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Water Footprint of Cotton Textile Processing Industries; a Case Study of Punjab, Pakistan

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Abstract

World over, many studies have been published on the water footprints (WFs) of different commodities. In Pakistan, there is lack of information and awareness on water footprints of processes and products. This study throws light on the water footprint of cotton textile production in Pakistan. Blue, green and grey water footprints have been included in this research communication. Water footprint assessment is essential in determining how much water is consumed in which process and how it can be managed effectively. It is a reliable method to plan sustainable, equitable and efficient use of water resources. The results of the study revealed that the blue water footprint (BWF) of cotton seed in Punjab is 1898 m^3/t. The water abstracted for textile processing is about 169 m^3/t of finished fabric, of which approximately 26 m^3/t is consumed (i.e. the BWF of textile manufacture) with the remainder being discharged as waste water. However, the water footprint of chemical inputs is not very high in comparison to other parts of the supply chain (less than 1 m^3/t). Overall, the blue WF of finished textile in Punjab, Pakistan is 4650 m^3/t on average.

Keywords: Water footprint; blue water footprint; green water footprint; grey water footprint; textile processing; sustainable water use.

1. Introduction

Freshwater is a crucial natural resource. It is imperative for the sustenance of life and plays an irreplaceable role in human lives [1]. Over the years, countries like Pakistan have faced serious water quality and quantity issues. Over abstraction and low rate of groundwater recharge has lead Pakistan to become one of the water scarce countries [2].

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Textile sector is the largest Industry of Pakistan in terms of employment, exports and production [3]. The sector has given huge boost to Pakistan's economy and the economic implications have been nothing but positive. However, it is undoubtedly a very water intensive industry and managing the water sustainably is a huge challenge for the sector [4]. In order to adopt sustainable water practices, it is first significant to assess how much water is being consumed in the processes [5]. Water footprint (WF) measures the allotment of freshwater resource to anthropogenic activities. The water consumed and polluted are both included in this assessment. The idea of water footprint draws from the idea of 'virtual water' which is the total volume of water used to produce a commodity [6]. The concept of water footprint was pioneered in 2002 by Arjen Hoekstra. The reason behind propagating these concepts was to account and regulate the water used in creating products and services by first estimating the amount of water being used at every production step [7]. One of the benefits of Water Footprint Assessment is the high level of precision obtained from the results as water consumption is studied at the lowest possible level. Such assessments have led to better water management practices in the corporate sector such as cotton textile. One such case is the Better Cotton Initiative 2012, which is a combined effort of potential companies with World Wildlife Fund (WWF) and local organizations to encourage sustainable farming practices for growers of cotton in Pakistan, Mali, Brazil and India. Information regarding how much water is being used is the first step in assessing how and how much water can be conserved in any production chain [8]. The main purpose of the study is to encourage water efficient production and consumption through the dissemination of information regarding high water footprints of industrial processes. The study aims at facilitating textile industries in reducing their water consumption through an assessment of how much water is being consumed in each process and where there is need for introduction of sustainable practices. Since data is not available on water consumption by cotton textile in Punjab, a water footprint study has been conducted as an effort to make information available on water footprints so that it may be considered for future endeavors.

2. Materials and Methods

A water footprint study has been conducted in the textile sector of Punjab, Pakistan. The study was conducted based on the methodology delineated in Water Footprint Assessment Manual written by Arjen Hoekstra and co-authors in 2011.

Water footprint is the measure of freshwater consumption during production and utilization of any product. It can be calculated at any level of production ranging from single process to entire factory production change. It gives the estimation of amount of water utilized from collection of raw materials till the distribution and consumption of a product [9]. At industrial level, water foot print is measured both directly and indirectly. This includes estimation of total water consumption by the industry which can be termed as direct water footprint (e.g. onsite ground water consumed by textile mill for weaving onsite). However, measurement of amount of water needed to produce raw material is stated as indirect water footprint (e.g. quantity of ground water used to grow cotton) [10].

Blue, green and grey are three subsections of the total water footprint. Green water footprints take account of all the water and moisture that evaporates naturally from soil surfaces, trees and other types of vegetation [11]. Blue water footprint caters water extracted from the ground and fresh water resources either for production and preparation of raw material (irrigation) or directly by the industry for processing [12]. Third section which is grey water footprint includes quantity or volume of water which is used by the industry for the purpose of waste water dilution in order to meet the standards of water quality [13].

Blue and green water footprints often create misconception that these WFs include water that is obtained from the on-site reserves only. However, the actual blue and green WFs measure both evaporated water, and that obtained from one reserve and returned to another catchment such as sea or is integrated into any other procedure and product. Blue and green water footprint does not include water obtained, utilized and returned to the same reserve with very little quality damage as this water could be reused for other purposes. But if the water once used, gets considerable amount of pollutants then this would be part of third section i.e., grey WFs [14].

Water footprint is sum total of all WFs. If in case one raw material is used to manufacture more than one end product, both value fractions and product fractions are included. Value fractions are assessed by considering relative market value and total market value of finished products. However, product fractions are calculated by dividing weight of output product per unit by weight of input product per unit of each finished product [15].

Figure 1 [16] shows the major steps in the textile industry for which water footprints are calculated. Water footprint for growing cotton has been dealt with separately in the results section.

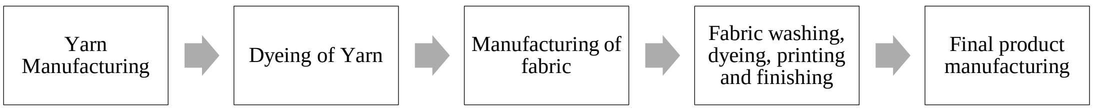

Figure 1: major steps in textile industry

The estimation of Water Footprint is actually a quantitative measure of the amount of water utilized in the production or manufacturing of any product in any industrial unit. Assessment of WFs is significant as it indicates the extent of sustainability of a process. With the help of water footprint assessment, areas within an industrial unit can be defined where efficient conservation methods could be installed to reduce overall water footprint. The idea of water footprint is actually derived from the negative anthropogenic impacts on fresh water resources. Human practices have caused serious damages to the already scarce freshwater natural reserves in the form of significant water pollution and shortages to an alarming extent. These environmental problems can only be solved by monitoring and analyzing production and supply at every step [17].

2.1 Data Collection

The data required for water footprint of cotton seed was obtained from the Water footprint Assessment Manual of Mekonnen and Hoekstra published in 2011. The blue WF of textile on-site process was assessed from a random sample of 21 textile processing industries in Punjab and the estimate was compared to the study conducted by Franke and Matthews in 2013 [18]. The data for blue WF of non textile raw materials was obtained from studies conducted by Hong and his colleagues Zah and Hischier, Unger and his colleagues and Wu and Chiu [19, 20, 21, 22].The water footprint data for finished textile also stemmed from study of Mekonnen and Hoekstra.

3. Results and Discussion

3.1 The virtual water content of Growing Cotton

Blue WF of cotton seed is 1898 m^3/t in Punjab [23]. As more than 65 per cent of the weight of cotton becomes either waste, cotton cake, or oil producing approximately 18 per cent market value [24], the blue WF of the non-textile product in Punjab can be calculated as 526 m^3/t (1898 x 0.18/0.65=526), with the remainder being allocated to cotton fabric and finished textiles. The Green water footprint of cotton seed is estimated at 1122 m^3/t and the grey water footprint is 709 m^3/t [25].

3.2 Virtual water Content of On-site processes

There is difference between water obtained and used onsite and water footprint of the finished product. Textile industry requires plenty of water for processing and finishing of products. This water is usually extracted from boreholes however after complete or partial usage of that water, it is returned to the surface or ground water resources. That water might not be clean enough to be reused but could be made available for other purposes and water users. Water footprint assessment for processing would be calculated by dividing amount of water supplied by total water withdrawn and water that is lost from the onsite reserve in the form of evaporation.

The primary data collected during the tenure of the study revealed that the average total process water abstracted per tonne of finished textile (i.e. dyed and printed fabric) was 169 m^3/t. Average effluent volumes are calculated to be 143 m^3/t. Difference between outflow and inflow of effluent tells about the total water loss throughout the process. Actual measurement of water loss during textile processing indicates blue WFs of processing textiles in Punjab to be 26 m^3/t. This figure is comparable to the estimate of Franke and Matthews [26].

Textile industrial effluent is mostly drained into surface water resources either directly or through sewerage discharge networks. Effluent is discharged in two forms. If the effluent still meets water quality standards, it will be drained to the nearby water body to be made able for downstream users. But if the waste water is significantly polluted, it will fall under grey water footprint as polluted water will require large amount of clean water for dilution. Audit data of the study indicates that wastewater discharged by the textile processing sector is about 143 m^3 per tonne of finished textile where organic loading of BOD, COD and TDS are 63 kg/t, 174 kg/t and 440 kg/t of fabric processed, respectively. Franke and Matthews, 2013, estimated the grey water footprint of textile processing in their study and concluded that it accounts for over 99 per cent of the holistic water footprint (green + blue + grey) of finished cotton articles. In some respect, grey is the easiest component of the WF to address. It is estimated that if cleaner production technologies are implemented, the amount of chemicals used in cotton industries can be reduced by 30 per cent, which will result in 60 per cent of COD content reduction [27].

3.3 Water footprint of raw materials other than cotton

Accounting of water obtained, consumed, evaporated and drained is not enough to find total water footprint of a processing industry. In case of textile processing unit, in addition to blue, green and grey WFs of finished product, the water footprint of all non-cotton raw materials will also be included. It would be a very challenging process to be carried out across Pakistan. Approximate WFs of key materials by weight have already been assessed and published by others. Based on the quantities of each raw material used, total water footprint can be assessed. Few chemicals and nonagricultural raw materials have very low water footprint as compared to cotton on a per tonne basis. Cotton is used in a very large quantity in comparison with non-cotton raw materials and thus has very less impact on overall water footprint of a finished textile product. Table 1 shows the estimated WF of raw materials used to produce one tonne of finished cotton fabric. All raw materials listed below contribute less than 0.01 per cent to the overall water footprint of finished cotton textile. Moreover it is difficult to trace source of some chemicals and the sustainability of blue WF resulting from the use of these chemicals becomes even more complicated. For these two reasons, blue WF related to the use of chemicals can be safely disregarded in the sustainability assessment.

Table 1: Water footprints of key non-cotton raw materials into cotton textile processing

Raw material	Blue water footprint of raw material (m^3/t)	Quantity of raw material used per tonne of finished fabric (tonne)	Raw material BWF per tonne of finished textile (m^3/t)	Data source
Caustic soda	3.2	0.063	0.20	Hong and his colleagues 2014
Sodium silicate	0.069	0.021	0.001	Zah and Hischier, 2007
Soda ash	3.76	0.0025	0.009	Unger and his colleagues 2013
Dyes	4 – 9.5			Wu and Chiu, 2011

3.4 Water footprint of finished cotton textile

In 2011, Mekonnen and Hoekstra estimated that the blue WF of finished textile is 4650 m^3/t for Punjab. The green WF is 2646 m^3/t and the grey WF is 1979 m^3/t.

4. Recommendations

The industrial sector has a major role to play in water management. Proper management of water resources cannot be done without knowing the volume of water being used in all processes. Once the water is quantified; unsustainable steams in industries can be identified and measures taken for water conservation. It is recommended that more in depth studies be conducted to assess the water footprint of industrial processes so that the industrial sector can plan to adopt sustainable practices using best possible methods. Industries use huge quantities of water and it is their responsibility to contribute to water conservation. Researchers need to focus more on understanding the water footprints by conducting in depth life cycle assessments of products in order to establish sustainable best practices in industries.

5. Conclusion

Cotton is the prime crop of Pakistan which makes textile sector very strong component of country's economy. Cotton which is the basic raw material of textile processing is grown and processed within the country. Cropping cotton consumes large quantities of blue, green and grey water. Green WF is applicable during growth stage where water from rainfall is consumed by the crop. Blue WF caters fresh surface and ground water obtained for irrigation purposes however grey WF is valid at stage where crop is exposed to fertilizers and pesticides. For cotton seed in Punjab, the blue water footprint (BWF) was found to be 1898 m^3/t. Water footprint of finished textile good is estimated on the basis of WF at all the stages of supply chain. In textile processing, all the water consumed is blue water from ground water abstraction. Green water is not majorly utilized at processing stage. Blue WF at processing stage is mainly due to water loss by evaporation from ground and surfaces of catchments in the factories. Grey WF originates when effluent with significant pollutants enters into freshwater without treatment. The water abstracted for textile processing is about 169 m^3/t of finished fabric, of which approximately 26 m^3/t is consumed (i.e. the BWF of textile manufacture) with the remainder being discharged as waste water. The water footprint of chemical inputs is not very high in comparison to the other parts of the supply chain (less than 1 m^3/t). Overall, the blue WF of finished textile in Punjab, Pakistan is 4650 m^3/t on average.

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Conflict of Interest

"The authors declare no conflict of interest

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