



(RESEARCH ARTICLE)



Water footprint and virtual water assessment for textile industries of Bangladesh

Nabil Ahemed Piyash and Salah Uddin Ahmed Dipu *

Department of Civil Engineering, Chittagong University of Engineering and Technology (CUET), Bangladesh.

World Journal of Advanced Research and Reviews, 2024, 24(01), 339–351

Publication history: Received on 13 August 2024; revised on 25 September 2024; accepted on 28 September 2024

Article DOI: <https://doi.org/10.30574/wjarr.2024.24.1.2909>

Abstract

The textile and garment industry in Bangladesh, a significant contributor to the national economy and major exporters, heavily consumes water and causes environmental pollution. This thesis evaluates the water usage and pollution in the sector by assessing its blue, green, and grey water footprints, focusing on the dyeing, printing, and finishing stages in three industries: KDS, FOURH, and AMBER. The study aims to provide insights into the virtual water footprint and current water management practices, identifying areas for improvement to promote sustainable water resource management in the textile industry.

Keywords: Water footprint; Virtual water; Textile industries; Groundwater depletion

1. Introduction

The textile and garment industry is a cornerstone of Bangladesh's economy, providing employment to over 4.5 million people and generating more than 84% of the country's export earnings [1]. Despite its economic significance, the industry is a major consumer of water and a source of considerable pollution, particularly in the dyeing, printing, and finishing stages of textile production [2]. This study aims to evaluate the water footprints—blue, green, and grey—of these stages in three specific industries: KDS, FOURH, and AMBER. By analyzing the water usage and pollution patterns, the research seeks to provide a comprehensive understanding of the industry's impact on water resources and propose strategies for sustainable water management. This is critical for mitigating environmental harm while sustaining the economic benefits of the textile sector in Bangladesh. The textile industry in Bangladesh is crucial for the country's economic growth, being the world's second-largest exporter of ready-made garments (RMG) [3]. However, this industry is also a major consumer of water, significantly impacting the environment through both consumption and pollution [4]. Global studies on the water footprint of the textile industry have largely overlooked Bangladesh. Research indicates that the annual water footprint of the textile sector is approximately 1.8 billion m³ [5]. The high water usage and resultant pollution potentially lower groundwater levels, leading to severe health issues for local populations. A study anticipated that by 2021, the textile industry in Bangladesh would generate around 349 million m³ of wastewater [5]. The blue water footprint refers to freshwater used in industrial processes like dyeing, printing and finishing while the grey water footprint pertains to the volume of freshwater needed to dilute pollutants from manufacturing. Studies show that the textile sector's blue and grey water footprints in Bangladesh are significant, with the grey water footprint comprising 86.15% of the total water footprint [6]. The rapid growth of the textile industry in Bangladesh has substantial economic benefits but also brings environmental challenges [7]. Conventional industrial methods, poor water management practices, and inadequate wastewater treatment facilities are key factors contributing to the high water footprint of the textile sector [8]. The depletion of groundwater due to excessive water use in the textile industry poses a significant threat to sustainable water resources [9]. Effluent from the textile industry often contains high levels of pollutants, further exacerbating environmental issues [10]. Virtual water, the hidden water embedded in the production of goods, plays a significant role in the textile industry. The process of growing cotton, dyeing fabrics, and manufacturing clothing consumes vast amounts of water, often in regions already facing water scarcity. By understanding and

* Corresponding author: Salah Uddin Ahmed Dipu

managing virtual water consumption, the textile industry can make more sustainable choices, reduce its environmental footprint, and promote water conservation practices globally [11]. Addressing the water footprint of the textile industry in Bangladesh is essential for sustainable development. Improved industrial practices, effective water management strategies, and advanced wastewater treatment technologies are critical to reducing the industry's environmental impact [5].

2. Materials and method

2.1. Blue Water Footprint

Using this simple manufacturing system, we can calculate the water footprint of product p (volume/mass) using the following formula:

$$WF_{prod}[p] = (WF_{proc}[s] / (P[p])) \dots\dots\dots (1)$$

[volume/mass]

where P[p] is the quantity produced for product p (mass/time) and WF proc[s] is the process water footprint of process step s (volume/time). The blue water footprint will be in (l/kg) if the process water is in (l/hr) and the production amount P[p] is in (kg/hr) [2].

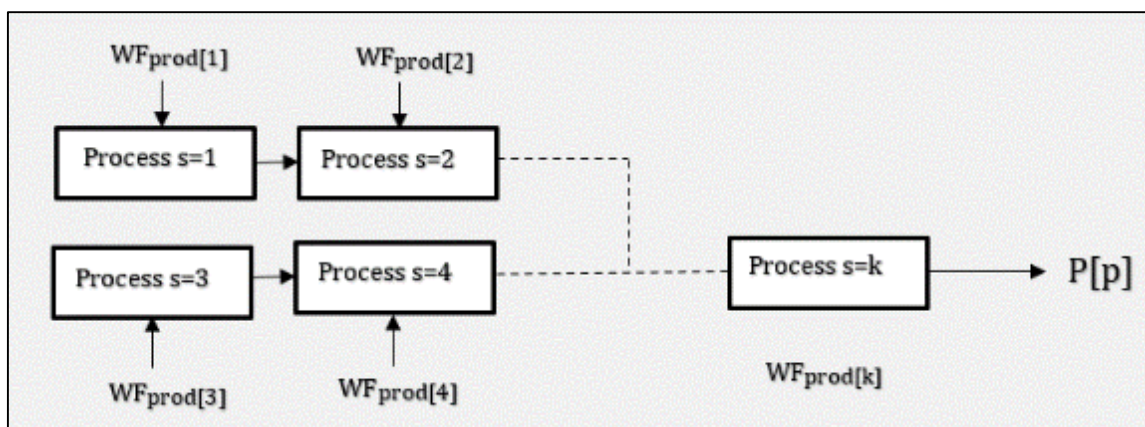


Figure 1 Schematization of the production framework into k process steps to create product P

2.2. Grey Water Footprint

The methodology to calculate grey water footprint is taken from The Water Footprint Assessment Manual.

$$\text{Grey water footprint} = L / (C_{max} - C_{nat}) = (Eff \times C_{eff} - Abs \times C_{act}) / (C_{max} - C_{nat}) \dots\dots\dots (2)$$

The pollutant load, denoted by L, that enters a body of water is contrasted with the maximum allowable concentration, denoted by C_{max}, and the natural background concentration, denoted by C_{act}. Here's how to figure out how much pollution is in the air: concentration of pollutants in effluent (C_{eff}, in mg/l) minus concentration of pollutants in abstract water (C_{act}, in mg/l) equals concentration of pollutants in intake water (C_{act}) [12].

2.3. Green Water Footprint

One indicator of how individuals utilise "green water" is the "green water footprint." "Green water" refers to precipitation that does not evaporate or run off, but instead is retained in the soil or briefly rests atop the soil and vegetation to replenish groundwater. Some of the rain that falls on the ground evaporates or soaks into the ground through the roots of plants. However, not all green water is usable for crop growth because of soil evaporation and the fact that not all seasons or places are optimal for crop growth.

The green water footprint is the total amount of water collected from rain that was used in manufacturing. Agricultural and forestry goods (things created from crops or wood) rely heavily on the total amount of precipitation

evapotranspiration (from fields and plantations) and the water incorporated into the harvested crop or wood. The "green water footprint" of a given process step is proportional to:

$$WF_{green} = \text{Green Water Evaporation} + \text{Green Water Incorporation} \quad (\text{volume/time})$$

The variation between the blue and green water footprints is critical because of the hydrological, environmental, social, and economic opportunity costs associated with using surface and groundwater for industry vs using rainfall [13].

2.4. Analysis Techniques

- **Biological Oxygen Demand (BOD):** A composite samples raw water, treated water, outlet before ETP and outlet after ETP of textile wastewater were obtained during the initial treatment stage. The samples were diluted with distilled water to accomplish nutrient addition, which supported microbial activity and provided a sufficient environment for biological processes. A calibrated DO meter was used to measure the initial dissolved oxygen (DO) content. The prepared samples were placed in a dark, temperature-controlled incubator set to 20°C. The incubation duration was set for 5 days to allow for microbial breakdown of organic materials. Following the incubation time, the DO concentration was tested again. BOD was estimated using the difference between the starting and final DO concentrations [14].
- **Chemical Oxygen Demand (COD):** A composite samples raw water, treated water, outlet before ETP and outlet after ETP of textile wastewater were collected in the same manner as for the BOD analysis. The samples were mixed with a known volume of potassium dichromate ($K_2Cr_2O_7$) solution in an acidic medium, using sulfuric acid (H_2SO_4) as the catalyst. The mixture was refluxed for 2 hours to guarantee that the dichromate completely oxidized the organic content. After cooling, the excess potassium dichromate was titrated from each solutions using a standard sodium thiosulfate solution ($Na_2S_2O_3$). The titration endpoint was obtained using a starch indicator. COD was calculated for each samples from the volume of sodium thiosulfate solution used in the titration [15]. The results were expressed as mg/L of wastewater.

$$COD = \frac{\text{Volume of } K_2Cr_2O_7 - \text{Volume of } Na_2S_2O_3}{\text{volume of sample}} \times \text{Factor}$$

Total Dissolved Solids (TDS) and Total Suspended Solids (TSS): A composite samples raw water, treated water, outlet before ETP and outlet after ETP of textile wastewater was collected from the same source used for TDS analysis. The samples were blended to maintain consistency. A specific volume of the samples were filtered via pre-weighed filter paper or membrane. The filter's pore size should be small enough to retain all suspended solids. The TDS was calculated as follows.

$$TDS = \frac{\text{Mass of residue}}{\text{volume of sample}}$$

The filter paper or membrane, with the retained solids, was dried in an oven at 105°C until a constant weight was achieved. After cooling in a desiccator, the filter paper or membrane with the suspended solids was weighed to determine the mass of suspended solids [16].

TSS was calculated as follows:

$$TSS = \frac{\text{Mass of solid in filter}}{\text{volume of sample}}$$

Results are typically expressed in mg/L.

2.5. Product and Water Usage Data

Data on the quantity of product (tons per day) and water usage (liters per day) in the production process were collected from three textile industries: KDS, FOURH, and AMBER.

Table 1 Amount of product per day and required water per day of KDS Textile

Process	Product per day	Required water per day
Printing	10-ton/24hr	160,000l/24hr
Finishing	16-ton/24hr	20,000l/24hr
Dyeing	18-ton/24hr	1255328l/24hr
Sum	18-ton/24hr	1595328l/24hr

Water used in administration zone 125,000l/24hr

Table 2 Amount of product per day and required water per day of FOURH Textile

Process	Product per day	Required water per day
Printing	12-ton/24hr	300,000l/24hr
Finishing	47-ton/24hr	477,000l/24hr
Dyeing	47-ton/24hr	2457,000l/24hr
Sum	47-ton/24hr	5986000l/24hr

Water used in administration zone 166,000l/24hr

Table 3 Amount of product per day and required water per day of AMBER Textile

Process	Product per day	Required water per day
Finishing	39-ton/24hr	272,000l/24hr
Dyeing	31-ton/24hr	1230,000l/24hr
Sum	39-ton/24hr	46588,000l/24hr

Water used in administration zone 136,000l/24hr.

Table 4 Amount of yarn used per day in the following textiles

Textile Name	Yarn used (ton per day)
KDS	38 ton/24hr
FOURH	94 ton/24hr
AMBER	ton/24hr

2.6. Effluent Characteristics Data

Both treated and untreated effluent samples were analyzed to determine the grey water footprint.

Table 5 Sample Characteristics of KDS Textile

Parameters	RAW water	Treated water	Inlet	Outlet After ETP
BOD	0.6	0.1	316	9
COD	12	3	700	75
TDS	674	662	2430	2100
TSS	136	128	220	29

Effluent Discharge =1435, 328 L/24hr,

Abstract water =1760, 328 L/24hr

Table 6 Sample Characteristics of FOURH Textile

Parameters	RAW water	Treated water	Inlet	Outlet After ETP
BOD	1	0.2	280	9
COD	10	2	720	36
TDS	696	682	2300	2100
TSS	185	138	140	2

Effluent Discharge =3134, 000 L/24hr

Abstract water =3478, 000 L/24hr

Table 7 Sample Characteristics of AMBER Textile

Parameters	RAW water	Treated water	Inlet	Outlet After ETP
BOD	0.9	0.2	270	19
COD	13	4	628	56
TDS	696	654	2200	2100
TSS	138	126	677	48

Effluent Discharge =1502, 000 L/24hr

Abstract water =1852, 000 L/24hr

In this study, the ambient water quality standard (C_{max}) was assumed to be 200 mg/l, the natural concentration (C_{nat}) in the receiving surface water body was 12 mg/l and the actual concentration (C_{act}) was 10 mg/l.

2.7. Imported Cotton Data

Bangladesh buys cotton from a number of international locations. India, the United States, Brazil, Vietnam, Uzbekistan, and Australia are the principal exporters of cotton to Bangladesh. These nations are significant producers of cotton and major exporters of cotton to other countries [17].

Table 8 The total amount of imports (cotton and yarn) and export (cotton produced and textile products) in kilogram unit in recent years

Year	Cotton Imports (kg)	Yarn imports (kg)	Cotton Produce (kg)	Textile product exports (metric tons)
2018	1.5×10^9	2.22×10^8	29×10^6	4,219,415
2019	1.62×10^9	3.31×10^8	30×10^6	4,42,220
2020	1.79×10^9	6.48×10^8	31.75×10^6	4,229,716
2021	1.77×10^9	1.07×10^9	32.61×10^6	4,37,198

Notwithstanding its strong spinning sector, Bangladesh depends on yarn imports to satisfy its requirements. Principal yarn suppliers to Bangladesh comprise India, Vietnam, and China [18]. Bangladesh generates a little quantity of cotton domestically, accounting for about 1% of the overall yearly demand [19]. [17][18][19] Provides data on cotton and yarn imports, as well as cotton production data. BGMEA provides data on the export performance of textile products [20].

3. Results

3.1. Blue, green and grey water footprint

Tables 1, 2, and 3 have determined the blue water footprint of these three industries (KDS, FOURH, and AMBER) using the chain-summation approach. We use Table 4 to calculate the green water footprint. Table 5, Table 6 and Table 7 were utilized to compute the grey water footprint. Pollutant load is nevertheless determined by COD because it offers a more complete measurement of organic matter and because its value is higher in textile effluent than in other parameters [21].

Table 9 Calculated blue, green and grey water footprint

Textile Name	Blue water footprint	Green water footprint	Grey water footprint
KDS	95.91 l/kg	3744l/kg	437.16l/kg
FOURH	96.389 l/kg	8335l/kg	488.23l/kg
AMBER	46.305 l/kg	4956l/kg	164.66l/kg

3.2. Import related water footprint

Bangladesh has imported large amount of cotton over the recent years. Along with these imports, footprints of blue, green, and grey water are produced. [22].

Table 10 Cotton imports and corresponding blue, green and grey water footprints

Year	Cotton imports (kg)	Blue water (l)	Green water (l)	Grey water (l)
2018	1.5×10^9	4.43×10^{12}	7.74×10^{12}	1.50×10^{12}
2019	1.62×10^6	4.79×10^{12}	8.36×10^{12}	1.61×10^{12}
2020	1.79×10^9	5.29×10^{12}	9.24×10^{12}	1.78×10^{12}
2021	1.77×10^9	5.23×10^{12}	9.13×10^{12}	1.76×10^{12}

Textiles also import a huge quantity of yarn. Hence blue, green and grey water footprint is produced.

Table 11 Yarn imports and corresponding blue, green and grey water footprint

	Yarn imports (kg)	Blue water (l)	Green water (l)	Grey water (l)
2018	2.22×10^8	8.85×10^{11}	1.54×10^{12}	2.89×10^{11}
2019	3.31×10^8	1.32×10^{12}	2.30×10^{12}	4.31×10^{11}
2020	6.48×10^8	2.58×10^{12}	4.51×10^{12}	8.45×10^{11}
2021	1.07×10^9	4.26×10^{12}	7.45×10^{12}	1.39×10^{12}

3.3. Export related virtual water

Huge quantity of virtual blue, green and grey water is associated with cotton production over the years.

Table 12 Yearly cotton production and associated virtual blue, green and grey water quantity

Year	Cotton Produce (kg)	Blue water (l)	Green water (l)	Grey water (l)
2018	29×10 ⁶	9.7×10 ¹⁰	2.037×10 ¹¹	3.43×10 ¹⁰
2019	30×10 ⁶	1.00×10 ¹⁰	2.11×10 ¹¹	3.54×10 ¹⁰
2020	31.75×10 ⁶	1.06×10 ¹⁰	2.23×10 ¹¹	3.74×10 ¹⁰
2021	32.61×10 ⁶	1.09×10 ¹⁰	2.29×10 ¹¹	3.85×10 ¹⁰

3.4. Total virtual water footprint

Export of textile products contribute to the quantity of virtual blue and grey water. Thus increase the total amount of virtual blue and grey water quantity.

Table 13 Virtual blue and grey water of product exports

Year	Textile product exports (metric tons)	Virtual Blue water (l)	Virtual Grey water (l)
2018	4,219,415	5.69×10 ¹¹	3.55×10 ¹²
2019	4,42,220	5.96×10 ¹¹	3.72×10 ¹²
2020	4,229,716	5.69×10 ¹¹	3.55×10 ¹²
2021	4,37,198	5.89×10 ¹¹	3.68×10 ¹²

Table 14 Virtual blue, green and grey water quantity over the years (Imports vs. Exports)

Year	Virtual Blue water (l)		Virtual Green water(l)		Virtual Grey water(l)	
	Imports	Exports	Imports	Exports	Imports	Exports
2018	5.31×10 ¹²	6.54×10 ¹¹	9.28×10 ¹²	1.15×10 ¹¹	1.79×10 ¹²	3.57×10 ¹²
2019	6.11×10 ¹²	6.84×10 ¹¹	10.66×10 ¹²	1.55×10 ¹¹	2.04×10 ¹²	3.74×10 ¹²
2020	7.88×10 ¹²	6.628×10 ¹¹	13.75×10 ¹²	1.64×10 ¹¹	2.62×10 ¹²	3.58×10 ¹²
2021	9.49×10 ¹²	6.854×10 ¹¹	16.58×10 ¹²	1.68×10 ¹¹	3.15×10 ¹²	3.71×10 ¹²

4. Discussion

The study analysed the water footprint of three textile companies—KDS, FOURH, and AMBER—using data from their peak production month. The water footprint includes blue, green, and grey water footprints, with results varying based on production amount, fabric type, and dyeing process requirements. These values indicate the volume of groundwater extracted and treated for use in textile production. AMBER Textile, being a denim industry, uses less blue water as it does not involve printing, which consumes significant water

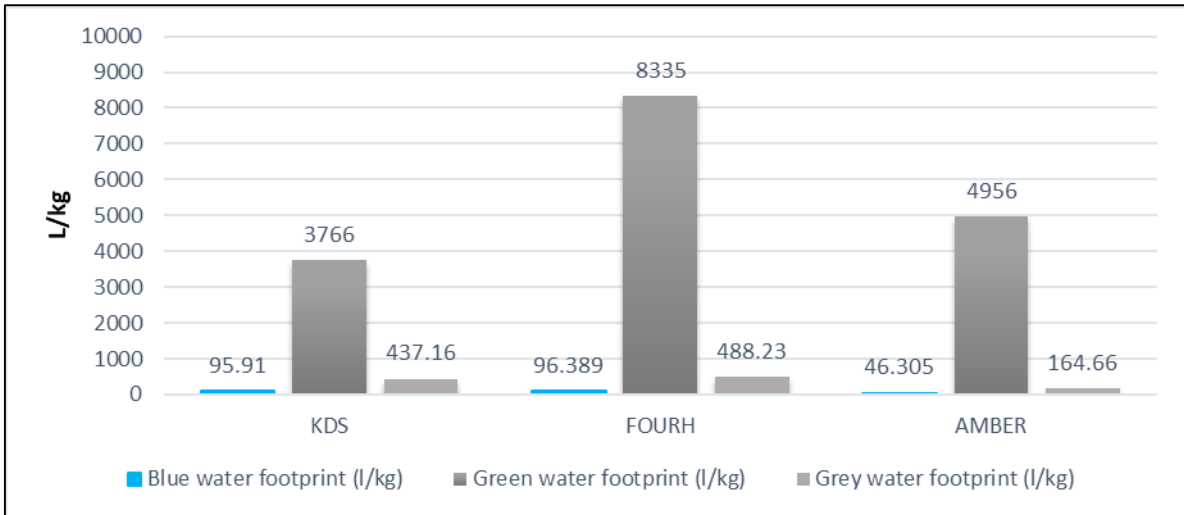


Figure 2 Blue, green and grey water footprint of KDS, FOURH and AMBR

FOURH has the highest green water footprint due to importing yarn from India, which has a large green water footprint for cotton lint. In contrast, KDS has the lowest due to China’s lower green water footprint [23]. AMBER Textile has the lowest grey water footprint as it avoids the printing process, leading to fewer pollutants in the effluent.

4.1. Comparison between studied industries

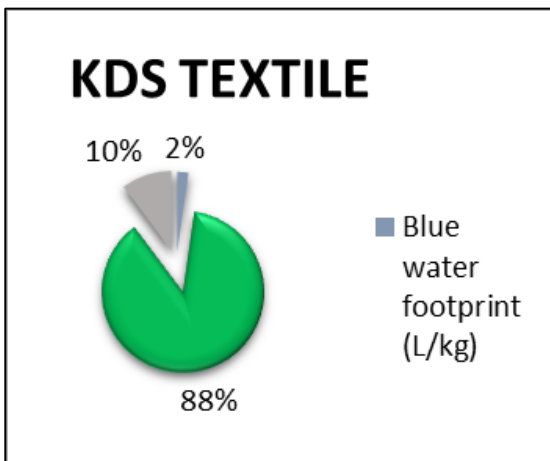


Figure 3 Total water footprint percentage

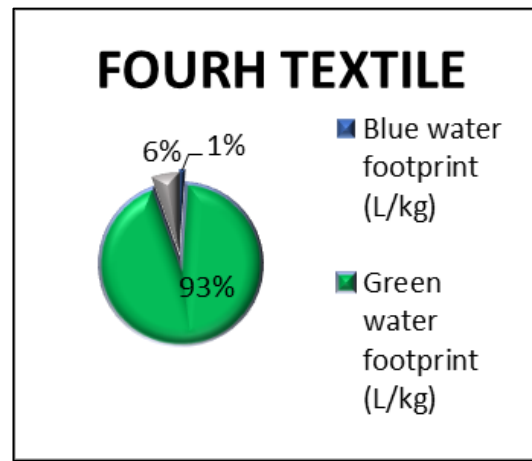


Figure 4 Total water footprint percentage Of KDS percentage of FOURH

Figures 3 and 4 indicate that FOURH has a higher green water footprint, suggesting a greater reliance on freshwater resources, and operates on a larger scale with a higher daily output than KDS. Despite its larger scale, FOURH demonstrates more efficient water management with a lower grey water footprint, indicating better wastewater treatment practices. Conversely, KDS produces more wastewater, reflected in its higher grey water footprint, suggesting less effective water management compared to FOURH. From Table 14 it is clear that Bangladesh's virtual import and export of green and grey water has increased overall in 2018,1019,2020,2021. Bangladesh exported fewer textile products in 2020 in comparison to 2019 due to the pandemic as a result, it exports less virtual water footprint [24].

4.2. Virtual water footprint

Figure 5 shows that the blue and green water footprint for imports has increased over time compared to exports. Virtual grey water export is greater than import because Bangladesh exports a large amount of textile products overall over the years. Virtual water footprint of cotton is calculated by the average global water footprint of cotton lint [25]. In 2020, producing a kilogram of textile products for export in Bangladesh required an average of 0.675×10^{12} liters of freshwater. In contrast, importing a kilogram of products brought in goods produced abroad with a virtual water content of 7.88×10^{12} liters per kilogram, reflecting the freshwater used in the exporting countries.

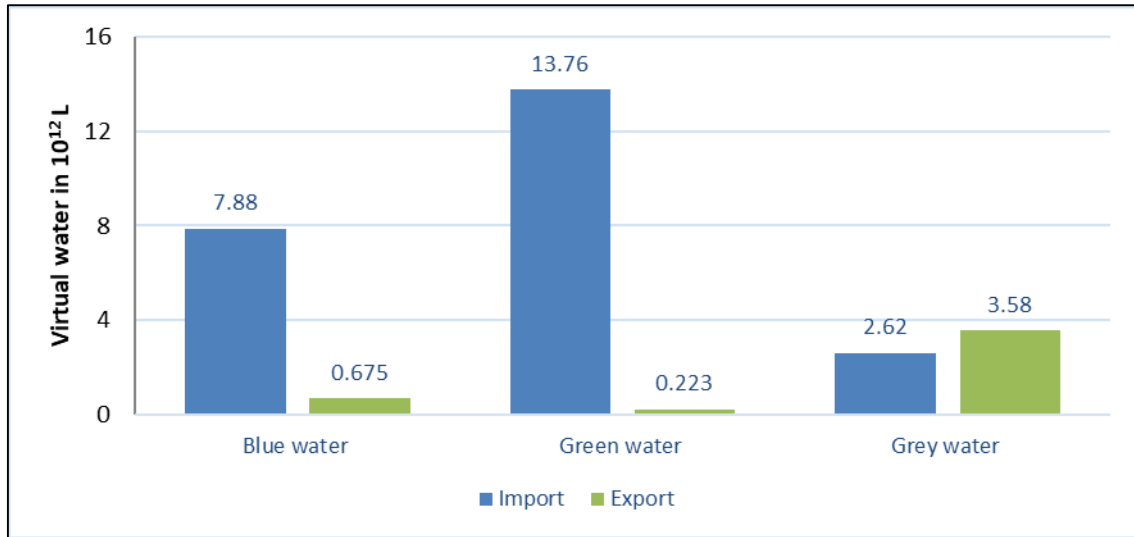


Figure 5 Virtual blue, green and grey water of Bangladesh (import vs export) in the year 2020

The green water footprint for exports is 0.223×10^{12} liters per kilogram, indicating that 0.09×10^{12} liters of rainwater or soil moisture were used for each kilogram of exported products. For imports, the green water footprint is 13.76×10^{12} liters per kilogram, showing that this amount of rainwater or soil moisture was used in the production of each kilogram of imported products, mostly cotton from countries like India, China, the USA, and Vietnam. This disparity indicates that Bangladesh uses less green water for its textile exports compared to the green water used by these countries for producing the imported cotton.

The grey water footprint for exports is 3.58×10^{12} liters per kilogram, meaning that this volume of water was polluted during the production of each kilogram of exported products due to wastewater containing chemicals and dyes. For imports, the grey water footprint is 2.62×10^{12} liters per kilogram, indicating that this volume of water was polluted during the production of imported goods. Thus, exporting products with a higher grey water footprint means Bangladesh indirectly exports the associated water pollution, while importing products with a lower grey water footprint means it brings in goods produced with less water pollution. Table 14 shows that Bangladesh's blue water exports decreased in 2020 compared to 2019 due to the pandemic.

5. Conclusion

It may be advantageous for Bangladesh to export less virtual blue water than it imports because it is experiencing water stress or scarcity inside its. It seems to imply that the country is depending on the water resources that are imbedded in the items that are imported from other countries, therefore decreasing the strain that is being placed on its own water resources. Bangladesh benefits from the comparative advantage of importing cotton rather than producing them domestically if it imports commodities with a greater green water footprint. Locating water-intensive production in locations with plenty of water resources, can result in more effective resource allocation and relieve strain on water-scarce places.

A higher greywater footprint in exports could mean that Bangladesh is shipping goods that generate a lot of wastewaters, which could be bad for the environment. This may involve harm to the public's health, ecosystem deterioration, and water body contamination.

It is an approximate calculation. The textile export related virtual blue, grey water is calculated by taking the maximum blue and grey water footprint of textile industries. Global average blue green and grey water footprint for cotton cultivation where used to calculate the cotton produce and import related water footprint.

Compliance with ethical standards

Acknowledgement

The authors would like to express their gratitude to the Department of Civil Engineering, Chittagong University of Engineering and Technology because all the tests were performed in the labs of Department of Civil Engineering.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Author contribution

Investigation: Nabil Ahemed Piyash, methodology and drafting manuscript: Salah Uddin Ahmed Dipu. All the author has read and agreed to published version of the manuscript.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article.

Disclaimer

The content of this article is solely the responsibility of the authors.

References

- [1] “Bangladesh Textile Mills Association (BTMA).” <https://btmadhaka.com> (accessed May 27, 2023).
- [2] L. Hossain and M. S. Khan, “Blue and Grey Water Footprint Assessment of Textile Industries of Bangladesh,” no. December, pp. 437–449, 2017.
- [3] “Report on Bangladesh Textile and Garment Industry”, [Online]. Available: https://www.ids.trade/files/actif_report_on_bangladesh_textile_and_garment_industry.pdf
- [4] A. Kumar, “Environmental Pollution by Textile Industries,” no. June, 2016, [Online]. Available: https://www.researchgate.net/publication/304158968_Environmental_Pollution_by_Textile_Industries
- [5] L. Hossain and M. S. Khan, “Water Footprint Management for Sustainable Growth in the Bangladesh Apparel Sector,” 2020, [Online]. Available: https://www.researchgate.net/publication/324134360_Evaluation_of_Present_and_Future_Wastewater_Impacts_of_Textile_Dyeing_Industries_in_Bangladesh
- [6] M. Egan, *The Water Footprint Assessment Manual. Setting the Global Standard*, vol. 31, no. 2. 2011. doi: 10.1080/0969160x.2011.593864.
- [7] M. S. Ullah, “Role of Textile and Clothing Industries in the Growth and Development of Trade and Business Strategies of Bangladesh in the Global Economy,” no. April 2024, 2016, doi: 10.5923/j.textile.20160503.01.
- [8] P. Restiani, “WATER GOVERNANCE MAPPING REPORT : TEXTILE INDUSTRY WATER USE IN,” pp. 1–49, [Online]. Available: <https://siwi.org/wp-content/uploads/2017/06/Water-governance-mapping-report-Bangladesh.pdf>
- [9] “Groundwater level in Chattogram drops by around 2.5 metres a year | The Financial Express.” <https://thefinancialexpress.com.bd/national/groundwater-level-in-chattogram-drops-by-around-25-metres-a-year-1647948627> (accessed May 25, 2023).
- [10] X. Wang, J. Jiang, and W. Gao, “Reviewing textile wastewater produced by industries: characteristics , environmental impacts , and treatment strategies,” vol. 85, no. 7, pp. 2076–2096, 2022, doi: 10.2166/wst.2022.088.
- [11] T. Oki and S. Kanae, “Virtual Water Trade and World Water Resources,” *Water Sci. Technol.*, vol. 49, pp. 203–209, 2004, doi: 10.2166/wst.2004.0456.
- [12] N. A. Franke, H. Boyacioglu, and A. Y. Hoekstra, “Grey Water Footprint Accounting: Tier 1 Supporting Guidelines, Value of Water Research Report Series No. 65,” *UNESCO-IHE Inst. Water Educ.*, no. November, p. 64, 2013.

- [13] C. C. Chiu, W.-J. Shiang, and C. J. Lin, "The Water Footprint of Cotton Production," *J. Clean Energy Technol.*, vol. 4, no. 1, pp. 43–47, 2015.
- [14] V. T. Wsmnd and W. Program, "Biochemical Oxygen Demand", [Online]. Available: [https://dec.vermont.gov/sites/dec/files/wsm/wastewater/docs/Section 12_Biochemical Oxygen Demand.pdf](https://dec.vermont.gov/sites/dec/files/wsm/wastewater/docs/Section_12_Biochemical_Oxygen_Demand.pdf)
- [15] "COD," pp. 24–26, [Online]. Available: [https://www.mlsu.ac.in/econtents/2190_expriment 3.pdf](https://www.mlsu.ac.in/econtents/2190_expriment_3.pdf)
- [16] N. Delhi, "How to measure dissolved, suspended and total solids," no. May, 1999.
- [17] "Bangladesh Imports : Related Indicators for Bangladesh Imports : Cotton," p. 2021, 2024, [Online]. Available: <https://www.ceicdata.com/en/bangladesh/trade-statistics-imports-by-commodity-bangladesh-bank/imports-cotton>
- [18] "Bangladesh Imports : Yarn Related Indicators for Bangladesh Imports : Yarn," p. 2021, 2024, [Online]. Available: <https://www.ceicdata.com/en/bangladesh/trade-statistics-imports-by-commodity-bangladesh-bank/imports-yarn>
- [19] D. M. F. Uddin and D. M. G. G. Mortyza, "Cotton Production in Bangladesh: Current Scenario and Prospect," *Cott. Bangladesh Agric. Res. Counc.*, 2016, [Online]. Available: https://www.researchgate.net/publication/275524220_Cotton_Production_in_Bangladesh_Current_Scenario_and_Prospect
- [20] "Export Performance of Bangladesh overall the years.," p. 2020, 2020, [Online]. Available: https://www.bgmea.com.bd/page/Export_Performance
- [21] A. No, "The Bangladesh Environment Conservation Act , 1995 The Bangladesh Environment Conservation Act , 1995," no. 1, pp. 153–166, 1995.
- [22] "Bangladesh Cotton Imports by Year (1000 480 lb. Bales)." <https://www.indexmundi.com/agriculture/?country=bdandcommodity=cottonandgraph=imports> (accessed May 25, 2023).
- [23] M. Mekonnen and A. Y. Hoekstra, "National water footprint accounts: The green, blue and grey water National water footprint accounts: The green, blue and grey water footprint of production and consumption.," vol. 2, 2011, [Online]. Available: <https://digitalcommons.unl.edu/wffdocs>
- [24] <https://www.bb.org.bd/pub/research/policynote/pn2201.pdf>, "Export Performance of Bangladesh during the Pandemic : the Impact of Export Concentration Chief Economist ' s Unit Bangladesh Bank," no. March, 2022, [Online]. Available: <https://www.bb.org.bd/pub/research/policynote/pn2201.pdf>
- [25] M. M. Mekonnen and A. Y. Hoekstra, "The green, blue and grey water footprint of crops and derived crop products," *Hydrol. Earth Syst. Sci.*, vol. 15, no. 5, pp. 1577–1600, 2011, doi: 10.5194/hess-15-1577-2011.

Appendix A: global average footprint of cotton LIN

M. M. Mekonnen and A. Y. Hoekstra: The green, blue and grey water footprint of crops

1587

Table 3. Continued.

FAOSTAT crop code	Product description	Global average water footprint ($\text{m}^3 \text{ton}^{-1}$)			
		Green	Blue	Grey	Total
249	Coconuts	2669	2	16	2687
	Copra	2079	1	12	2093
	Coconut (husked)	1247	1	7	1256
	Coconut (copra) oil, refined	4461	3	27	4490
	Coconut/copra oilcake	829	1	5	834
	Coconut (coir) fibre, processed	2433	2	15	2449
254	Oil palm	1057	0	40	1098
	Palm nuts and kernels	2762	1	105	2868
	Palm oil, refined	4787	1	182	4971
	Palm kernel/babassu oil, refined	5202	1	198	5401
	Palm nut/kernel oilcake	802	0	31	833
260	Olives	2470	499	45	3015
	Olive oil, virgin	11 826	2388	217	14 431
	Olive oil, refined	12 067	2437	221	14 726
265	Castor oil seeds	8423	1175	298	9896
	Castor oil	21 058	2938	744	24 740
267	Sunflower seeds	3017	148	201	3366
	Sunflower seed oil, refined	6088	299	405	6792
	Sunflower seed oilcake	1215	60	81	1356
270	Rapeseed	1703	231	336	2271
	Rape oil, refined	3226	438	636	4301
	Rape seed oilcake	837	114	165	1115
280	Safflower seeds	6000	938	283	7221
289	Sesame seed	8460	509	403	9371
	Sesame oil	19 674	1183	936	21 793
292	Mustard seeds	2463	1	345	2809
296	Poppy seeds	1723	0	464	2188
299	Melon seed	5087	56	41	5184
328	Seed cotton	2282	1306	440	4029
	Cotton seeds	755	432	146	1332
	Cotton lint	5163	2955	996	9113
	Cotton linters	1474	844	284	2602
	Cotton-seed oil, refined	2242	1283	432	3957
	Cotton seed oilcake	487	279	94	860
	Cotton, not carded or combed	5163	2955	996	9113
	Cotton yarn waste (including thread waste)	950	544	183	1677
	Garneted stock of cotton	1426	816	275	2517
	Cotton, carded or combed	5359	3067	1034	9460
	Cotton fabric, finished textile	5384	3253	1344	9982
333	Linseed	4730	268	170	5168
	Linseed oil, refined	8618	488	310	9415
	Linseed oilcake	2816	160	101	3077
336	Hempseed	3257	12	417	3685
358	Cabbages and other brassicas	181	26	73	280

Appendix b: Virtual water content of cotton producing countries

18 / Water footprint of cotton consumption

Table 3.5. Virtual water content of cotton products at different stages of production for the major cotton producing countries (m^3/ton).

	Cotton lint		Grey fabric		Fabric		Final textile		Total
	Blue	Green	Blue	Green	Blue	Green	Blue	Green	
Argentina	5,385	12,589	5,611	13,118	5,971	13,118	6,107	13,118	19225
Australia	3,287	2,031	3,425	2,116	3,785	2,116	3,921	2,116	6037
Brazil	107	6,010	112	6,263	472	6,263	608	6,263	6870
China	1,775	2,935	1,849	3,059	2,209	3,059	2,345	3,059	5404
Egypt	9,876	0	10,291	0	10,651	0	10,787	0	10787
Greece	4,221	1,237	4,398	1,289	4,758	1,289	4,894	1,289	6183
India	5,019	15,198	5,230	15,837	5,590	15,837	5,726	15,837	21563
Mali	3,427	8,752	3,571	9,120	3,931	9,120	4,067	9,120	13188
Mexico	3,863	1,990	4,026	2,073	4,386	2,073	4,522	2,073	6595
Pakistan	9,009	2,460	9,388	2,563	9,748	2,563	9,884	2,563	12447
Syria	7,590	204	7,909	213	8,269	213	8,405	213	8618
Turkey	6,564	672	6,840	701	7,200	701	7,336	701	8037
Turkmenistan	13,077	951	13,626	991	13,986	991	14,122	991	15112
USA	1,345	3,906	1,401	4,070	1,761	4,070	1,897	4,070	5967
Uzbekistan	10,215	195	10,644	203	11,004	203	11,140	203	11343
Global average	4,242	4,264	4,421	4,443	4,781	4,443	4,917	4,443	9359