WATER FOOTPRINT SIGNIFICANCE IN STEEL SUPPLY CHAIN MANAGEMENT

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Abstract

Significance of water footprint assessment in steel supply chain will be discussed in the paper. Water footprint (WF) is new concept which allows quantification of freshwater appropriation. The main goal of WF is quantifying and mapping of indirect water use in the relevance of involving producers and consumers along chosen supply chain. This helps by sustainable water resource management. Components and phases of water footprint will be presented. Steel supply chain encompasses all those activities needed to design, manufacture and deliver steel. The aim of this paper is to show importance of water footprint in steel supply chain to demonstrate the effect of effective inventory management of water use for higher eco-efficiency of steel supply chain. This paper can help practitioners and decision makers in the steel supply chain field understand their impacts sustainability of water sources and formulate strategies to decrease water footprint.

Keywords: water footprint, steel supply chain, eco-efficiency, life cycle assessment

1. INTRODUCTION

Problem of water resources consumption and water management becoming more important for the iron and steel industry. According to World Steel Association water is an essential resource for steel production and water management is one of the most important part of the steel industry's sustainability roadmap. The consumption and discharge of water for the steel production (integrated steelmaking route) are 28.6m^3 and 25.3m^3 per tonne of steel respectively while the consumption and discharge of water for the electric arc furnace route (EAF) are 28.1m^3 and 26.5m^3 per tonne of steel produced. The steel industry uses saltwater, brackish water and freshwater. Water is used mainly for once through cooling - over 81% in relation to total intake [1] but also for direct and indirect cooling, gas cleaning, scale breaking and washing operations including waste gas cleaning with scrubbers [2]. Polish steel industry water usage in 2012 was drop by 15% on the back of lower steel output. Effluent discharged to sewage systems was up 15%, while clean water discharged to water bodies or soil decreased to water bodies or soil decreased by 1.5. [3] Other problems related with steel supply chains were presented in [4,5]. Up to now the most often was presented carbon footprint and improvement in raw materials for steel industry [6, 7, 8]. Determinants of eco-efficiency improvement in energy supply chain within coal were presented in [9]. Fang [10] presented a selection of footprint indicators by combining the ecological, energy, carbon, and water footprints as potential members into a footprint family. In this paper the water footprint is presented as a factor which influences decisions in steel supply chains.

2. WATER FOOTPRINT CONCEPT AND METHODOLOGY

The importance of environmental protection in supply chain management leads to solutions for water resources. Life cycle assessment (LCA) also takes into account the importance of water use and included impacts related with water use in research with life cycle approach.

The water footprint methodology was introduced by Hoekstra [11, 12] as an indicator of freshwater appropriation, with the aim to quantify and map indirect water use and show the relevance of involving consumers and producers along supply chains in water resources management. LCA community developed comprehensive methodologies to include environmental impacts related to water in LCA studies and started to frame the main concepts in the forthcoming international standard on water footprint (ISO 14 046) [13]. A water footprint is the amount of water used to produce a product. To complete a full water footprint, it is necessary to include direct and indirect water usage. Direct use is water that physically is used during a process, while indirect use is water needed to create something used in the process. So the water footprint is an indicator of freshwater use (direct and indirect) in production or consumption.

Cradle-to-grave analysis is used to break down the total production, from raw materials to final product, into individual processes. The LCA technique aims at quantifying potential environmental impacts on a wide range of environmental issues. Water use is one of the potential causes of impact. LCA includes potential impacts from the emitted contaminants affecting water, through many impact category: eutrophication, acidification etc. A full Water Footprint assessment methodology consists of four phases (see **Fig. 1**) [12, 14, 15].

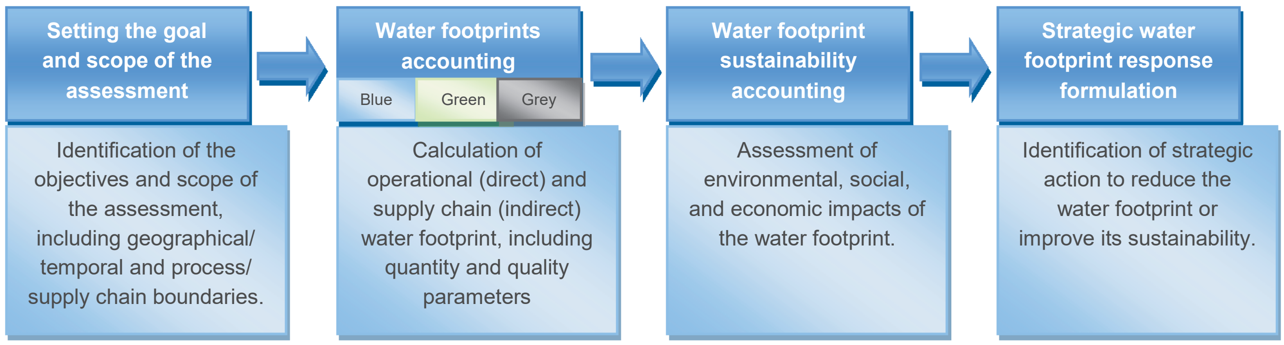

Fig. 1 Phases of Water Footprint assessment [12]

The water footprint accounting stage includes the quantification and mapping of freshwater use with three types of water use [12]:

- Blue water footprint - refers to consumption of surface and groundwater through evaporation, incorporation into the product or return flow to a different water body than from where it was drawn.
- Green water footprint - refers to evapotranspiration by plants of rainwater stored in the soil as soil moisture.
- Grey water footprint - refers to pollution and is defined as the volume of freshwater required to assimilate the load of pollutants to meet local ambient water quality standards.

Water scarcity, one of the environmental assessment aspect, is quantified as the ratio of water use to water availability. Water Footprint Assessment focuses on studying the sustainable, efficient and equitable allocation and use of freshwater in local and global context with either a technology, product and geographic focus [13]. Water Footprint should be measure with life cycle approach and global analysis [14]. It shows that the non-consumptive part of water withdrawals (the return flow) is not part of the water footprint. It also shows that, contrary to the measure of “water withdrawal”, the “water footprint” includes green and grey water and the indirect water-use component [12]. The distinction between direct and indirect is made in WF accounting. The total WF of a consumer or producer refers, by definition, to the sum of the direct (operational) and indirect (supply-chain) WFs of the consumer or producer.

3. WATER FOOTPRINT CONCEPT IN STEEL SUPPLY CHAIN MANAGEMENT

The form of water footprint assessment depends on the focus of interest. It can be the water footprint, which focus on the specific process or step in a whole production in supply chain, or on a final product. The analysis of water footprint in steel supply chain is complicated and can be conducted in many ways. Hoekstra A.Y. [12] gives possible ways for water footprint assessment:

- of an intermediate or final product (good or service) is the aggregate of the water footprints of the various process steps relevant in the production of the product,
- of a producer or whatever sort of business is equal to the sum of the water footprints of the products that the producer or business delivers.
- within a geographically delineated area - be it a province, nation, catchment area or river basin - is equal to the sum of the water footprints of all processes taking place in that area.
- of consumers is related to the water footprints of the producers in the supply-chain.

Connections between presented varieties of water footprint accounts are shown in the **Fig. 2** and leading to water footprint of one single process.

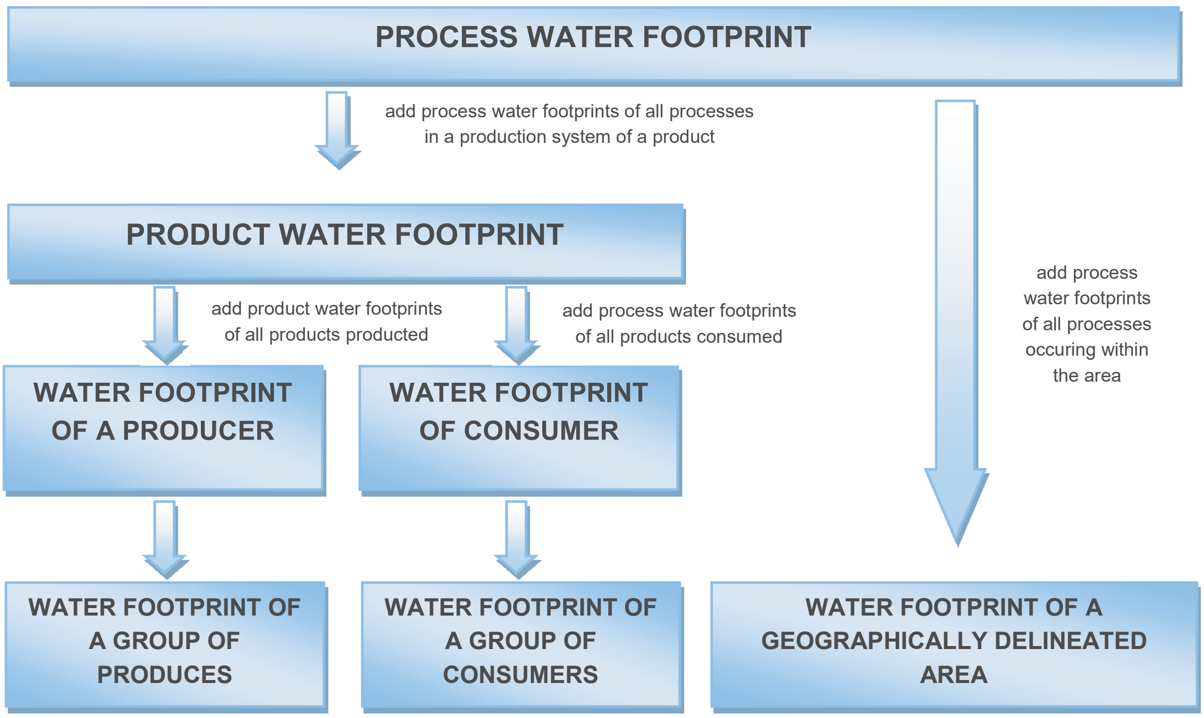

Fig. 2 Process water footprint as the basic building block for all other water footprints [12]

Steel supply chain consists several entities (such as customers, distributors, manufacturers, and suppliers), each of them contributes materials, resources, and activities and become an important part of value creation process in the chain. Optimal result of process realization in supply chain requires integration of the entities at the structural level and integration of their individual systems. **Fig. 3** present a typical steel supply chain structure from the mining of the iron to the product and direct and indirect water footprint at each stages of the supply chain.

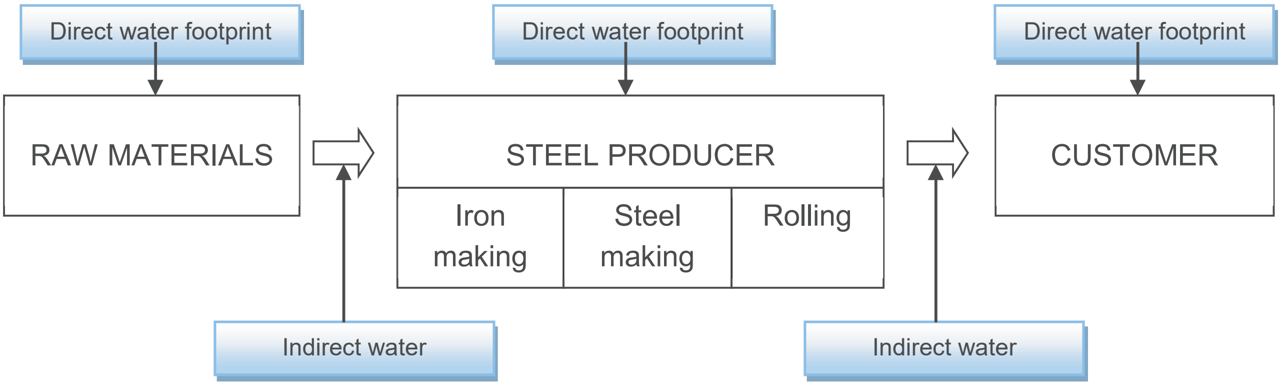

Fig. 3 Steel supply chain and its water footprints

There are not so many study containing the water footprint assessment in steel industry, but the first comprehensive industrial water footprint assessment of steel supply chain was performed by Tata Steel [17]. Case study - The Tata Steel Ltd. (TSL) plant under study is the Jamshedpur facility (TSL-Jamshedpur) in the Subarnarekha river basin. The data used in the water footprint accounting for TSL-Jamshedpur come from fiscal year 2012 and the first five months of 2013. Steel supply chain for TSL-Jamshedpur contains: Raw Materials Division, Coke, Sinter & Iron Division, Flat Products Division and Costumers. The direct blue and grey water footprint of TSL-Jamshedpur includes water footprints for all of the above processes. TSL-Jamshedpur's direct blue water footprint is 24.9 million m^3/year.

Apart the direct blue water footprint, also other kind of water footprints was also being analysed [17]:

- Direct Grey Water Footprint cover five different pollutants within total suspended solids is the critical pollutant for Tata Steel. The total grey water footprint of the facility was 15.2 million m^3 in 2012.
- Direct Green Water Footprint isn't associated with production, but it was calculated as part of the facility's overhead. The green water footprint of approximately 18 hectares of greenery is 122 500 m^3/year.
- Three raw materials that contribute most to Indirect Blue Water Footprint are iron, ore, coal, and limestone. Total indirect blue water footprint was approximately 5 million m^3 for 2012.
- Tata Steel Blue Water Footprint of the Product includes both direct and indirect blue water footprints and total amount to 30 million m^3, resulting in a product blue water footprint of 4.21 m^3/ton of steel.

As a result of water footprint assessment in Tata Steel supply chain there was developed a strategy of short and long term cost limitation which includes blue water footprint reduction. Eight response strategies were detailed for the water footprint reduction cost. The detailed cost calculation and efficiency analysis showed that five of them and the installation of new drains would result in cost savings.

Other example of water footprint assessment for steel production was presented by Kluender [18]. It takes into consideration steel production in United States from iron ore to raw steel, to quantify a whole water footprint. It was calculated three scopes for water use in steel production (see **Table 1**) [19]. Each of the three scopes can be split into two categories in their own right: use and withdrawal.

The process that was responsible for the largest portion of water use was the production of coke. Coke processing (scope 3) uses 98% of the total water needed and should receive the greatest attention in efforts to reduce water use in steel production. For the full steel manufacturing process, from raw materials to unalloyed steel, eight processes were analysed, each with respective scopes 1 and 2. Scope 2, the energy water footprint, gives a consumptive water use of 0.279 l and a nonconsumptive water withdrawal of 6.327 l. These numbers were calculated using the energy breakdown of the entire United States in 2010. Because steel is made all over the world and different locations within the U.S. differ, scope 2 calculations will vary by location. Ecoinvent does not explicitly include any data for nonconsumptive water use for any processes; all water data is classified as an input (direct).

Table 1 Scopes for water use in steel production (based on [17, 19])

No	Description		Water use to create 1 kg of steel	
			[liter]	[%]
Scope 1	Direct water use in the process	Direct water usage is the most straightforward use of water - This includes any water used during the process such as the water that is incorporated into the final product and the water used to cool or lubricate.	12.800	1.81
Scope 2	Indirect water usage through the energy used to perform the process	Indirect water consumption is more challenging to visualize and is accounted for in scopes 2 and 3	0.279	0.04
Scope 3	The inputs of the process - the water used during manufacturing to create the materials that are consumed.	To calculate a complete scope 3, it is necessary to fully work up the product's life cycle (cradle-to-grave).	692.100	98.15

The first study of water footprint in for steel industry in Taiwan was performed by CSC appointed the Utility Department and Rolling Mill Department [20]. It was established the water consumption data for the steel coil process, major raw materials (coal, iron and limestone) and upstream processes (iron, steel making and billet) of the 1st hot rolling plant.

Horie et al. [21] calculated the water footprint for basic oxygen furnace (BOF) and electric arc furnaces (EAF) crude steel and amount of water withdrawal for upstream life cycle until producing crude steel in Japan and China. It was determining the WF as the quantity directly water used (direct withdrawal), and the quantity indirectly water used (indirect withdrawal). In Japan WF for BOF crude steel was estimated as 0.62 m^3/t, whereas WF for EAF crude steel was estimated as 0.85 m^3/t. In China WF of crude steel was estimated as 0.99 m^3/t.

CONCLUSIONS

In recent years water resources availability has become one of the most important element of sustainable steel supply chain management. The main goal of this paper was to develop a water sustainability framework and promote sustainable water use over the entire the steel supply chain. Application of WF concept can bring many benefits in steel supply chain management and allows calculation of water use within direct operations and indirect in the steel supply chains, creation environmental management strategies to WF decrease and benchmarks the various water-using processes along the steel supply chain.

Water Footprint Assessment provided practitioners and decision makers in the steel supply chain field the foundation for developing a comprehensive sustainable water management strategy. Examining the amount of water within both direct operations and throughout the supply chain, and assessing the sustainability, efficiency and equitability of water use bring instructions for future activities concern technology, operations and organization of supply chain. It could also bring benefits from restraining impacts on cost and environment through decrease water footprint.

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