

Original Article

A Breakthrough in Sustainable Textile Dyeing Waterless dye Technology - An Innovation Textile Industry

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Abstract

The requirement for freshwater has increased in recent years. Thus, the textile sector has adopted a more sustainable future. The textile industry is now shifting toward ecologically and environmentally conscious methods. By relying on waterless dyeing methods, large amounts of clean water can be preserved. Water contamination from wastewater outflow into freshwater resources was avoided using a waterless dyeing technique, which also removes the washing stage. The energy consumption required in this process is lower than that required to heat water in conventional dyeing methods. The unnecessary drying process helps to save both energy and time, and the dyeing cycle is shorter than that of traditional methods. Advanced fabric dyeing strategies, such as these, have the potential to improve textile companies dyeing procedures. Adopting this cutting-edge technology would help the textile industry increase its manufacturing efficiency, limit chemical contamination, and substantially reduce its water impact. These advancements are bringing the textile and clothing industries and consumers one step ahead of achieving a cleaner and greener world. It goes without saying that it will further value ecological resources and solve the issue of water scarcity and value the ecological resources.

Keywords: Ingenious technologies, environment, consumption, environmental problem, chemical, conventional, contaminated, advancements

Introduction

Dyeing is a major cause of water pollution worldwide. A large amount of clean water was used for color or dye items. Furthermore, the process is energy-intensive and inefficient. Clean water becomes wastewater because garments are dyed with chemicals. Conventional textile dyeing uses a large amount of water and produces extremely contaminated water that must undergo elaborate treatment procedures before it is released into rivers. The textile sector has one of the largest water users. Water usage and depletion are significant environmental issues when textile fabrics are dyed using traditional processes, and the cost of waste water treatment will continue to be a major issue in the future.

An appropriate dyeing procedure that utilizes less water is necessary because of the paucity of fresh water and to address these pollution issues. In light of this, a number of businesses have developed various dyeing techniques and technologies that use very small to nonexistent amounts of water in comparison to standard dyeing procedures.

Recently, new environment-friendly dyeing techniques have been developed. One of the most widely discussed methods is waterless dyeing. The dry dyeing method, a revolutionary technique in textile dyeing, does not use water. Dyeing does not involve the use of water. Compared with conventional dyeing techniques, this method requires less energy and no water; however, it still yields brilliant colors for solids and patterns. In the waterless dyeing process, fewer chemicals, auxiliaries, times, and methods are employed.

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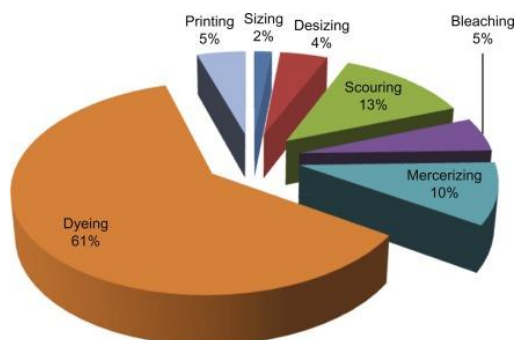
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Review of Literature

Devrent reported that a more ecologically friendly alternative to conventional dyeing was developed using waterless textile dyeing procedures. Supercritical coloring using CO₂ is only used for synthetic fabrics. Water dyeing takes longer than supercritical dyeing, which has shorter dyeing cycles. The primary benefit of supercritical CO₂ is that it can be used to color textiles without the need for water or effluents, resulting in significant water and energy savings.

Zitkus et al. investigated how the fashion sector uses chemically tainted wastewater for textile manufacturing, which is a revolutionary technique that excludes the need for water. Instead, the waterless dyeing technique uses CO₂ to color fabrics. In addition to being more ecologically friendly, using CO₂ to dye textiles, which is frequently used in textile dyeing, will save freshwater. Conventional dyeing techniques require large amounts of water, energy, and chemical additives to fix the dye onto the fibers. The pollution levels can be decreased, and the quantity of chemicals used for textile dyeing can be greatly decreased by replacing CO₂.

Eren et al. investigated supercritical carbon dioxide (scCO₂) waterless dyeing as a sustainable and eco-friendly method for the textile industry. However, scouring and desizing are additional finishing methods in addition to dyeing. Supercritical carbon dioxide dyeing is an anhydrous dyeing technique that requires less energy and chemicals than conventional water dyeing techniques, potentially leading to operational costs that are up to 50% lower. Owing to the advantages of the supercritical carbon dioxide dyeing process, particularly for synthetic fiber materials, top textile companies are moving to this unique waterless dyeing technology.

Methodology

The paper is based on secondary data, and information is retrieved from the Internet through

journals, research papers, and expert opinions on the same subject matter.

Water less Dyeing Techniques

Supercritical Carbon Dioxide Dyeing: An innovative dyeing technique that utilizes carbon dioxide is known as "DyeCoo." This method eliminates the need for water and processing chemicals by using CO₂ as the primary solvent. CO₂ dyeing, also referred to as carbon dioxide dyeing, is a modern, eco-friendly alternative to traditional methods, which typically require large amounts of water, chemicals, and energy, often leading to environmental damage and water pollution.

In this method, colors are efficiently dissolved and delivered into textile fibers using supercritical carbon dioxide, a state that lies between that of a gas and a liquid. Pure powdered chromophores were used as the dye source. In this technique, carbon dioxide is compressed to a supercritical state, allowing it to break down the dyes and disseminate uniformly onto the cloth. Water is not used in this carbon dioxide dyeing method, which produces even coloring with nice, deeper hues. CO₂ is emitted as a gas when the fabric is dyed and recycled, which helps reduce energy use.

This controlled method not only ensures vibrant, long-lasting colors but also minimizes the environmental impact. Major companies, such as IKEA and Nike, have already adopted DyeCoo technology, and based on its success, Adidas is also planning to integrate CO₂ dyeing into its supply chain.

Air Dyeing: Colored dyes are applied to textiles using compressed air rather than water. Without the need for water, dyes can be transformed into gaseous forms and incorporated into textiles. This produces vivid, long-lasting colors with excellent color accuracy. Instead of only covering the surface of the fabric, this method guarantees uniform dye penetration, reaching the filaments inside the yarn. Because it uses specialized software, color accuracy is maintained. This method dyes or colors not only

the yarn, but also the filament inside it. Sustainable fashion businesses striving to reduce energy and water use have embraced this technique.

Benefits of Waterless Dye Technology

- **Water Saving Technique**

One of the clearest advantages of waterless techniques is the significant reduction in water usage. This allows companies, especially those in the textile industry, to conserve water more effectively, without placing a burden on the environment.

- **Minimized Wastewater**

Biodiversity is negatively impacted by the contamination of lakes, rivers, streams, and seas. These methods greatly limit the production of chemically rich effluents because they do not require water. The influence on aquatic ecosystems was almost zero and there was no water contamination. Because the release of such chemicals into water bodies is extremely dangerous, they also reduce chemical pollution by enormous grades.

- **Better Colour Penetration**

Waterless techniques are superior to the traditional methods. This results in enhanced color quality, and the color is the most consistent color.

Conclusion

A shift in perspective and the encouragement of initiatives to replace traditional technologies have resulted from growing awareness of the ecological effects of textile industry operations and laws that require the avoidance of environmental issues. Waterless dyeing (WLD) is an innovative method. This dyeing technique has numerous benefits compared to traditional aqueous dyeing. There were no wastewater issues because no water was used during the dyeing procedure. Compared to traditional dyeing procedures, this approach requires a comparatively smaller amount of energy to heat water. This helps save time and energy because there is no need for a drying process, and the dyeing cycle is shorter than that of conventional methods. Carbon dioxide is non-flammable and nontoxic.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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