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CONTENT

Water Footprint in Sustainable Home Textile Production

Mihriban KALKANCI [1]*
Çiğdem AKDUMAN [2]

[1] Denizli Vocational School of Technical Sciences, Pamukkale University, Turkey, (ORCID: https://orcid.org/0000-0003-3287-1428)
[2] Denizli Vocational School of Technical Sciences, Pamukkale University, Turkey (ORCID: https://orcid.org/ 0000-0002-6379-6697)

* mkalkanci@pau.edu.tr

ABSTRACT

The textile industry has one of the longest and most intricate supply chains in manufacturing and is among the sectors with the highest water consumption in its processes. The textile industry, consist of three main end-use areas—clothing, home textiles, and industrial applications—is among the largest industrial consumers of water, playing a substantial role in global water consumption. In a world where every drop of water counts, the textile industry, like many others, must adopt smart water management strategies. To mitigate water consumption, measures such as water recycling systems, low-liquor dyeing techniques, enzymatic treatments, and the use of sustainable fibers need to be implemented. This study focuses on production processes within the home textiles sector—an essential branch of the textile industry—and proposes strategies to minimize its water footprint.

Keywords – Textile Sector, Water Footprint, Home Textile.

INTRODUCTION

The rapid growth of the global population, increasing per capita consumption, and the escalating effects of climate change are accelerating the depletion of water resources, turning water scarcity into one of the most critical global challenges of the future. Rising demand for water across agriculture, industry, and domestic use is already pushing many regions to the brink of crisis. According to UNICEF, by 2040, nearly one in four children will be living in areas experiencing extreme water stress, highlighting the urgent need for sustainable water management and conservation efforts worldwide. This underscores the urgent need for the sustainable management of existing water resources to ensure long-term availability and resilience against future challenges. One of the key concepts in this context is the water footprint, which provides a comprehensive measure of water consumption based on usage patterns. The water footprint consists of three components: blue water (surface and groundwater used in production), green water (rainwater stored in soil and used by plants), and gray water (the amount of freshwater required to dilute pollutants to maintain water quality standards). By assessing water footprint data, it becomes possible to quantify the total volume of water consumed throughout the entire lifecycle of goods and services, from raw material extraction to final consumption. This approach not only helps businesses and policymakers understand their direct and indirect water usage but also enables them to develop more sustainable strategies, minimize environmental impact, and promote responsible water management.

The concept of water footprint was first introduced by Arjen Hoekstra at UNESCO-IHE in 2002. UNESCO-IHE is the largest institution in the world that provides postgraduate education on water, located in the Netherlands [1]. Water footprint is measured by the amount of water used and/or polluted per unit of time, including evaporation. This term is defined as the total amount of fresh water resources used by an individual, community or business for the production of goods and services consumed by them or used by the producer for the production of goods and services [2]. Assessing and transparently reporting the water footprint of a country, industrial sectors, or even individuals in their daily lives serves as a crucial tool for monitoring and managing water consumption more effectively. By quantifying the direct and indirect use of water across different activities, this approach helps identify inefficiencies, optimize resource allocation, and promote more sustainable practices. Whether on a national scale, within industries, or at a personal level, understanding water footprint data enables informed decision-making, encouraging responsible usage and long-term conservation efforts

The water footprint is a key measure of freshwater consumption by individuals or businesses, taking into account not only direct water use but also the hidden, indirect water embedded in goods and services [3]. In order to implement the water footprint idea, Hoekstra established the Water Footprint Network (WFN). WFN provides a platform for the exchange of knowledge and innovation among stakeholders on increasing water scarcity and pollution levels and their consequences for people and nature [1].

Arjen Hoekstra, who first introduced the concept of the water footprint, emphasizes that water scarcity and pollution can be better understood when analyzed within the broader context of production and supply chains. He argues that global water challenges are deeply intertwined with the structure of the world economy. The water footprint serves as a key indicator of freshwater consumption, capturing not only the direct water use of individuals and industries but also the hidden, indirect water embedded in goods and services. The water footprint of a product refers to the total volume of freshwater consumed during its production, including all stages of the supply chain [4]. This term refers to the total amount of freshwater resources used by individuals, communities, or businesses for the production of the goods and services they consume, as well as by producers in the manufacturing process [2].

WATER FOOTPRINT ASSESSMENT STAGES

To ensure transparency in decision-making, water footprint assessment studies begin with a clear definition of their objectives and scope. These studies not only help quantify water consumption but also identify critical water dependencies across the supply chain. By assessing the water footprint, companies can pinpoint the scarce water resources they rely on and develop strategies for more sustainable and efficient water use. This approach supports long-term resource management, minimizes environmental impact, and promotes responsible water stewardship in both production and consumption processes [4].

To facilitate the calculation of the water footprint and obtain more detailed data, three distinct types of water footprints are considered: blue, green, and gray. The blue water footprint refers to the amount of surface or groundwater used during production that is either evaporated, directly incorporated into products, or discharged into bodies of water. The green water footprint represents the volume of rainwater used throughout the production or supply chain process. The gray water footprint is the volume of freshwater needed to dilute pollutants in wastewater and restore water quality to acceptable levels, ensuring that contaminants are reduced to safe limits. [1].

The water footprint assessment process generally consists of three main stages (Figure 1):

1. Measuring the water footprint by identifying a process, product, producer, or consumer to be evaluated, or assessing the water footprint within a specific geographical area considering time and location.
2. Evaluating the environmental, social, and economic sustainability of the calculated water footprint.
3. Concluding the evaluation by developing a response strategy to monitor the effectiveness of the measures taken and the resulting benefits [4, 5].

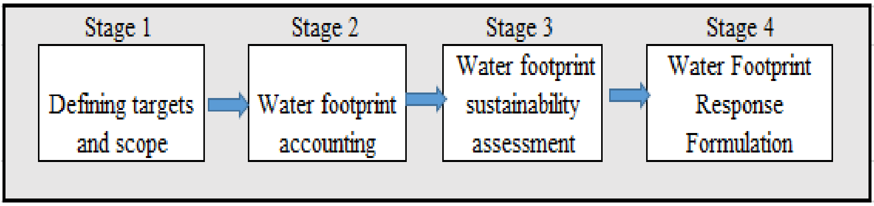

Figure 1. Stages of water footprint assessment [4, 5]

The water footprint accounting stage involves collecting data and developing accounts. The level of detail in these accounts depends on the objectives set and the decisions made in the prior stage. Following the accounting process, the sustainability assessment stage evaluates the environmental, social, and economic viability of the water footprint. In the third stage, the situation is examined in greater detail from a water perspective. The final stage focuses on formulating response strategies, implementing action plans, and setting policies. It is not necessary to include all these stages in a single water footprint study. Once the goals and scope are defined, it may be sufficient to focus solely on accounting, or to assess sustainability after accounting and conclude the evaluation. In some cases, revisiting earlier stages may be necessary to reassess the results from a different perspective. [4,5].

WATER USE IN THE TEXTILE INDUSTRY AND THE ENVIRONMENTAL IMPACT OF TEXTILE WASTEWATER

The textile industry is one of the largest consumers of water and a major source of pollution [6,7,8]. Processes such as washing and dyeing wool and yarns require significant amounts of water. In textile manufacturing, particularly in wet processes, only a small portion of the water used is incorporated into the final products, with the majority ending up as wastewater. The wastewater discharged by the textile industry is a critical concern for wastewater treatment facilities in industrial zones. With a high pollution load and contributing over 20% of industrial wastewater in our country, untreated discharge from the textile industry poses a significant threat to both the environment and public health. [9].

Textile industry wastewater, which varies depending on the specific process, typically contains suspended solids (SS), color, chemical oxygen demand (COD), biological oxygen demand (BOD), oil and grease, nitrogen (N), phosphorus (P), iron (Fe), and sulfate (SO4). One of the most significant challenges in treating textile wastewater is managing the color parameter. Textile wastewater treatment methods are categorized into physical and physicochemical techniques (such as coagulation-flocculation, adsorption, ion exchange, and membrane filtration), chemical oxidation, biological methods (like aerobic or anaerobic degradation), and electrochemical methods (including electrodialysis). Before being discharged into the receiving environment, the pollutant parameters in textile wastewater should be thoroughly analyzed, their sources identified, and appropriate treatment processes tailored to the characteristics of the wastewater should be applied [10].

The textile industry is known for its substantial waterborne pollution, driven by high chemical usage and water consumption, leading to a considerable environmental impact. However, it also holds significant potential for advancing sustainable development. In response to increasingly stringent wastewater discharge regulations, industrial clusters within the textile sector are exploring collaborative solutions to address water-related challenges [11]. These clusters can implement a two-stage wastewater treatment system, combining on-site and centralized treatment facilities. Such a system has the potential to greatly reduce both environmental and economic burdens, presenting a promising pathway toward more sustainable practices [12].

In the textile industry, water serves two primary functions in wet processes: as a solvent for chemical treatments and as a medium for washing and rinsing. Additionally, water is also consumed during processes such as ion exchange, boiler operations, cooling, steam drying, and cleaning. The specific water usage rates for different processes within the textile industry are presented in Table 1.

Table 1. Water usage rates by processes in the textile industry [13].

PROCESS	CONSUMED WATER RATE
Bleaching	%38
Dyeing	%16
Printing	%8
Boilers	%14
Other Uses	%24

WATER FOOTPRINT OF HOME TEXTILES AND MEASURES FOR ITS REDUCTION

Home textiles, including towels, bed linens, curtains, and upholstery, are essential items in our daily lives. These products are not only constantly consumed but also driven by shifting trends in fashion. As a result, home textiles form a significant segment of the textile industry. However, the production cycle of these items generates a large amount of textile waste, which, after serving its purpose in households, often becomes an environmental concern. The disposal of such waste, combined with the increasing demand for new products, contributes to growing environmental challenges, highlighting the need for more sustainable production, consumption, and waste management practices in the home textile sector [14].

The total water footprint of cotton fabric production throughout its lifecycle ranges from 4,573 to 7,583 m^3/ton. The majority of this water footprint, about 93-97%, is attributed to cotton cultivation, with the remaining 2-6% corresponding to cotton fabric production. The water footprint associated with ginning, transportation, and consumer use accounts for approximately 1% of the total [15].

The key wet processes involved in the production of cotton home textiles include:
• Mercerization
• Desizing
• Dyeing
• Bleaching

To ensure sustainability, it is crucial to adopt innovative practices like the Better Cotton Initiative, particularly those emphasizing social and environmental sustainability, both globally and within Turkey. Managing the environmental impact of cotton production, especially in relation to water footprint, is essential for mitigating its ecological effects and fostering a more sustainable textile industry [16].

Water is extensively used throughout the cotton processing stages for textiles. Nearly 60% of the total water consumed in the processing, production, and distribution of cotton is utilized during the 'processing' phase of the supply chain. As long as Turkey continues its cotton processing activities, the amount of water consumed by the textile sector is likely to keep rising. Moreover, the disposal of wastewater generated during cotton processing—commonly referred to as the grey water footprint—poses a significant environmental concern [2].

The textile sector relies heavily on water at various stages, from washing yarns and semi-finished products to bleaching, rinsing, dyeing, and final product washing. To reduce the water footprint and enhance sustainability within the home textiles sector, a number of strategies can be adopted. These strategies include improving water efficiency across the entire production cycle, integrating advanced water treatment technologies, and promoting water recycling practices. By adopting these approaches, the industry can contribute to more sustainable practices and mitigate the environmental impact of textile manufacturing.

Suggestions for improving water efficiency and reducing the water footprint in the home textiles sector within the framework of sustainability are outlined below:

- Better Cotton Initiative (BCI): The Better Cotton Initiative (BCI) aims to transform global cotton production into a more sustainable practice. The Better Cotton Standard System provides clear production criteria, along with monitoring and follow-up mechanisms, ensuring that the impacts of cotton production are both measurable and transparent. By promoting the sharing of best practices and fostering information exchange, the initiative works to enhance the sustainability and reliability of Better Cotton as a key global commodity [16].

- Water Consumption Control and Reduction: Gathering data on water usage across processes is fundamental to any strategy aimed at minimizing unnecessary water consumption. Accurate data on water usage serves as a benchmark for assessing whether current consumption is excessive and provides a solid foundation for tracking improvements over time. Process analysis is crucial for identifying potential water-saving opportunities and setting priorities for action. Monitoring water usage on a machine-by-machine basis, along with regular calibration and maintenance of water meters, ensures accurate data. Additionally, implementing automatic control systems, reducing the liquor ratio, improving washing efficiency, and consolidating certain processes can all contribute to significant reductions in water usage. These improvements not only reduce water consumption but also decrease overall process costs (including chemicals, dyes, energy, etc.) and increase efficiency by shortening production cycles [17].

- Water Reuse: Market-ready machines with integrated systems can effectively separate and collect wastewater streams for reuse. For instance, washing water from one batch can be recycled, and once all the water has been used in a bleaching bath, it can be repurposed for the hydrophilization process in the next batch. This approach allows each bath to be used multiple times, significantly reducing water consumption and optimizing the overall production process [17].

- Measures for Wet Processes (Energy and water consumption are often interconnected, as energy is primarily used to heat process baths):

• Optimization of the Production Program: In processes such as dyeing, dyeing dark tones after light ones can significantly reduce the consumption of both chemicals and water used for machine cleaning.
• Adjustment of Pretreatment Processes: Tailoring pretreatment stages to the specific quality needs of subsequent processes can improve efficiency. For example, when producing dark tones, bleaching may be unnecessary.
• Automatic Stop Valves and Flow Control Devices: Installing automatic stop valves and flow control systems that regulate water flow according to the main drive mechanism (e.g., continuous washing machines) ensures better management of water usage.
• Automatic Control Systems: Implementing automatic mechanisms that precisely control liquor temperature and volume (e.g., for dyeing

machines operating on specific methods) helps reduce resource consumption.

- Intelligent Rinsing or Filling Systems: Opting for intelligent rinsing or filling and emptying washing systems rather than traditional overflow washing methods can minimize water use.
- Combining Wet Processes: Merging multiple wet processes into a single step (e.g., combining desizing and bleaching or hydrophilization and desizing) reduces water and energy consumption by streamlining production.
- Reuse of Cooling Water: Cooling water can be reused as process water, reducing the overall water demand for the production cycle.
- Reuse of Water from Various Processes: Water from processes like dye floats, final wash floats, continuous washing reverse flow, or cooling water can be recycled for reuse in other stages of production.
- Preventing Steam Losses: Using covers that completely seal machines will help prevent steam losses, improving energy efficiency.
- Insulation to Minimize Heat Losses: Proper insulation of machines, valves, and pipes will minimize heat loss, further improving energy efficiency.
- Heat Recovery Systems: Installing systems that recover heat from waste gases helps to optimize energy use across the production process [17].

CONCLUSIONS

Textile manufacturers have the opportunity to significantly reduce water consumption, enhance sustainability, and minimize their environmental footprint by adopting various measures. Sustainable production techniques, such as using alternative washing systems and low liquor dyeing equipment, can decrease both water and energy usage. Reusing less contaminated water from different stages of production, optimizing water softening systems, and improving transmission lines also contribute to substantial reductions in overall water demand.

In addition, adopting advanced water treatment processes and integrating closed-loop systems can further reduce waste while boosting resource efficiency throughout the production cycle. Innovative technologies, like UV light applications for bleaching, present effective alternatives to traditional chemical-based methods. These approaches not only lower water consumption but also reduce the pollutant load in wastewater, contributing to a smaller water footprint and benefiting the environment.

Moreover, shifting towards fibers with a lower water footprint for production can further help reduce the overall water demand in textile manufacturing. Improving water management systems, recycling wastewater within the facility, and implementing energy-efficient practices can also mitigate the environmental impact. By adopting these strategies, textile manufacturers can transition to more sustainable operations, reduce operational costs, and comply with increasingly stringent environmental regulations, thereby supporting a greener industry.

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