Water Footprint for Different Industries-An Overview

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***Abstract*— Water footprint (WF) method is a compressive approach for evaluating direct and indirect water consumption in different sector, including the industrial, agricultural and domestic sector. In this review paper we are focusing on different case studies of water footprint for different industries. We are able to know about water consumption for various production process through this paper. The study revel water risk, water scarcity and other water related challenges faced by human beings and helps in decision making for strategic actions based on the impacts on water resources that may be caused due to production process for different industry.**

Keywords*— *Water footprint, Industry, water scarcity.

I. INTRODUCTION

Water is life. This statement refers to the worth of water for individuals and life on the planet. Water is essential for human beings, and thus access to clean water is considered a human right. Water crisis is a crucial issue because approximately 1.2 billion people face severe water scarcity [1]. The desirability of reducing our carbon footprint is generally recognised, but the related and equally urgent need to reduce our water footprint is often overlooked. Recent research has shown that about 4 % of the water footprint of humanity relates to water use at home [2]. To manage the global concern of freshwater scarcity, water footprint (WF) has emerged as an interactive tool for exploring the water use among the policy makers to encourage effective, justifiable and sustainable water use. The concept of WF, was initially introduced by Hoekstra[3]and consequently elaborated by Hoekstra and Chapagain [4]. WF is a consumption or pollution based indicator of water use allocated for producing a product, commodity or a service. Knowledge of how allocated surface and groundwater resources are consumed over the production process is highly valuable for effective planning, management and sustenance of water resources by policy makers [5] [6]. The WF of a product refers to the amount of water required for producing the product over the complete production chain. WF assessment is an analytical tool that can describe the relationship between human activities and water scarcity, and offers an innovative approach to integrated water resources management [7].

WF is divided into three components, blue WF, green WF and gray WF. Thus, blue WF refers to the water that is consumed and / or incorporated into the process of surface and underground water sources, which has the characteristic of not returning to the source of collection or returning in a long period of time [8]. The green WF represents the water stored in the form of moisture in the soil from precipitation and which is mainly consumed by the water requirements of agricultural crops [9] [10]. Finally, the gray WF refers to the quality of the water resource. It represents the theoretical volume of water required by a water body to dilutea pollutant load to the limit values allowed by environmental authorities [11] [12]. The WF can be measured and expressed per day, month or year depending on the level of information needed [13], and the WF of products is always expressed as water volume per product unit. Some of the examples are water volume per unit of mass (litre/kg or m3/t of products) if weight is chosen as a quantity indicator; then the water volume per piece of the product or number of pieces is measured. If the WF of processes is measured, it is usually expressed as water volume per unit of time. When this unit is divided by the units of products measured during that time, then it can also be expressed as water volume per unit of product [14].

II. WATER FOOTPRINT ASSESSMENT (WFA)

WAF helps to feed the discussions in both public and private sectors on environmentally sustainable, economical efficient and socially equitable water use, allocation, helps to assess environmental, social and economic impacts of water use and can inform a broad range of strategic actions and policies from environmental, social and economic perspectives. WFA consist of four phases (1) Setting goals and scope, (2) Water footprint accounting, (3) Water footprint sustainability assessment, (4) Water footprint response formulation [15]. There are different methodologies and valuable tools for industrial water footprint. The International Organization for Standardization has developed frame work for calculating the water footprint, by following the guide lines of ISO 14046:2014 WAF can be conducted based on a life cycle assessment (according to ISO 14044) that identifies potential environmental impacts related to water [16]. Different methodologies and tools used for water accounting to calculate water footprint. There are two methodologies available for water footprint i.e. AWARE and Pfister et al. approach. These methodologies based on the water gap model. Pifster approach; utilized the Water Scarcity index (WSI) as characterization factor for water consumption use in life cycle impact assessment to measure potential environmental damage of water use for human health, ecosystem quality and resource. This approach considers both mid-point and endpoint characterization factor for assessing the environmental impacts of fresh water consumption [17].

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III. WATER FOOTPRINTS FOR DIFFERENT INDRUSTRIES

A. *Water Footprint For Food Industry*

Mesfin M. Mekonnen and Winnie Gerbens-Leenes had carried the study on the water footprint of global food production. According to their study agricultural production is the main consumer of water. Future population growth, income growth, and dietary shifts are expected to increase demand for water. This study is a brief review of the water footprint of crop production and the sustainability of the blue water footprint. The estimated global consumptive (green plus blue) water footprint ranges from 5938 to 8508 km3/year. The water footprint is projected to increase by as much as 22% due to climate change and land use change by 2090. Approximately 57% of the global blue water footprint is shown to violate the environmental flow requirements. This calls for action to improve the sustainability of water and protect ecosystems that depend on it. Some of the measures include increasing water productivity, setting benchmarks, setting caps on the water footprint per river basin, shifting the diets to food items with low water requirements, and reducing food waste. Conclusion of their study is that, the unsustainable footprint is dominated by only six crops, wheat, rice, cotton, sugar cane, fodder, and maize, and are located in only five countries, India, China, the US, Pakistan, and Iran. Population growth and dietary shifts, e.g., larger meat consumption, is expected to increase demand for water. The estimated global WF ranges from 5938 to 8508 km3/year, increasing by as much as 20% to 30% between 2010 and 2050 [18].

K. Das, P. Gerbens-Leenes, S. Nonhebel Leenes had carried the study on the water footprint of food and cooking fuel: A case study of self-sufficient rural India. Their study showed the importance of including the WFs of cooking fuel in WF analysis. In self-sufficient rural India, the total WF for cooking, mainly due to the use of fuel wood is twice the WF for food, showing that in the rural areas of India, a developing country, especially fuel wood is water intensive with large impact on freshwater resources. In rural India, the average WF for food is 800 m3/cap/year and for fuelwood m3/cap/year. Green water accounts for 57%, blue water for 30% and grey water for 3% of the total WF of food. Rice and wheat are the main staple foods with large WFs and large contribution to total WFs of food consumption. Rice, wheat, oils and fats contribute most to the total WF of food in rural India. In the north-eastern provinces, rice and wheat WFs together contribute 70% to the total WF. 10-20% of the WF related to wheat consumption. In Madhya Pradesh and Puducherry, in the central and southern part of India, the wheat WF contribution is larger than the rice WF contribution. This is due to the combination of large wheat WF and large wheat consumption. The blue WF ranges from 6m3/cap/year in the north-east to 334m3/cap/year in the central and west region. Blue WFs for food are largest in central India, and in some provinces in the south region. Variations are large among the provinces. Madhya Pradesh has the largest blue WF for food (334 m3/cap/year) and the blue WF from wheat contributes 87%. The smallest blue WF is in Mizoram (6 m3/cap/year). The relatively small blue WF in the east and north-east is due to large rain fed rice consumption. Large blue WFs in the southern provinces are caused by irrigated rice consumption [19].

B. *Water Footprint For Agro Industry*

Alfiana Aulia Firda, Purwanto had carried the study on Water Footprint Assessment in the Agro-industry: A Case Study of Soy Sauce Production. They studied that the sustainable use of water resources nowadays bring challenges related to the production and consumption phase of water intensive related goods such as in the agro-industry. The objective of the study was to assessment the total water footprint from soy sauce production in Grobogan Regency. The total water footprint is equal to the sum of the supply chain water footprint and the operational water footprint. The assessment is based on the production chain diagram of soy sauce production which presenting the relevant process stages from the source to the final product. The result of this research is the total water footprint of soy sauce production is 1.986,35 L/kg with fraction of green water 78,43%, blue water 21,4% and gray water 0,17% [20].

C. *Water Footprint For Textile Industry*

SUN Qing-qing, HUANG Xin-yu, SHI Lei had carried the study on Corporate Water Footprint of Textile Industry: Methodology and Case Study. According to their study corporate water footprint can provide guidelines for enterprises to reduce water consumption and protect the water environment. Based on field survey and literature review a general corporate water flowchart was outlined and a framework was established to calculate corporate blue water, green water and grey water footprint. The blue water footprint refers to consumption of blue water resources along the supply chain of a product. The green water footprint refers to consumption of green water resources. The grey water footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural concentrations and existing ambient water quality standards. Their study explores the potential to calculate the contribution and/or reduction of different measures and seeks to comprehend the internal water use information, such as the entire plant's water balance, detail of water use, water yield for water conservation and recycling measures. Considering a textile and dyeing plant as an example the water footprints before and after a cleaner production audit were calculated. The results show: 1) By measuring per unit production the blue water footprint was reduced by 26.3% to 171t/t; the green water footprint per unit production increased from 0 t/t to 8 t/t; and the grey water footprint per unit production was reduced by 31. 1% to 146 t/t. 2) By conserving and recycling water the blue water footprints were reduced by 17, 700t and 16, 000t, respectively and the grey water footprints were reduced by 486, 000t and 578, 000t, respectively. The research aims to further refine the methodology of the water footprints so that it serves various purposes in different sectors of the industrial society, while striving for coherence, consistency and scientific validity [21].

Sohail Ali Naqvi, Dr Masood Arshad, Farah Nadeem had carried the study on Water Footprint of Cotton Textile Processing Industries; a Case Study of Punjab, Pakistan. Their 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 [22].

D. Water Footprint For Construction Industry

P.W. Gerbens-Leenes, A.Y. Hoekstra, R. Bosman had carried the study on the blue and grey water footprint of construction materials: Steel, cement and glass. As per their study numerous studies have been published on water footprints (WFs) of agricultural products, but much less on WFs of industrial products. The latter are often composed of various basic materials. Already the basic materials follow from a chain of processes, each with its specific water consumption (blue WF) and pollution (grey WF). We assess blue and grey WFs of five construction materials: chromium-nickel unalloyed steel, unalloyed steel, Portland cement (CEM I), Portland composite cement (CEM II/B) and soda-lime glass. Blue and grey WFs are added up along production chains, following life cycle inventory and WF accounting procedures. Steel, cement and glass have WFs dominated by grey WFs, that are 20–220 times larger than the blue WFs. For steel, critical pollutants are cadmium, copper and mercury; for cement, these are mercury or cadmium; for glass, suspended solids. Blue WFs of steel, cement and glass are mostly related to electricity use [23].

Young Woon Kim, Yong Woo Hwang, Hyun Jung Jo, Junbeum Kim had carried the study on Water footprint assessment in expressway infrastructure system. According to their study the water footprint is a useful and important method for calculating water consumption in products and systems. Up to date, many studies on water footprints have focused on the high water consumption sectors of agriculture and livestock products, but few have looked at social infrastructure. The aim of this study is to calculate the water footprint using previous water footprint evaluation methodologies for the expressway infrastructure system and compare the results of each different methodology used for expressway infrastructure systems. Boulay's methodology, the Ministry of Environment's methodology using Ecoinvent, and Ministry of Environment's methodology using Korean life cycle inventory were used and compared. As a result, 58,801 m3 H2Oeq of direct and indirect water was used for 1 km expressway with Boulay method, also 42,030 m3 H2Oeq, and 27,485 m3 H2Oeq, of direct and indirect water was consumed using Ministry of Environment's methodology using Ecoinvent and Ministry of Environment's methodology using Korean life cycle inventory. The study approach and results can support for more sustainable water management in infrastructure system [24].

E. Water Footprint For Steel Industry

Madhuri. G, Ravi Tej Hegde, Sadashiva Murty BM, Srinivas rao RT carried the study on A Review on Water Footprint Study For Steel Industry. According to their study fresh water scarcity is a relevant problem around the globe. Due to increase of pressure on the freshwater resources there is an increase in the water consumption and pollution, the water footprint and subsequently, water footprint assessment developed for sustainable environment. Their study mainly discusses about the components and phases of water footprint, different methodologies used for conducting the water footprint study in the industry and significant use of water footprint assessment in steel supply chain. This paper helps the decision maker to understand impacts of production process on water resources, formulates the strategic actions to reduce the impacts on water resources and this will also help for sustainable water management [25].

IV. CONCLUSION

This review paper summarizes on water footprint and water footprint assessment can be helpful for sustainable water use for different industrial purpose. The methods presented in this paper help to know about the water risk, water scarcity and other water related challenges faced by human beings and helps in decision making for strategic actions based on the impacts on water resources that may be caused due to production process for different industry. This review required updates and developments, which can support and improve further studies for better water governance.

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