Water footprint and sustainability analysis in emerging markets: Colombian case

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Abstract
Existing information related to water footprint in emerging markets like Colombia is scarce. This project aims to contextualize to the Colombian case the Water Footprint Network´s methodology. A Colombian company was examined and the parameters of the calculation model for the local context of three industrials centers were defined.

Keywords: water footprint, emerging markets, Colombia

Introduction
Water is the most valuable natural resource since all human activities depend on it. As world population increases exponentially so does the demand of products and services and therefore water consumption. According to the World Bank, by 2035 world population will increase by 2,5 billion, where 90% will be located in emerging markets (World Bank, 2001); moreover, less than 1% of the world's fresh water is really accessible for direct human use (UNEP). The availability of this resource will be constrained by several factors like climate change, which is exacerbating its inherent variability as a result of the extreme weather conditions and on the other hand, the lack of strong policies for the proper management and protection of the available water resources. This restriction represents operational, regulatory and reputational risks for the companies and community.

Current estimates indicate that by 2025 "water stress" will be a reality for half the world's population. According to the World Resources Institute (WRI, 2000) the term 'water stress' is used when there is not enough water to meet all the agricultural, industrial or domestic needs. This will mean higher water prices reflecting scarcity and competition for water, and will require that all companies measure, monitor and reduce their water use needs and impacts on society and the environment (SABMiller & WWF UK, 2009)

Colombia is the third largest country in South America and is ranked seventh for water availability after Brazil, Russia, USA, Canada, Indonesia and China. The annual average water supply in Colombia is about 2.300 billion of cubic meters (IDEAM, 2010) and the annual demand is 34 billion of cubic meters, where 32% of water is used by the energy and industrial sector (CNPML, 2011). However, the water demand associated with the geographic distribution of the population in Colombia does not match with the water resources availability, since nearly 80% of the population (IDEAM, 2011) and 75% of the Gross Domestic Product (GDP) (CNPML, 2011) is located in watersheds with natural water deficit. Additionally, 73,6% of the manufacturing plants are located in metropolitan areas (Bogotá, Medellin and Cali) (DANE, 2012). However the areas with the largest concentration of water supply in the country have only 10% of the national population (IDEAM, 2011)

If the water demand increases and water supply is reduced, about 20% of the municipalities in Colombia could reach a scarcity index above 20% for 2025, assuming the absence of adequate measures of watershed conservation and adequate wastewater treatment (CNPML, 2011), which means that there is a high demand pressure compared with the supply of water resources, considering that currently only 11% of the national wastewater is treated properly (IDEAM, 2010)

Therefore, measuring water footprint becomes a valuable decision-making tool that helps companies to identify how, when and where the water is being used, and to assess the environmental, social and economic impacts along with associated risks. To achieve this, it is necessary to analyze the water footprint from the local context of water resources, regulations and operating conditions. Existing information and public awareness related to water footprint calculation in emerging markets like Colombia is scarce. This project aims to contextualize the methodological framework developed in 2008 by the Water Footprint Network (WFN), co-founded by Prof. A. Hoekstra from the University of Twente (Netherlands), considering the three components of water footprint: blue footprint, green footprint and grey footprint. A company from the "Manufacture of other non-metallic mineral products" industrial sector (United Nations Statistic Division, 2008) was analyzed.

Water footprint calculation and analysis was made considering the Colombian national legislation for wastewater treatment and discharge under three different scenarios: the requirements of the current regulation, legislation under development which is expected to take effect from this year (2013) and finally, the “Agreement of water quality" made by the Colombian environmental authorities to meet a long term quality goal for the major and most critical water receiving bodies in Colombia. (World Bank, 2001)

Methods

The proposed research methodology is based on the framework on water footprint measurement developed by the Water Footprint Network (WFN). The water footprint, defined as "the volume of freshwater used to produce the product, measured along the supply chain" (Hoekstra, 2011), is a multidimensional indicator that shows the volume of water consumption by source and its contamination volumes. According to the Water Footprint Network, the water footprint is measured in three important components: blue footprint, green footprint and grey footprint.

Blue Footprint
The blue footprint refers to consumption of blue water sources (wells and surface) through the supply chain. The consumption refers to the amount of water non-returned to the system due to evaporation, water incorporation into the product, or because the water is delivered in other water source. Blue footprint is determined from freshwater consumption given under one of the following four scenarios:

1. Water is evaporated
2. Water is incorporated into the product
3. The water does not return to the same source from which it was taken
4. The water returns to the source in the same time period (Hoekstra & Chapagain, 2008).

The blue water footprint is calculated by equation (1) (Hoekstra, 2011):

$$WF_{blue} = Blue\ Water\ Evaporated\ + Blue\ Water\ in\ the\ product\ + Flows\ lost\ in\ the\ return \quad (1)$$

It may also be interpreted as the resulting difference between the amounts of water that is taken from the system minus the amount of water returned to the system as shown in the following equation (2):

$$WF_{blue} = Fresh\ water\ input - Water\ discharged \quad (2)$$

For both equations result from the blue water footprint is expressed in volume of water per unit time.

Green Footprint
The green footprint refers to consumption of water from green sources. The water from green sources refers to rainwater (as it does not become runoff) contained in the raw materials used to produce the product.

The green footprint is determined as the volume of rainwater consumed during the production process. The green footprint is particularly important for products related to agriculture and forest products.

To calculate the footprint of green water is used the equation (3) (Hoekstra, 2011):

$$WF_{green} = Green\ water\ Evaporated\ + Green\ Water\ in\ the\ product \quad (3)$$

It is important to make a distinction between the green footprint and the blue footprint, because due to the hydrological, environmental and social impacts (Falkenmark & Rockström, 2004) and by determining an economic opportunity related to the source of water used to produce the product (Hoekstra & Chapagain, 2008).

Gray Footprint
The gray footprint refers to water pollution, and is defined as the volume of freshwater required assimilating the load of pollutants to take them to natural concentrations and water quality standards existing (Hoekstra, 2011).

The gray footprint is determined under the concept of the amount of water required to dilute the contaminants to the point where they become harmless. The gray water mark is calculated from the division of the pollutant load (L, expressed in units of mass / time) by the difference between the standard of water quality (the maximum acceptable concentration C_{max} expressed in mass / volume) and its natural concentration in the receiving water body (C_{nat} by mass / volume). This is shown in equation (4) (Hoekstra, 2011):

$$WF_{gray} = \frac{L}{C_{max} - C_{nat}} \tag{4}$$

To simplify the equation should if there is no information regarding the pollution load, one can determine the pollutant load (*L*) by the volume of effluent (*Effl*, in volume per unit time) multiplied by the concentration of pollutant in the effluent (*Ceffl*) minus the natural concentration of the receiving water body (*Cnat*). This is shown in equation (5) (Hoekstra, 2011):

$$WF_{gray} = \frac{L}{C_{max} - C_{nat}} = \frac{C_{effl} - C_{nat}}{C_{max} - C_{nat}} \times E_{ffl} \tag{5}$$

Natural concentration (*Cnat*) is used as an indicator to be consistent with the methodology, which seeks to determine the assimilative capacity of the receiving source of discharge water. It is not compared with the current characteristics of the receiving water body since conditions may change as a result of the level of contamination. For both equations, the result from the blue water footprint is expressed in volume of water per unit time.

The water footprint of the supply chain is the result of the sum of the three traces of water-footprint blue, green footprint and gray footprint, as shown in equation (6)

$$WF_{total} = WF_{blue} + WF_{green} + WF_{gray} \tag{6}$$

The parameters to be used in measuring the gray footprint depend on the type of dumping (domestic or industrial), the most restrictive parameter according to local law, the most dangerous parameter or the one that the organization considers as the most difficult to dilute and take into natural condition.

Sustainability Analysis

In addition to water footprint accounting, a comparison between water demand in a geographic area and water availability can be performed in terms of blue and green water. In essence, the sustainability analysis of the water footprint is made to "make the comparison of human water footprint with earth's capacity to supply sustainably" (Hoekstra A. Y., Chapagain, Aldaya, & Mekonnen, 2011). This analysis enables to consider or identify in the water footprint, the geographical capacity in terms of water supply, along with element of responsible consumption and the effectiveness of local legislation.

Results

Using the methodology described above was performed the measuring of the water footprint for a supply chain of manufacturing sector "Manufacture of other non-metallic mineral products".
For the measurement of green footprint various processes were considered along the supply chain. The measurement indicated that for the full supply chain, the value of the green water footprint is significant only in the extraction of minerals due to moisture contained in each of the minerals. In the manufacturing processes the amount of water from green sources represents a low percentage compared with the use of fresh water from blue sources. For retail outlets, green footprint is insignificant.

For blue footprint measuring the same processes were considered, the volume of water taken from different sources blue and discharges water volumes in the different receptors (sewers, surface waters, groundwater sources). It was determined that the amount of water used from blue source has a larger proportion in the manufacturing processes, followed by retail outlets and the minimum portion used in extraction processes of nonmetallic materials.

To calculate the gray footprint the same processes are considered. It was determined that for the mining extraction process is not necessary the calculation because there are no discharges into the nearby water bodies. Was determined that manufacture has a high percentage of participation in the gray footprint. Similarly for retail was found that the higher water footprint participation was given by the gray footprint.

When calculating the gray footprint particularities were found related to measuring the water footprint due to the Colombia national legislation regarding concentrations in wastewater discharges.

Currently in Colombia the discharges are regulated under the legislation of Decree 1594 of 1984. This decree has a restriction of some parameters of the discharges given in percent removal, i.e. is not established limit as a maximum permissible value, but according to the waste from each sector of the manufacturing industry, is restricted to remove 80% of them before being returned to the receiving water body.

In 2010, progress was made with regard to the development of a decree that was more restrictive than the current 1984. Decree 3930 of 2010, aims to "set the parameters and maximum permissible values to be met by discharges to surface waters, marinas, a public sewer systems and soil associated with an aquifer" (MinAmbiente, 2012). This decree has been modified and is currently in its review version five (V-5.0), which proposes to take effect from this year.

The major cities have an "Agreement of water quality" of receiving bodies, where they pose parameters and maximum permissible values to meet in a time horizon (long term). Such agreements are proposed as periods of two (2) to five (5) years and five (5) to ten (10) years, which poses a greater decrease of threshold values in the horizon of time. The cities of Bogotá and Medellin have quality agreements and 2020, suggesting a significant and a major constraint to the maximum permissible values of wastewater discharge.

Considering the three characterizations of the permissible limits of the wastewater discharges, both domestic and commercial, were performed a comparative table (Table 1) for each of the processes, where each parameter and their limits were analyzed.

Table 1 - Comparison between the permissible limits of the various regulatory

		Decree 1594 of 1984	Decree 3039 of 2010	Agreement of water quality 2020 (Bogotá)	Agreement of water quality 2020 (Medellin)
Parameter	Units	Required Value	Required Value	Required Value	Required Value
PH	Units	5 - 9	6 - 9	6,5 - 8,5	6,5 - 8,5
Temperature	°C	< 40	< 40		
Oils and fats	mg/l	> 80%	20		<20
BOD	mg/l	> 80%	200	50	<50
QOD	mg/l	> 80%	600		<100
Total Suspended Solids	mg/l	> 80%	200	40	<200

Source: the authors, 2012

As seen in Table 1, the parameters and their maximum permissible values of wastewater discharges to receiving water bodies, vary according to the projection of the time horizon. For the research were taken as maximum values (Cmax) the values that meet the time horizon given by quality agreements, since they are the most restrictive and ensure a longer horizon to set goals for reducing water footprint of industry under study.

The analyzed parameters to calculate the gray footprint were identified according to the type of dumping made, both industrial and domestic. For the type of domestic dumping was considered as a relevant parameter the biochemical oxygen demand (BOD), while for industrial wastewater was considered as the critical parameter the Total Suspended Solids (TSS).

BOD measurement is performed in the domestic water to determine the "amount of oxygen used in the stabilization of the carbonaceous and nitrogenous organic matter by action of microorganisms in conditions of time and temperature specified (usually five days and 20 ° C)" (MDE, 2000).

In industrial wastewater is important to determine the presence of TSS, because these "diminish the light passing through the photosynthetic activity avoiding water in streams, leading to the production of oxygen" (OAB, 2012).

The aforementioned parameters were chosen due to their relevance for the analyzed manufacturing industry, realizing that the SST parameter applies to discharges of industrial wastewater, while the BOD parameter applies only to domestic wastewater discharges.

According to the methodology, it should be measured only one of the parameters for the individual wastewater discharges. It was found that sometimes shedding becomes a shared, meaning that at one point the mixture is poured industrial wastewater and domestic wastewater. This characteristic was analyzed from two perspectives:

- First, when presented the case where both discharges were mixed before being discharged into the water body, the calculation was made of the two measurements for each of the parameters (BOD for domestic and TSS for industrial), was held on comparative volumes of dilution water and was chosen the larger of both, under the assumption that the volume of virtual water required to dilute the most difficult parameter, would dilute also the other parameter.
- The second, when was presented the case where the discharges are performed in two separate tubes (one for industry and one for domestic) and then mixed in the water body. For this case, the volumes of water were calculated for both parameters and was performed the sum of these volumes. This is done because these two separate discharges correspond to the same process and are discharged into the same receiving body.

Regarding the *Sustainability Analysis*, the amount of water used by industry and the company under analysis was examined considering the geographical area and the type of water source in relation with the available water supply for the same time and space unit.

For the company, about 60% of water consumption comes from surface water, 30% from public water service providers and the remaining 10% comes from groundwater sources along with a small portion of rainwater.

According to the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM, 2010), 74% of the national territory has potential for groundwater extraction, which is about 5.848 billion cubic meters, almost three times the available surface water supply. In this case, the agricultural sector is the one that makes greater use of groundwater (75%), followed by domestic sector (9%) and industry (7%). For industry 96% of water consumption comes from surface water, if we consider only the direct water extraction from surface and ground sources, excluding water supply from public service providers. However, the geographical area where the main industrial regions are located only represents about 21% of the national surface water supply. In addition, 83% of national groundwater use only represents 17% of the hydrogeological reserves.

Conclusions

The highest percentage of water footprint is related to the gray footprint, due to the pollutants and the required virtual water to dilute them. This percentage, in average, is above of 50% and it has major participation in manufacturing process and retail points.

The blue footprint has the biggest impact in manufacturing due to water used in different processes, where the water is integrated into the product and also some of this water is evaporated, being retained or returned to the system. On the retail, it was determined that the amount of water from blue sources have a high participation rate due to water consumption by the people attending the place. In the extraction processes, water was considered related only to people consumption in the extraction points since the blue-source water is not employed in the process of extracting non-metallic minerals.

The decision to select one of the parameters and the maximum permissible limits, was made considering the lifetime of the current decree (Decree 1594 of 1984) and the decree to take effect (Decree 3039 of 2010), as the new decree could be modified in order to get closer to the parameters of quality agreements. Also considering that "Agreement of water quality" has a larger time horizon and determines more restrictive limits, thus the company can create a large horizon sustainable plan to diminish the water impact.

The geographical distribution of water demand in Colombia is not balanced with the surface water and groundwater supply, which generates a higher demand pressure compared with the supply of water resources, especially where the industry is located.

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