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COMPARING WATER FOOTPRINT METHODS: THE IMPORTANCE OF A LIFE CYCLE APPROACH IN ASSESSING WATER FOOTPRINT

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Keyword: Water footprint, Water use, Life cycle assessment

Summary

Today many people are suffering because of water scarcity, and still, water scarcity is supposed to be a growing problem. Water footprint is a tool developed to assess impact related to water use and consider both water consumption and degradation. This study aims to compare two such water footprint methods, the H2Oe-method and the WFN method, and identify the different hotspots for water use in a supply chain at Volvo Trucks. The overall result of the first method, the H2Oe-method, was 2.6 Mm^3 H_2Oe while the result for the second method, the WFN-method, was 13.1 Mm^3. The largest contribution to water footprint for the first method was the degradative part, mainly from the background process of a precipitation chemical. The second method had the largest contribution from water consumption in the use electricity. The results show the importance of a life cycle perspective when calculating water footprint and the difficulties to compare water footprint calculated with different methods.

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1. Introduction to the concept of water footprint and the aim of this study

Water is an important resource for all life on our planet and clean water and sanitation should be a human right. But today, more than 780 million people do not have access to safe drinking water and 2.5 billion people do not have enough water for sanitation (The world bank, 2013). The global scarcity is supposed to increase in the future (Jefferies, et al., 2012). But we may yet be able to prevent an increased scarcity, if our water resources are correctly managed.

This study focuses on one of the many areas where water is used: the automotive industry. Industrial activity is a huge contributor to the pollution and the unstable situations of water resources (Yan, et al., 2013). Since water is used in many steps in a value chain, it was of interest to include the total amount of water by making a life cycle assessment. The aim of the study was to use and compare different methods to specify environmental impact from water use.

The concept of water footprint was introduced in 2002 by Hoekstra et al. as a comprehensive indicator for freshwater use (Hoekstra, et al., 2011). The concept has since then been developed into many different methods, and the calculation of water footprint can vary (Chapagain & Orr, 2008). This study concerns water footprint methods using volumes of water for both consumptive and degradative use, in a life cycle perspective. This means that the methods consider the actual amount of water used and the water affected by pollution, also for background processes.

2. Theory of selected methods and description of the case study

This study uses two separate methods to calculate water footprint for a case study of truck production at Volvo Trucks, Sweden. The methods in this study use different approaches for calculation of water footprint, thus making it interesting to compare the results. The selection of methods was based on the criteria that the methods should consider both water use and degradation (emission to water). They were also selected to reflect a general expression of water footprint in terms of volume, instead of focusing on a certain area of protection. A life cycle assessment (LCA) was made on the case study's baseline technology scenario, and the water footprint methods were used to assess water use based on inventory data.

Life cycle assessment and water use

Water has not been an important category in LCA, but today there are methods developed to evaluate freshwater use in LCA. Water footprint methods related to LCA vary from simple water inventories to complex impact assessment methods. An LCA consist of four phases, Goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation (Hoekstra, et al., 2011). Those phases should be included according to the international standards for LCA. The goal and scope phase clarifies the reason to carry out the study and the system boundaries, the inventory phase results in the input and output flows, the impact assessment evaluates the environmental impact related to the flows and in the last phase, the interpretation, the results are evaluated regarding to the goal and scope of the study (ISO 14040).

The case study of Volvo Trucks, a part of the FP7 project EcoWater

The case study of this study was the water value chain at Volvo Trucks, representing Swedish automotive industry, in the research project EcoWater. This research project is supported by the 7th

Framework Programme of the European Commission and the purpose of the project is to *develop meso-level eco-efficiency indicators for technology assessment* (EcoWater, 2011).

The results are here presented for the manufacturing site in Umeå, where the annual production was 30,000 cabins, which also was used as functional unit of the LCA model. The water value chain was defined as four different steps in the model; water abstraction, water treatment, water use and wastewater treatment. The flows included in the system were water, electricity, thermal energy, precipitation chemical, chemical for pH adjustment, chlorine and pollutants of COD, P, Ni, Zn in wastewater (Table 1).

Table 1. The four different steps in the case study listed together with the component used during the different steps.

Steps in the case study	Component at the step (percent of total component)
Water abstraction	Water, Electricity (7)
Water treatment	Electricity (1)
Water use	Electricity (91), thermal energy
Wastewater treatment	Electricity (1), precipitation chemical, chemical for pH adjustment, measurements of COD, Tot-P, Ni and Zn in wastewater

The first method, the H_2Oe-method, using WSI and Eco-points to calculate water footprint

The H_2Oe-method uses water equivalent (H_2Oe) as the reference unit, and accounts for consumptive (CWU, equation 1) and degradative (DWU, equation 2) water use (Ridoutt & Pfister, 2012). In this method the total water consumption is summarized, in terms of local water stress index (WSI_i) and local water consumption (CWU_i). DWU, the critical dilution volume for water degradation, is expressed in terms of ReCipe points for the product system and the global ReCipe point value. The global Recipe point is weighted for the global average consumption of one litre CWU and is calculated to 1.86 x 10^{-6}. Water footprint is calculated as the sum of consumptive and degradative water use (equation 3).

$$CWU(H_2O) = \sum_i \frac{CWU_i \times WSI_i}{WSI_{global}} \tag{1}$$

$$DWU(H_2Oe) = \frac{ReCipe\ points\ (emission\ to\ water\ for\ product\ system)}{ReCipe\ points\ global\ (average\ for\ 1L\ consumptive\ water\ use)} \tag{2}$$

$$Water\ footprint\ (H_2Oe) = CWU(H_2Oe) + DWU(H_2Oe \tag{3}$$

Recipe point is itself an LCIA method (Goedkoop, et al., 2013).

The second method, the WFN method, using amount of water and a dilution volume to calculate water footprint

Water footprint with the Water Footprint Network (WFN) method is calculated as the sum of water used in all processes included to produce the product. This method considers blue, grey and green water. Green water is not included in this study, since green water footprints primarily are calculated for products based on plants or wood. But the other two, blue and grey water footprint, are included. Blue water is the consumptive use of fresh surface or groundwater and grey water is the volume of freshwater needed to dilute the outgoing waste water to a harmless concentration. The grey water volume is a fictional water volume, not actually used (Hoekstra, et al., 2011).

3. Results

There are both differences and similarities between the methods. One difference is that the results vary by an order of magnitude of 10 between the two methods. Since the input of water was the same in both calculations, the results clearly show a difference between the methods. Another discrepancy is the difference among the method when the water use processes are assumed to be located in other countries. One important similarity of the two methods is that the main contributors to the water footprint are located in background processes.

Water footprint calculated with the different methods

The total water footprint calculated with the H2Oe-method for 30,000 cabins is estimated to 2.6 Mm^3 H_2Oe. For this method the largest footprint arises from the degradative part, around 66 percent, where eco toxicity stands for 63 percent and eutrophication for three percent. For the WFN method the corresponding value is 13.1 Mm^3, almost five times the first method. For this method the grey water footprint was calculated for nickel. In contrast to the other method, the WFN-method got its largest footprint, 99.8 percent, from the consumptive part (Figure 1).

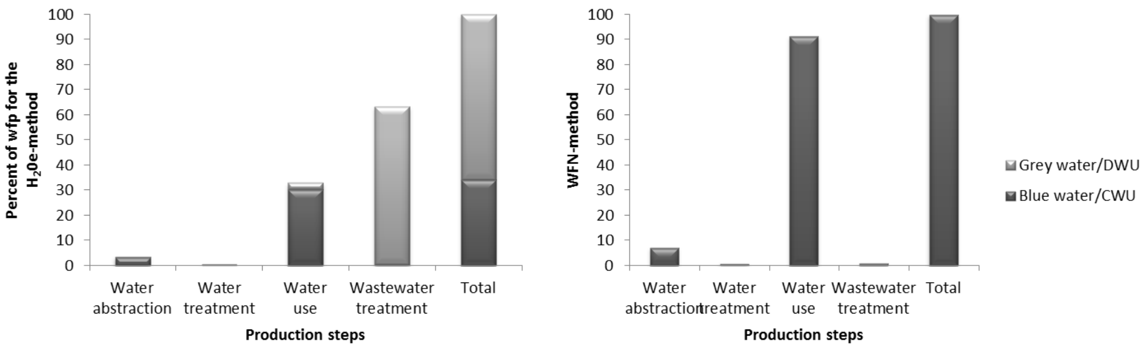

Figure 1. *Total water footprint and water footprint for the different steps in the case study, calculated with the H2Oe-method (left) and the WFN-method (right). The steps include the components for the case study. The contribution from consumptive and degradative water use is highlighted in the bars for each method*

Water footprint for the production and its background processes

Water footprint was also divided into the different components for the case study. Those components were a precipitation chemical, a chemical for pH adjustment, electricity and thermal energy. The largest contributor to water footprint for the H2Oe-method was the precipitation chemical, around 46 percent, followed by electricity on 43 percent. For the WFN-method it was electricity, with 99 percent (Figure 2). This result shows that most of the water footprint occurs in background processes (Figure 3).

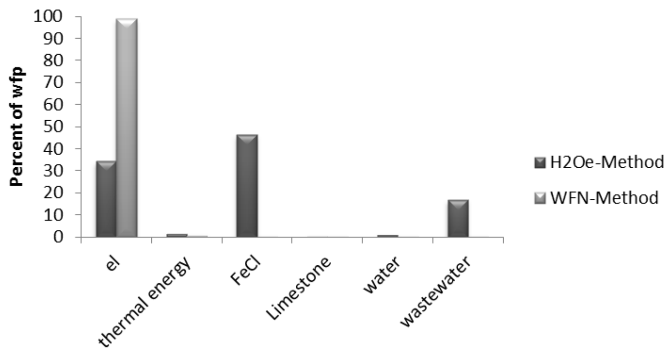

Figure 2. *Percent of water footprint contributed for the different components in the case study*

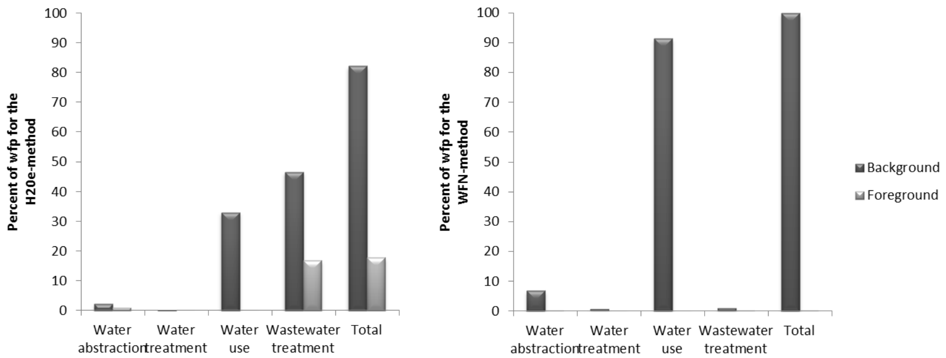

Figure 3. *Percent of water footprint from background and foreground process for the H2Oe-method (left) and the WFN-method (right)*

Comparing water footprint: between locations and carbon footprint

Water footprint was also calculated as if water use for the system occurred in Switzerland, Spain and Saudi Arabia instead of Sweden. The geographical location was accounted for in the H_2Oe-method, but not in the WFN-method (Figure 4).

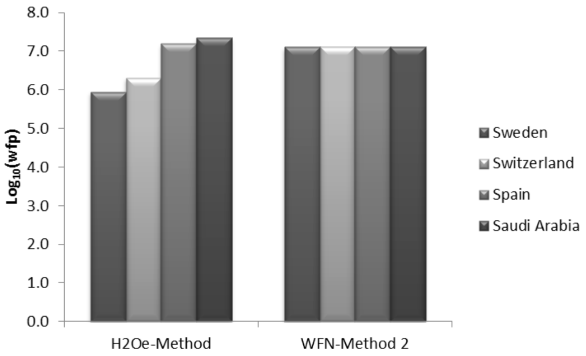

Figure 4. *Water footprint calculated with the H2Oe-method and the WFN-method for the same water use processes located in Sweden, Switzerland, Spain and Saudi Arabia*

4. Discussion

Water footprint is a growing concept and there is an increased interest about impact from water use. But still, there are many aspects that need to be considered when assessing water use. In this section some of the aspects are considered, as for example the importance of a life cycle approach, the difficulty in comparisons between methods and the need for a unified methodology for water footprint.

The importance of a life cycle perspective for water footprint

The LCI data derived from the software consisted of more than 200 different flows. Therefore, one can understand that all of those are not considered in a time limited study. But the discussion about the scope concerns almost all LCA studies, and is not specific for water. Another point in this study is that it shows that most of the water use in this case study takes place in the background processes of the life cycle. The result illustrates the importance of having a life cycle approach when discussing WFP for a product or production process. Still, there was no information in the LCA about where and when water use occurred, which would be an alternative for water footprint in the future.

Differences and difficulties in comparison of different water footprint methods

It is not possible to compare water footprints derived from different methods, because this study show that there are large differences between the methods, even if the calculations are based on the same data. There are various reasons for the differences and one example is the amount of considered emissions, where the H_2O-metod includes a number of emissions while the WFN-method only considers the most critical one. Other examples for the differences are that the first method accounts for the water scarcity situation, based on WSI, and relate local water use to global water use, which is not accounted for in the second method. Also, the characterization factors for the first method are based on country level while the characterization factors for the second method, are based on watershed level.

It is the author's opinion that countries with low water priority strategies or poor guidelines for water should not be used. If the methodologies use available local guidelines to calculate water footprint a company can locate their production in a country with lower water priority strategy to decrease their footprint. Also companies with production within countries having high water priorities would be affected reversed, resulting with a relative high water footprint. This issue needs to be considered, water footprint should be used for the environmental impact, not for political targets. Another point of view is the use of water footprint in global trade. Water footprint methodologies that account for water scarcity will give products produced in countries with water scarcity a higher water footprint. If water footprint develops to a powerful tool the high water footprint can affect countries economy, though the consumer can refrain from product with high water footprint. Therefore it can be necessary to find a method for water footprint that support good water policies even for the countries already exposed to scarcity.

Large differences in performance of water footprint methods can cause other problems as well. One example is that producers can select a method favoring their WFP, and therefore reduce their footprint without any actions. For this, and probably many other reasons, there is a need for a WFP reference method.

ISO 14046 – the new standard for water footprint – one way to unify methods

There is a need to unify the methodologies of water footprint assessment. One document for this is the new ISO standard for water footprint assessment (ISO 14046). ISO 14046 intends to work as a tool for a consistent assessment technique, helping to understand the impact related to water and identify water footprints in a worldwide perspective at local, regional and global levels (Humbert, et al., 2013). This standard considers guidelines as for example that the method should be based on

LCA, be modular, contain quality and quantity change and consider temporally and geographically dimensions. It is clear that not all of the elementary flows for LCI data named in the standard are considered in the two methods evaluated in this study. Some arguments for uniformity are

- the wide range of methods
- the uncertainty of content in performance for the users
- the opportunity for the public to compare water footprint for different products, in a consumption perspective.

The potential of water footprint in LCA

It is important that water use are considered separate from other environmental impacts in LCA. The methods in this study does all generate a single value for water footprint, this is a good indicator for a general public, but more informed actors would possible argue that those values may not give enough information. But the developments of water footprint together with the increased problem of water scarcity indicate a growing interest for sustainable water use. Therefore, water footprint as a tool has potential to assess environmental impact from water use.

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