COMPARATIVE ANALYSIS OF CONVENTIONAL SCOURING & BIO-SCOURING ON COTTON FABRICS

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ABSTRACT

This research aims to assess the environmental impact and efficacy of eco-friendly bio-scouring versus conventional chemical (primarily NaOH) scouring techniques for cotton in the textile industry. Many less developed countries, such as Bangladesh, lack stringent regulations for wastewater discharge from textile mills engaged in wet processing of fibers, yarns, and fabrics, resulting in the release of harmful chemicals and severe environmental pollution, including water and air pollution. Consequently, the population faces waterborne diseases and a scarcity of potable water, while ecosystems suffer gradual degradation. Effluent Treatment Plants (ETPs) have been proposed as a viable solution for treating wastewater contaminated with hazardous chemicals. However, the substantial water requirements of textile processing (approximately 200 liters per kg of textile fabrication) impose significant financial burdens on manufacturers, reducing their profitability. In this complex scenario, bio-scouring processes offer a potential alternative to chemical scouring, presenting the advantage of lower ETP costs. Nevertheless, bio-scouring may not consistently yield the desired outcomes in all cases. Consequently, conventional cotton scouring remains the predominant method for eliminating impurities and enhancing fiber absorbency in the commercial textile sector. While both approaches have their limitations in the textile industry, their judicious selection hinges on a thorough evaluation of their respective benefits and drawbacks. This study furnishes experimental findings, discussions, and a comparative analysis of these two scouring processes to aid in informed decision-making within the textile sector.

***Keywords**: Absorbency test; Bioscouring; Bleaching; Conventional Scouring; Cotton structure; Dyeing; Scouring mechanism.*

INTRODUCTION

Raw fibers, yarns, or fabrics typically contain a diverse range of impurities, including specks, remnants of seed coats, pesticide residues, soil particles, chemical deposits, various types of metallic salts, and immature fibers. During the initial blow room processing, external impurities are eliminated, while scouring processes are employed to eliminate internal impurities within cotton fibers [1-5]. It is worth noting that cotton fibers comprise distinct layers within their structure. A schematic representation of cotton fibre structure is shown below:

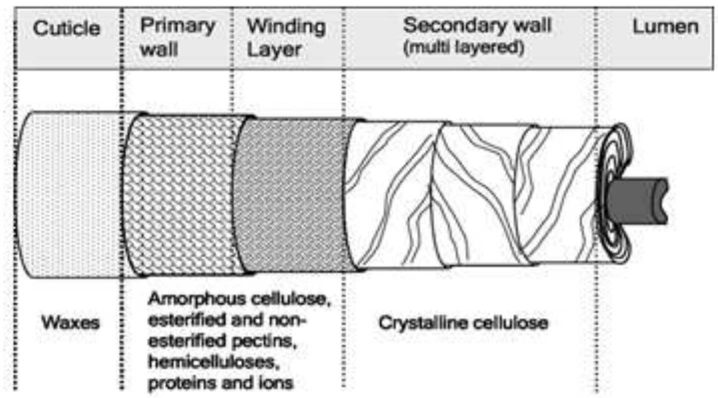


Fig: A schematic representation of mature cotton fibre showing its various layers.

Different constituent of cotton fibres are cellulose (90%-94%), waxes (0.6%-1.3%), pectic substances (0.9%-1.2%), protein (0.6%-1.3%), ash (upto 1.2%), organic acids (upto 0.8%) and others (1.2%). The main target of scouring is to remove waxes, pectins, hemi-celluloses and minerals from the raw cotton fibres during the early stage of textile wet processing to make the fibres highly absorbent, which is necessary for the subsequent processes such as mercerizing, bleaching, dyeing, printing and finishing. For this purpose, Caustic soda (NaOH) treatment is used in conventional scouring, whereas, Enzymes (Cutinases, Pectinases etc.) treatment is applied in bioscouring process [5-11].

While various scouring materials are employed in the textile industry, such as NaCO3 and Ca(OH)2, alkaline solutions, particularly sodium hydroxide (NaOH), are the most commonly used for scouring processes. Traditional chemical scouring entails immersing the fabric in a hot solution of NaOH, typically heated to temperatures ranging from 90°C to 100°C, for a duration of 45 to 60 minutes. The specific conditions are contingent upon the desired quality of the scoured fabric.

Additionally, various auxiliary agents are utilized in this process, including reducing agents, detergents, sequestering agents (also known as chelating agents or sequestrants), and wetting agents. The role of each of these agents is as follows:

- Sequestering agents are employed to reduce water hardness.
- Reducing agents prevent the oxidation of cellulose by atmospheric oxygen at high pH levels.
- Detergents function as emulsifiers, aiding in the removal of waxy substances.
- Wetting agents serve to reduce the surface tension of water, facilitating the swelling of fibers.

However, use of enzymes in textile wet processing has added a new line research and likely eco-friendly substance to give a good solution to the problem of highly toxic chemicals causing environmental pollution. Enzymes, generally, act in low temperature with excellent efficacy. It saves high cost of energy consumption compared to conventional process. Moreover, it reduces Biological/Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), and other waste water effluent load thus reduces ETP operational cost. The fabrics treated with harsh chemicals are also unsafe for human health (may affect on human skin) but bioscoured fabrics are completely safe [12-15].

MATERIALS AND METHODS

Methodology

While this study primarily focuses on comparing the effectiveness of scouring processes, it is crucial to evaluate performance at various stages to assess the overall efficacy. To achieve this, effectiveness and performance are assessed after each step, including dyeing and finishing, in the experimental process. The following steps are systematically followed for each stage of the experiment:

Alkaline/ Bio-scouring
↓
Scouring & bleaching (4 sets each)
↓
Drop test
↓
Column test
↓
Weight loss
↓
Dyeing with different shades
↓
Fastness test (wash, perspiration, acid, alkali, rub fastness)
↓
Fault analysis
↓
Cost analysis
↓
Quality analysis
↓
Effect on environment (BOD, COD, DO etc)
↓
Overall advantages & disadvantages analysis
↓
Comparison of effectiveness

Mechanism:

1. ***Conventional scouring***

In the conventional scouring, dilute sodium hydroxide (NaOH) solution is used which swells the cotton fibres and opens up the cell of the fibres to access H_2O_2 (Hydrogen peroxide) in the next process bleaching (NaOH also cleans outer chemicals residue and impurities by dissolution). Some of the waxy substances melt in the high temperature and other parts make water soluble compounds with NaOH. Non-cellulosic substances like pectins, proteins and hemi-celluloses, are also converted into water soluble compounds. Caustic soda (NaOH) neutralizes the fibres which contain some acidic com- pounds in it such as amino acids, pectic acids etc. Since some of the NaOH is absorbed by fibres, the intra and intermolecular hydrogen bonds becomes stronger in the cellulosic fibres.

In the recent years, enzymes (Biocatalysts) are becoming important materials in the wet processing of textile's pretreatment and finishing for their desirable results and promising process to cover the requirement expected. Biocatalysts act in comparatively low temperature, atmospheric pressure, wide range of PH. Different biocatalysts are experimented for textile scouring, where pectinase and cutinase based enzymes are proved to be better in use. Enzymes remove the pectin from the outermost layer of the fibres which acts as glue to bind wax to fibres. After removal of pectin, fibre wettability increases and removing of wax becomes easier. Since Ca- compounds slow down the removal of pectin and fatty acids, sequestering agent is used. After treating with enzyme, fabrics should be washed in boiled water to melt and remove wax.

Scouring Process

1. ***Conventional Scouring Process***

For conventional scouring, 2-4 g/l NaOH (different concentration for different sample) is used. Since water used in the wet processing may have hard-water compounds, 1-3 g/l sequestering agent can be used. Moreover, 1-2 g/l wetting agent, 1-3 g/l detergent and, sometimes, 0.5-1 g/l soda ash can be used. Process curve for this scouring is shown below:

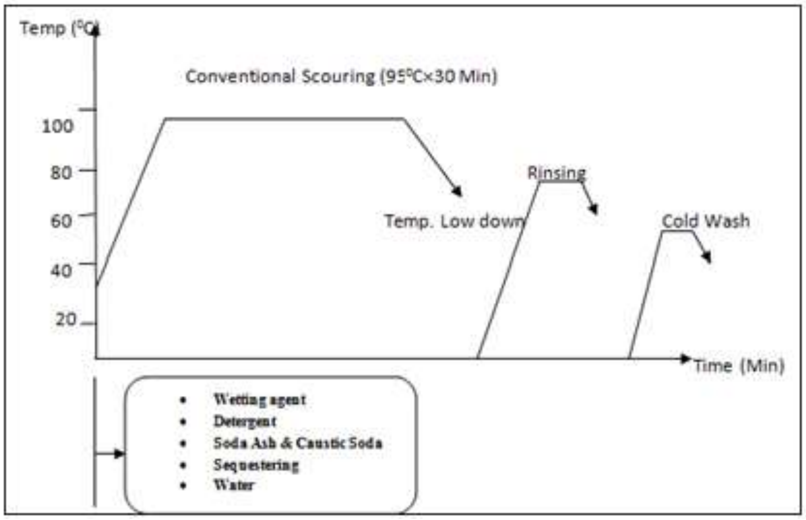


Figure: Conventional Scouring curve for cotton fabric

2. Bioscouring Process

For bioscouring, 0.4-2 OWF (On the weight of fabric) Enzyme can be used. A pH buffer is employed to establish the scouring bath at an optimal pH for enzyme activity. The pH level of the scouring bath can range from 6 to 9, depending on the specific enzyme employed in the process. Moreover, 0.5-1 g/l wetting agent, 0.5-2 g/l sequestrant, and 0.5-1.5 g/l emulsifier can be used. A process curve for bioscouring is shown in the following:

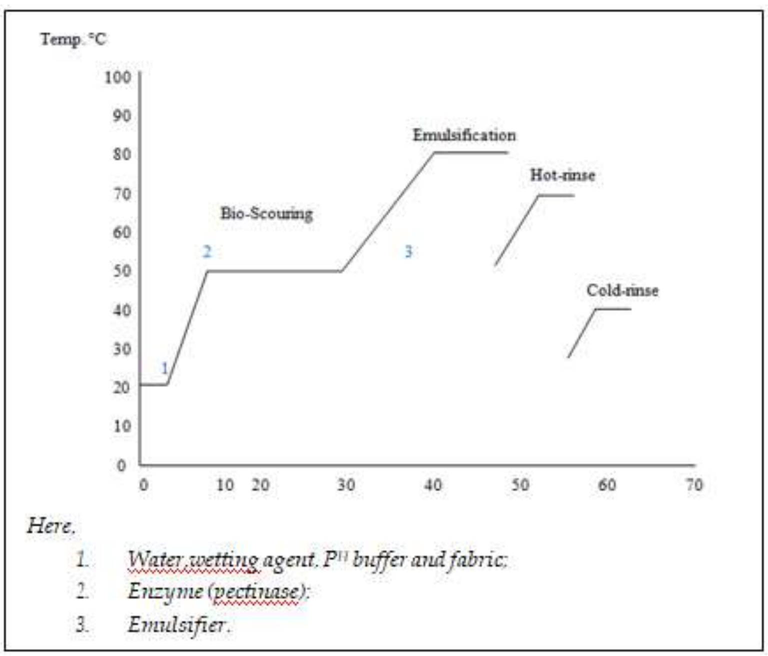


Figure: Bioscouring processing curve

RESULTS AND DISCUSSION

Weight loss

Weight loss of the scoured fabrics, fibres or yarns is an important factor of the textile manufacturers, because, it is related to profit and finished fabrics quality, durability, comfortability and other properties. Therefore, weight loss is determined after scouring this is shown below:

SAMPLE NAME	WEIGHT LOSS (%)	
	SINGLE JERSEY	DOUBLE JERSEY
Conventional Scoured-1	6.80	7.21
Conventional Scoured-2	6.55	7.54
Conventional Scoured-3	7.93	8.22
Conventional Scoured-4	5.64	6.45
Bioscoured-1	1.48	1.70
Bioscoured-2	1.28	1.53
Bioscoured-3	1.35	2.30
Bioscoured-4	2.15	2.52

Table: Weight Loss In Conventional and Bioscoured Fabrics

Absorbency Test

Since main purpose of scouring is to improve the absorbency of the textile materials, absorbency of the scoured materials should be evaluated. Different methods exist for evaluation of absorbency of scoured materials.

1. Drop Test

In this test, time taken to absorb a colored drop on the fabric is measured which color drop comes from a solution of 0.1% direct red (Congo red). I have seen, in my experiment, that both types of scoured fabrics give nearly same time for absorption which is less than one second.

2. Column Test

A 18cm×5cm scoured fabric sample is allowed to immerse in a beaker of 0.1% Congo red solution and after 5 minutes dipped length is measured. A standard dipped length lies between 30mm and 50mm.

Sample Name	Length Of Immersed Fabric (mm)	
	Single Jersey	Double Jersey
Conventional Scoured-1	35	29
Conventional Scoured-2	35	32
Conventional Scoured-3	42	35
Conventional Scoured-4	38	30
Bioscoured-1	34	30
Bioscoured-2	37	34
Bioscoured-3	35	32
Bioscoured-4	36	33

Table: *Length of immersed fabric (mm) in column test*

Reflectance of Bleached Fabrics

Bleaching qualities and standards depend on scoured fabric's performances. So, scoured fabric is bleached with H_2O_2, a widely used traditional process and evaluated its performances. Bleaching is mainly measured by the reflectance of the bleached fabrics. Here, a result of bleached fabrics is shown in the table:

Sample Name	Reflectance (%)	
	Single Jersey	Double Jersey
Conventional Scoured-1	79	81
Conventional Scoured-2	81	80
Conventional Scoured-3	82	86
Conventional Scoured-4	84	85
Bioscoured-1	80	82
Bioscoured-2	80	83
Bioscoured-3	82	86
Bioscoured-4	84	84

Table: Reflectance of bleached fabric followed by conventional & bioscouring.

Color fastness of the dyed Fabrics

Color fastness can be defined as the resistance of color of the dyed or printed fabrics to fade or bleed in case of various types of influences like as water, rubbing, washing, perspiration, acids, alkalis etc. In my research, I have determined fast-ness of the reactive dyestuff dyed fabrics to washing, rubbing, perspiration, acid and alkali. Results are shown below:

Fastness	Dyeing followed conventional scouring & bleaching	Dyeing followed by bioscouring only
Washing	4-5	3-4
Rubbing	4-5	4
Acid	4	4
Alkali	5	4-5
Perspiration	4-5	5

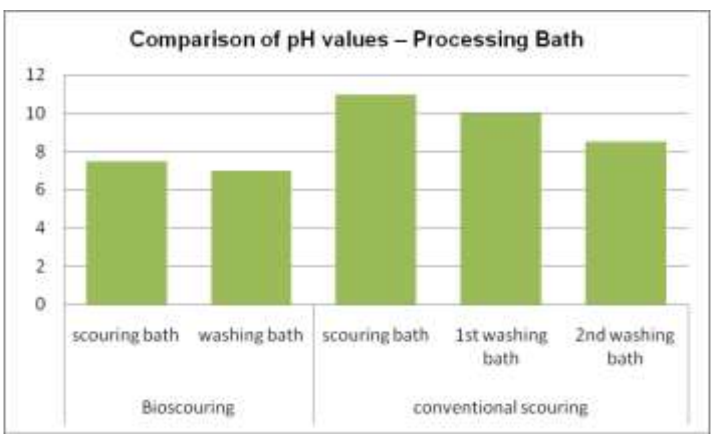
Table: Color fastness of Conventional and Bioscoured Fabrics after dyeing

EFFLUENT COMPARISONS

The comparison of effectiveness between conventional and bioscouring is done in different perspectives. These are discussed below:

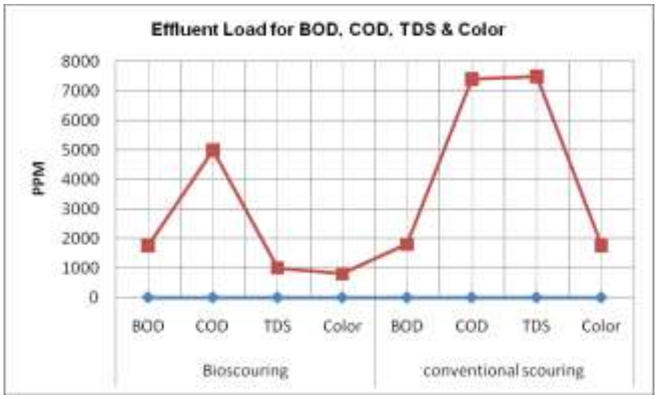
Effluent Treatment Plant load

1. P^H of processing bath:



Curve: Comparison of pH values– Processing Bath.

2. Effluent Load for BOD, COD, TDS & Color:



Curve: Comparison of pH BOD, COD, TDS and Color.

OVERALL COMPARISONS

While my research primarily focuses on comparison, my primary objective was to assess the usability and substitutability of the bioscouring process in comparison to conventional scouring methods. Consequently, I have endeavored to delineate the advantages and favorable aspects of bioscouring. The potential for bioscouring can be inferred from the ensuing discussion:

- **Fabric strength:** The use of harsh chemicals in conventional scouring results in a notable reduction in the strength of fibers or fabric. In contrast, bioscouring leads to significantly lower strength loss. This distinction arises because the bioscouring agent primarily targets the fibers' primary cell wall, which is essential for dye absorption. In contrast, conventional scouring agents affect both the primary and secondary cell walls, causing more substantial damage to the strength of the fibers.
- **Whiteness:** Conventional scouring generally yields a whiter fabric compared to bioscouring. Consequently, conventional scouring is more effective in the production of white-colored fabric shades. However, when it comes to manufacturing dark-colored fabric shades, bioscouring provides similar results. If bleaching is performed prior to bioscouring, it becomes possible to achieve white fabric outcomes using the bioscouring process.
- **Weight loss:** Since bioscouring can also affect the secondary cell wall and lead to a significant removal of pectin, it's important to highlight that pectin removal does not significantly contribute to improving hydrophilicity or absorbency. Instead, this process tends to result in a higher weight loss for fabrics, typically falling within the range of 3% to 10%. Manufacturers should be aware that this increased weight loss can lead to additional production costs associated with these fabrics.

- **Dye loss:** Higher removal of pectin causes higher space in the fibres for dyestuff penetration, reaction and fixation. Thus conventional scoured fabrics dyeing needs higher amount of dyestuffs than dyeing of bioscoured fabrics need.
- **Energy and time required:** Bioscouring requires significantly lower temperatures compared to conventional scouring. Bioscouring is typically conducted below 70°C, whereas conventional caustic scouring is performed at temperatures ranging from 90°C to 105°C. The need for these higher temperatures in conventional scouring necessitates greater heat energy production, thereby increasing overall scouring costs. Furthermore, after conventional scouring, a two-step washing process is necessary to neutralize the high alkalinity, which adds both time and cost to the production process.
- **Effluent concern:** The conventional scouring process relies heavily on the use of harsh chemicals, which significantly contributes to the elevation of parameters such as BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), DO (Dissolved Oxygen), and TDS (Total Dissolved Solids) in the effluent water. This, in turn, places an undesirable burden on the environment. Caustic scouring, in particular, accounts for a substantial portion of the overall effluent generated by a factory. In fact, it is responsible for 10% to 20% of the total pollution load generated throughout the entire textile processing operation.
- **Color fastness:** The color fastness of dyed fabrics remains relatively consistent after both bioscouring and conventional scouring processes. However, it's important to note that color fastness can vary depending on factors such as the type of dyestuff used, the dyeing process employed, the depth of the shade, the finishing processes applied, and other related variables.
- **Risk in handling:** The handling of harsh chemicals poses an increased risk of accidents and can potentially impact the health of workers involved in the textile industry. Furthermore, certain health-hazardous chemicals may persist in fabrics even after finishing processes, potentially posing risks to human health when the finished textiles come into contact with consumers.

CONCLUSIONS

While the conventional scouring process is currently widely used, its significant environmental impact has prompted many developed countries to shift towards enzymatic and eco-friendly scouring methods. Bioscouring, being an eco-friendly alternative, holds great promise for the future. This new enzymatic approach plays a pivotal role in reducing energy, water, chemical usage, time, and associated costs.

One notable advantage of bioscouring is that after the process, fabrics can be dyed directly without the need for bleaching, further reducing costs. However, it's important to acknowledge that bioscouring may pose challenges when trying to produce light-coloured shades or achieving precise color matches. In contrast, conventional scouring and bleaching processes offer greater ease in producing light-colored shades for dyed fabrics.

Both processes have their merits and drawbacks, but the environmentally friendly and cost-effective nature of bioscouring, despite some operational complexities, positions it favorably as a potential replacement for conventional scouring in the future of textile wet processing on a global scale.

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