after dyeing. Catalase converts hydrogen peroxide into water and oxygen.

g. Laccases: Laccases in combination with redox mediators are used in textile processing to bleach denim fabrics, decolourising indigo. Research efforts have been made to use laccase as a bleaching and/ or oxidative coupling agent for dyeing animal fibres and human hairs.

The potential to degrade and remove the undesired components from the cotton fibres with different enzymes, such as pectinases, cellulases and lipases and their mixture as well as different process conditions were used to improve the cotton properties. **Bioscouring offer following advantages:** Softer cotton textiles, No cellulose or fibre damage, less chemicals used, Environment friendly and mild conditions allow treatment of linen and blends. For enzyme scouring, pectinase is the only enzyme needed for wettability / dyeability, while other enzymes may have beneficial effects. The pectinase action does not create full wettability alone. Therefore, wetting agents and non-ionic surfactants should be added together with the enzyme to enhance enzyme penetration and adsorption, fibre swelling and the removal of waxes. The process is most efficient when run at slightly alkaline conditions. A buffer is needed, e.g. a phosphate or citrate buffer, to maintain the pH between 7.0 and 9.5 (optimal pH 8.5 -9.0). The temperature of the process is important for optimum performance of the enzyme. The temperature only affects the speed of the process and not the efficiency of pectin degradation. Increasing the temperature above 60°C helps to improved the wax removal, although the enzyme gets unstable. Depending on the enzyme manufacturer's recommendations bioscouring can be done at temperature 55°C - 65°C, at pH up to 8.5. Many a times better absorbance of the enzyme is observe at lower temperatures, and thus better performance of the process. Hence it is recommended to start the impregnation at temperature around 30°C - 40°C and raise to the application temperature. As these enzymes are not stable for a very long time at elevated temperature, it is advisable not to keep / store the enzyme in a heated premixing tank.

Cellulases are specially suited for scouring of cotton fabrics. Some pectinase enzyme preparations contain cellulase. The surface of cellulose structure of cotton, which normally acts as support for non-cellulosic impurities, can be hydrolysed by the latter enzyme. Those impurities are removed by subsequent washing. However the combined action of both types gives greater weight loss and strength loss as compared to the action of pectinase or lipase alone. Cotton fibres, or their blends with other fibres, can be treated with aqueous solutions containing protopectinases for 18 hours at 40°C to give scoured yarn with good tensile strength retention. Pectinases and cellulases are more effective compared to the proteases and lipases. The change in water absorbency of cotton is rapidly catalysed by pectinases, cellulases or by their mixtures. Pectinases can destroy the cuticle structure by digesting the inner layer of pectin in the cuticle of cotton. Cellulases can destroy the cuticle structure by digesting the primary wall cellulose immediately under the cuticle of cotton. Cellulases break the linkage from the cellulose side and pectinases break the linkage from the cuticle side. The result of the synergism is a more effective scouring in both the speed and the evenness of the treatment[22].

The bioscouring process results in textile being softer than those scoured in the conventional NaOH process, however the degree of whiteness is often less and the process is not suitable for removing seed coat fragments and motes adequately[1,6,14,22,36].

1.5.3 Waste Management (Bioremediation)[1,3,36]:

Environmental issues can no longer be ignored by the textile industry. The effluents generated in the textile processing house can be characterized into those, which cause chemical pollution and physical pollution. The compounds which cause chemical pollution are metallic ions (Cr, Cu, and Zn etc.), surfactants, carriers, pesticides, resins, oils and greases, inorganic compounds (acids, alkalis, salts etc.).Physical pollution is characterized by the colour, suspended solids and temperature. The effluents contain high biochemical oxygen demand (BOD), suspended solid (SS) such as fibre and grease, Chemical oxygen demand (COD) and Total dissolved solids (TDS). For textiles, BOD, COD and TSS are the main parameters for which current emissions are above local and international standards. The effluent is generally hot alkaline and strange smelling and coloured by chemical used in dyeing processes. High BOD and COD lower the dissolved oxygen of the receiving waters; threaten aquatic life, damaging both the aesthetic value and water quality downstream. TDS are the inorganic salts and substances that are dissolved in the water. This process accelerates corrosion in the water systems and pipes and depresses crop yield if used for irrigation. Liquid wastes mostly arise from washing operations and it is estimated that 100kg of effluents are generated by 1kg of textiles.

Table: 3. Characteristic of process waste streams of textile mills.

Sl. No.	Unit Process	Possible pollutant in the waste water	Waste water volume	Nature of the waste water
1.	Desizing	Starch, Glucose, carboxy methyl cellulose, PVA, resin, fats and waxes	Very small	High BOD (35% to 50% of the total) carboxyl methyl cellulose and PVA do not exert a high BOD.

2.	Scouring	Caustic soda, waxes and grease, soda ash, sodium silicate and fragments of cloth.	Small	Strongly alkaline, dark colour, high BOD (30% of total).
3.	Bleaching	Hypochlorite, chlorine, caustic soda, Hydrogen Peroxide, acids etc.	Mostly washing	Alkaline, constitute approximately 5% of the BOD.
4.	Mercerising	Caustic soda	Small, mostly washing	Strongly alkaline, low BOD (less than 1% of the total)
5.	Dyeing	Various dyes, mordants and reducing agents like sulphide, hydrosulphide, acetic acids & soaps	Large	Strongly coloured, fairly high BOD (6% of the total)
6.	Printing	Colours, starch, gums, oil, china clay, mordants, acids and metallic salts.	Very small	Highly coloured, fairly high BOD and oily appearance.
7.	Finishing	Traces of starch, tallow, common salts, glauber salts etc.	Very small	Slightly alkaline, low BOD.

The best way to reduce pollution is to prevent it at the first place. The application of biotechnology is mainly attributed to the removal of colour from the dye house effluents. The various methods of effluent treatment can be categorized under the following headings; **Membrane Technologies, Chemical Treatment** and **Biological Treatment.**

In Biological treatment, most material of animal and vegetable origin can be broken down into simpler compounds such as water and carbon dioxide by micro-organisms such as bacteria, fungi, protozoa and so on. This can be done in the presence of oxygen by aerobic digestion or in the absence of oxygen by anaerobic fermentation. Both happen as the bacteria and other microorganisms' convert the effluents into more acceptable products. It is important that the type and concentration of the substances and condition such as pH, temperature and so on that will kill off the microorganism population are carefully controlled.

Table below shows, the conditions necessary to ensure no inhibition of biological treatment.

Table: 4. Conditions necessary to ensure no inhibition of biological treatment

Variable	Condition
Temperature	35°C maximum (can be higher for anaerobic treatment)
Ratio BOD: Nitrogen	Approx. 17 : 1
Ratio BOD : Phosphorous	Approx. 100 : 1
pH	6.5 – 9.0 (preferably 7.0 maximum)
Metals (Zn, Cu, Cr)	Less than $10 mg/dm^3$

1.5.4. Advantages of using Enzymes in Textiles[35]:

Enzymes carry out a rapid conversion of their substrate at moderate temperatures and near neutral pH. Unlike other substances, enzymes are bought and sold on the basis of activity, not weight per se. If the activity is unstable and has been lost in storage or transit, the enzyme is valueless.

1.5.5. Microbiological Scouring treatment[41]:

From the title, it is clear that this to be concerned with a biological engineering process by which a complex feedstock is converted into a range of simpler compounds, including methane by microbes in the absence of air (oxygen). The term anaerobic is simple enough in that it implies the absence of oxygen usually by the strict exclusion of air. This means that all the reactions are brought about mainly by anaerobic microbes. To sustain the process a suitable microbial population must be established and maintained.

Scouring is an important pretreatment operation in the processing of cotton and cotton blended materials. The main objective of this operation is to remove the non-cellulosic constituents of cotton fibre, which make the fibre non-absorbent, posing serious technical problems in the subsequent wet processing operations. In fact, the scouring operation determines the ultimate quality of the finished product. It is estimated that the scouring operation consumes about 1% of the total water used, contributes, 54% of the total BOD and is responsible for 10-25% of the total pollution load of the entire processing operations. It is pertinent to observe that in view of the ever widening gap between the demand and the supply position of energy, serious efforts are being made in almost every field of activity either to cut down the unnecessary expenditure of energy or to adopt a low energy process.

In light of the above observation, it is not surprising that a number of studies have been initiated over the years to make scouring operation less energy intensive and more effective one. Hence, the studies have been aimed at scouring the cotton fabric with less pollution and less energy consumption through biochemical approach. This technique is cost effective as the desired enzymes are produced *in situ* by a consortium of microorganisms.

Microbial consortium was used to treat the fabric. The consortium comprised both aerobic and anaerobic types. Species belonging to *Bacillus* and *Micrococcus* sp. from Gram positive group and *Beijierinckia, Pseudomonas*, *Xanthomonas* and *Flavobacterium* were Gram negative ones. *Aspergillus, Penicillium* and *Mucor* were from fungi and *Streptomytes* was the lone *Actinomycete*. All these were from the aerobic ones surviving under the anaerobic conditions. As and when the system was disturbed, these were acting as scavengers of oxygen and aid in setting anaerobiosis. Among anaerobic groups, species of *Methanomicrobium, Desulfotomaculum, Clostridium, Chlorobium, Ectothiorhodospira, Thiodictyon and Rhodospirillium* were predominant. One species of protozoan belonging to the genus *Monocercomonas* was also present in the consortium.

The studies showed that the above process can be easily coupled to the existing hand processing units. The new process may result in considerable reduction in pollution load with appreciable saving in energy. (Varadarajan and Balasubramanya, 2008)[282]

Polyester fibre and their blends with cellulosic fibres may also be dyed under high temperature conditions (125° to 135°C but generally at 130°C). Above 100°C, the fibre swells to a greater extent (due to wider and more violent thermal vibration of the fibre molecules) and hence there is rapid penetration of the dye molecules in the fibre structure. The disperse dye is much more soluble in water at higher temperature than it is below 100°C and this increased solubility of the dye in water also facilitate the dyeing process. The high temperature dyeing method has certain advantages[13]:

1. Heavy shades can be obtained with disperse dyes.
2. A shorter dyeing cycle is possible under high temperature conditions using rapid dyeing machines.
3. A better combination of level dyeing and fastness properties is obtained by high temperature dyeing.
4. Dye selection for high temperature dyeing is not restricted.

The **purpose** of present study is to evaluate the impact of *in-situ* microbiologic treatment under strict anaerobiosis on cotton and blended woven fabric in comparison with the conventional kiering process.

1.6 Aims and Objectives

1. To standardize the method of *in-situ* microbiological treatment under strict anaerobiosis for optimum scouring of cotton and blended (polyester/cotton) woven fabrics

2. To undertake semi-bulk trials of bioscouring on the optimized condition to selective woven fabrics

3. To compare and evaluate the quality parameters in comparison with the conventional ones.

4. To undertake dyeing trials on biologically scoured fabrics.

5. To make a techno-economic feasibility of the study

1.7 Scope of the study

1. The study will give an insight about the new bioscouring technique with specific advantages

2. Process being more ecofriendly, discharge of chemicals to the environment is minimal

1.8 Significance of the study

1. It is expected that the proposed new process will score over the conventional chemical method which is energy intensive and polluting

2. Presently, suitable for handloom Sector

3. Suitable for cotton and its blends

1.9 Limitation of the study

1. Recommending to the existing textile processing industries

2. Bioscouring process will be restricted to the cotton and polyester/cotton blended woven fabrics