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Exploring Low-Impact Pretreatment Techniques for Textiles

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Abstract

Textile Pretreatment is an essential procedure that gets cloth ready for dyeing, printing and finishing by eliminating contaminats including waxes, oils, and dirt. Desizing, scouring, and bleaching are examples of conventional pretreatment techniques that use a lot of water, energy, and chemicals. Which polutes the environment and damages fabrics. This study investigates sustainable and low impact pretreatment methods to lesson environmental effect without sacrificing fabric quality. The study emphasizes the possibility of creating effective and ecologically friendly pretreatment systems by fusing biological and physical methods. All things consider low impact pretreatment methods offer a viable route towards environmentally friendly and sustainable textile manufacturing.

Key Words: Textile Pretreatment, Sustainable processing, Enzymatic Treatment, Plasma treament, UV radiation, Eco friendly textiles, Water conservation, Energy efficient, wet processing.

1. Introduction

1.1 Understanding Pretreatment in Textiles

Pre treatment in textiles is the most important preparatory stage in textile wet processing. It carried out before dyeing, printing, or finishing to remove natural and add impurities from the fabric. It removes impurities like Greece, dust, waxes, oils. Raw fabric, especially cotton Grey fabric, contains various unwanted substances that interfere with dye absorption and fabric performance. Pre treatment ensures that the fabric becomes clean, absorbent, and suitable for further processing like printing, dyeing, finishing. So pretreatment includes scouring, bleaching, desizing. This leads to excessive water and energy consumption. It makes the fabric harsh due to damage to cellulose walls. This study aims to combine desizing and scouring with the assistance of UVC on industrial starch-sized Grey fabric and to find its suitability for industrial applications. (Panda, S. K. B. C., et al. 2024). In the Textiles pretreatment is done for all the fabrics before it goes to dyeing or printing and final finishing. it will give the dye or print uptake properly and evenly. Plethora of Chemicals and water are required for each process. In the process of bleaching and scouring 7.3% alkali, 6.9% hydrogen

peroxide are utilized. Attempts were made from the scouring, bleaching process to reutilise the un exhausted 92.7 alkali and 93.1 % hydrogen peroxide (Harane, R. S., & Adivarekar, R. V. 2016).

1.2 Conventional Method:

In the conventional pretreatment it uses huge water, it consumpts excessive energy, High chemicals used that causes environmental pollution. Each step required fresh chemicals each time. In a conventional process, scouring and bleaching is done once which results in under utilization of alkali and hydrogen peroxide. In the proposed process, waste-water from scouring and bleaching has been recycled three times for optimal utilization of chemicals and water the fabric properties were compared with the conventionally processed fabrics. After recycling the process water three times, the baths still contain alkali and oxidizing agents. (Emrie, Y. M., & Govindan, N. 2018). (COD) Chemical Oxygen Demand It has a high pollution load it can includes that microorganisms cannot breakdown. (BOD) Biochemical oxygen demand

It is more biodegradable organic matter water will consume oxygen it is harmful to aquatic life. For scouring and bleaching chemicals are used is sodium hydroxide (alkali), hydrogen peroxide (bleaching agent). Mixed recycling scouring and bleaching baths in various ratios like 50:50, 70:30, 30:70. They measures degree of whiteness, absorbency properties, dye-ability, colour fastness, colour difference on the fabrics treated with recycled baths. (Harane, R. S., & Adivarekar, R. V. 2016).

1.3 Sustainable Pretreatment:

In sustainable pretreatment approach instead of discarding the bath after one use, measured how much chemicals remained In the bath afterward. The exhausted liquor is reusing instead of adding fresh chemicals. Even after three cycles of reuse alkali and hydrogen peroxide is still remained in bath it means it still have the chemical for dyeing or scouring potential. This still works well enough for scouring, bleaching, dyeing, accepted for absorbency and whiteness. When recycled bath is used for pretreatment resource savings like water saving is 83%, energy savings 74% . This process makes better for the environment and industrial economical. Even after multiple reuses, the chemicals are still effective, giving fabric quality comparable to conventional methods, it saves 83%water, 74% energy, it reduces the processing cost significantly. It includes Plasma Treatment, Enzymatic treatment, UV radiation. (Harane, R. S., & Adivarekar, R. V. 2016).

1.4 Plasma Processing :

This is the another eco-friendly pretreatment technique, that textiles surface are modified without using water or chemicals making the fabric suitable for dyeing. Plasma is generated by applying high voltage to gases like air , oxygen, nitrogen. It creates the ions, electrons, radicals and also UV radiation. These are interact with the surface of the textile fibers. Plasma can be used as a pretreatment it will increase surface energy, wettability improvement, it absorbs dye accurately. improve uniform in dyeing, no uneven patches. Plasma uses low pressure plasma and atmospheric pressure plasma. It removes surface impurities, increases surface roughness, fabric becomes more hydrophilic, dye can penetrates more easily and also less dye and auxiliaries are consumed.

Water free process, energy efficient, enveronmentally friend, suitable for sustainable textile processing. It reduces the wet processing. Plasma treatment significantly reduces water and chemical usage and energy consumption compared to conventional methods. (Deshmukh ,R.R., & Bhat,N.V).

1.5 Enzymatic Pretreatment

Enzymatic desizing with indigenously produces amylase and combined chemical-enzyme approaches have been shown to reduce effluent load and water consumption while maintaining fabric quality (Dutta et al., 2020, Hasan & Islam, 2024, Rehman et al.,2023). similarly, Pre treatment with alternative radiations has been employed to improve colour strength and fastness in reactive dyeing, offering a promising route to reduce chemical dependency (Farooq et al., 2019).

1.6 UV Radition

UV radiation it is a type of electromagnetic energy present in sunlight, but in textiles it is artificially generated using UV lamps. It has a high energy that can modify the surface of fibers. When fabric is exposed to uv light it breaks down impurities on the fiber surface. It improves wettability and absorbency. UV radiation consider ecofriendly because less water usage, fewer chemicals, energy saving, reduved pollution. This makes the fabric ready for better dye uptake, improved printing quality.

1.7 Comparative study between Conventional pretreatment & Sustainable pretreatment

Harsh alkalis and bleaching chemicals are replaced by enzymes. In the conventional method, high temperatures are used by strong alkali and oxidizing agents, it consumes excessive energy and which may damage cellulose fibers. Specific enzymes is remove impurities such as pectins, waxes, and natural oils for this the contrast sustainable method is used. The fabric properties including weight

loss, percentage, absorbency, tensile strength, and whiteness. The finding showed that enzymatic pretreatment provided sufficient impurity removal while maintaining better fabric strength and reducing chemical and energy consumption. The study concluded that sustainable processes are environmentally friendly and not harmful compared to conventional method Siddiquee, A. B., et al (2014).

1.8 Integrated and Hybrid Approaches

Hybrid methods that combine enzymes, natural extracts, radiation, and advances processing technologies have shown the most promise. For example : low temperature chemical baths combined with enzymes, Plasma treatments followed by eco-friendly chemical treatments. These integrated strategies optimize fabric quality, resources efficiency, and environmental sustainability. In combined or one-step pre treatment processes, researchers aim to carry out two or more pre treatment actions in a single bath. Studies by “Harane, R.S. & Adivarekar, R.V”.

Past (Conventional Method)

In earlier times textile wet processing, for the pretreatment mainly used the strong chemicals most commonly sodium hydroxide was used for scouring These scouring and bleaching processes required large quantity of water and energy, and it is ususally performed at high temperature. mostly the conventional method was used, these method were effective in cleaning the fabric and it improves dye absorbtion, they consumed excessive chemicals and produce large volume of waste water it containing pollution. The processes performance were satisfactory for fabric quality and also dyeing the overall impact was significant. The process generated high levels of polluted waste water containing toxic chemicals and surfactants. Although fabric quality was good, the environment impact was very high, making these methods unsustainable.

Present (Sustainable pretreatment)

Currently, now they are focusing on eco-friendly alternatives such as enzymatic desizing, plasma pretreatment and bio scouring it works under mild conditions and it reduces usage. Plasma treatment, ozone treatment, UV assisted treatment, ozone processing and low temperature combined pretreatment these are the techniques that is used for pretreatment to remove impurities and it helps to minimize water and energy consumption. These sustainable approaches aim to maintain fabric quality while significantly reducing environmental impact.

2. Future (Suggestions)

Although significant advancements have been made in sustainable pretreatment processes such as enzymatic scouring, plasma treatment, Uv assisted combined processes, and low temperature bleaching, large scale industrial implementation remains limited. future research should focus on developing integrated hybrid system combined biological and physical methods to reduce chemical load, water consumption and energy usage simultaneously. Instead of using Harsh chemicals like NaoH and synthetic surfactant , use natural alternatives such as soap-nut extract, baking soda, lemon derived citric acid, and enzyme based systems can be explored. These are the sustainable methods and it reduce toxicity, energy consumption, and environmental impact and also it maintains good fabric quality.

3. Conclusion

Earlier studies focused on optimizing traditional desizing, scouring, and bleaching processes using strong alkali's and oxidizing agents, these processes were associated with high water consumption, energy demand, and environmental pollution. In conventional pretreatment process there is a need of high energy and high water consumption that is harmful to environment and using the chemicals cause the damage and also pollution. Instead of using conventional method use plasma treatment, UV radiation, enzymatic pretreatment and hybrid pretreatment these are the sustainable methods and also avoid using harsh chemicals instead of harsh chemicals use sustainable materials which is not harmful to environmental and also health.

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