Comparison of Water Footprint for Industrial Products in Japan, China and USA

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Abstract Recently, water scarcity has received attention. With the development of industries and the growth of population, the amount of water use has increased. In order to evaluate the water use of industrial products, the method of estimating water footprint (WF) has been developed. WF is defined as the amount of water use during the lifecycle of products or service. In this study, we estimated WF of industrial products in Japan, China, and the U.S. using input-output analysis. It was found that WF for BOF crude steel in Japan was estimated as 0.62 m^3/t, whereas WF for EAF crude steel in Japan was estimated as 0.85 m^3/t. WF of crude steel in China was estimated as 0.99 m^3/t. In the U.S. the pig iron, crude steel and ferroalloy can not be devided into each sector, so we cannot compare the results of the U.S. to those of Japan and China. In WF for a passenger car, the indirect water use dominated their WF in all countries. To compare the results in each sector between countries appropriately, consistency of industrial sector in the data for water use is required.

1 Introduction

Water is indispensable for life. According to Japan’s statistics for 2006, approximately 15.7 billion m3 of water was used in private households, while approximately 12.6 billion m3 was used in industries, and 54.7 billion m3 was expended in the agricultural sector. Looking at worldwide figures, as populations grow and industries continue to develop, it is clear that we will require larger quantities of water in the future. Thus, potential shortages are cause for concern. This situation highlights the increased importance of accurately evaluating water withdrawals during product manufacturing. To facilitate such evaluations, the water footprint (WF) concept is being put forward as a means for quantifying the water amounts required to produce a certain product, as well as the quantity that product will require over its lifecycle. When determining the WF, we designate the quantity of water required in the various manufacturing processes as the quantity directly used (direct withdrawal), and the quantity indirectly used (indirect withdrawal). Kondo et al. calculated the water quantities used directly in various industries, and then, using input-output analysis, calculated the WF of various Japanese industrial products [1]. Blackhurst et al. calculated the WF for the primary, secondary and tertiary industry segments of the U.S., using input-output analysis [2]. Zhao et al. used a comparable method to calculate the WF for 23 segments in China [3].

In this work, we focus on water consumption for industrial products, especially, in the iron and steel industry. In order to investigate limitations to the water necessary for future steel production demands, it was first necessary to calculate the WF for various regions where steel is produced and compare them. However, no detailed analysis has been conducted to determine China's steel WF. Furthermore, no studies have yet been performed that compare the WF of the same industrial products in different regions and countries. Thus, the objective of our research was to calculate the WF of industrial products (primarily steel) in Japan, China and the U.S., and then to conduct a comparative evaluation.

2 Method

In our research, we used input-output (I-O) analysis to calculate the WFs of various industrial products. Using I-O analysis we can calculate the WF with the equation(1)

$$W = d(I - (I - M)A)^{-1} \quad (1)$$

Here, I is the identity matrix, M is the import coefficient matrix, A is the input coefficient matrix, and d is the vector for direct water withdrawals.

The data availability of water withdrawal varied from one country to another. Therefore, when calculating the vector d for direct water withdrawals, we used different methods for each country.

For Japan, according to the Industrial Statistics Report by Industrial Site and Water [4], a publication of the Ministry of Economy, Trade and Industry, direct withdrawals in various industries have been determined for the water quality such as industrial water, public water consumption, groundwater, other freshwater, and seawater. Also the withdrawals have been determined for the water usage such as cooling usage, boiler usage, water for material use, product treatment, rinsing, and other applications. In our research, in order to calculate freshwater withdrawals, we considered both direct and indirect withdrawals for industrial and private water consumption, in addition to groundwater use. In contrast, seawater withdrawals were not considerd. Because the number of industrial sectors in the statistics [4] is larger than that in the I-O table in 2005 [5], we aggregated the industrial sectors (560 sectors) into 246 in accordance with the literature[6].

For China, data for industrial waste water were obtained [7]. Then, we assumed that the water withdrawals could be equivalent to the waste water quantities. The industrial waste water data for China were obtained for 38 industrial sectors. Therefore, we allocated them into 89 corresponding industry sectors in the Chinese input-output table in 2007 [8], based on the transaction value for the "Production and Distribution of Water" item in Chinese input-output table in 2007.

For the U.S., obtained were water withdrawal data [9] for eight different items (Public Supply, Domestic, Industrial, Irrigation, Livestock, Aquaculture, Mining and Thermoelectric). So, these were allocated to 279 industry types in the U.S. input-output table in 2002 [10] according to the previous study [3]. WF per economic value of each industry were calculated by equation (1). Then, we multiplied this by the producer price of each product to find the per-ton or per-unit WF.

Tab. 1: Comparison of data sources and estimation methods in the three countries

Country	Data on direct water withdrawal	The number of sectors for industry in I-O tables	Method of allocation or aggregation
Japan	Industrial water withdrawals for 560 sectors	246 sectors	Using the code correspondence table
China	Industrial waste water for 38 sectors	89 sectors	Using the transaction value for the "Production and Distribution of Water"
The U.S.	Water withdrawals for 8 sectors	279 sectors	Referring to the former study [3]

3 Results

Figure 1 and 2 show the results of the WF calculated for Japan, China and the U.S. using the technique described in Section 2.

Figure 1 shows the results of the WF for the iron and steel industry in each country. As shown in Figure 1, the industrial classifications are defferent in each country. For example, classification of the industry in the U.S. I-O tables includes pig iron, crude steel and ferroalloy, so we can not compare the result to other countries. Figure 1 shows that the WF for the pig iron and crude steel in Japan were smaller than those in China. Especially for the pig iron, the WF in China is about twice as large as that in Japan.

Figure 2 shows the WF for a passenger car in each country. Every country has a sector related to passenger car in I-O tables. The Chinese I-O table has a setor named "Automotive", which includes trucks, buses, passenger cars, motor cycles, and bicycles. Therefore, we converted all of them into passenger car equivalent on the basis of the price ratio in Japan. The WF in the U.S. is about 1.4 times as large as that in Japan. For all three countries, we found that indirect withdrawals accounted for almost all WF in the automotive sector. However, there are uncertainties due to the data availability, so further study is required with more accurate data in detail.

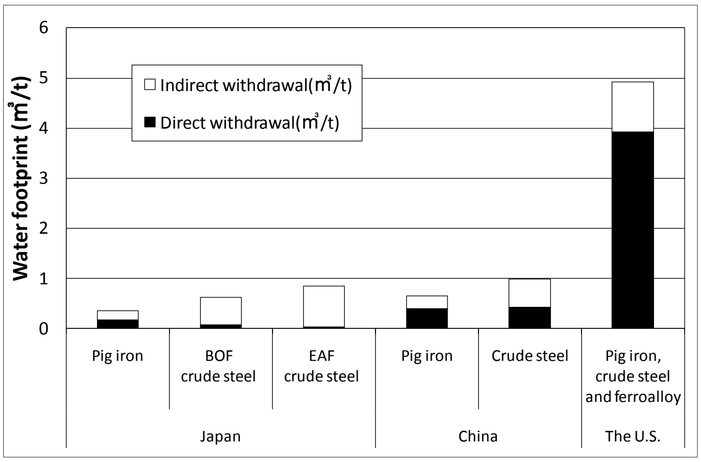

Fig. 1 The WF for iron and steel industry in Japan, China and the U.S.

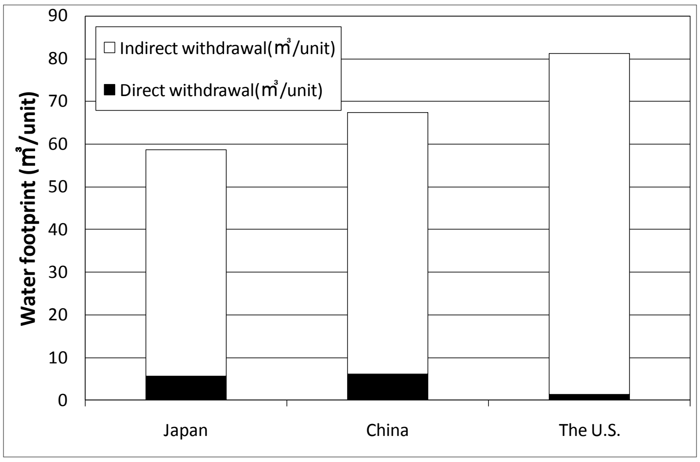

Fig. 2 The WF for a passenger car in Japan, China and the U.S.

4 Discussions

Using the calculated WF, we estimated the total amount of water withdrawal for upstream life cycle until producing crude steel in Japan and China. Table 2 shows the WF for crude steel and the amount of crude steel production [11]. The results are shown in Table 3. As Table 3 shows, 73 million m^3 of water was used for crude steel in Japan, and 620 million m^3 in China. If we can produce the amount of Chinese annual crude steel production with the water efficiency in Japan , we can save one-third of water use for crude steel in China.

Tab. 2: The WF for crude steel and the amount of crude steel production in Japan and China.

		Annual crude steel production in 2007 (1,000t)	**WF for crude steel(m^3/t)**
Japan	BOF crude steel	85,756	0.62
	EAF crude steel	23,845	0.85
China		626,654	0.99

BOF: basic oxygen furnace

EAF: electric arc furnace

Tab. 3: Total amount of water withdrawal for upstream life cycle until producing crude steel in Japan and China

		Total amount of water withdrawal for upstream life cycle until producing crude steel (million m^3)
Japan	BOF crude steel	53
	EAF crude steel	20
China		620

5 Conclusions

In our study, we calculated the WFs of industrial products (such as iron, steel and passenger cars) for Japan, China and the U.S. and compared them. It is expected that the needs for steel products and cars will be larger. We quantified the water needs for producing process of industrial products. However the water data from different sources was used when calculating the WFs of the three countries, as were differences in the industrial classifications in the input-output tables of the countries. Therefore the WF in three countries were compare under some assumption. In the future, we believe it will be necessary to determine the WFs more precisely, by use of various other methods, such as compiling more detailed data concerning each classification.

6 Reference

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