A Review on Water Footprint Study For Steel Industry

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Abstract- *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. This paper 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.*

Keywords- Water footprint, Water footprint assessment, Water consumption, indirect water, direct water use.

I. INTRODUCTION

Water is one of the important fundamental resource of life on earth. Our earth is covered by 70% of water. However, 97.5 % of this water available as sea water (i.e. salty). Fresh water Availability only 35 m Km^3, out of the total fresh water, 68.7 % frozen in ice caps, 30 % of it-stored underground, and 0.3 % is available as fresh water on the surface of the earth. Out of surface water, 87 % is stored in lakes, 11 % in swamp and 2 % in river. Only 1 % is available for human beings [1]. Due to increase in population, there is an increase in the demand of fresh water, approximately 69 % of global fresh water used for agriculture, and 22 % for industrial activities, 8 % for domestic purpose and 1 % for recreational purpose. Due to displacement or degradation of Freshwater, water can become unavailable to some users [2]. Among various continents, the availability of fresh water reserves in Asia is 36 %, with over 60 % of world population where water is scarce commodity. Availability of natural resources for the people of India inequitably distributed at global level. Presently with, 2.4 % of land and 4 % of water resources, India has to support 16 % of the world population and 15 % of the livestock. Per capita water availability in India for 2010-977 m^3, 2025- 806 m^3 and 2050- 685 m^3. Industrial consumption in India for 2010-37 Km^3, 2025- 67 km^3 and 2050- 81km^3. Indian steel industry consumption for 2017-450Mm^3 considering around 90 million tonne of production with average 5 m^3/t steel produced. India is the third largest producer of steel in the world with a capacity of 90 million tonnes. Iron and steel plants in India have a specific water consumption of nearly 3.3 m^3/tonne of crude steel. Globally best benchmark of nearly 1.0 m^3/tcs represents a significant opportunity for water conservation [3]. The quantity of water used in the iron and steel industry varied and depends on the availability of water, kind of plant process, equipment, age and condition of plant. Water use in iron and steel industry generally classified based on the definitions given by [4] process water, cooling water, boiler feed water, sanitary and service water. Most of the water in iron and steel industry used for cooling, protecting the equipment and a small amount of water is used for concentrate of iron ore, quenching of coke and slag, coke oven gas cleaning and descale steel. (Water Requirements of the Iron and Steel Industry report). Due to this, there is an increase of pressure on the fresh water resources. Currently, more than 2.7 billion inhabitants in 200 basins live with water scarcity at least one month in a year [5]. In order to sustain life on earth, the impact of human activities (industrial production included) on fresh water resources have to be assess and included in sustainability assessment [6]

To better, understand the linkages between humanity's productive activities and growing pressure on the world's freshwater resources. The water footprint and subsequently Water Footprint Assessment (WFA) developed to measure the amount of water consumed and the pollution assimilation capacity used throughout a product's value chain and to assess its sustainability within both the local and global context [7]. The International Organisation for Standardisation has developed a framework standard for calculating a water footprint (ISO 14046:2014), published in July 2014 (world steel association) A WF assessment is based on an LCA approach (Environmental Management-Life Cycle Assessment-Requirements and Guidelines) which is commonly used in different sector both for environmental and sustainability analyses.

II. THE WATER FOOTPRINT CONCEPT

The origin of water footprint came from concept virtual water used by [8], virtual water is the volume of water required to grow, produce and package agricultural commodities and consumer goods, virtual water referred as embedded water' or 'hidden water'. Based on the concept of virtual water, [9] have quantified virtual water for international food trade that leads to the development of water footprint concept. Later [10] subsequently elaborated water footprint as an indicator of human appropriation of fresh water resource that incorporates both direct and indirect water use of a consumer or product. Water footprint in case of products, is the total volume of fresh water used to produce product, summed over the various steps of the production chain [11]. As per ISO define 14046:2014 water footprint can be defined as metric(s) that quantifies the potential environmental impacts related to water [12] (Environmental management **-** Water footprint **-** Principles, requirements and guidelines). Water footprint has three components blue, green and grey water footprint. The blue water footprint is the amount of surface and ground water consumed or incorporated in to the product or returns to other catchment area. The green water footprint refers to the volume of rainwater evaporated, which is stored in the soil. The grey water footprint refers to the volume of water required to assimilate the load of pollutants to meet the ambient water quality standards. **[**13]. In addition to the above components there are other components of water footprint, which is used for industrial water footprint of a product they are direct or operational water footprint and indirect or supply chain water footprint. Direct or operational water footprint refers to the amount of fresh water consumption associated with the water use of a consumer or a producer or fresh water consumed at a specific business unit. Indirect water footprint refers to the fresh water consumption that can be associated with the production of the goods and services consumed by the consumer or the amount of fresh water consumed to produce all the goods and services that form the input of production at the specific business unit [14]

III. 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 [7] Earlier studies mainly focused on the agricultural water footprint for national and regional level. This paper discusses about literature on water footprint for steel industry. Industrial water footprint mainly focuses on the water use in the operations; it includes both direct and indirect water footprints. Direct water footprint calculated for particular business unit, while the indirect water footprint calculated for production of all goods and service inputs for production. 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 [12]. 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 end-point characterization factor for assessing the environmental impacts of fresh water consumption [15]. A water scarcity index (WSI), indicates the water consumption impacts in relate to the water scarcity, is proposed as a mid-point characterization factor. [15] Recommended the water use assessed at watershed level. It also accounts for monthly and annul variability precipitation as well as watersheds with strongly regulated flows. The severity of water scarcity of watersheds ranked as follows: WSI < 0.1 low; 0.1 < WSI < 0.5 moderate; 0.5 <water stress indicator < 0.9 severe and WSI > 0.9 extreme Using WSI water footprint calculated as

WF (Pfister) = (water withdrawal-discharge) * WSI (Eq 3.1)

AWaRe approach; Available Water remaining (AWaRe) used as a water use mid-point indicator. That represents relative Available Water remaining per area in watershed, after meeting the demand of humans and aquatic ecosystem. AWaRe assesses the potential of water deprivation, to either humans or ecosystem, building on the assumption that the less water remaining available per area, the more likely another user will be deprived it can be calculated as follows,

Water scarcity footprint=water consumption (inventory)* (1/availability-demand) (Eq 3.2)

[16] have calculated Water footprint of iron and steel industry in Eastern china. The study includes Direct and Virtual water footprint; they propose system boundary for production process of steel industry. They studied the life cycle withdrawals consumptive water use and wastewater discharge of china's regional energy sectors by using a Mixed-unit multiregional input-output (MRIO) model. For selected

iron and steel industry, the blue water footprint (total water consumption) footprint was $2.44*10^7$ m^3 and the grey water footprint was $6.5*10^8$ m^3 in 2011, this indicates that the enterprise poses a serious risk to the water environment. [17] conducted the water scarcity assessment of steel production in national integrated steel making rout, the water scarcity indicators for each unit processes in the integrated steel making rout was calculated, the water scarcity indicators were calculated with SimaPro8 software and Ecoinvent database 3. Raw material that contributing to indirect blue water footprint are iron ores, iron pellets, refractory, iron scrap, electricity and lubricant oil. The largest water scarcity in the entire steel production system occurred in the basic oxygen furnace system and major scarcity was tape water and iron ores. [18] Tata Steel- Jamshedpur (TSL-Jamshedpur) performed water footprint assessment of steel supply chain, which is located on the Subarnarekha river basin. For water footprint, accounting TSL-Jamshedpur considered fiscal year 2012 and the first five months of 2013. The direct blue and grey water footprint conducted for TSL-Jamshedpur, which includes Raw Materials Division, Coke, Sinter & Iron Division, Flat Products Division and Costumers. The direct blue water footprint was 24.9 million m3/year, the total grey water footprint was 15.2 million m3/year which was calculated for the pollutants TSS, NH3, CN, phenol, oil and grease, BOD5 and COD. The green water footprint of approximately 18 hectares of greenery was 122,500 m3 /year. The total indirect blue water footprint was 5 million m3 /year. The blue water footprint of TSL-Jamshedpur includes both direct and indirect water footprint and total amount was 30 million m^3 and the product blue water footprint of 4.21 m3/ton of steel. The results of water footprint assessment of Tata steel supply chain have developed eight strategic responses to reduce the water footprint of the supply chain. [19] Have conducted the water footprint study for Basic oxygen furnace (BOF) crude steel and Electric arc furnace for crude steel in Japan, China and US. They calculated the water withdrawals for upstream life cycle till the production of the crude steel. The estimated WF for BOF crude steel and EAF crude steel in japan was 0.62 m^3/t and 0.85 m^3/t, in china the estimated WF for 0.99 m^3/t. They have not compared the results of US pig iron, crude steel and ferroalloy with japan and china because it is difficult to segregate each sector. [20] Presented the water footprint assessment for steel production. They consider steel production in the United States from Iron ore to raw steel. To quantify water footprint, three scopes were consider, (scope 1) water use in the process directly; (scope 2) indirect water use through the energy used to perform the process; (scope 3) water used to produce process inputs. Each scope splits in to two categories: water use and water withdrawals. Coke production process was the largest portion of water use in steel making, 98 % of total water used in the coke production process. For steel manufacturing process, from raw materials to unalloyed steel, eight processes were analysed, with respective to scope 1 and 2.scope 2 water employed to produce energy used was 0.279 l and non-consumptive water withdrawal of 6.327 l. The data for water use calculation taken from Ecoinvent Database (Swiss Centre for Life Cycle Inventories, 2007). For scope 1 the water usage for the production of 1kg of steel was 12.800l and percentage of water used was 1.18 %. For scope 2, the indirect water footprint was 0.279l/ kg of steel produced and percentage of water used was 0.04 %. For scope 3 the water used to produce the process inputs was 692.11l and percentage of water used was 98.11%.

IV. CONCLUSION

This review paper summarizes on water footprint and how water footprint, water footprint assessment can be helpful for sustainable water use for industrial purpose, assess relevant methodologies for conducting the water footprint study for different industry. 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. This review required updates and developments, which can support and improve further studies for better water governance.

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