CHAPTER 2

LITERATURE REVIEW

Enzymatic pretreatment may be one of the greatest alternatives to the traditional pretreatment technique to satisfy the need for inexpensive processing. Enzyme has good flexibility when several pretreatments are coupled by optimizing the working bath conditions.

In the current work, an effort is made to reduce the amount of energy and pretreatment time by combining enzyme. The pretreatment samples have undergone several tests and comparisons with traditional. The samples are colored, examined for colour difference properties using both conventional and enzyme-treated samples.

When compared to regular samples, enzyme-treated samples exhibit better physical features. Although enzyme-pretreated dyed samples have greater colour strength than conventional dyed samples, it has been observed that the fastness qualities of enzyme-pretreated samples are to some extent inferior to those of traditional pretreated fabric.

Researchers nowadays are more aware than ever of the need to save water due to the serious water shortage caused by population development, fast industrialisation, etc. Every human on the planet must be aware of the importance of conserving water and reducing water waste. Water is primarily utilised in the textile business, and particularly in wet processing, for two purposes: first, as a solvent for processing chemicals, and second, for washing and rinsing. Moreover, some water is used to produce steam.

Pretreatment of the textile sector uses around 60% of the energy. Hence, using biotechnology to lessen this energy use is a possibility.

The intricacy of the process and the design of the equipment have a bigger impact on how much water is used. Various machines each have unique features that place fewer restrictions on the amount of water used.

For cotton fibres, the range of water consumption for dyeing is 80–300 litres per kilogram of material. Therefore, it is crucial to practice conservation, and numerous studies are being conducted to lower water usage in the processing industry. There are number of different ways to save water, but they can all be neatly categorized as: Savings from machinery changes, process changes, and current machine process.

According to reports, integrated processing, in which processing stages are frequently merged with the elimination of separate rinse processes, should always be taken into account. A combined desizing, scouring, and bleaching process with a single washing off step may replace the outdated method of separate desizing, scouring, and bleaching phases with intermediate washes.

One of the best ways to reduce the pollutant load in the textile sector is with enzymes:

- Have a specific range of operation parameters (e.g., pH, temperature, ionic environment) for their optimum performance;
- Act as a catalyst, so little enzyme is needed to carry out the reaction;
- Can react with specific substrate based on the ability of the substrate to fit within the active site;
- Capable of replacing harsh chemicals with 100% biodegradable and have no negative impact on the environment;
- Less energy, less waste, and less mining **(Mishra, 2007)**

2.1 TEXTILE FIBRES

Simply put, a fibre is viewed as a flexible linear strand having a length that is numerous times larger than its breadth. It sets itself apart from other assemblages like tapes, films, and rods because of this. Fibers and filaments may be viewed by the designer as the tiniest component of a textile construction. I'll go through various textile fibres and how to classify them in this article.

The use of fibres in textiles and clothing dates back to the evolution of humans. Clothes first came into creation to shield people from cold, heat, rain, dust, and other elements, not for aesthetic or decorative purposes. Clothing has been made from fibres since 5000–4500 BC, when hemp, flax, cotton, silk, and subsequently sericulture was used. Up until the Industrial Revolution, nature served as the sole supply of fibre. The industrial revolution and the development of equipment for processing and using fibres occurred in the 18th and 19th centuries. The monopoly of natural fibres was gradually reduced with the arrival of recycled fibres like rayon and then synthetic fibres like nylon and polyester. It also sparked a competition for the production of novel and innovative fibres.

The idea of synthetic and regenerated fibres added a new dimension to research efforts to create novel fibres. As long as the chemical behavior and structure, structural alignment, molecular characteristics, and processing conditions can be studied and controlled, fibre can be designed, made, or synthesized from any material. This implies that a vast variety of materials will be developed as fibres, as well as a wide variety of fibres.

The fundamental and primary raw material used to create a variety of finished textile items is textile fibre. Textile fibre is any fibre that may be turned into textiles including woven fabrics, knit fabrics, lace, felt, non-woven materials, etc. using an appropriate interlacing technique. **(Deopura, 2008; Kiron, 2021)**

Initially, only natural fibres like cotton, wool, mohair, linen, ramie, and vicuna were used to make textiles. All of them were only available as staple fibres that needed to be spun into yarns in order to be made into fabric. The first monofilament material was silk, and for many years scientists were fascinated with creating "fake" silk. This was accomplished in the middle of the 19th century when rayon was made by dissolving cellulose and regenerating it into glossy strands that looked like silk. Acetate, which was created by treating cellulose with acetic anhydride and "dry spinning" the syrupy solution to extract the organic acetone solvent, was quickly introduced after that.

The scientific theories that Wallace Carothers of the Du Pont Company used to create nylon and polyester fibres and yarns were established by these advancements. Nylon was and continues to be a hugely successful business. Greater strength, abrasion resistance, resilience, wrinkle healing, and ease of maintenance were all features it provided. Because of its superior strength, nylon has mostly replaced rayon cord in tyres.

Stereo regular polypropylene was created by Ziegler and Natta, and Phillips Petroleum Company obtained the patent for controlled regularity. Nowadays, indoor/outdoor carpets and furniture are frequently made of polypropylene, which can be cleaned with detergent and water to remove spills and stains. The textile industry has also discovered that non-wettable polypropylene fibres with waxy bases can be spun into fine-diameter fibres. Fibers that are designed to absorb as much moisture as naturally highly absorbent fibres. Such tiny threads absorb fluid through capillary action between fibres to the same extent that natural fibres do. Hence, to keep the body dry today, cold-weather thermal underwear is worn adjacent to the skin, drawing perspiration away from the body by capillary action to a more absorbent outer layer. **(Deopura, 2008)**

2.1.1 CLASSIFICATION OF TEXTILE FIBERS

The two primary categories of textile fibres are natural fibre and synthetic fibre, often known as manmade fibre or artificial fibre. The following categories are also applicable to textile fibres:

1. Polymer-based classification of textile fibres
2. Source-based classification of textile fibres
3. Grouping fabric fibres based on their botanical, zoological, or chemical names
4. Dividing textile fibres into groups based on their uses
5. Dividing textile fibres into categories based on their thermoplasticity
6. Dividing textile fibres into groups based on how well they can absorb moisture

A polymer is a substance made up of identical tiny molecules that combine to make larger molecules. The polymers can be any of a wide range of natural and synthetic molecules, typically having huge molecular weights and composed of millions of repeatedly connected units, each of which is a very light and straightforward molecule.

The word "polumeres" comes from the Greek words "polus" (which means many) and "meros" (which means pieces). The repetitive nature of several identical, comparable, or complementary molecular subunits in these chains is a significant characteristic that sets polymers apart from other compounds. **(Britannica, 2023; Islam, 2020)**

The basic components of polymers, macromolecules, large polymers, gigantic molecules, and other similar structures with a high molecular weight are these repeating subunits. These substances could be synthetic or natural in origin, organic, inorganic, or organometallic. Nearly every industry relies on polymers for products including coatings, liquid crystals, photo resists, paper, textiles, fibres, coatings, plastics, ceramics, and building materials.

These polymers might be organic or inorganic, natural or artificial. Because there is a carbon atom in the primary chain, organic polymers may be separated from inorganic polymers. Carbochain polymers are substances that are entirely composed of carbon atoms. Heterochain polymers are those in which the primary chain contains primarily of elements other than carbon. Sand, asbestos, agates, feldspars, mica, quartz, and talc are a few examples of natural inorganic polymers.

Polysaccharides or polycarbohydrates like starch and cellulose, nucleic acids, lignin, rubber, and proteins are examples of natural organic polymers. Concrete, boron nitride, numerous high-temperature superconductors, and several glasses are examples of synthetic inorganic polymers. Synthetic organic polymers, such as polyethylene, polypropylene, polyamides, polyesters, vinyl polymers, polyurethanes, and synthetic rubbers, are used to make fibres, plastics, and coatings. **(Islam, 2020)**

Polymeric polymers known as fibres are lengthy (more than 100 times longer than their breadth) and strong only in one direction. It is known as the l/d ratio. Elastomers, often known as rubbers, are polymeric materials that can be deformed by the application of force and return to their original shape when the force is removed. Plastics are materials that combine the hardness of fibres with the flexibility of elastomers.

High molecular weight natural polymeric materials are also sources of natural fibres. This implies that fibres, whether natural or manufactured, are made of polymeric components. All fibres can also be categorised in the manner depicted in Figure 2.1 based on the polymeric components that are present in them.

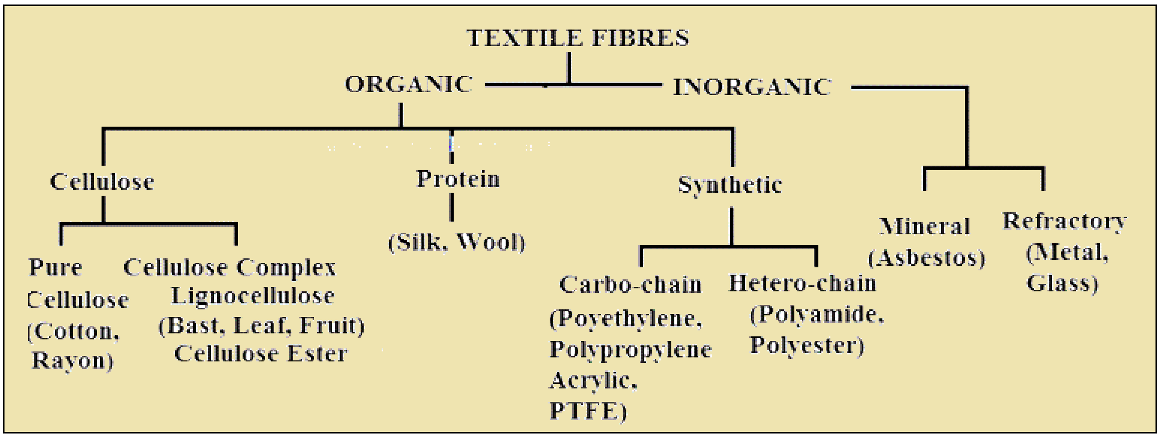


Figure 2.1 Polymer-based classification of textile fibres **(Kiron, 2021)**

2.1.2 IMPORTANCE ON CELLULOSIC FIBERS

Although the technology for making cellulose fabrics is not brand-new, recent advances in new sustainable technologies have given it a sort of resurgence. Although there is a constant rise in the demand for materials, cotton cultivation - the most common raw material used in textile manufacturing - imposes significant ecological obligations.

George Audemars, a French scientist, created rayon in 1855, the first regenerated fibre manufactured from wood pulp. Yet, the first large-scale commercial manufacture of this fibre didn't start until 1905, when cuprammonium rayon and viscose rayon, two different chemically modified fibres, were created.

Since cellulose fibres release moisture, they have special capabilities when it comes to moisture absorption. Particularly when compared to synthetic textiles like polyester, this stops the growth of microorganisms. Moreover, it is hypoallergenic, which is why it is beginning to be utilized in cosmetics and medical apparel.

Clothing made from cellulose fibre has a distinctive feel in addition to being an advanced technological fibre and an environmentally beneficial one.

- The moisture absorption (sweat) capacity is also significantly larger than that of Synthetic, making the fabric perfect for daily-use clothing.
- It is possible to notice that they are softer and smoother.
- Does not produce static electricity in the same way as synthetic materials. **(Marialma Blog, 2020)**

Natural fiber-based textiles have been an integral part of human existence since the beginning of time, and they continue to be employed extensively in the modern textile industry due to their distinctive qualities as premium textile materials. Natural fibres with short staple length cannot be used to make yarn because of the diversity in staple length. Natural fibres like wool, silk, cotton, and hemp are therefore wasted during processing and final applications. The excellent inherent qualities of these fibres make a novel usage of them highly marketable. These bio-compatible materials are required by many other businesses as well, including the bio-medical sector. **(Karimah, 2021)**

The synthesis, characterization, and use of nanocellulose are covered in this chapter. Viscose was converted into nanoscale cellulose polymers using a straightforward method that was established. Then, the nano polymers were used to enhance polyester's various qualities. Nano-whiskers are marvel molecules that can add a variety of functional qualities to textiles as well as make a substantial contribution to the fields of electronics and medicine. There have been a number of recent publications detailing the synthesis of nano-whiskers from a range of materials using fresh, improved methods.

Some potential uses for nanocellulose include dry strength agents, surface strength agents, nanocoatings and nanobarriers, bio-nanocomposites, food applications, cosmetic and skin care products, pharmaceutical and medical products, hygiene and absorbent products, emulsion and dispersion applications, and oil recovery applications.

Native cellulose (also known as cellulose produced by plants) is made up of different numbers of glucan chains that are organised to create microfibrils, a type of nanostructure. It is known that these microfibrils contain both regions of order (crystalline forms) and regions of disorder (amorphous forms). These microfibrils' crystalline portions make up the nanocrystals, which can be successfully derivatized and applied to a variety of industrial applications, including nanocomposites.

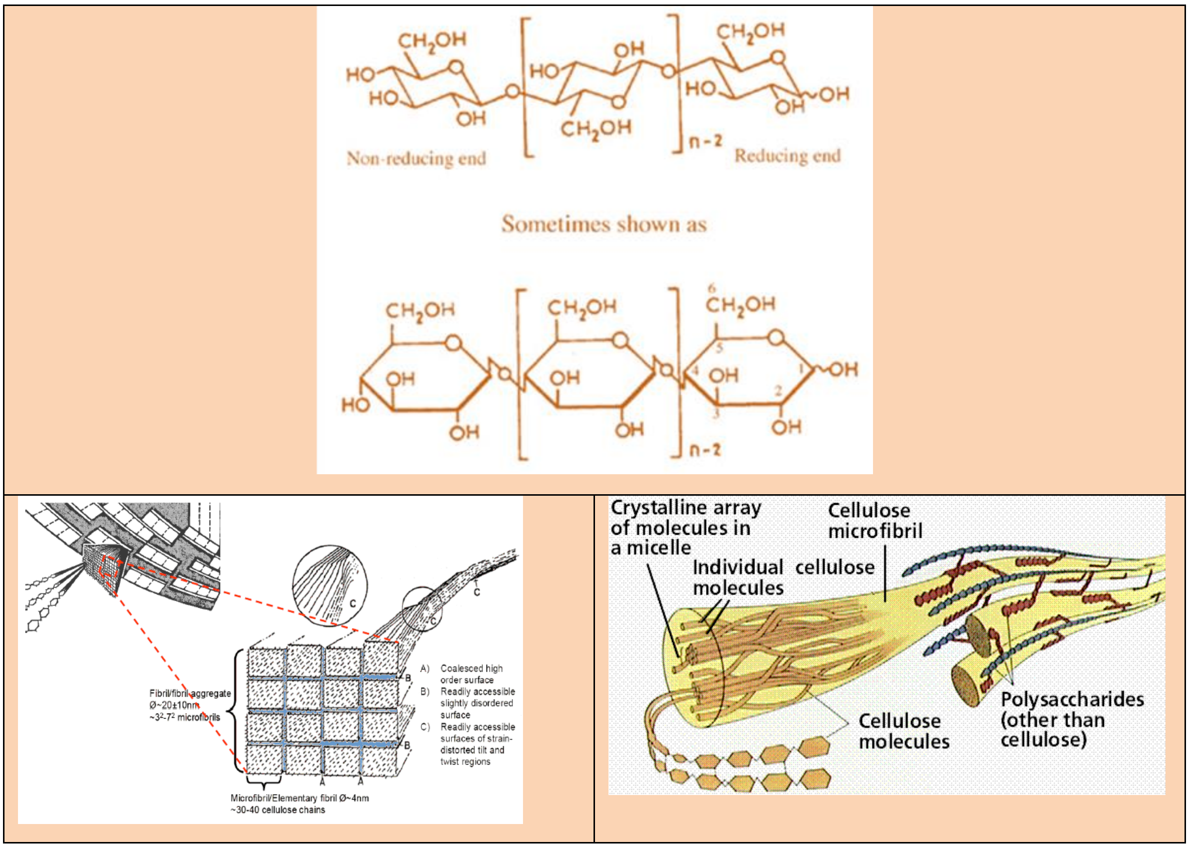


Figure 2.2 Cellulose's chemical composition and arrangement in fibre **(Keshk, 2017); (Microfibrillated cellulose: Energy-efficient preparation techniques and key properties Mikael Ankerfors - Licentiate Thesis, 2012); (Ameram, 2019)**

This action, which was originally noticed in the textile business, was first explained as the hydrolysis of cellulose fibres by a scientist by the name of Girard **(Jadhav, 2010).** It was evident from structural research that cellulose microfibrils contained both high-order and low-order areas. The highly organised crystalline portion of cellulose is where cellulose nanocrystals are found, whereas the cellulose chains are randomly arranged in the amorphous (less ordered) parts. These haphazardly ordered chains are easily attacked by an acid, where the hydronium ions penetrate the low order regions and trigger a hydrolytic cleavage of glycosidic links. Highly organised crystalline areas that resemble individual rods are separated when glycosidic connection is broken. In essence, the reducing end of these rod-shaped nanoparticles is on one side, and the non-reducing end is on the other. Acid hydrolysis is the name given to the process of generating cellulose nanocrystals in an acidic environment, which Ranby first described in 1951 **(Achwal, 2001)**.

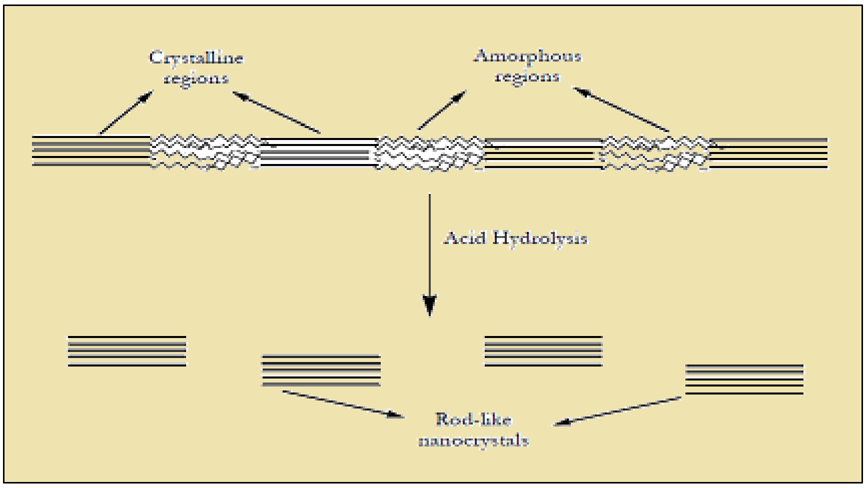


Figure 2.3 Cellulose crystals are created when cellulose fibres are dissolved in acid **(Achwal, 2001)**

2.1.3 COTTON

2.1.3.1 Brief description of cotton fibre production

Both cellulose and non-cellulosic substances make up cotton. The cuticle, which is made of cellulose, pectin, waxes, and proteinic substance, is the cotton fiber's outermost layer.

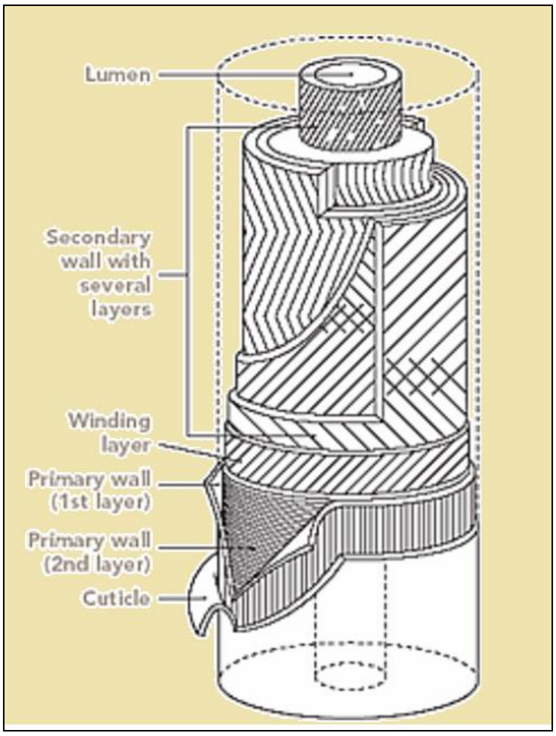


Figure 2.4 Cotton's morphological structure **(Mohamed)**

It is covered with waxes and pectin, and it surrounds a main wall. The secondary wall, which is split into a number of parallel layers of cellulose fibrils, and the lumen make up the inner portion. Crystalline and amorphous regions alternate in the longitudinal direction to form the smallest unit of fibrils.

2.1.3.2 Cotton characteristics

The most significant fibre characteristics are those of cotton. It is also the foundation of all trade in the textile sector. In essence, seed cotton is used to produce cotton fibre. Cellulose makes up the majority of cotton. It is a member of the "Gysspium" genus. Moreover, it is grown in tropical nations like Pakistan, India, Egypt, and the United States.

Cotton's physical characteristics:

1. **Cotton's colour**
- Cotton is often creamy white in hue. Cotton that is delayed in being picked may turn excessively white, yellow, or grey.

2. **Cotton's Strength**
- Because to the inherent structure of the layers of minutely spirited fibre that make up the fibre cell, cotton fibre has a reasonably robust structure. Also, the characteristics of the cotton yarn -which should have a long staple and be tightly twisted—determine the strength of the fabric. Moreover, moisture content has an impact on it. Tensile strength and tenacity are thus two ways that cotton fibre strength is described.
- The tenacity of cotton is 3–5 grammes per denier. Its tensile strength typically ranges from 40,000 to 120,000 pounds per inch. Moreover, cotton's strength is crucial and can be increased through mercerization. Typically, a "Pressley strength tester" is used to determine the strength of cotton.

3. **Cotton's Tensile Strength**
- The tensile strength of cotton, for example, determines its quality. Cotton's tensile strength with grading

Table 2.1 Tensile strength of cotton with grading

Tensile strength (10^3 ponds per inches^2)	Grading
89~97	Strong
81~88	Average
72~80	Fair
71~blow	Weak

4. **Cotton's elasticity**

- Natural cotton fibre elasticity is really low. Fundamentally, by forcefully twisting the fibres into creped yarn and by using processes for creating fabrics like knitting, this property may be adjusted to varied degrees. Moreover, it recovers elastically at a rate of 74% at 2% extension and 47% at 5% extension.

5. **Elongation at cotton fibre break**

- Elongation at break is the term for the stretching that occurs when a fibre stretches slightly before breaking under stress. Cotton is difficult to stretch. In general, depending on the type of cotton, it elongates at a break by 5–10%.

6. **Cotton's specific gravity**

- The mass of an equivalent amount of water at 4°C divided by the mass measured in the air is known as the specific gravity, and cotton has a specific gravity of 1.54.

7. **Cotton fibre length**

- The phrase for the length of cotton is staple length. Hence, the average length of the fibre in a mass of cotton is known as the staple length. Moreover, cotton is divided into three classes based on staple length.
    - S.L (1″–2 1/2″) - This length category includes Egyptian cotton, premium sea island, and fine twisterious fibre.
    - S.L. (1/2" x 1 5/16") - This kind of cotton is not as fine as the comparable American upland cotton.
    - S.L. (3/8″ x 1″) - This kind of cotton has coarse, low-quality fibre. In essence, it is mostly produced in China, India, and Pakistan, with smaller amounts also being made in Iran, Iraq, Turkey, etc.

8. The cotton fiber's maturity

- The degree to which the cell walls of cotton fibres have formed determines the maturity of cotton. The age of cotton plants cannot be determined by the fibre maturity, though. As a result, mature fibre will have formed cross sections and be shiny.

9. The cotton fiber's fineness

- It is described as the weight in grammes of one inch of fibre. A fibrograph is the name of the tool used to measure the fineness of fibre.

Table 2.2 Cotton's fineness after grading

Fineness microgram per inch	**Grading**
Below 3	Very fine
3~3.9	Fine
4~4.9	Average
5~5.9	Coarse
6~above	Very coarse

Cotton has chemical characteristics

Chemical finishes or treatments can change the chemistry of cotton. For instance, mercerization involves treating cotton or other yarn with sodium hydroxide to improve the lustre, absorbency, softness, strength, and suppleness of the material. As a result, during mercerization, the fibre wall expands and adopts a more rounded cross-section. Moreover, the fibres' strength increases noticeably, and as a result, their extensibility reduces as a result of the swelling effect, which also leads the fibres to creep and untwist. Therefore, further lowering its crystallinity.

10. Acids' effects

- Cold, diluted acids have little effect on cotton, but heated, diluted, or concentrated acids dissolve it. A 2-gram/liter H_2SO_4 solution at 80 °C decreases the fabric's strength by 25% in an hour. As a result, such acid should be employed at moderate temperatures and low concentrations. Temperature has a significant impact on the hydrolytic activity of acids. For instance, a minor increase in processing temperature (80–90°C) has a larger effect than doubling the concentration of H_2SO_4.

11. Alkalis' effects

- Cotton is extremely resistant to them; it swells into caustic alkali without being harmed. Moreover, it can be safely washed separately in soapy water. The glucosidic bond of the cellulose molecule is what gives it its great alkali resistance. At room temperature, cellulose is unaffected by a mild solution of caustic soda and lime, but when NaOH is heated to a boil, a small amount of cellulose dissolves into the solution. The solubility of cellulose can be significantly increased by alkali.

12. How oxidising and reducing agents work

- While oxidising chemicals easily transform it into oxycellulose, reducing agents have little impact. Oxidizing agents are widely used for chemically treating fibrous materials as well. The glucoside linkage repature caused by this regent results in less or more intense oxidation of cellulose functional groups and chain breakage. Oxy-cellulose is the term used to describe the mixture of the many products of cellulose oxidation. NaOCl, H_2O_2, NaCl, HNO_3, and other oxidising regulators are examples.

13. How salts solution acts

- Acid salts in solution have some impact on cellulose as acids. The natural salts NaCl and $MgCl_2$, which undergo hydrolysis when heated, have a similar effect. When progressively heated, cellulose expands into a concentrated solution of some natural salts, initially turning to jelly before dissolving in solutions. The swelling and resolving of cellulose are significantly influenced by the solutions of the salts LiI, Li(NS), KCN, and $Ca(CNS)_2$. A particular solvent for cellulose is the ammoniacal solution of copper oxide.

14. Organic solvent effects

- There aren't many solvents that can totally dissolve cotton. As a result, it is very resistant to substances like gasoline, benzene, ether, and alcohol. However, it is upset by copper complexes, cuprammonium hydroxide, cupric-ethylene diamine, and the 70% H_2SO_4 concentration.

15. Water's action

- The cellulose fibre used to create the dry cotton fibre has a fairly stiff and inflexible ability. A band formed between molecules laying next to one another holds the cellulose molecules securely together inside the fibrils bundle.
- Moreover, water molecules tend to push cellulose molecules apart, weakening the forces that held them together and partially eroding the stiffness of the overall cellulose structure. As a result, the glucoside bond in cellulose molecules is easily hydrolyzed, or they separate when they combine with water, which causes the breakdown of molecules that act as a plasticizer for cotton.

$$(C_6H_{10}O_5)\ n + n\ H_2O \text{ to } n\ (C_6H_{12}O_6)$$

16. Microorganisms' effects

- Bacteria, fungus, and mildew all affect cotton. In cotton that has received starchy finishes treatment, mildews are especially problematic. Cotton will grow mildew and germs, especially in humid, warm environments.

17. The impact of heat

- Excellent heat resistance is a property of cotton. So, at 120°C, it starts to turn yellow after a few hours, and at 150°C, it decomposes dramatically. Within a few minutes at 240°C, cotton suffers significant damage.

18. Light's impact

- When cotton is exposed to sunlight, it gradually loses strength and turns yellow for a very long time. The shorter wavelength of visible light and UV light both do a great deal of harm. **(Institute, 2022)**

2.1.3.3 Natural and added impurities present in Cotton fabric

One of the most significant natural textile fibres is cotton. Contaminants in natural fibres are the hardest to remove, especially from fabric that needs to be removed. The following table lists the elements in ginned fibre.

Table 2.3 Contamination in cotton

Components	% dry basis
Cellulose	88 to 96

Protein matter	1.1. To 1.9
Pectins and natural colorings matter	0.7 to 1.5
Minerals	0.7 to 1.6
Wax	0.4 to 1

Even after scouring, naturally occurring colorings are still present in natural fibres and fabrics. The flavone pigments of the cotton flower may be responsible for this brown and yellowish colouring. In varying degrees, the soil, dryness, and frost can also contribute to yellowness. When the damp ball is in contact with the tips of leaves or stalks after it has opened, dark stains and discolouration result. Insects, dust, and grime can also cause discoloration, as can oils and greases from harvesting and processing machinery. The goal of bleaching is to create white garments by removing colourants with the use of bleaching agents while causing the least amount of fibre deterioration possible. The colourants that are removed by the bleaching chemicals are either reduced or oxidised, and the resulting permanent whiteness. The inclusion of optical brighteners helps chemical bleaching of textile fibres even more.

A substrate must be completely free of any contaminants, whether they are acquired or natural, in order for the colourants to sit correctly on the surface or enter the substrate as needed by the specific system. Moreover, the colourant should be easily visible without any interference from impurity colour. There are a variety of preparation steps that cotton fabric or yarn must go through before it can be coloured. The conventional methods used to prepare cotton fibre, yarn, or fabric have one of the most detrimental effects on the environment of the entire textile production process. One example is the typical extremely alkaline processing of cotton. While the first continuous peroxide bleaching process to be commercially effective was created in 1940, the usage of H_2O_2 to bleach textiles has been in use for a very long time.

Preparation or bleaching is the process of purifying cotton fabric of contaminants. The fabric as it comes off the loom is impure in the following ways: 1) fibre or yarn impurities, 2) added impurities, 3) natural impurities, and 4) in-process impurities.

Long threads, loose threads, little projecting fibres, or fibre ends imbedded in the spaces between the warp and weft are examples of fibre impurities.

The additional impurities may include sizing components that were added to the warp yarns to give them resistance to abrasion and tension experienced during weaving, such as starches, PVA, gums, waxes, softeners, etc.

Cotton seed fragments, also referred to as "kitties," leafy particles, sand, and oil stains are examples of process impurities. Hemicellulose, oils, lipids, waxes, pectins, proteins, mineral debris, and natural colouring materials can all be found in natural impurities. The age, fineness, and place of origin of the cotton all affect the levels of these contaminants. Although finer fibres contain more waxes, mature fibres may contain less impurities. These imperfections give the fabric a hydrophobic quality and a fuzzy appearance.

2.1.4 VISCOSE RAYON

2.1.4.1 Production of viscose rayon fibre

1. **Cellulose:** Typically, specially treated wood pulp is where purified cellulose for rayon is obtained.

Figure 2.5 Sheet made of wood pulp **(The Manufacturing Process for Viscose Rayon; Viscose Rayon Fibre Manufacturing Process: Summary)**

2. **Steeping & pressing:** For one to four hours, this white sheet of board with 90–94% pure cellulose is immersed in a 17.5% caustic soda solution. Steeping or mercerizing is the name for this procedure. The hemicelluloses in the caustic soda disintegrate as the boards swell significantly. The extra alkali is then forced out of the board by a hydraulic ram in the press to remove extra caustic soda. The soda cellulose that remains after pressing is a moist material that is immediately fed

into a shredding machine. The following response will occur during the steepening operation.

3. **Shredding:** To increase surface area and make the soda cellulose easier to process, the cellulose is mechanically shred. This cellulose that has been shred is frequently called "white crumb."
4. **Aging:** The crumbs are aged after being shred. They are kept in a galvanised container with a lid, and as a result of oxidation with oxygen from the air, degradative changes start to occur. Depolymerization does take place, and as a result, the degree of polymerization decreases from 1000 to 350.

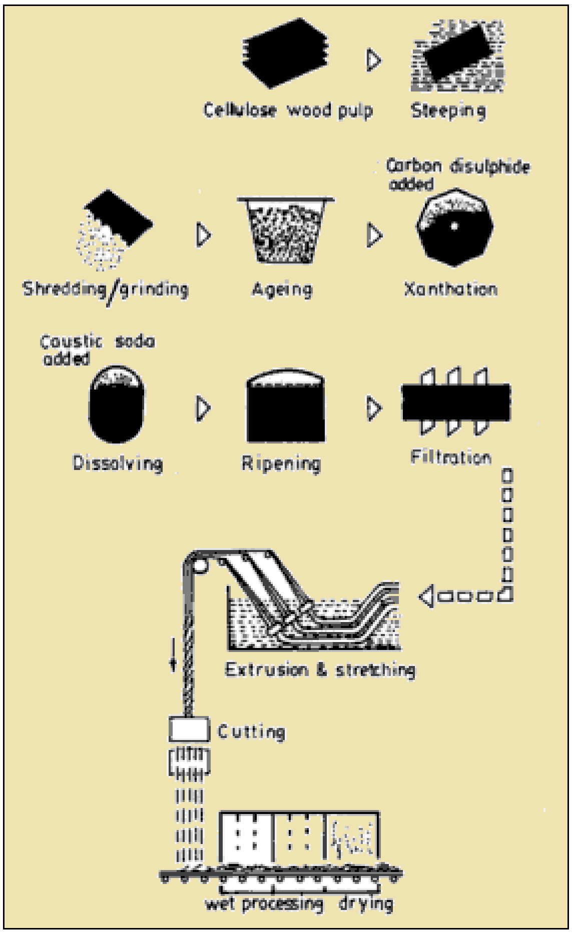


Figure 2.6 Viscose rayon manufacturing process phases **(The Manufacturing Process for Viscose Rayon; Viscose Rayon Fibre Manufacturing Process: Summary)**

5. **Xanthation:** The soda cellulose fragments are added into spinning, airtight hexagonal churns after maturing.

Figure 2.7 Airtight hexagonal churns **(The Manufacturing Process for Viscose Rayon; Viscose Rayon Fibre Manufacturing Process: Summary)**

After adding about 10% of the weight of the carbon disulphide to the crumbs and mixing the two substances, sodium cellulose xanthate is produced as a deep orange, gelatinous mass. It continues to churn for almost three hours.

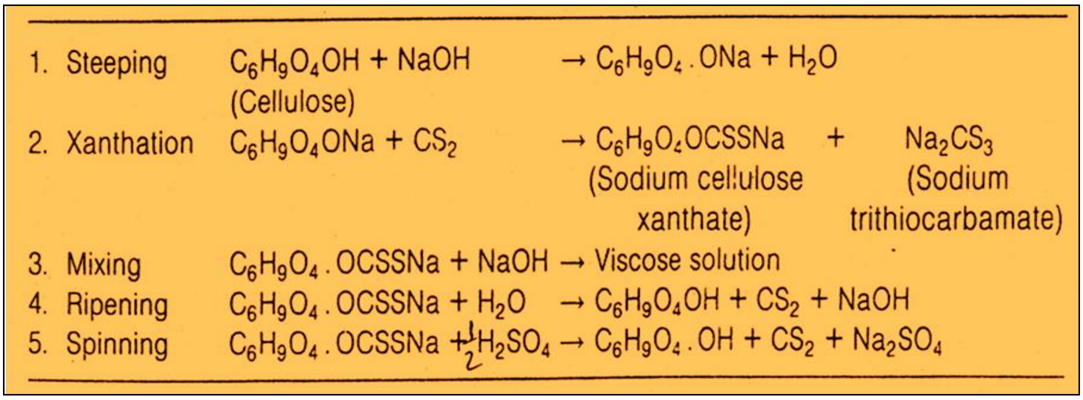
6. **Dissolving/Mixing:** Sodium cellulose xanthate and a diluted caustic soda solution are swirled in mixers for four to five hours while the vessel is being cooled. The xanthate dissolves into a thick, clear-brown liquid that resembles honey in appearance.
7. **Ripening:** The viscose solution ripens while being stored for 4 to 5 days at 10 to 18 degrees Celsius. The most significant alteration that takes place during ripening is the spontaneous breakdown of xanthate together with modifications in the distribution of xanthate groups. The xanthate solution's viscosity initially decreases as redistribution of xanthate groups improves dispersion, and subsequently it rises as cellulose molecules are xanthated. Since coagulability is a measure of maturity, it is possible to track the development of ripeness by assessing the willingness to coagulate in solutions of common salt.
8. **Filtration:** Undissolved elements that could obstruct the spinning process or lead to flaws in the rayon filament are taken out of the viscose through filtering.
9. **Spinning:** Viscose fibre is produced using the wet spinning technique. The basic process of regeneration is used in the spinning of viscose fibre, which is just the recovery of cellulose from cellulose xanthate by an acid decomposition reaction. The viscose filament is coagulated when it enters the bath, and acid then diffuses

into the filament to regenerate cellulose. In order to align the cellulose molecules with the direction of the fibre axis, the viscose fibre is stretched during this period.

The following components are found in the typical viscose bath used with regular rayon:

i. Na_2SO_4 is a salting agent.
ii. H_2SO_4 is a regeneration agent,
iii. whereas $ZnSO_4$ is a compound-forming agent.

The following list outlines the reaction order in the viscose process:



1. Steeping	$C_6H_9O_4OH + NaOH$ (Cellulose)	$\rightarrow C_6H_9O_4.ONa + H_2O$		
2. Xanthation	$C_6H_9O_4ONa + CS_2$	$\rightarrow C_6H_9O_4OCSSNa$ (Sodium cellulose xanthate)	+	Na_2CS_3 (Sodium trithiocarbamate)
3. Mixing	$C_6H_9O_4.OCSSNa + NaOH$	$\rightarrow$ Viscose solution		
4. Ripening	$C_6H_9O_4.OCSSNa + H_2O$	$\rightarrow C_6H_9O_4OH + CS_2 + NaOH$		
5. Spinning	$C_6H_9O_4.OCSSNa + \frac{1}{2}H_2SO_4$	$\rightarrow C_6H_9O_4.OH + CS_2 + Na_2SO_4$		

Figure 2.8 Reaction sequence in the production of viscose rayon

2.1.4.2 Properties of viscose rayon

Physical Characteristics:

1. ***Tenacity and elongation***: Regular viscose rayon has an average tenacity of 2.0–2.6 g/den when dry and a strength of 1.0–1.5 gpd when wet. When wet, normal viscose fibre stretches by 23-32% and returns to its original length after around a 17 to 25 percent stretch.
2. ***Initial modulus:*** The viscose fibre has an initial modulus of 54 grams/den.
3. ***Density:*** Like cotton, viscose rayon has a density of 1.52 gm/cc.
4. ***Moisture content:*** The rayon has a moisture content of 11–13% under typical conditions (65 RH and 22^{o}C). The moisture content of the yarn will be lower the lower the atmospheric humidity is, and vice versa.
5. ***Creep:*** Viscose rayon has a low degree of elasticity. It does not return to its previous length after being stretched and subsequently freed from tension. Because to this characteristic, yarn ends that are exposed to unexpected pressures when weaving may permanently stretch, which may cause steaky colouring.

Chemical Characteristics:

6. ***Acidic action:*** Similar to cotton, mineral acids that are hot dilute or cold concentrated attack viscose rayon, weakening and dissolving the fibre.

Similar to cotton, viscose rayon has significant levels of resistance to diluted alkalies. Alkali solutions that are too strong cause edoema and tensile strength loss.

Thermal Characteristics

7. ***Rayon is not thermoplastic*** and does not melt when heated, so high temperatures have no effect on it. At 150 °C, it starts to lose strength. At 185-205 °C, it starts to disintegrate after continuous heating.
8. ***Flammability:*** Rayon burns easily and emits a distinct burnt-paper smell.
9. ***Sunlight's effects:*** Oxide rayon withstands sunshine exposure without discolouring, but extended exposure results in a gradual loss of tensile strength. If the fibre contains titanium, this will be worse.

Microorganisms:

Mildews feed on the size that is left on the fibres after processing, rather than the cellulose of the fibre itself, which they do not readily attack. If the infestation is severe, mildews will weaken the fibre and discolour it.

Electrical properties:

Rayon's high moisture absorption rate tends to reduce its usefulness as insulation. Viscose does not generate static charges under normal circumstances, however antistatic chemicals must be used if the relative humidity is less than roughly 30%.

2.1.4.3 Added impurities present in Viscose rayon

In some cases, different substances are added to viscose, such as matting agents (to eliminate glass gloss in the finished fibre), dyes (for uniform and stable coloration of finished products), modifiers and surfactants (to produce high-strength and structurally homogeneous fibres), Antistatic oil, to name a few (for reducing static charge during spinning). The additional impurities may include sizing components that were added to the warp yarns to give them resistance to abrasion and tension experienced during weaving, such as starches, PVA, gums, waxes, softeners, etc.

For consistent and appropriate depth of hues, these additional contaminants must be eliminated during the pretreatment procedure prior to colouring viscose rayon cloth. **(Tissura, 2018)**

2.2 ECO-FRIENDLINESS CONCEPT

Each industry needs to be environmentally conscious in the current competitive market in order to maintain its own prospects and diversification. This eco-awareness campaign heavily relies on the textile sector. Ecology, which includes people and other animals, is what is meant by the word "eco," which refers to these living things and their surroundings. The surroundings we live in are referred to as the environment. Ecology is the study of how living things interact with their surroundings, which includes the air, water, and pollution.

Using dyes, chemicals, and processing elements that are biodegradable and devoid of poisonous or dangerous ingredients falls under the definition of being eco-friendly. Eco-friendly refers to both energy efficiency and environmental protection **(Patel, 2004).**

The environment is currently impacted by numerous chemicals used in the chemical and textile industries. These compounds can occasionally be replaced by different substances. The primary environmental problems connected to the textile sector are caused by emissions into the water. Numerous industries are experiencing major issues as a result of the evolving environmental legislation, and the textile sector is no different. Ecology is a new factor that is becoming more and more important today. Eco-logo labeling's is a key component that is gaining importance. The majority of the environmental issues that the textile industry is responsible for on a global scale involve water pollution from the release of untreated effluents and those brought on by the use of harmful chemicals, particularly during processing. If these substances are left in the fabric, they may harm consumers.

These days, environmental regulations are likewise getting stricter. As a result, it is becoming more and more important for the sector to adopt cutting-edge trends that are kind to the environment. So, from an environmental point of view, it becomes extremely crucial to examine the usage of chemicals and their eco-alternatives in depth **(Jadhav, 2010)**

2.3 THE ENVIRONMENTAL IMPACT OF TEXTILE WET PROCESSES

2.3.1 The effect of wastewater on the ecosystem

One of the industries that uses the most process water and significant amounts of complicated chemicals is the textile industry. Different chemicals and auxiliaries, including dyes, mineral and organic acids, alkali, sequestering agents, salts, optical whiteners, sizes, non-biodegradable surfactants, formaldehyde-based products, and others, which are used at various processing stages in units, contaminate water in the industries.

Water bodies such as rivers, ponds, streams, and lakes, among others, become contaminated when effluents are discharged directly into them. Because of the high BOD, COD, pH, temperature, colour, odours, turbidity, and hazardous compounds present in the polluted water, it is damaging to both plants and animals. The following table lists the most frequently used chemicals, the wastewater they produce during particular processes, and their effects on the environment. **(Mishra, 2007)**

Table 2.4 Waste water types from various textile processes **(Shah, 2014)**

Process	**Composition of Waste water**	**Nature of waste water**
Desizing	Starch, glucose, Carboxymethyl cellulose, PVA, fats and waxes, Acid	High BOD, TDS, slightly acidic
Kiering	Caustic soda, waxes, and grease, soda ash, sodium silicate	Strongly alkaline, dark coloured, high BOD, TDS, Temperature
Bleaching	Hypochlorite, chlorine, caustic soda, hydrogen peroxide, acids, etc	Alkaline, Temperature
Mercerising	Caustic soda, Wetting agent, Acetic acid	Strongly alkaline, low BOD, High COD, TDS, Temperature
Dyeing	Dyes, mordents and reducing agents viz. Sulphides, hydrosulphite, acetic acid	Strongly coloured, fairly high BOD and COD, Alkaline, TDS, Temperature
Printing	Dyes, Pigments, starch, gums, oil china clay, mordents, acids metallic salts	Strongly coloured, fairly high BOD and COD, Alkaline, TDS
Finishing	Traces of salts, tallow, Cross-linking agents, Softeners, etc	Slightly acidic, low BOD

The pollutant burden of various chemical processing procedures can be expressed as follows:

Table 2.5 Pollution generated by several chemical processes

Parameters	Desizing	Kiering	Bleaching	Mercerising	Dyeing	Printing
pH	8.6-10	10.9-11.8	8.4-10.9	8.1-9.8	9.2-11.0	6.7-8,2
TDS (mg/lit)	5580-6250	12260-38500	2780-7900	2060-2600	3230-6180	1870-2360
SS (mg/lit)	2290-2670	1960-2080	200-340	160-430	360-370	250-390
BOD (5d,20^{0}c, mg/lit)	1000 -1080	2500-3480	87-535	100-122	130-820	135-1380
COD (mg/lit)	1650-1750	12800-19600	1350-1575	246-381	465-1400	410-4270

2.3.2 Negative effects of toxic substances on human health:

Textiles, which are in fact our "Second Skin," were originally created to protect the human body. Yet, as consumer demand increased, the textile industry was forced to adapt to current tastes in design, comfort, and cost, all of which put human health at risk. The term "environmental pollution" refers to all the ways that individuals pollute their surroundings. Unwanted changes to the physical, chemical, or biological properties of the environment have a negative impact. One of the most important issues facing humanity is environmental pollution.

The following is a list of hazardous colours that emit toxic amines that are cancer-causing and allergic to humans:

- 2,4 Diaminoanisol
- 4,4 –Diaminodiphenylmethane
- 3,3- Dichloro benzidine
- 3,3- Di ethoxy benzene
- 3,3- Di methoxy benzidine

According to government regulation, certain chemicals that are very harmful and widely utilised in India's textile chemical processing industry must be phased out. These compounds include:

1) Acetic acid is used to neutralise all operations.

2) Benzidine-based dyestuff.
3) Chlorine bleaches are utilised in bleaching.
4) Starch-based warp size is utilised in sizing, and
5) pigment printing uses kerosene
6) Polycarboxylic acid with formaldehyde, used in finishing.
7) Pentachloro phenol, an antifungal and preservative,
8) 1,2 Di chloro ethane: utilised in stain removers as a solvent for fats and oils,
9) Carbon tetra chloride: utilised in scouring and stain removers as a solution,
10) Flame retardant pentachloro bi phenyl,
11) 1,1,1 Tri chloro ethane is utilised as a cleaner and solvent.
12) Nonyl phenol ethoxylates are employed as a detergent surfactant and emulsifier.
13) Tris (2,3 dibromopropyl)-phosphate, a flame retardant
14) Triphenyl phosphate - utilised as flame retardants and plasticizers

In addition to these dangerous substances, there are a number of commonplace chemicals that are utilised in excess of what is necessary and result in heavy effluent. **(Jadhav, 2010; Arya, 2009; Koushik)** The following Table 2.6 lists the most frequently used chemicals, their function or effect, and how those issues relate to health and safety:

Table 2.6 Typical chemicals used in textile manufacturing, their uses and their impact on issues with health and safety **(Shah, 2014)**

Process	**Effect/ Purpose**	**Chemicals employed**	**Possible health and safety related problems**
Desizing	Removal of Size	Hydrochloric acid	Hazardous to handle
Scouring	Removal of Fats, Waxes, Oils, Dirt	Soda ash, sodium Hydroxide	Inhalation of product mists may irritate nose, throat, and lungs, Corrosive
Bleaching	Whitening	Hydrogen peroxide sodium hypochlorite	Respiratory & skin allergies
Mercerization	Improve luster, strength and absorbency	Sodium hydroxide, Ammonia	Severe skin burns, Blindness, Corrosive

Dyeing	Diverse range of colors	Diverse dyestuff Heavy metal,	Skin allergies Carcinogenic
Printing	Dyeing at prescribed area	Urea, Kerosene, Reducing agents	Irritation eyes, skin, nose, throat, burning in chest, headache, Weakness
Finishing	Anti-crease & shrinkage control	Formaldehyde content cross linking agent	Skin allergies, carcinogenic tendency
Softening	Improvement of handle	Quaternary ammonium siloxanes. Fatty acid-modified melamine resins	Skin allergies
Flame-proof finish	Prevention of flame formation	Halogenated hydrocarbons, Phosphorous	Carcinogenic tendency, allergenic substances

2.3.3 A comparison of the GPCB, MPCB and CPCB's effluent requirements

The following table lists the typical raw effluent properties of textile waste water. While designing a successful waste water treatment plan, the parameters need to be carefully considered. **(Kanimozhi, 2011; Gujarat Pollution Control Board; Effluent Standard)**

Table 2.7 GPCB, MPCB and CPCB discharge effluent parameters

Parameter	Raw effluent of Textile wet processing	GPCB Norms	MPCB Norms	CPCB Norms
pH	6-10	6.5-8.5	6.0-8.5	6.5-8.5
Temperature(^{0}c)	35-45	40	-	40
TDS (ppm)	8000-12000	2100	1500	1500
BOD (ppm)	300-500	100	100	30
COD (ppm)	1000-1500	250	250	250
TSS (ppm)	200-400	100	100	100
Chloride (ppm)	3000-6000	600	-	600
Free chlorine (ppm)	<10	1.0	1.0	1.0
Oil & Grease (ppm)	10-30	20	10	10

2.3.4 Comparison of eco-parameters on textiles for various eco-labels:

Table 2.8 Several eco labels' eco criteria applied to textiles (**Subramanian S. P., 1995)**

Eco parameters	Clothing Type	Eco Lables		
		M.S.T.	Okotex STD 100	Eco Mark (India)
Core pH	Baby Clothing	4.0-7.5	4.0-7.5	4.0-7.5
	Close to skin	4.0-7.5	4.0-7.5	4.0-7.5
Free Formaldehyde	Baby Clothing	0.002%	20 ppm	20 ppm
	Close to skin	0.0075%	75 ppm	75 ppm
Residual Pesticides	Baby Clothing	1.0 ppm	0.05 ppm	0.1-1.0 ppm
	Close to skin	1.0 ppm	0.5 ppm	1.0 ppm
Pentachlorophenol (PCP)	Baby Clothing	0.5 ppm	0.05 ppm	0.5 ppm
	Close to skin	0.5 ppm	0.5 ppm	0.5 ppm
Heavy metals	Baby Clothing	0.1-3.0 ppm	1.0-25.0 ppm	0.1 ppm
	Close to skin	0.1-3.0 ppm	2.0-50.0 ppm	0.1 Ppm

2.4 ADVANCEMENTS IN ECO-FRIENDLY COTTON AND VISCOSE RAYON WET PROCESSING TECHNIQUES

Wet processing that is environmentally friendly is done while using water and biodegradable processing components. Many businesses, including Rossari, Clariant, and others, started good environmental practises, such as internal improvements, cleaner production methods, and pollution prevention planning. Pollution prevention promotes adjustments that can minimise production costs, boost productivity, eliminate unintentional and operational releases, lower treatment and disposal costs, and improve environmental protection.

Toxic dyes and chemicals used in the wet processing of textile products that come into contact with the skin and directly harm health in the form of allergies, skin cancer, etc. Consequently, reducing waste at the source i.e., using less water and other exhaustible materials will be a crucial step in the creation of eco-friendly textile. Therefore, it is important to avoid or utilise safe chemicals, auxiliaries, and dyestuffs whenever possible.

Consequently, in order to implement an eco-friendly textile process, the essential areas of textile wet processing, such as pretreatments, dyeing, printing, and finishing, should produce the least amount of pollution while also consuming the least amount of resources, such as water and power **(Arya, 2009)**. The following techniques can be used to make the procedure environmentally friendly:

1. Advances in Chemicals and Auxiliaries
2. Machine developments
3. Techniques Developments
4. Recycling chemical waste, textile waste, and water
5. Use of natural resources such as natural thickeners, natural dyes, and natural mordants **(Patel, 2004)**

2.4.1 SINGEING

Although though singeing is a dry process, it is included under the wet processing category. Apart for cooling the material after singeing, hardly much water is needed while processing cotton wet. This procedure is therefore environmentally beneficial. An enzymatic procedure called Bio-polishing, which is described in the finishing process, can enhance cotton material **(Patel, 2004)**.

2.4.2 DESIZING

The fabrics get stiffer as a result of sizing. For weaving, both natural sizes (Incl. starches like potatoes, rice, and corn) and synthetic sizes (like PVA, CMC, etc.) are employed. The most commonly utilised substance, starches, has a substantial BOD and COD contribution to the effluents. The sizes must be removed from the fabric since they obstruct future processing processes, are non-biodegradable, can pass through standard wastewater treatment systems, and are frequently connected to aquatic toxicity in receiving water bodies. Acid desizing, enzyme desizing, and oxidative desizing are three techniques that are often employed in textile processing. The first and most crucial step to getting nice and soft washing results is good desizing. Operations for downsizing provide a significant contribution to pollution **(Jadhav, 2010)**.

2.4.2.1 Pollution-reduction strategies for desizing

Polyvinyl alcohol can partially replace starches to reduce pollution in effluents, and the use of acrylates as a size in place of starch reduces BOD due to the recovery of size. Up to 50% of the size in the effluents can be recovered in this procedure by using low viscosity sizes like PVA and CMC **(Jadhav, 2010).**

1. **Enzymatic desizing:**

This technique is the most well-liked and efficient. Enzymes hydrolyze starch to produce molecules that are soluble in water. Amylase is an enzyme used in desizing. The starch molecule's a-1,4 glycosidic connections can be hydrolyzed by an a-amylase. This enzyme, however, can only convert starch to glucose. This is an enzyme's key characteristic. Below is a reaction.

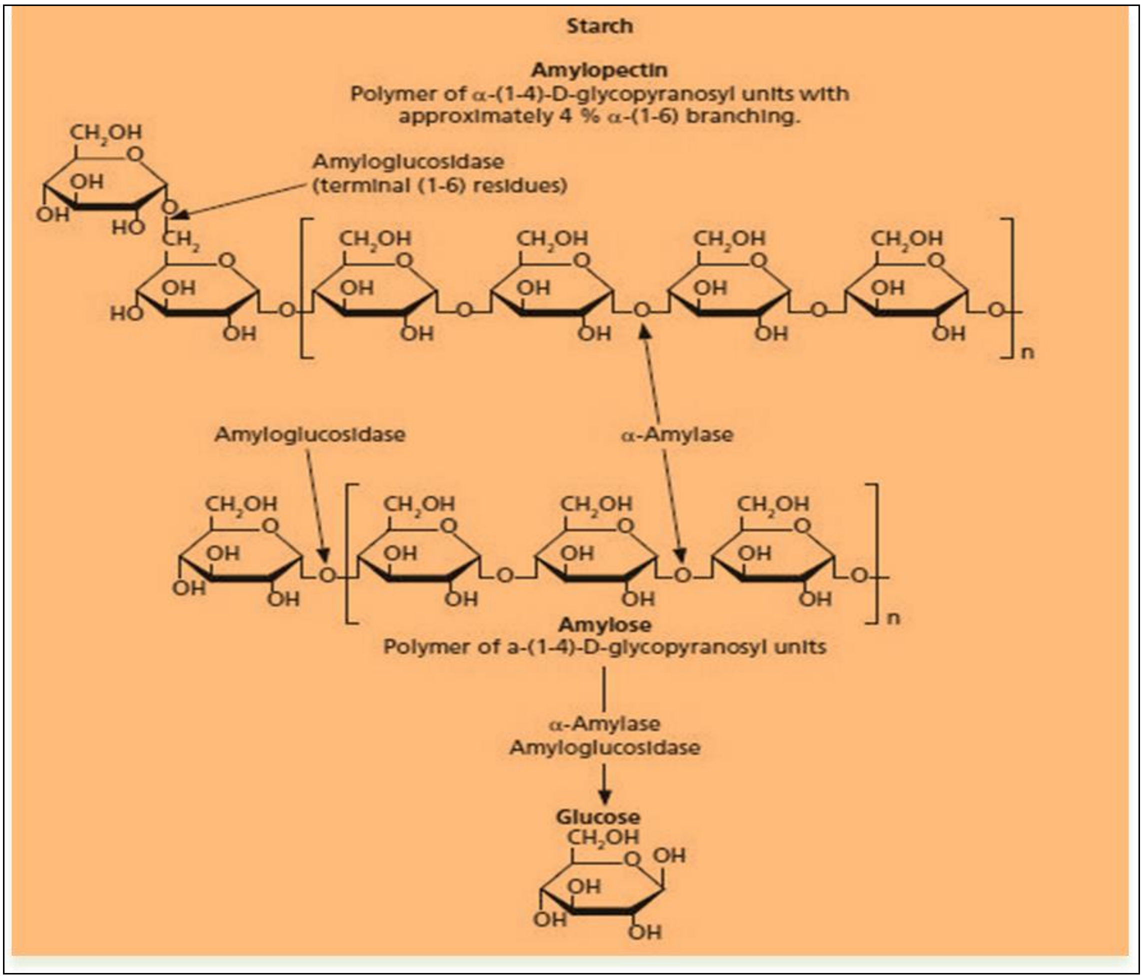


Figure 2.9 Enzymatic hydrolysis of starch **(Jadhav, 2010; Cegarra, 1996)**

This process totally disintegrates the glucose molecule. At temperatures between 40°C and 60°C, the majority of enzymes perform optimally around or close to pH 7. Furthermore, salt is required for enzymatic treatment. While a wetting agent aids in a quick wetting of the cloth and greater enzyme penetration, salt increases the heat stability of the enzymes. The enzyme bath contains 1% to 2% of the enzyme, 0.5–1% common salt and Non-ionic wetting agent, 1-3 gm. Table 2.9 provides the ideal temperature and pH for the three different types of enzymes.

Table 2.9 Several enzyme varieties and how best to use them pH and temperature

Enzymes	**Temperature(˚C)**	**pH**
Pancreatic	35-55	6.8-7.0
Malt	45-65	4.5-5.5
Bacterial	60-80	6.2-6.5

By converting starch size to ethanol or anhydroglucose using newer enzymes, it is possible to recover ethanol by distillation, significantly lowering the BOD load in the desized effluent. To make the vegetable or animal size water-soluble (hydrolysis), acids should be substituted by enzymatic and/or oxidative desizing. Starch from all sources can also be eliminated.

Benefits of Traditional Desizing

- Quick processing time; some scouring and bleaching activity; ability to combine scouring and desize.

Disadvantages

- Oxidative desizing agents require precise control over process settings and may affect polyester in blends during oxidative desizing
- Higher pollutant load.
- Fibre damage
- Inability to recover and reuse water soluble sizes.

Benefits of Enzymatic Desizing

- Water and time are saved, starch is effectively removed, the process is flexible (it can operate at low or high temperatures, desizing can be done continuously), there is no fabric degradation, and the enzymes are biodegradable.

Disadvantages

- May be time-consuming
- Just starch is eliminated **(Patel, 2004; Jadhav, 2010; Cegarra, 1996)**

2.4.2.2 Product used in cotton and rayon desizing

Some desizing enzymes:

1. Synkrolase HT 2 Conc - A concentrated desizing agent based on the alpha amylase enzyme from Synkromax, tamilnadu.

2. Arrowsize MAX CONC - A bacterial alpha-amylase enzyme with high activity and thermostability from Anthem Biosciences.
3. Resil Enzyme MAX– A powerful enzyme for desizing starch and its mixture with other sizes. even in the alkaline pH range applicable. possesses the distinctive ability to become more active as the temperature rises from Resil ltd.
4. Bactosol PHC LIQ CONC - Based on alpha amylase, Bactosol PHC Liq Conc is a highly concentrated desizing agent from clarinet.
5. Palkozyme: Alpha amylase used in low- to medium-temperature conventional desizing from Maps.
6. Palkozyme Ultra: Alpha amylase for low-to-medium temperature desizing from Maps.

Products from other companies:

Desizing/Starch Removal: Pelite CWL, Pimaze V60 Conc, ALB. High activity with a wide operating temperature range of 30 to 100 degrees Celsius and a wide pH range of 5.0 to 9.0. Products that have been treated have a softer hand feel, superior wettability, and excellent absorption; they are also free from issues typically related to fabric size.

2.4.3 PROCESS OF SCOURING

In an alkaline solution and hot environment, scouring is often done. The process of saponification at a high pH is used to remove natural contaminants. Natural impurities can be eliminated in a single step or in conjunction with desizing and/or bleaching. As a result, the fabric becomes more absorbent without changing chemically or physically.

1) Proteins are hydrolyzed into soluble breakdown products during the scouring process.
2) Ammonia is hydrolyzed from simpler ammonia compounds.
3) Soaps are made from saponifiable oils.
4) Pectin and pectose are converted into soluble pectic or metapectic salts.
5) The detergent used removes dust particles and keeps them suspended in the kier liquid.
6) The saponifiable oils created by the soluble soaps are used to emulsify unsaponifiable waxes and oils **(Jadhav, 2010).**

2.4.3.1 Methods to reduce pollutants in cotton scouring

1. Utilize or recycle scraped alcohol.
2. Chemical and auxiliary developments:
   a) By substituting sodium carbonate for sodium hydroxide, the amount of sodium hydroxide can be reduced by 25%.
   b) The use of Green soda, a product that CHT has created in place of soda ash and caustic soda.
   c) APEOs (alkylphenolethoxylates) should be replaced in detergents and dispersants with rapidly biodegradable surfactants, or at the very least, they shouldn't end up in the final effluent.

   Other non-readily biodegradable surfactants should be subject to similar regulations, too.
3. **Solvent scouring**: The cotton fabric is passed through a vessel containing trichloroethylene that is maintained at a temperature close to boiling (87°C) during the ICI scouring process. The fabric is then moved through a different vessel where a new solvent is flowing against the fabric. The fabric that has been saturated with solvent is then run through a mangle, and any remaining solvent is subsequently steamed off. Solvent quickly evaporates due to the steam. In a solvent recovery plant, the water and trichloroethylene vapour are separated after being condensed and returned to the solvent seal. After being washed, the cloth is ultimately squeezed.
4. **Enzymatic cleaning**:

   Enzyme is used in the enzymatic-scouring process, which lasts an hour at 40 °C and a pH of 4-5. In which Pectinase works as a pectin-degrading enzyme, Protease removes protein, Lipase removes fats and waxes, and Cellulase breaks down cellulose. **(Patel, 2004; Jadhav, 2010; Selvakumar, 2008; Li, 1997)**

There are two different sorts of raw enzymes available here:

- Individual effect enzymes, which each provide a unique impact when combined with all other enzymes.
- Synergistic effect enzymes: A single enzyme is a combination of all enzymes that is used to produce a single but cumulative impact.

The following table compares various factors between alkaline and biological scouring:

Table 2.10 Comparisons of various Bioscouring and Alkaline Scouring parameters

Measure	**Bio scouring**	**Alkaline scouring**
pH	5.0-5.5	13-14
Temperature	50-60^{Q}C	90-100^{Q}C
Weight Loss	< 1.5%	3-9%
Absorbency	<1 Sec	<1 Sec
Mots Removal	Nil	Complete
Fibre Swelling	No	Yes
Water Consumption	40-50%	100%
Energy	50-60%	100%
BOD	25-50%	100%
COD	25-50%	100%
TDS	20-40%	100%

The increased degree of whiteness produced by these enzymatic treatments. Large BOD, oil, and grease loadings are produced by scouring operations and enter the sewer system. Caustic soda is used for traditional scouring, which weakens the environment. Cellulosic material can be scourged using enzymes using a process called enzymatic bioscouring (EBS).

Traditional Scouring Benefits:

Excellent brightness; efficient continuous pad procedure; Bug removal

Disadvantages:

Risky, expensive to rinse (labour, water, corrosion), affects cotton fibre shape, and causes more weight loss

Advantages of the Enzymatic Bio-Scouring (EBS) system include a milder process, lower environmental impact in terms of TDS, BOD, and COD, and energy and water savings. It also improves whiteness and absorbency while reducing strength and weight loss.

5. **Mineral acids** (hydrochloric acid, sulfuric acid) should only be used as a last resort for neutralization.

2.4.3.2 Use of products in cotton scouring

1. SANDOCLEAN JSF LIQ: A non-ionic, APEO-free, extremely low foam wetting agent and detergent for all types of fabrics.
2. SANDOCLEAN MWP LIQ CONC is a multidimensional, all-in-one, low foaming scouring surfactant that may be used on all kinds of fibres.
3. SANDOCLEAN PCJ LIQ - A very low foaming, environmentally friendly wetting agent/detergent for all fibres.
4. SANDOZIN MRN LIQ CONC - Non-ionic wetting, washing, and cleaning agent for all types of fibres that is free of APEO, silicon, and solvents.
5. SANDOZIN MRZ LIQ - Powerful solvent-free wetting, washing, and cleaning agent for all textiles.
6. PIDET TOP / TOP-100: Non-ionic, low foam, quick-wetting, emulsifying, and dispersion qualities. An active substance with a very low foaming surface that can withstand extremely alkaline conditions. Outstanding penetrating and deterrent qualities.
7. PIDET SW777 - Formulated anionic and nonionic surfactants. Excellent and extremely quick wetting agent. Good stability in strong alkaline baths; appropriate for use in bath finishing processes such as scouring, bleaching, dyeing, and mercerizing.
8. PIDET XL180 - A non-ionic surface active agent with excellent penetrating and dispersion capability that is environmentally benign. suitable for use as a scouring aid during the pre-treatment of knitted fabrics made entirely of cotton as well as cotton mixes. strong alkaline and good compatibility with hard water. suitable for treatments using enzymes.
9. PIDET LF CONC - Low foam, environmentally friendly, non-ionic surface active agent, especially created for multiple uses in wet processing of textiles and apparel. A very adaptable substance that can withstand harsh water conditions, acidic and alkaline baths, and high temperatures while oxidising. suitable for enzymatic treatments, desizing, bleaching, dyeing, soaping, and scrubbing. Used in procedures involving jets, winches, pad baths, and pad steam.

Some of the scouring enzymes are:

1. BioPrep 3000 L Novozyme (pectinase) - More cost-effective to utilise, Operates at mild pH Levels over a wide.

2. Synkroscour Series: Alkaline Enzymatic Scouring for Cellulosic & Blends. Both convenient and environmentally responsible. Woven, knitted, and yarns made of cellulosic fibres can be cleaned of non-cellulosic contaminants in an efficient and cost-effective manner.
3. Piscean Bioscour APL: Mild Acid Type Enzymatic Scouring for Knits. Pectins, natural waxes, and other impurities in cellulosic fibres were designed and produced specifically for use on cellulose knits. to efficiently increase the fabric's hydrophilicity and capacity for absorbing additives, chemicals, and colours. It might not be necessary to bio-treat treated fabrics with cellulases. operational between low and middle temperatures.
4. Arrow Scour Series: Weak Acid Type Low Temperature Enzymatic Scouring for Woven Textiles. functional in a warm to ambient (30°C to 60°C) environment. Good at removing natural ashes, starches, pectins, waxes, and other impurities from cellulosic fabrics. increases the hydrophilicity and chemical, auxiliaries, and dye absorption of woven fabrics. **(Jadhav, 2010; Clarient)**

2.4.4 PROCESS OF BLEACHING

Practically all cellulosic-containing fabrics are bleached to get rid of the natural colouring. Cotton gets more hydrophilic after scouring. Due to coloured materials that washing and alkaline extraction cannot entirely remove, the original colour remains unchanged. Three substances are frequently employed:

1) Peroxide of hydrogen (H_2O_2)
2) Salt hypochlorite (NaClO)
3) $NaClO_2$ (sodium chlorite) **(Jadhav, 2010)**

2.4.4.1 Methods for reducing pollutants during cotton bleaching

1. Textiles that need to be dyed in deep colours shouldn't undergo severe bleaching, which lowers the amount of bleach used and, in turn, lowers pollution.
2. The use of continuous bleaching machines to prepare fabrics instead of batch processing results in reduced water and chemical usage, which lowers the pollution burden. cotton that has undergone both continual scouring and bleaching.
3. Peroxide bleaches should be used rather than more dangerous reductive sculpture-containing bleaches. The bleaching agent should be hydrogen peroxide (H_2O_2)

rather than substances that include chlorine, such as hypochlorite. The usage of hypochlorite is also prohibited by many certifying organisations. Also, hydrogen peroxide reduces the amount of dangerous organhalogen substances in the final effluent, gets rid of a dangerous and poisonous chemical from the workplace, and enhances the working environment. **(Sekar, 1999; Jadhav, 2010)**

4. **Advances in chemicals and auxiliaries:**

a) Pisequest 1000P, Sequestering Agent an organic chelating substance with polyphosphonate derivatives that is primarily intended for use as a water softener. High resistance to oxidative, reductive, alkaline, and acidic conditions of use. compatible with the majority of textile auxiliaries well. whiteness during peroxide bleaching should be improved.

b) All organic compounds, including stabilisers, wetting agents, emulsifiers, and surfactants, should be easily biodegradable without releasing metabolites that are harmful to aquatic animals. **(Shukla, 2006; Achwal, 2001)**

5. **Enzymatic bleaching:** The Glucose Oxidases (GOD) enzyme produces the first peroxide during enzymatic bleaching. Flavoproteins are GOD. The active side of GOD is a Flavin Adenine Dinucleotide (FAD). This enzyme catalyses the reaction for hydrogen peroxide formation at pH 4.5-7 and temperature close to 400C. It is highly selective for Is-D-glucose.

$$\begin{aligned} &B-D-Glucose + GOD-FAD \\ &\qquad \rightarrow GOD + ADH2 + d-D-Gluconolactone - GOD - FADH2 \end{aligned}$$

When d-D-Gluconolactone is in the presence of water, it converts to D-Gluconic acid, a sequestering agent used in the bleaching process. Variables include treatment duration and glucose and GOD concentrations in the bleach bath. Hence, the actual bleaching following H_20_2 production is between 85 and 90 ^{o}C between 60 and 120 minutes. **(Patel, 2004)**

Traditional versus Bio Bleaching

- **The benefits of bio-bleaching** (Laccase) include:

  Time savings, enhanced abrasion without stones, decreased backstaining, minimum strength loss, reduced strength loss, reduced grey cast, simple process control, and clean technology

- **The drawbacks of conventional bleaching** include:

problems with strength loss, offensive chlorine odour, yellowing caused by lingering chlorine, and AOX.

6. **Bleaching with peracetic acid**

Hydrogen peroxide and either acetic anhydride or acetic acid are combined to create peracetic acid.

$$CH_3COOH + H_2O_2 \longrightarrow CH_3COOOH + H_2O$$

2,2'-Bipyridine and Sodium Lauryl Sulphate (SLS) are added to the bleach solution to catalyse the bleaching of cotton fibres with peracetic acid. At temperatures as low as 30°C, bleaching is successful, and a pH of 7 is ideal. Triquelates were created when bipyridine reacted with the naturally occurring iron (ferrous ion) in cotton. The fibres have trischelates connected with them ionically.

$$\text{Bipyridine + Ferrous ion present in cotton} \longrightarrow \text{(Cell - O -)}_2\text{ Fe (Bipy)}_3\text{ (Trischelale)}$$

Moreover, for complete formulation of trischelates rather than mono and bischelates for optimal bleaching, the bipyridine concentration must be sufficient. The per-acetate anion is drawn into the trischelate's co-ordination sphere, where it is in close proximity to the fibres' colour impurities and where its reactivity is enhanced. By combining SLS with trischelate, peracetic acid's wasteful breakdown is also reduced. The best bleaching catalysts are ferrous trilelates found in the fibres. At temperatures as low as 30 °C, peracetic acid can be catalysed to bleach cotton fibres in situ from H_2O_2 by adding SLS and 2% bipyridine. **(Patel, 2004; Sekar, 1999; Chavan, 2000)**

7. **Usage of Ozone Gas in Cotton Fabric Bleaching:**

Several inorganic and organic contaminants can be oxidised using ozone, which has three oxygen atoms. This study looked into the possibilities and limitations of using ozone gas to bleach cotton garments due to its high oxidising capacity. If the water content of the cotton-woven fabric is 60% and the pH of the water impregnated is 7, it has been discovered that cotton fabrics can be bleached in a relatively short amount of time. Moreover, it has been demonstrated that ozonation at room temperature is more effective than ozonation at high to medium temperatures.

8. **Peroxide Killers:**

   If the remaining peroxide on the fabric after bleaching is not neutralised, it causes fabric tenderness and causes uneven colouring. Because they raise the TDS of the effluent, conventional reducing agents used for peroxide neutralisation are not environmentally benign. On the other hand, catalases catalyse the oxidation of hydrogen peroxide. Five million molecules of hydrogen peroxide can be broken down by one catalase molecule each second. Ultrox series is used to neutralise leftover peroxide effectively, preventing issues with subsequent processing. Using catalases, which catalyse the decomposition of hydrogen peroxide into water.

$$H_2O_2 \longrightarrow H_2O + \tfrac{1}{2} O_2$$

   It is an alternative to reduce the consumption of water, energy, and time. In addition to being highly precise, powerfully catalytic, and environmentally friendly, they also do not interfere with dyeing, allowing dying to continue in the same solution.

9. Installing holding tanks for reused bleach baths, where the bath is reconstituted to the proper strength following titration analysis. By using this method, BOD was reduced by nearly 50%, and less water was used.

10. The hydrogen peroxide in bleaching effluents can be recycled for use as a clean oxidant in the activated sludge process or other chemical oxidation processes to treat the combined wastewaters.

2.4.4.2 Products used in Cotton Bleaching

The following stabilisers are employed in hydrogen peroxide bleaching:

1. STABILIZER AWNI LIQ is a cost-efficient, environmentally friendly peroxide stabiliser.
2. STABILIZER ECO LIQ - Affordable, environmentally responsible, and efficient peroxide stabiliser.
3. STABILIZER FCB LIQ CONC - A special stabiliser for the bleaching of cotton and its component in fibre blends using silicate-free alkaline peroxide
4. STABILIZER SIFA LIQ - An organic stabiliser for continuous and semi-continuous silicate-free alkaline hydrogen peroxide bleaching of cotton and cotton-based blends.

5. STABILIZER SIFAM LIQ - This stabiliser was created specifically for the silicate-free alkaline hydrogen peroxide bleaching of cotton and the cotton component of blends.
6. STABILIZER SOF LIQ - A stabiliser specifically made for alkaline peroxide bleaching cotton and its constituent fibres without the use of silicates.

Some of the bleaching enzyme (Achwal, 2001)

1. BiofinaseBP-300 - Successful bleaching can be accomplished at temperatures as low as 30°C and an ideal pH of 7, producing whiteness values that are comparable to those of chemically bleached cotton and greatly softening 100% cotton woven and knit materials.

Peroxide killer enzymes include some of the following (Chinta, 1993; Clariant Ltd; Cegarra, 1996):

1. BACTOSOL APN LIQ - An enzyme-based biocatalyst that selectively uses hydrogen peroxide as an anti-oxidant.
2. BACTOSOL ARLI LIQ CONC is a brand-new hybrid catalase enzyme that is specifically designed to neutralise hydrogen peroxide over a broad temperature and pH range.
3. Hydrogen peroxide scavengers that use enzymes - Percatalase 6Y, Perozyme K8, etc. Extremely efficient at removing residual peroxide that remains after hydrogen peroxide scouring and bleaching. operational at temperatures between 30°C and 70°C and a wide pH range of 5.0 to 9.0. contains no animal products or extracts. exceptional storage stability at temperatures below 30°C.

2.4.5 PROCESS OF MERCERIZING

A strong caustic soda solution (often 280–300 gpl) is used to mercerize pure cotton garments or yarn in order to increase strength, colour substantivity, smoothness, and strength. Mercerization's impacts

- Better luster
- More capacity to absorb dye
- Enhanced responses to various substances;
- Better form stability
- Better strength/elongation;
- Smoothness is now better **(Jadhav, 2010)**

2.4.5.1 Methods for reducing pollutants during cotton mercerization

1. **Liquid ammonia** replaces traditional mercerization with less pollutants (NaOH). Liquid ammonia treatment on heavy cotton fabrics reduces the amount of dye needed to get a particular shade depth, which reduces pollution by requiring less chemical.

2. Following concentration and regenerative treatment to eliminate dirt (coagulation, flotation, microfiltration, and nanofiltration), alkali should be recovered and reused. To reduce alkaline treatment discharges and the accompanying pollution effluents, diluted alkali from mercerizing should be reused in scouring, bleaching, or dyeing activities.

3. **Recovery of NaOH**: In numerous large mills, recovery of NaOH from waste results in significant cost and NaOH savings. The pH of the waste is significantly reduced as a result of caustic recovery. TDS. Reverse osmosis, dialysis, and multiple effect evaporators are used to recover NaOH. **(Patel, 2004)**

4. Using a countercurrent washer

5. **Biotechnology in Mercerization**: Enymes were the focus of Buschle-Diller and Zeronian's studies. Provide substitutes for the current alkalis in the near future. **(Cegarra, 1996)**

6. By utilising **biodegradable non-crysilic wetting agent** types **(Achwal, 2001; Chinta, 1993; Clariant Ltd)**

2.4.5.2 Product usage in cotton mercerizing

Many non-crysilic wetting agent varieties for mercerizing

1. MERCEROL QWNI LIQ is a potent, high-active, cresol-free, low-foaming wetting agent for mercerizing cotton and cellulose blends in yarn, woven fabric, and knitted goods.
2. MERCEROL RWLF LIQ - Low foaming mercerisation wetting agent for yarn, woven, and knitted forms of cotton and cellulose blends.

2.4.6 PROCESS OF DYEING

Dyeing procedures produce uniform colour on textile materials while utilising a variety of supplementary materials and dyes. The combinations are frequently created to address issues unique to the procedure. The effects of other chemicals are countered or enhanced by the development of some speciality compounds. In other instances, the speciality compounds have unfavourable side effects on the entire process. For instance, wetting agents are frequently used to the preparation and dyeing processes to ensure chemical penetration. The majority of the emissions resulting from the dyeing process are emissions to water, with a few exceptions (such as the thermosol process, pigment dyeing, etc.). Aquatic toxicity, metals, and colour are a few examples of compounds that can come from dyes themselves that can pollute water. Other sources include auxiliaries used in dye formulations (e.g. dispersing agents, anti-foaming agents, etc.). Alkali, salts, reducing and oxidising agents, among other basic chemicals and auxiliaries, are utilised in dyeing processes **(Patel, 2004; Jadhav, 2010).**

2.4.6.1 Ways to reduce dyeing pollution:

1. Choosing a dye:

   Metal-containing dyes (Cu, Cr, Ni, Co, etc.), benzidine-based azo-dyes, and dyes found to contain PCBs (such as some sources of Cu-phtalocyanine) should all be replaced right away. Azo dyes have the potential to release aromatic amines, which are thought to be carcinogenic, under reductive circumstances.

   Direct or reactive dyes made from benzidine ought to be avoided right away. In due course, it is also advisable to steer clear of intermediate-based dyes such dichloro-aniline, benzopyrine chloroaniline, and hexachloro pentadiene. It is best to stay away from colours based on copper and chromium metal complexes as well.

2. Pigments that contain cadmium shouldn't be utilised.

3. If the after-treatment chemicals are compatible with the dye bath chemicals, the rinse bath should be employed as the next dye bath in order to minimise the discharges of BOD, COD, etc. as well as of coloured compounds in the case of repeated dyeing. **(Jadhav, 2010)**

4. Cotton cationization for salt-free or low-salt dyeing**.**

Cellulosic fibres produce a little negative charge when they come into contact with water due to the ionisation of hydroxyl groups. Moreover, the majority of dye classes that work well on cotton are anionics in solutions. The slightly negative charge on the fibres causes anionic dyestuff to repel one another, limiting the dye bath's ability to be exhausted. However, the charge repulsion effect can be overcome by the addition of an electrolyte like NaCl or sodium sulphate, leading to greater dye exhaustion. Thus, a dyeing process that results in high dye fixing could be very helpful to minimise the environmental issues. To manage the effluent issue, cationization of cellulose through chemical interaction with substances having cationic group has been advised. Apart from these, Japanese businesses like Kurabo Industries have commercialised the method of making fabrics using yarns of both cationic and regular cotton. Toyobo and Kanebo Textiles. These fabrics exhibit a cross-dye effect and varied colours upon subsequent dyeing. Cotton. Some of the brand names of cationic cotton that Japanese producers sell on the global market are Colo-cotton and View line.

5. Reducing the use of chemicals:

   Some strategies for doing so include:

   - Dyeing with a low liquor ratio
   - Process improvements in continuous dyeing;
   - The right approach the first time **(Patel, 2004)**

2.4.6.2 Environmentally friendly methods for various dye application

2.4.6.2.1 Vat dyeing

- **Glucose-based colouring**

  It is best to avoid reducing dyes with sulphide, and glucose works as a reducing agent but is very temperature-dependent. Even at 350°C, the salt potential of glucose is extremely stable and can lower the vat's overall potential.

Recipe:

Dye ……… X%
Glucose/Dextranil…..2 gpl (Reducing agent)
NaOH ………. 2 gpl.
Saline sulphate …….1.5 gpl

In the continuous pad-steam process, the glucose condition is highly good in preventing the over-reduction of sensitive dyestuff. According to the type of dye class being used, dyeing is done using the traditional method for 45 minutes. After that, 1 gpl of H_2O_2 is exposed to oxidation for 15 minutes at 50°C. At the boil, soaping is finally completed. Peroxide or air oxidation should be used to replace dichromate oxidation of vat dyes.

2.4.6.2.2 Sulphur dyeing

- **Hydrol,** a byproduct of **sulphur dyeing** and an alternative reducing mechanism to sulphide, includes around 50% reducing sugars. In an alkaline solution at 80°C, it exhibits a redox potential of 500 mv. Moreover, 100 parts of Na_2S can be replaced by 65 pounds of hydrol and 2 parts of NaOH. Typically, dyeing is done in the Jigger trough using the exhaust method. In terms of shade depth, fastness qualities, etc., the dyeing produced using this approach is equal to conventional dyeing.
- **Thioglycol:** Although the colour output is lower than from sulphide reduction systems, thioglycol can be used in combination with NaOH to apply the majority of soluble sulphur dyes. Thioglycol has the benefit of having no sulphide and little to no smell from the dye bath.

  To make a 1% stock solution of **glucose/dextran**, mix 1 g of dye paste with 1 ml of T R Oil and 20 ml of boiling water. The solution is heated up before 3 gpl of dextranil or glucose, 4 gpl of sodium carbonate, and 2 gml of sodium hydroxide are added for reduction. Ultimately, by adding cold water, it was manufactured up to 100 ml, and it was then utilised as slock solution.
- **Mercaptoethanol** is a substance that BASF sells under the brand name Molleskal-SF. Using mercaptoethanol, caustic soda, exhaust methods, and one bath pad-steam process, it is possible to apply soluble sulphur dyes.

  The oxidation of sulphur dyes with dichromate should be replaced with oxidation with peroxide.

2.4.6.2.3 Direct dyeing

- Avoid direct dyeing after treatment using copper or chromium salts to increase fastness.

- To increase the wet fastness of the dyed material, a dye fixing agent based on HCHO should not be employed.
- Upon application of a cationic dye-fixing agent with reduced HCHO or an HCHO-free product.
- Choose dyes with a high fastness. **(Chinta, 1993; Achwal, 2001)**

2.4.6.2.4 Reactive dyeing

- The first environmentally friendly method is to modify the dye to make it more reactive in order to boost fixing.
- Increasing the substantivity with a modification to reduce the need for electrolytes.

Two reactive groups that can establish covalent connections with the fibre make up a **bifunctional reactive dye (Patel, 2004; Taylor, 2000; Renfrew)**. There are two categories of bifunctional dyes:

1. Homoglycated reactive dyes
2. Reactive heterobifunctional dyes

The sumifix supra dyes (Sumitomo Corporation, Japan), which are combined bifunctional reactive dyes having both vinyl sulphone and monochloro triazinyl groups, are a development in reactive dyes. These dyes get over issues including poor levelness and repeatability, low fastness properties, and low exhaustion and fixation levels.

The I'rocion Supra line was created by ICI and contains two monochlorotriazine groups per molecule. This is for making a variety of exhaust dyes at high temperatures that have significantly increased exhaustion and fixation. This results in better dye use and less efficient, hyprolyzed processing. Moreover, Procion HE (ICI) has two monochloro triazine groups for with a strong fixation and exhaustion component.

- **Trifunctional reactive dyes (Renfrew)**: Though there aren't many products on the market with three reactive groups, this is a growingly popular topic for patent applications. Several chromogenic types with bis-VS/MCT and bis-VS/MFT reactive groups have been revealed by Ciba, Sumitomo, Hoechst, and BASF.

- Ciba has also asserted ownership of dyes with the combinations bis-VS/difluorochloropyrimidinyl, bis-MCT/VS, or bis-MFT/VS. The intriguing trifunctional combination of two (masked) vinylsulphonyl groups joined to a single triazinyl ring has just been patented by Hoechst. There have also been described reactive dyes that contain three halotriazinyl or triazinylpyridinium groups, VS/MCT with a difluorochloropyrimidinyl group, or a bis-VS/triazinylpyridinium combination.

  Many chromogens with two VS/MCT or VS/MFT reactive group combinations are covered by patents Ciba has filed. Similar to Hoechst, this company has expressed interest in reactive dyes that contain four reactive groups, and they have once more used two pairs of VS/MCT or VS/MFT to achieve this. The reddish-gray to black chromium complex is an illustration of this. There have also been other reactive group combinations mentioned, such as two vinylsulphonyl, a-bromoacrylamido, or b-chloropropionamido groups with two triazinylpyridinium reactive groups. BASF has four monohalotriazinyl group dyes under patent.

- **Neutral-fixing reactive dyes (Renfrew)**: It was demonstrated in 1959 by ICI scientists that a variety of tertiary amines react with monochlorotriazines, as well as with di- and trichloropyrimidines, to produce stable yet fiber-reactive quaternary ammonium salts.

  It was discovered that the quaternary ammonium products attached to cellulose more quickly than the chloro precursors. Because that ICI had a virtual monopoly on short batching dichlorotriazinyl dyes in the early days of reactive dyeing, this rise in reactivity sparked a great deal of interest in this field. To benefit from this improved reactivity, tertiary amines in catalytic proportions were then utilised. This method's premise was that the tertiary amine could be recycled if the quaternization and fixation/hydrolysis reactions happened quickly. As fixation catalysts, reactive pre-formed quaternary ammonium compounds were also patented.

  When a quaternary nicotinic acid group replaces a chloro group in the triazine series, the reactivity is increased and fixation can continue essentially in a neutral environment. This is a crucial and unique characteristic of this kind of reactive dye. A hardly detectable organic base is released under neutral fixation conditions.

pH impact on dyebath (unlike, for example, release of chloride ion in the case of monochlorotriazinyl dyes).

Lewis' research has demonstrated that a variety of quaternary ammonium groups coupled to triazinyl systems can produce effective neutral fixation. Although the exact method for neutralising quaternary ammonium reactive dyes is unknown, it undoubtedly involves deprotonating cellulose. When applied to cellulose at 95 °C in the presence of salt and buffered at pH 7, neither monochlorotriazinyl nor vinylsulphonyl dyes exhibit any discernible levels of fixing. Kayacelon Reacts make use of neutral fixation while Procion Blue H-EG was advised to be administered in the presence of sodium carbonate solution. In the latter instance, high levels of fixation are observed with application temperatures ranging from 95 to 130 °C.

- **Reactive dyes that fix in acidic condition (Renfrew)**

  As a result, only a small number of dye product lines have been introduced that adhere to cellulose in an acidic rather than a basic environment. Currently, all commercially available active products with the exception of Kayacelon React dyes (neutral fixing) require fundamental fixing conditions. In an acidic environment, Procion T dyes that were based on the chemistry of phosphonic acids were fixed to cellulose. Unlike to the acid fixing groups employed in the late 1950s and early 1960s, Procion T dyes needed a catalyst to allow the creation of covalent bonds. Usually, dicyandiamide was employed to fix it on cellulose in an acidic condition.

- **E-control method:**

  Using Na_2CO_3 to dye with highly reactive dichloro triazinyl Procion MX dyes (developed by Zeneca and Monforts). This type of continuous dyeing includes fixing colours in hot flue dryers with controlled relative humidity levels of 25 to 30%. Continually dyeing is done using the pad-dry-wash method. The fixation level is comparable to that of the pad-steam technique.

- **Low salt dyeing technique to reduce salt burden**
  - Dying with little liquor content
  - Reactive dye dyeing, which results in significant depletion and fixing at low salt concentrations.

- **The dye CUBACRON LS**

  Its primary attributes are:

  Bifunctional reactive dyes have the following benefits: medium reactivity, high dye affinity, and high dye fixation; stable dye-fibre link; less dye needs to be removed from fabric after dyeing; faster rinsing step; less water required for wash off; and reduced dye effluent.

- **POLYRON SAR**

  Alternative to environmentally friendly soda ash for fixing all reactive dye types.

  Important Details:

  - Polyron SAR is a safe alternative to alkalis.
  - When it is added to a reactive dyeing bath, it promotes effective fixing and exhaustion, which results in a good colour yield on cellulosics.
  - When reactive dyeing is used, Polyron SAR neutralises core alkali significantly more quickly and effectively than typical alkalies.
  - As a result, less hydrolyzed dye is present for consumers.
  - Improving wash fastness
  - Polyron SAR is a financially advantageous alternative to soda ash and is appropriate for dyeing in all kinds of equipment and on all kinds of substrates. Only 1/5th to 1/6th the amount of soda ash needs to be used, depending on the type of colours used and the depth of the dyeing.
  - Because there is less Polyron SAR used in dyeing than soda ash is needed, there is proportionally less acetic acid needed to neutralise the colour. Lower TDS results from this, which lowers the effluent load on the ETP plant. **(Clariant Ltd)**

- **In the reuse of reactive dyes, hydrolysis is compensated**:

  The alkali speeds up dye hydrolysis in traditional exhaust procedures for applying reactive dyes, preventing further reuse. Accurate colour copying with recycled dyes can also be hampered by step-up and chemical build-up. The risk of alkali-induced hydrolysis, step-up, and chemical build-up effects is eliminated by using a two-bath approach that involves first applying the dye from a salt and dye bath and then treating in a separate alkali bath. **(Scheyer, 2000)**

2.4.6.2.5 Natural dyeing:

- Natural dyes are colourants (dyes and pigments) made without the use of chemicals from plant or animal waste. Although certain vat, solvent, pigment, and acid types are known, they are primarily mordant dyes.

  Natural dyes are used to colour clothing, food, medicine, and cosmetics. Moreover, very little amounts of dyes are used to colour paper, leather, shoe polish, wood, cane, candles, etc. In the past, only natural sources were used to create dyes. Yet because dyes obtained from comparable plants or other natural sources are affected and prone to the whims of temperature, soil, cultivation techniques, etc., natural dyes suffer from some intrinsic drawbacks of consistent application and the standardisation of the dye itself. In order for natural dyes to be truly commercialised and to compete well with synthetic dyes, standardisation techniques are crucial and play a huge role.
- **Grouping of natural dyes:**

  Generally speaking, three different types of natural dyes are categorised based on Chemical Class, Application Class, and Color.

  1. **Organized according to chemical classes**: There are numerous chemical classes represented by natural organic dyes and pigments. Polymethines, Ketones, Imines, Quinines, Anthraquinonoids, Naphthoquinones, Flavones, Flavanols, Flavanones, Indigoids, and Chlorophyl are just a few examples.
  2. Depending on the **type of application**: within two groupings

  - **Substantive dyes**: -Dyes that directly colour the fibre are referred to as substantive dyes.

    Example: Orchil, indigo, and turmeric.
  - **Adjective dyes**: These dyes only colour the fabric when it has been mordanted with metallic salt or when metallic salt has been added to the dye bath.

    Example: Fustic, Cochineal, Madder, and Logwood.

  An equal classification for direct dyes and mordant dyes later superseded the previous one.

  Adding the following classification

  - Monogenetic dyes: Regardless of the mordant, these dyes only create one colour.
  - Polygenetic dyes: - The type of mordant used determines the colour these dyes produce.

3. **On the basis of colour**: The dyes are categorised in the Colour Index based on their chemical make-up as well as the main application classes. The colours are organised in application class according to hue. The area for natural dyes is separate. Each color's number of dyes is listed below. Several hues can be produced by some dyes.

- **Mordants:**

A substance known as a mordant can attach to fibres and interact with dyestuff. As a result, a bond is created between the dye and the fibre, enabling some dyes with no affinity to adhere to the fibre.

Three different types of mordants include:

1. Metallic mordants or metal salts.

Alum - Potassium aluminium sulphate; Copper - Copper sulphate; Chrome - Potassium dichromate; Iron - Ferrous sulphate; Tin - Stannous chloride, Stannic chloride; are a few of the different metal salts that can be used for mordanting.

2. Tannic acid and tannins.

Depending on the sort of phenolic nuclei involved and how they are connected together, the structural division of vegetable tannins into two separate classes was made.

Condensed tannins like catechin obtained from acacia catechu; hydrolysable tannins found in myrobalan fruit, oak bark, gallnuts, pomegranate rind, and sumac leaves. Harda, tannic acid, and other tannins are regarded as natural mordants. Tannic Acid makes up 60–77% of gallnuts.

3. Mordants or Oil:

Turkey Red Color is primarily dyed with oil-mordants using madder. The primary purpose of the oil-mordant is to create a complex with the principal mordant, alum. Alum is easily removed from the treated cloth because it is soluble in water and has no attraction for cotton. The fatty acids palmitic, stearic, oleic, and others, as well as their glycerides, are present in naturally occurring oils. Fatty acid -COOH groups interact with metal salts to form -COOM, where M stands for the metal; in the case of alum, this would be Al. The introduction of the sulphonic acid group, $-SO_3H$, caused by the treatment of oils with concentrated sulphuric acid results in sulphonated oils, which have stronger metal binding capacity than natural oils. Metal salts and sulphonic acid can react to form $-SO_3M$. The mordant dye, such as madder, can then form a complex with the bonded metal to provide the exceptional fastness and hue of Turkey Red.

- **Methods for mordanting**

  Aluminum ions are introduced into the fibre by a subsequent treatment of the tannin-treated substrate with metal salts, such as alum. By producing a metal-complex or metal salt, the tannin-treated material at the hydroxyl or carboxyl groups sorbs these ions. Then, the metal ions serve as sites for the mordant pigments. Therefore, metal ions are introduced into the fibre. The substrates' affinity for natural dyes can be increased directly or as tannin-metal complexes. Because of this, tannins by themselves do not function as mordants; nevertheless, the combination of tannin and metal salt does so for the natural mordant dyes.

- **Techniques for mordanting**

  The three techniques for mordanting are as follows:

  - Pre-mordanting: The substrate is first given a mordant treatment before being coloured.
  - Meta-mordanting: The mordant is infused directly into the dyebath.
  - Post-mordanting: A mordant is applied to the dyed material.

  The techniques differ in how they affect both the fastness qualities and the shade that results from dyeing. The substrate and the dye both play a role. The right procedure must be chosen in order to optimise the parameters and get the desired shade and speed.

- **Extraction methods include**:

  - Basic Aqueous Methodologies
  - Difficult Solvent System
  - Supercritical Fluid Extraction Methods; Ultrasonic Extraction in a Sonicator.

- **Benefits of using natural dyes:**

  - Fabrics with natural dyes will be stronger than those with artificial dyes.
  - It would smell like the customary herbs used to process the same.

- Why Lime discharges on naturally coloured textiles because it is nature's most powerful acid source.
- They are very calming to the eyes and the mind, have biodegradability, and a tendency towards compostability. The colours may change with other physical/chemical and external environmental changes.
- Natural dyes are produced using minerals and plants. All herbs have medicinal use as either botanicals (herbs), homoeopathic (diluted), or dietary supplements (minerals)
- It is exceptionally smooth and conducive to perspiration
- Because the colours are special and cannot be replicated with dyes, new shades can be created.

Poor colour production is one of **natural dyes' drawbacks**.

- Prolonged dying time.
- Expensive manufacture;
- Limited repeatability.
- Some metallic mordants can be dangerous. **(Chakrabarti; Bhargava, 2011)**

2.4.7 Printing process

The technique of adding colour to a substrate is known as printing. To achieve the desired pattern, print colour is applied selectively to specific places as opposed to colouring the entire substrate (cloth, carpet, or yarn) as is the case with dyeing. Compared to dyeing, this includes distinct methods and equipment, although dyeing's physical and chemical processes are equivalent to this procedure' physical and chemical interactions with the fibre. Aliphatic hydrocarbons (C10-C20) from binders are a pollutant found in exhaust air.

- Monomers such butadiene, acrylonitrile, acrylamide, styrene, vinylacetates, and acrylates.
- Methanol derived from fixatives.
- Esters, polyglycols from emulsifiers, and other alcohols.
- Formaldehyde produced by fixatives.
- Nitrogen (from urea decomposition and from ammonia present, for example, in pigment printing pastes).

- Emulsifier-derived N-methyl pyrrolidone.
- Esters of phosphoric acid.
- Phenyl cyclohexene, a component of binders and thickeners **(Jadhav, 2010)**.

2.4.7.1 Printing pollution reduction strategies:

1. Using synthetic thickeners based on poly carboxylic acids in pigment printing rather of kerosene. Synthetic thickeners based on acrylic polymers can replace kerosene. The equivalent of kerosene-based prints is the half of kerosene replacement with synthetic thickening.
2. Avoid treating printed fabrics with hypochlorite to make them whiter.
3. When possible, use pigment printing.
4. You can use "Sunnyfix NF" in place of traditional melamine, a fixer made of formaldehyde, to carry out pigment printing. Print-dry-cure is the next step, which is performed for 5 minutes at 150°C.
5. Careful planning to prevent print paste from becoming bad before use.
6. **Laccase enzyme-based discharge printing** on cotton fabrics

   The chromophore system of the dyestuffs that are applied to the textile material is thought to be degraded by chemical reagents in the discharge printing theory. Oxidizing and reducing agents are the two basic types of discharge agents. Usage of Zinc Sulphoxylate Formaldehyde and $SnCl_2$ should be limited or, better still, avoided in discharge printing. The laccase enzyme formulation was utilised in discharge printing on cotton fabrics treated with various reactive dyes, and it was discovered that the enzyme works best at 4.5 pH, 60 °C, and 1 hour. **(I Abd El-Thalouth, 2008)**
7. **Enzyme-assisted print cleaning**
   - Enzymes and surfactants were carefully combined to hydrolytically separate the chains, reducing viscosity and making it simple to wash the gum off. Enzymatic washing has the following benefits:
   - Good Specificity: Only works on reactive dye hydrolysate
   - Eco-Friendly - Biodegradable, Leaves rinse bath clear
   - Saves water and energy: Works at 55-60°C
   - Reduces number of rinse baths
   - Economical
   - High Quality Standards: Enhances the attributes of fastness. **(Mishra, 2007)**

8. Potential **Urea Replacement** Strategies:

   Three strategies are now being investigated to reduce or replace urea in cellulose printing:

   - Convert to two-phase printing (Flash age printing);
   - Replace all or part of the urea with an alternate chemical, such as Matexil FN-T (dicyandiamide);
   - Provide moisture mechanically before the substrate enters the steamer.

9. Printing with **Inkjet**:

   New technologies are being developed to reduce waste and stop pollution. Instead of using a photographic screen or a kitchen to mix colours, dye solution droplets are applied to fabric to create patterns.

   The term "spray printing," which is occasionally used, is incorrect because, in all real jet printing methods, the ink is projected onto the surface of the substrate as a cohesive and controlled series of drops. Typically, a set of inks called CMYK inks is employed, which consists of at least three or four primary colours: cyan (turquoise), magenta, yellow, and possibly black. Although in these applications the three primary are either printed as dots of different diameters (amplitude modulation) or as evenly sized dots of various randomised density configurations, these colours are still used in gravure and offset lithographic colour printing (frequency modulation). Less frequently, as is done in traditional textile printing, so-called spot colours may be pre-mixed to match the precise tones in the design. The phrases used in, for example, technical specifications are more closely connected to those used in the reprographics sector than to those that a textile printer would typically use because the majority of inkjet printers were initially intended for paper printing. Consequently, inks rather than dye solutions, pigment dispersions, or print pastes are typically mentioned. As opposed to mesh or raster, print resolution is typically expressed in dots per inch (dpi) or lines per inch (lpi).

   Nowadays, rotary- or flat-screen machines are utilised to generate 90% of all printed textiles; the choice of technology is primarily based on the length of cloth that needs to be printed. Machine design and operation, particularly in the field of rotary printing, are continually being improved. As an example, pattern fitting and setup can now be completed quickly using laser light alignment devices and individually driven screens, while screen changing times can be decreased to as little as 10-15 min. So what are the benefits of switching completely to a jet printing system? The highly frequent usage of CAD systems followed immediately by either laser engraving or exposure of screens covered with appropriate lacquers is the primary driver of rising interest in digital printing methods.

It would be even more appealing to completely do away with the need for screens, which is what direct ink-jet printing on textiles allows for. The advantages right now are:

Extremely quick client reaction for bulk prints and strike-offs, and minimal waste from pre-production sampling. The number of colours and the size of the pattern are virtually unlimited, enabling the production of very long repeats (e.g., fully bordered bed sheets) and full tonal (photorealistic) prints. Instant fitting of patterns at start-up, thus minimising fabric and paste wastage. Minimal downtime, because patters are fitted immediately, and patterns are stored on CD-ROMs or other similar storage media. **(Agarval, 2001; Miles)**

10. Cellulase enzyme printing in the Brasso style for paper/cardboard blends.

2.4.8 PROCESS OF FINISHING

The importance of multifunctional finishes for high-end fabrics is rising today. Wrinkle free/Durable press/Easy care finish are a few of the finishes that are increasingly in use.

- Biofinishing and enzyme washing.
- Softeners improve resilience, bounce, and occasionally hydrophilicity.
- Finishes that are waterproof and stain-resistant but breathable.
- Deodorant and antimicrobial coatings.
- Finishes that are flame-resistant.

2.4.8.1 Ways to reduce pollution in finishing:

Finishing chemicals should be reused whenever possible Biocides like DDE, DDT, and benzothiazole used in preservation finishing should be replaced by UV treatment, or mechanical procedures, or enzymatic finishing. **(Jadhav, 2010)**

2.4.8.2 Environmentally appropriate methods for various finishing:

2.4.8.2.1 Durable press finishes

Cotton and other cellulosic fibres lack any inherent cross-links or bridges. The cellulose chains do not return to their original configuration after being deformed under stress (such as after washing or wrinkled). In order to give cotton fabrics smooth drying qualities and dimensional stability, durable press finishes are applied. To generate wash and wear and durable press qualities, cross-linking agents are used. They are used on materials that dry quickly and can be easily washed. They have outstanding crease recovery. The fabric is impregnated with a catalyst-containing resin solution, dried, then heated to cure it into rein finished cloth. Urea formaldehyde resin and dimethyl dihydroxy ethylene are two examples.

Durable press finish issues include the following:

- Formaldehyde is commonly used as a cross-linking agent in DP finishes. Whether present in gaseous or dissolved form, formaldehyde is a hazardous chemical.
- When tested on rats, formaldehyde is thought to be carcinogenic and cause lung cancer. It causes significant eye irritation, dissolves in eye fluid, and releases formaldehyde, which is carcinogenic. Free formaldehyde can cause allergic reactions and irritate the mucosa.
- Ammonia fumes can cause respiratory discomfort, itchy eyes and skin, shortness of breath, nausea, and vomiting.

Formaldehyde scavengers are the solution.

- The effectiveness of the local ventilation.
- The regulation of air conditions since high temperatures and humidity speed up the emission of formaldehyde.
- Use of steam in pressing and shaping processes for clothing.
- A partial replacement of the N-methylol group that contains no formaldehyde. Several cross-linking agents may be used in treatment **(Hauser)**:
  1) Use of BTCA in treatment
  2) Utilization of Citric Acid
  3) DMDHEU treatment
  4) Glyoxalz treatment

Using a two-bowl laboratory padding mangle, the pre-scoured and bleached cotton fabric was individually padded with varying concentrations of citric acid, catalysts, polyethylene softener (15 g/l), PEG-600 (15 g/l), non-ionic wetting agent (10 g/I), and various types of additives to achieve a 70% wet pick up. After padding, the textiles were heated to 80 °C for five minutes with lab stenter, then cured at 140 °C and 160 °C for one minute, two minutes, and three minutes. The cured fabrics were then carefully cleaned and dried. Sodium hypophosphite is the catalyst, and the concentrations were 1 gpl, 2 gpl, and 3 gpl. Citric acid concentrations ranged from 60 gpl to 140 gpl and from 80 gpl to 140 gpl.

- **Green cross-linking agents provide the following benefits**:
    - Costly bulk manufacture
    - Outstanding efficacy in preventing wrinkles, long-lasting launderability, and excellent strength retention
    - Show between ten and twenty percent greater fabric strength retention than dimethylol dihydroxy ethylene urea (DMDHEU) in terms of durability press performance. **(Patel, 2004; Jadhav, 2010; Chinta, 1993)**

2.4.8.2.2. Antibacterial finish

- Wastewater treatment for mothproofing finishes should avoid creating an excessive amount of sludge. The best course of action for this sludge is either wet (catalysed) oxidation detoxification or incineration as chemical waste.

  Piscean AB500 antibacterial is the product. dependable antibacterial treatment aids for textiles and cellulosic materials. Simple to use, long-lasting effectiveness. greatly increases the tear resistance of a fabric over time: The antibacterial qualities of properly treated cellulosic fabric can withstand up to 100 cycles of washing at home. **(Jadhav, 2010)**

2.4.8.2.3 Finish Softness/stiffness

- The fabric feels softer thanks to softeners. Moreover, they are combined with starch and other ingredients to give the fabric body and suppleness. There are several varieties of softeners, including cationic, reactive, and emulsion. All other softeners aside from silicone are transient and disappear after two or three washings. Moreover, silicones provide water repellency, which dries quickly after washing and drying. With other finishing chemicals, it works well. It is simple to apply on the cloth. The air porosity of fabrics treated with silicones is unaffected.

  Employ non-ionic latex-based softeners, such as Siotex or Durafill amino Silicon type acrylics, in small amounts.

- Stiffeners: It is important to use polyvinyl acetate copolymers without plasticizers like triphenyl phosphate. **(Patel, 2004; Jadhav, 2010; Chinta, 1993)**

Table 2.11 Environmentally friendly substitute chemicals

Non–ecofriendly chemical.	• Polysiloxanes & derivatives(Softening agents) • Quaternary ammonium siloxanes • Fatty acid modified melamine resins
Problems associated	• Many times the exhaustion of the softening agent is low which causes health problems if the softener is hazardous. • Unpleasant odor of the softening agents. • Skin irritation. • Softener is not biodegradable.
Eco- substitute	• Vinyland acrylic copolymers Polymeric softeners • Cellulase enzymes • Epoxy modified silicones
Advantages	• Good results are obtained • Do not require emulsifying agent

The following eco-friendly substances are used for softening purposes:

a. Pisoft Q95 and Silkysoft 90 are cationic softeners. The wetting capabilities of treated items are retained, but their softness, hydrophilicity, breathability, and anti-static qualities are considerably improved. Animal extracts are not commonly used in products; instead, plant extracts are used.
b. The AK series of antiozone softeners. Effective cationic antiozone gentleness to stop indigo denim clothing from prematurely yellowing. provides suppleness to fibres and protective colloids over indigo dyes.
c. Pisoft QD2000MB, a weak anionic softener. made with cutting-edge cosmetic raw components for absorption. Products that have been treated have hydrophilic, fluffy, non-yellowing, high water absorbency, high wicking, and exceptionally good lubricating properties. 100% cotton knits are ideal for usage in hosiery, especially on white textiles.

d. Pisoft B200, a non-ionic polymer softener. Concentrated softener of the prill type that produces lubricating, thick soft hand feel and anti-static characteristics. gives treated fabrics outstanding anti-tear, anti-wear strength, robust hydrophilicity, and anti-static properties.

e. Micro to nanosize amino reactive silicone softeners: Pisicons WS123E, WS800K, and WS128E. Applyable from low to high temperatures, it produces inexpensively treated fabrics with a slick and pleasant handfeel.

f. Softonic Conc: Silicone emulsions with high active ingredients, alkaline pH (up to pH 9.5), and resistance to high temperatures (up to 95°C). produces a pleasant, hydrophilic hand sensation. Non-yellowing.

2.4.8.2.4 Finish that is flame-resistant

In order to stop the burning process within a reasonable amount of time, fire retardancy involves interrupting it.

Three methods can be used for creating polymeric flame-retardant materials:

1. Creating the fundamental polymer in a way that prevents combustion when exposed to heat and oxygen. High decomposition temperatures and thermally stable polymers are needed for this.
2. Using polyol, chlorination, or replacement to change the current polymer. Reactive type flame-retardant is the name given to this group.
3. Adding organic or inorganic ingredients to the polymer to improve its performance when exposed to fire. (This group is known as the additive type flame retardants). Silicone is regarded as an all-purpose addition for enhancing the flammability characteristics of polymers. The hydrogen chloride that forms in the combustion zone quickly participates in flame inhibition and is thus particularly effective, making silicon flame-retardant unique. In the presence of silica gel and potassium carbonate in very tiny concentrations, the flammability of a wide variety of materials is decreased.

Typically, they are used with synthetic and cotton fibres. Even while wool is already naturally flame resistant, in some circumstances, especially in the carpet industry, they may also be necessary. A variety of chemicals are used, either as additives or in chemical reactions with the textile, to give materials their flame-retardant qualities. **(Jadhav, 2010; Chinta, 1993)**

Table 2.12 Chemicals used as flame retardants and their eco-substitute

Non–ecofriendly chemical	• Organo-phosphorous and Polybrominated organic compounds, • Halogenated hydrocarbons(bromated diphenylethers and heavy metal containing compounds) • Asbestos
Problems associated	• Possibly carcinogenic. • Allergic substances
Eco- substitute	• Inorganic salts and phosphonates
Remarks	• Compatible results are obtained

2.4.8.2.5 Finish bio-polishing

An enzymatic process called Biopolishing can enhance cotton and other natural fibres. The prevention of pilling is the primary benefit of biopolishing. The microfibrils (hairs or fuzz) that protrude from the surface of yarn are the most vulnerable to enzyme attack, thus cellulases hydrolyze them. The microfibrils become weaker as a result, and they are more likely to separate from the fiber's main body and create a smoother surface on the yarn. A fuzzball is referred to as a "pill" in the textile industry. These pills can cause a major quality issue since they give the appearance of a knotted, unsightly cloth. The cloth exhibits a significantly decreased Pilling tendency after biopolishing. Other advantages of getting rid of fuzz include cleaner, softer, smoother feeling, and better colour brightness. Traditional methods involve singing, or quickly passing the fabric over a flame to burn the surface fibres that stick out.

These cellulases catalyse the hydrolysis of the 1, 4-beta-glucosidic linkage of the cellulose molecule into smaller portions that may be further reduced. The machine eliminates the material's surface fibres by combining mechanical action with enzyme hydrolysis. **(Cegarra, 1996)**

- **Singeing Vs Biopolishing**
  - Disadvantages of Singeing: Flame Gaps: smoky streaks Melt Balls: potentially darker dye
  - Benefits of Bio-polishing: Enhanced Fabric Appearance and Characteristics; Enhanced shine, brighter colour, improved surface appearance, removal of neps and motes, and prevention of pilling. These advantages are long-lasting.

- **Cellulase vs. pumice stones**
  - Disadvantages of Pumice Stone: The cloth lost strength; A significant amount of sludge, fibre remnants, and indigo colours accumulated and needed to be disposed of. The removal of the split-off remnants of the stones from the trousers after stone treatment makes it very difficult to unload the machine. Pumice stones are a naturally occurring raw material that are uncommon.
  - Advantages Cellulase Enzymes: Impart Softness; Excellent Contrast Seen; No Sludge Problem; Reduced Loss of Fabric Strength; Abrasion-Faded Look Highlighting Seams, Hems, Pockets, etc.; Easy Handling

Some Cellulases utilised for bio-finishing

Table 2.13 Cellulase enzymes available on the market

Sr. no.	Name of products	Manufacturer	Specificity
1	Bactosol BW LIQ CONC	Clarients	It is a cellulase enzyme for biopolishing of cellulosic substrates & garment washing
2	Palkosoft	Maps	Cellulase for bio-polishing cotton and blended fabric and garment
3	Ezysoft BSE	Resil (Acid cellulase)	Acid cellulase: Economical range cellulase enzyme for non-denim biopolishing with low colour loss properties.
4	Ezycare Neutramax	Resil (Neutral cellulase)	Imparts high contrast finishing and salt and pepper effect with maximum processing flexibility. It has broad operating pH from 4.5 to 8, and temperatures from 40°C to 60°C.
5	Sigma ZYME BP	Sigma chemical industries	Specialty enzyme formulation for effective bio-polishing without color loss

2.4.8.2.6 Water, oil, and stain-repellent coating

- Employ N-methylol stearamide fluro chemical type; avoid using lead or other metals;

- Piscean Hydroil Guard Series: Aids for Water, Oil, and Dust Repellent. polymeric, weakly cationic kinds. does not affect the softness or colour of the fabric. produces long-lasting water, oil, and dirt repellant. Improved shape retention and a smoother hand feel are characteristics of treated materials. **(Patel, 2004; Chinta, 1993)**

2.4.9 General Eco-Friendly Methods for Cotton Pre-Treatment

2.4.9.1 Desizing, scouring, bleaching and mercerizing cotton fabrics in one step

The one-step therapy, according to Dr. N. Sekar, involves impregnating cotton with a solution of sodium hydroxide, hydrogen peroxide, and trichloroethylene, each at a certain concentration. Yet, this study's findings are as follows:

- Cotton fabric's enhanced strength retention and colour strengths are attained at low dipping temperatures
- Whiteness, stiffness, and wettability are boosted at high temperatures.

2.4.9.2 Two-step processes:

Combining the scouring & bleaching and separately desizing operations can save water, chemicals, energy, and processing time. **(Jadhav, 2010)**

2.4.9.3 Textile mercerization, souring and bleaching electrochemically

A low voltage electrochemical cell that mercerizes (or scours), sours, and optionally bleaches textiles efficiently and without generating waste or requiring the purchase of caustic, neutralising acids, or bleaches in bulk. The cathodic chamber of the cell generates base for mercerization, while the anodic chamber generates an equivalent quantity of acid for neutralising the fabric. Gas diffusion electrodes can simultaneously produce hydrogen peroxide for bleaching and are utilised for either one or both electrodes. A stack of bipolar electrodes with either one or both anodes and cathodes that are gas diffusion electrodes and no hydrogen gas evolution at the cathode is the preferable arrangement.

2.5 BRIEF OF ENZYME

2.5.1 What is Enzyme?

The idea that enzymes are living things is a frequent one. However, in actuality **(Doshi, 2002)** enzymes are a class of proteins that work as biocatalysts. The word "enzyme" is a Greek word that means "in the cell" or "ferments" **(Rekha, 2002)**.

They are categorised as bacterial, pancreatic (blood, lever, etc.), malt (germinated barley), etc. depending on the preparation media. **(Manickam, 2006)** They catalyse certain metabolic reactions occurring in the life process either by themselves or in collaboration with non-protein organic/inorganic substances. With careful substrate selection from a complicated mixture, enzymes quickly convert their substrate at a moderate pH and temperature. Enzymes are complex proteins made up of 200–250 amino acids. **(Verma, 2003)** The peptide chain, which is a linear array of amino acids, is the fundamental structural component of all proteins, including enzymes. All enzymes are protein molecules made from a long chain of amino acids that are condensed during the production process. The (-CO-NH) connections in the peptides are what keep them together. The complex molecules adopt specific 3D shapes as the length of the polymeric chain rises due to increasing amounts of ionic and other interactions. This mixture of polymers transforms into a protein that serves as an enzyme. **(Verma, 2003)** Hydrolysis, oxidation, reduction, coagulation, and breakdown are their primary roles. The textile sector uses enzymes of the hydrolysis type most frequently. **(Manickam, 2006)**

2.5.2 Need of Enzyme Technology

Environmental concerns had been disregarded by textile processors for years when manufacturing textiles. However, social pressure on the textile processing industry to employ environmentally friendly chemicals and processing methods is growing as a result of increased knowledge of the damaging nature of the textile effluents. The textile industry is now required or required to assess the environmental impact of all its processes and products. The world over, conventional, labor-intensive, and frequently environmentally damaging processes are being replaced by quick, effective, and environmentally friendly technology. **(Verma, 2003)**

Due to their inherent environmental friendliness, enzymes have taken the lead in textile processing and have improved it over conventional processing. Enzymes are successfully used in some of the processing steps of textile manufacturing, revolutionising the textile industry in the process. The use of enzyme is discovered to be more beneficial, effective, and highly specialized. **(Verma, 2003)**

Many chemical reactions utilized in the industry are typically non-specific reactions that frequently produce undesirable byproducts and can call for extreme conditions like high temperatures, strongly acidic or alkaline pH levels, significant amounts of water, etc. The pricey disposal of undesirable byproducts could be another issue and raise the cost of wastewater treatment. The introduction of biotechnology (enzymes) in textile processing can virtually eliminate all these problems. **(Manickam, 2006)**

2.5.3 History of Enzyme

Genetic engineering is substantially more recent than enzyme technology. Over a century has passed since the discovery of enzymes, although only roughly 60 years have passed since the commercial use of refined enzymes. However, the fact that just a small portion of the enzymes discovered so far have been employed commercially suggests that the field of technology is still in its infancy. Scientists are seeking to increase the production of an enzyme by transferring the gene encoding the enzyme to a bacterium capable of generating the enzyme in greater quantities using contemporary biotechnology methods. **(Mishra A. R., 2007)**

Around 1857, the use of enzymes in industrial textile processes started when amylase sizes were removed from some textiles before printing using malt extract. Rapidases were first offered on sale in 1919. These enzymes cause starch to liquefy into compounds that are water-soluble. Since that time, research has been done to modify rapidases for use in industrial operating environments. **(Rekha, 2002)** In 1987, enzymes for textile applications were created for the purpose of stone washing jeans. It didn't take long for practically everyone in the denim finishing industry to learn about and begin using these enzymes. **(Prabhakaran, 2008)**

2.5.4 Sources of Enzyme

These are crucial elements of all biological systems, including those of plants, animals, and microorganisms, and they act as catalysts in a number of cellular reactions. **(Rekha, 2002)** You can make enzyme from both plant and animal sources. The slooter house waste, such as pancreas, clots of blood, liver, etc., is used to make pancreatic enzymes. After extracting the waste with water and concentrating it under vacuum, it is then precipitated by adding alcohol. Alcohol renders enzymes insoluble, while they are soluble in water. Enzymes from precipitate are filtered, then dried. While malt extract is created from germinated grains, bacterial enzymes are manufactured by cultivating a culture of certain microorganisms. **(Verma, 2003)** Enzymes are present in all living things, including plants, animals, and microbes, and they are crucial to the functioning of cells. **(Das, 2000)**

2.5.5 Classification of Enzymes

- **Amylases:** The enzyme amylase is utilised in the desizing process. The disadvantage of traditional desizing with an oxidising agent is a reduction in strength; the disadvantage of acid desizing is that the fabric must remain moist to prevent cellulose hydrolysis. The usage of amylase enzymes, which act on the 1-4 alpha glucoside linkage of amylase (linear chain) and amylopectin (branched chain), allows for the resolution of the aforementioned issue. **(Manickam, 2006)**
- **Pectinase:** Scouring is used in bio-preparation to improve the dyeing properties by removing oils, fats, waxes, and pectin compounds. The traditional method of scouring, which involves adding sodium hydroxide to a boiling solution, is very general in action and eliminates more main wall than is necessary. Additionally, it raises BOD, COD, etc. Pectinase is a new enzyme that attacks the cuticle primary wall matrix, digests the pectins, and depolimizes water soluble compounds that have been shown to be particular in nature without compromising the strength of the fabric. Due of the little amount of pectinase they contain, cellulases and lipases are also employed. It offers benefits including lower chemical consumption (COD), slower weight loss and loss of strength, better hand, less water consumption, combined scouring and bio polishing, etc. **(Manickam, 2006)**
- **Catalase:** Native catalase is used in discontinuation washing operations to speed up and completely decompose any leftover peroxide. Catalase that has been immobilised was more resistant to changes in temperature, pH, and the presence of surfactants. The use of immobilised Catalase in a washing system resulted in a decrease in the amount of peroxide and the cost of water in stimulations. **(Rekha, 2002)**
- **Cellulases:** In the wet processing of textiles, it serves as an agent for fibre surface modification. More and more cellulase enzymes are being employed in denim washing to achieve a stone wash effect without using stones, or with fewer stones. The surface fuzz is removed, and cellulose changes the handle and drapability.

The best-known uses of this technology are the ageing of fabric surfaces to give denim clothing the appearance of having been stone washed, as well as the cleaning and renewal of fabric surfaces that have been harmed by microfibers, fluff, and loose fibers. **(Rekha, 2002)**

- **Xylanases:** Aspergillus yersicolor's xylanolytic system is regulated by induction and carbon catabolic repression. The processing of cellulose pulps and the creation of textile fibres can both be done with cellulase-free xylanase. **(Rekha, 2002)**
- **Lipases:** Before dyeing and finishing, cotton fabrics must be cleaned of both natural and artificial impurities (dirt, wax, pectin, protein, and hemicellulose). Remains of the substance used for machine lubrication can be found in woven fabrics. These contaminants may cause issues during dyeing and finishing if not adequately removed. Enzyme reactions were highly successful in comparison to aqueous hydrolysis in a wider range of circumstances, including relatively low conc., a shorter reaction time, a lower ambient temperature, and the absence of a buffer. **(Rekha, 2002)**
- **Lacasses and Other Oxygenases:** Both the enzymatic activation of hydrogen peroxide by peroxidase and the activation by laccases did not prove effective for bleaching. However, the employment of glucose oxidase in conjunction with glucoamylase's desizing action resulted in a notable gain in brightness value, as well as the bonus of bestowing a soft handle. The advantages of the enzymatic method were minimising waste water pollution loads and reducing chemical usage when compared to an alkaline hydrogen peroxide procedure. **(Rekha, 2002)**

2.5.6 Mechanism

Enzyme activity first creates an enzyme-substrate combination. To create the complex, the enzyme and substrate must come into direct physical contact. Enzymatic hydrolysis of cellulosic materials occurs, although the exact mechanism is difficult and not entirely understood. In the form of 3D structures like fissures, holes, pockets, cavities, or hollows, enzymes have a genuine activity core. Per molecule, there are often only one or a very small number of active sites. The time needed to produce the enzyme-substrate complex and the time needed to form the finished product affect the overall rate of reaction. The enzyme molecule must combine with the substrate to catalyse the reaction. **(Rekha, 2002)**

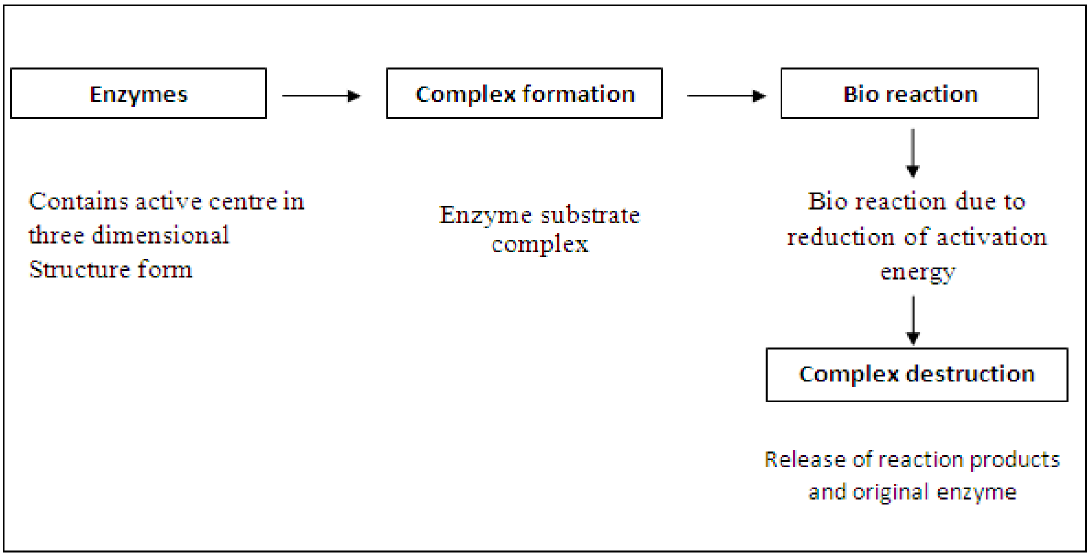


Figure 2.10 Mechanism of Enzyme **(Manjrekar, 1999)**

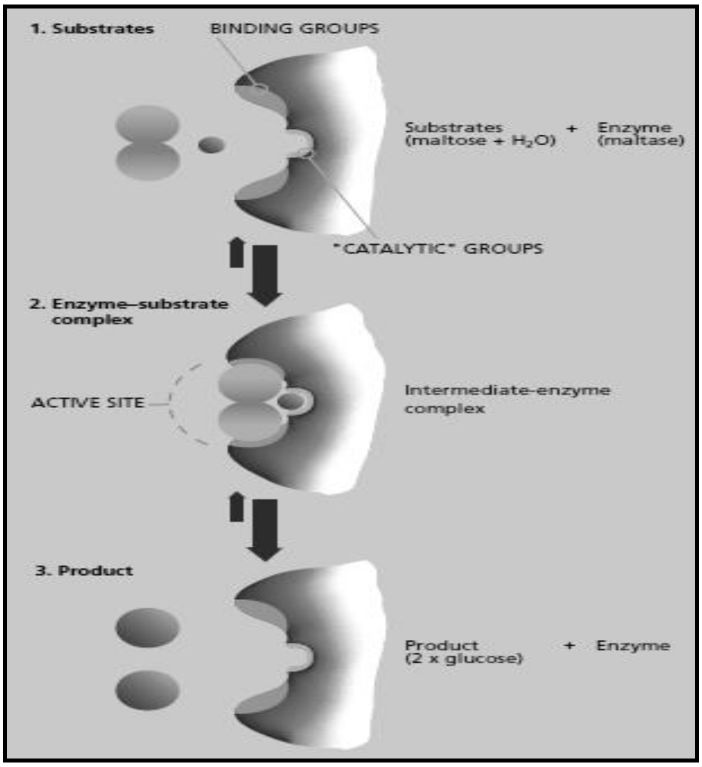


Figure 2.11 Enzyme – Substrate Complex Theory **(Verma, 2003)**

Enzymes have a three-dimensional form and bind to substrate surfaces like a lock and key. Substrate hydrolysis is enhanced at the enzyme's active site. An enzyme is released onto various locations on the substrate, and a product of the substrate's degradation is created. The procedure is carried out until the enzymes are rendered inactive. **(Verma, 2003)** When an enzyme's active site completely encloses its substrate, a process known as "lock and key," interaction between the substrate and active site occurs.

This leads to the formation of numerous weak bonds, such as hydrogen bonds, van der Waals interactions, etc.

The binding and reactive sites of the enzyme recognized the corresponding domains of the substrate molecules to produce the E-S complex. The enzyme becomes substrate-specific as a result. The international unit known as "KATAL" is defined as the amount of enzyme that transforms one mole of substrate per second under standard conditions. The kinetics of reactions depends on the diffusion of the enzyme into the solid phase of the substrate and the diffusion of the reaction products out of their solid phase into the liquor. Alpha amylases, cellulases, and proteases are three enzymes that are now used in the textile industry and fall under the category of hydrolases. These enzymes cause the hydrolysis of a variety of bonds, including amide, ester, and acetyl. Temperature, system pH, activators, inhibitors, and incubation time are all factors that affect how effectively an enzyme catalyses a process. **(Rekha, 2002)**

2.5.7 Factors Influencing Enzymatic Activity

- **Temperature:** Enzymes are most active within a very limited range of temperature. Other system variables including pH, buffer systems, and concentration all have an impact on temperature. Once an enzyme's activation has reached a certain point, the enzyme's protein begins to denaturize, which results in a loss in activity. **(Verma, 2003)** Enzyme activity is at its peak at a particular temperature range **(Manickam, 2006)**
- **pH of Reaction bath:** Enzymes are sensitive to changes in pH. At a specific pH, their activity is at its peak. It is crucial to maintain pH at the ideal level in order to obtain the high yield from enzymes. Any pH shift that occurs during the reaction could affect the protein structure of the enzymes, denaturing them, or ionise the active areas. From enzyme to enzyme, the pH needs to be suitable. **(Verma, 2003)** Proteins like enzymes have a zwitter ion characteristic that makes them neutral at a certain pH. Therefore, a pH change might result in the ionization of active sites, which eventually causes denaturation **(Manickam, 2006)**
- **Activators:** Bivalent metallic cations that are active in specific enzymes include Ca^{++}, Sr^{++}, Mg^{++}, Zn^{++}, Co^{++}, and others that make the substrate more susceptible to enzyme assault. It is possible for some metals to integrate themselves into the enzymes. They join the prosthetic group's constitution and participate in the ion exchange. Only indirectly can the activation be done. **(Verma, 2003)**

- **Inhibitors:** The activity of some compounds, such as alkalis, antiseptics, and acid liberating agents, is often inhibited. By preventing the activity of some beneficial groups, enzyme activity is reduced. Since the inhibitor has an affinity for the enzymes it is coupled with, it really puts the substrate and itself in competition. Because reducing and oxidising agents function as enzyme inhibitors, heavy metal cations including lead, copper, mercury, and iron are toxic to enzymes. **(Verma, 2003)**

2.5.8 Enzyme as a Catalyst

The metabolism of living cells is accelerated by enzymes. The majority of biochemical reactions call for a catalyst. the do not participate in the chemical process, but they have an impact on its pace. Despite having all the characteristics that catalysts do, enzymes differ from catalysts in some ways. Below are a few of the distinctions.

1. Reaction parameters including pH, temperature, activators, and inhibitors can affect how sensitive an enzyme is.
2. Enzymes have a particular character.
3. Enzymes are more effective as catalysts than other types.
4. Prior to a reaction, an enzyme's active sites bind substrate.
5. They differ from catalysts of non-biological origin in terms of effectiveness, specificity, and control sensitivity. **(Verma, 2003)**

2.5.9 Properties of Enzyme

1. Enzymes are colloidal in nature and are proteins chemically.
2. High molecular weight proteins (>10,000 molecular weight) are present in enzymes.
3. Drive reactions are 108 to 1020 times faster than average because to their extreme efficiency.
4. When temperatures are high, enzymes become inactive.
5. Only a small pH range is where enzymes are active.
6. Very precise in action
7. Cellular versus extracellular
8. Enzymes degrade naturally.
9. Specificity differs from one enzyme to another in terms of range.
10. Cyanides, sulphides, and other chemicals block enzymes.

11. The rate of a reaction is accelerated by enzymes.
12. Enzymes are secure and simple to manage **(Verma, 2003; Mishra A. R., 2007; Manickam, 2006)**

2.5.10 Benefits of Enzymes

Enzymes are helpful for the textile industry because they can:

- Work in mild temperature and pH conditions
- Replace harsh chemicals with 100% biodegradable substances that do not harm the environment
- Have a specific range of operation parameters (such as pH, temperature, and ionic environment) for their optimum performance
- Act as catalysts, so little enzyme is needed to complete the reaction;
- Can react with specific substrate based on the temperature and pH of the environment.
- Less energy, less waste, and less mining. **(Mishra A. R., 2007)**

2.5.11 Enzymes in Textile Processing

In the many steps of textile processing, such as desizing, scouring, softening of cotton, washing denim, and silk degumming, among others, a variety of chemicals are utilised. When these compounds are released after processing, contamination results. However, the use of enzyme in textile processing is thought to be environmentally benign. Enzymes are natural products that biodegrade and carry out their tasks effectively without producing any waste**. (Verma, 2003)**

Table 2.14 Enzyme applications **(Verma, 2003; Mishra A. R., 2007)**

Enzymes	**Application**
Amylase/ Lipase	Desizing
Xylanase / oxidoreductase	Scouring and bleaching
Catalase	Peroxide killer
Pectinase / Cellulase	Scouring /Bio stoning
Laccase	Denim finishing

- **Desizing of the Fabric:** To increase the weavability of the warp yarn, sizing is carried out using polymeric compounds **(Mishra A. R., 2007)**. Starch, either by itself or in combination with other polymers, makes up the majority of the size material. Desizing is the removal of the size. Acid hydrolysis can eliminate it, but this method has the following drawbacks.

- Negative impact on the cotton fabric's strength
- A large volume of wastewater was released.

Enzymatic hydrolysis is therefore favoured today over acid hydrolysis. Cellulose is unaffected by the process because of how specifically the enzyme acts on the substrate. Amylase enzymes are utilised in the desizing process, and the enzyme's unique mode of action is what makes it stand out. Starch is hydrolyzed by the enzyme, however cellulose is not softened. Since cellulose may also get hydrolyzed or oxidized if the chemical concentration is higher than the ideal value, enzyme desizing is safer than conventional desizing.

Alpha amylase can only hydrolyze up to dextrin, but glucoseamylase can hydrolyze amylose up to a single glucose unit. For the one bath processing, this is helpful.

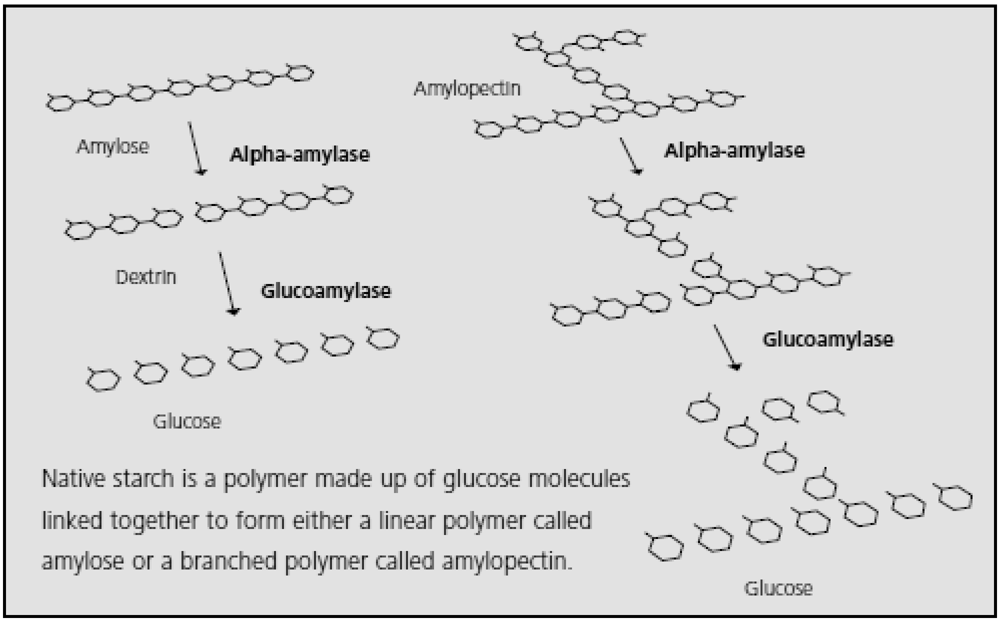


Figure 2.12 Hydrolysis up to single glucose unit with Glucoamylase enzyme **(Mishra A. R., 2007)**

- **Enzymatic Desizing Process Consist of Three Stages**

1. The process of impregnation, in which the fabric is treated by enzymes at the proper temperature, pH, and concentration; the use of a suitable wetting agent is advantageous.

2. The incubation step is where the starch is broken down and transformed into a water-soluble substance called dextrin, albeit the incubation period is quite brief and also depends on the type of material.
3. The fabric is then cleaned to get rid of the size breakdown products from the fabric.

- **Advantages of Enzymatic Hydrolysis**

  Improved starch and triglyceride removal; decreased incidence of dye defects; increased whiteness after scouring and bleaching; increased dye uptake; and a softening impact on the fabric

2.6 BRIEF OF POLYMER

2.6.1 Polymer and polymerization

A polymer is a big molecule, or macromolecule, that is composed mostly of several monomeric components. The words "polymer" and "mer" are Latin words meaning "many" and "unit," respectively. Small, low-molecular-weight molecules known as monomers are the building blocks of polymers. From the strand of our DNA, a naturally occurring biopolymer, to polypropylene, a plastic that is used all over the world, polymers are all around us. Natural and synthetic polymers are both generated by humans and can be found in both plants and animals. A variety of polymers have different physical and chemical characteristics.

The degree of polymerization is determined by the quantity of monomers utilised in the process. A polymer's degree of polymerization can be used to estimate the polymer's length. So, Average molecular weight of the polymer divided by the molecular weight of the polymer's repeating unit equals the degree of polymerization. **(Islam, 2020; Subramanian M. N.; Nair)**

2.6.2 Characteristics of Polymers:

Both crystalline and amorphous regions can be found in polymers. Amorphous portions give the polymeric material flexibility, whereas crystalline parts give it strength, hardness, and stiffness.

Polymers exhibit great corrosion resistance and are thermal and electrical insulators.

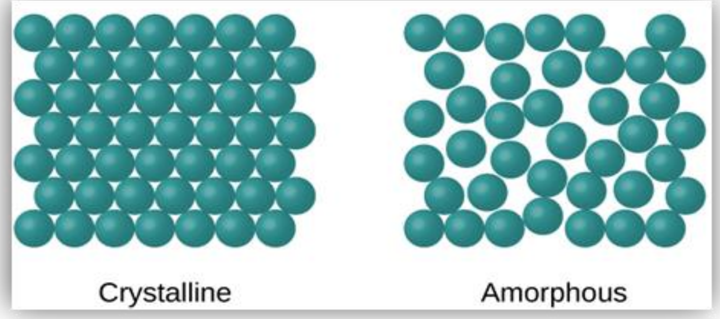


Figure 2.13 Crystalline and amorphous region in polymer **(bartleby, 2022)**

2.6.3 Classification of Polymers

1. Based on the source of availability:
    - Natural polymers: These can be found in both plants and animals and are produced spontaneously. for instance, proteins, carbohydrates, cellulose, rubber, etc.
    - Semi-synthetic polymers, such as cellulose acetate and cellulose nitrate, are generated from naturally occurring polymers and go through additional chemical modification.
    - Artificially created polymers are known as synthetic polymers. The most popular and commonly used synthetic polymer is plastic. Nylon-6, 6, Polyester, PVC, Polystyrene, Teflon, Plexiglass, and Polyethylene are a few examples of the industries where it is employed.
2. Based on Polymerization process:
    - Addition polymerization: In this process, the monomers combine or join one another end-to-end without releasing any byproducts as they polymerize. A few examples include acrylic, modacrylic, polyethylene, polypropylene, polyvinyl alcohol, and polyvinyl chloride.
    - Condensation polymerization: In this process, the monomers combine or connect end-to-end to release a by-product. This byproduct is often water, but depending on the particular monomers involved, it could also be hydrogen chloride or ammonia. such as polyester, nylon, and elastomeric.
3. Based on structure of polymers:
    - Linear polymers: These are made up of lengthy, slender chains. for instance, PVC, high density polythene, etc.

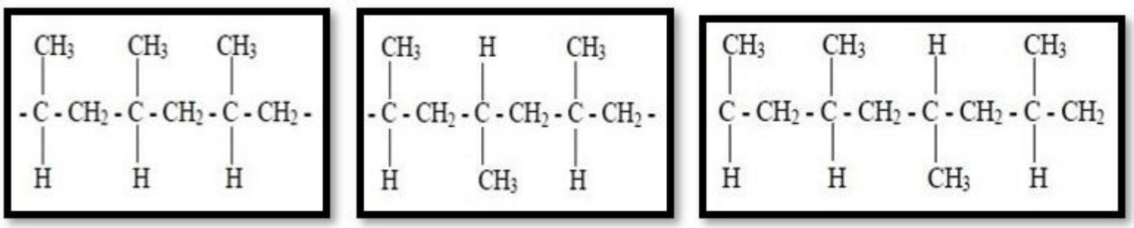
- Branched polymers are made up of linear chains that have some branches. Low density polythene, for instance.
- Crossed linked polymers: These are typically created from monomers with two or three functions, and they have strong covalent bonds between different linear polymer chains. In most circumstances, cross-linked polymers are solid and do not melt, soften, or dissolve. vulcanised rubber, urea-formaldehyde resins, etc.

4. Based on Composition of polymers:
    - Homopolymer: Polymers made from the same or only one type of monomer, such as polyvinylchloride, polyacrylonitrile, polyvinylidene chloride, nylon 6, nylon 11, polyethylene, polypropylene, etc.
    - Copolymers are made up of two or more distinct monomers and are a type of polymer. Following are the four subcategories of co-polymers.
        - Alternate copolymer: In this case, two monomers polymerize in an alternating pattern (A-B-A-B-A-B), for example, Nylon 6, 6, and Polyester.
        - Block copolymer: Here, a single type of monomer is gathered with another type of monomer and joined together.
        - Graft copolymers are created when two or more distinct monomers are combined to form a segment that connects to the polymer as a side chain. Sometimes the side chain of a polymer made from three monomers may only be made from one of the three monomers.
        - Random copolymer: These kinds of polymers are polymerized randomly or in no specific order. Random copolymers often only contain two distinct monomers, such as -A-A-B-A-A-B-B-B-A-B, for example, acrylic, modacrylic, etc.
5. Based on Thermal Behavior:
    - Lower molecular weight polymers are known as thermoplastic polymers. Polystyrene, Teflon, acrylic, nylon, PVC, and polyethylene are a few examples.
    - Thermosetting polymer: High molecular weight polymers, etc. Examples include phenol formaldehyde resin, vinyl ester resin, vulcanised rubber, and polyurethane. **(Islam, 2020; Subramanian M. N.)**

Table 2.15 Difference between Thermoplastic and Thermosetting Polymer

Thermoplastic polymer	**Thermosetting polymer**
Thermoplastic polymers can be synthesized by the process called addition polymerization.	Thermosetting polymer can be polymerized by the process called condensation polymerization.
Thermoplastics polymers have secondary bonds between molecular chains and held together by Vander Waal's forces.	Thermosetting polymers have primary bonds between the molecular chains and held together by strong cross-links.
Thermoplastic polymers have low melting point and low tensile strength.	Thermosetting polymers have high melting point and high tensile strength.
Thermoplastics polymers can dissolve in solvents and can be recovered after solvent evaporates.	These are cannot be reprocessed.
Can be remoulded.	Can't be remoulded.

6. Based on Tacticity (configuration):



$$-\underset{H}{\overset{CH_3}{C}}-CH_2-\underset{H}{\overset{CH_3}{C}}-CH_2-\underset{H}{\overset{CH_3}{C}}-CH_2-$$

$$-\underset{H}{\overset{CH_3}{C}}-CH_2-\underset{CH_3}{\overset{H}{C}}-CH_2-\underset{H}{\overset{CH_3}{C}}-CH_2-$$

$$\underset{H}{\overset{CH_3}{C}}-CH_2-\underset{H}{\overset{CH_3}{C}}-CH_2-\underset{CH_3}{\overset{H}{C}}-CH_2-\underset{H}{\overset{CH_3}{C}}-CH_2$$

Figure 2.14 Representation of Isotactic, Syndiotactic and Atactic polymer respectively **(UNIT-II-Polymers; Ouederni, 2020)**

- Isotactic Polymer: The macromolecular backbone of this type of polymer has all of the substituent on the same side such as Polypropylene
- Syndiotactic polymers feature alternative locations for the substituent along the chain. Syndiotactic Polystyrene, for example
- In an atactic polymer, the substitutes are distributed erratically around the main chain. e.g., PVC **(UNIT-II-Polymers; Ouederni, 2020)**

2.6.4 Preparation, properties and applications of some textile chemical polymers

2.6.4.1 Silicone

Alternative silicone-oxygen structures with organic radicals bound to silicon atoms can be found in silicone resins. Their structure is as follows: R being either an alkyl or phenyl radical.

Preparations

using the Grignard reagent to react silicon with silicon halide or an alkyl halide. Different organo-silicon chlorides are obtained from the reaction product using fractional distillation, and they are later polymerized through carefully monitored hydrolysis.

- The 'bifunctional' compound dimethyl-silicon dichloride can produce polymers with extremely long chains.
- Trimethyl silicon chloride is a "chain-stopper" because it is "monofunctional." Therefore, this is employed in proportions to set the chain-length limit.
- "Trifunctional" monomethyl silicon chlorides go cross-linking to the finished polymer. The quantity of cross-linking that can be obtained depends on its proportion in the polymerization process.

Properties

- Silicones can be liquids, viscous liquids, semi-solids, rubber-like solids, or solids, depending on the ratio of different alkyl silicon halides used in their synthesis.
- They have exceptional stability at high temperatures, superior water resistance, and good oxidation stability due to silicon-oxygen linkages, although their chemical resistance is typically lower than that of other plastics.
- The range of their specific gravities is 1.03 to 2.1.
- Temperature changes have a far smaller impact on their physical characteristics.
- They are non-toxic in nature.

Applications

- Liquid silicones, often known as silicone oils, are typically dimethyl silicones with a relatively low molecular weight. They have high metal wetting power, low surface tension, and hardly any temperature-related changes in viscosity.
- They are employed as damping and hydraulic fluids, high temperature lubricants, antifoaming agents, water-repellent treatments for leather and textiles, and heat transfer media. They are also utilised in polishes and cosmetics.

- Silicone greases are silicone oils that have undergone modification by the addition of fillers like silica, carbon black, lithium soap, etc.
- They are utilized as lubricants in particular when extremely high or extremely low temperatures are present.

2.6.4.2 Polyester Resins

Polyester resins, which are synthetic resins widely used in textiles and packaging, are created when polyhydric alcohols (dialcohols) and dibasic organic acids (dicarboxylic acid) combine in the presence of a catalyst. When compared to other resins like epoxies and urethanes, polyester resins are very inexpensive.

Properties:

- Polyester resins are a thick, mostly clear, pink liquid that is exceedingly viscous and uncured when uncatalyzed.
- Polyesters have a powerful, acrid smell that goes away after curing.
- Excellent in strength and water resistance, these polymers have a high density.
- Uncured polyester resin has a density of 1.2–1.5 kg/m^3.
- Thermally set resins.
- Have good mechanical strength, high thermal and heat stability, and minimal shrinkage.
- The molecular weight of unsaturated polyester resins ranges from 1000 to 3000 kDa.

Applications

- Fibreglass is commonly created by mixing polyester resin with glass fibre reinforcement in composite applications.
- Polyester filament and polyester spun sizing, cotton sizing, and blend yarn sizing are all done with water-soluble unsaturated polyester resin.

2.6.4.3 PET-PEG Co-polymer

Polyester polymer and polyethylene glycol are copolymerized to create low to high-molecular-weight co-polymers. Its hydrophilic and lipophilic chain lengths are equal. Normal polyester preparation using the PTA or DMT process and PEG copolymerized in the presence of catalyst.

Properties:

Polyester represents the hydrophobic part of the chain, whereas PEG represents the hydrophilic component of the chain. It is a solid lump type polymer that can be melted at 110 °C and made into a dispersion in water. It is creamish white in colour.

Applications

- It can be used as a moisture-managing finish for athletic fabrics.
- On polyester fabric, it functions as a soil-release finish, and on synthetic fibres, it lowers static electricity.
- Used as a wetting agent for various wet processing activities Formulation with ethoxylate to give nonwoven fabrics extremely hydrophilic properties

2.7 THE STUDY'S OBJECTIVE

Since the textile wet processing sector is the main source of pollution, it is important to examine it closely from an ecological standpoint. Eco-alternatives to these chemicals will benefit society as a whole because it is directly impacted by them as well as the customer. Since they are the first to be impacted by any immediate exposure, a detailed look at worker safety is also necessary. Some alternatives are even more beneficial and cost-effective than their predecessors. So, using such things shouldn't be postponed. "Substitution is better than cure" ought to be the motto of the textile industry.

The influence of its manufacturing techniques on the environment and human health is a concern for the textile industry. These problems must be solved utilising cutting-edge, water-based chemistries that are durable, environmentally benign, and use as little water as possible in order to create a healthier and more sustainable future.

With the goal of "Conserving limiting resources through innovation, for a sustainable world," and the knowledge that the textile wet preparatory department produces the highest amounts of effluent from the production of yarn to the finishing of clothing, research is being done to reduce water use and shift towards a solvent-free methodology. Desizing and wetting agents with low and high molecular weight polymeric surfactant-based formulations that have excellent cleaning action for cotton and viscose rayon surface materials, waxes, and oils. The fibre surface is cleaned by the wetting agents, which also contribute to the dyeing's improved firmness. Enhancing the post-finish experience lowers the cost of finishing. Low molecular weight surfactants alone do not naturally wet surfaces instantly, and thus artificial wetting does not always result in high-quality dyeing. High molecular weight surfactants provide far better levelling and dyeing depth than traditional emulsifiers, although being slow to wet. The usage of enzymes also serves as a replacement from an ecological and environmental standpoint.

In light of this, the present study & work plan will focus on the following areas:

a) Coming up with an appropriate process formulation for the environmentally friendly pretreatment of cellulosic fabrics like low GSM cotton and viscose. to create desizing and scouring solutions using polymers, enzymes, soda, etc. At the conclusion of each stage of the pretreatment of cellulosic textiles, the formulation will be standardised and its performance adjusted.

b) Applying produced formulations to cotton and viscose textile samples, then comparing those samples' chemical and mechanical attributes to those of those processed using more traditional pretreatment methods.

c) Quantitative examination of water use in comparison to water use in cotton and viscose conventional preparatory processing.

d) Qualitative evaluation of COD, BOD, and TDS levels in effluent water during a sequence of preparatory activities.