Concrete production and potential water related impacts

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Abstract: Water is the most used substance in the world, followed by concrete. Everyday water scarcity is more common due to concentrated population growth, and climate change will make this situation worse. Concrete demand is approximately 30 billion tonnes per year fulfilling humans' need for more and better housing and infrastructure for a growing and wealthier population. Since there is no other material in enough quantities to fulfil this demand, concrete needs to be produced in the most sustainable way possible, minimizing environmental loads such as water related impacts. The water footprint is a tool that allows measuring water use over a products' life and estimating the potential environmental impacts due to this water use. The aim of this paper is to identify potential water impacts due to concrete production. An extensive study on water related impacts in concrete production from cradle to gate was performed. There are many water related aspects and impacts divided in water quantity such as water consumption and water quality such as acidification, eutrophication and ecotoxicity. The results are interesting for the research community as well as to the cement and concrete industries and a contribution to sustainable construction since the study of water related impacts of concrete is fundamental to executing actions for improved water efficiency and quality.

Keywords: Cementitious materials. Construction materials. Water consumption. Water footprint. Life cycle assessment. Sustainable construction.

1. Introduction

Concrete is the most consumed material worldwide and is second only to water in terms of consumption (Flower & Sanjayan, 2007; Hasanbeigi et al., 2012; Scrivener et al., 2018; World Business Council for Sustainable Development, 2009a). In 2018, more than 4 billion tonnes (t) of Portland cement were produced worldwide (USGS, 2019), enough to produce about 30 billion t of concrete, representing almost 4 t of concrete per person per year.

Although, cementitious materials have several advantages as construction materials (Alfahad et al., 2022), they also have potential environmental impacts. The concrete industry is consuming large amounts of resources and energy (Mehta, P.K., 2002). It is expected that the world cement production, which represents the greatest environmental impact in the production of concrete, will increase 2.5 times between 2005 and 2050 with most of this growth in developing countries (Nicolas Müller, 2008; World Business Council for Sustainable Development, 2007).

Due to the broad global use of concrete, it is essential to properly assess the environmental impact of this material. Among the main environmental aspects in concrete production are: high energy consumption, raw material consumption, water consumption, waste generation and CO_2 emissions (Amato, 2013; Hasanbeigi et al., 2012; Metz et al., 2007; US EPA, 2010; Van Oss & Padovani, 2003; World Business Council for Sustainable Development, 2009a; Worrell et al., 2001). However, most of the efforts are focused on energy and CO_2 emissions and almost nothing on water (Conselho Brasileiro de Construção Sustentável, 2014; Jefferies et al., 2012; Petek Gursel et al., 2014a).

The world situation according to the Water Facts and Trends of the World Business Council for Sustainable Development (WBCSD) (World Business Council for Sustainable Development, 2009b) is that less than 3% of the world's water is freshwater, the rest is seawater and undrinkable. Of that 3%, approximately 2.5% is frozen. Less than 1% is left for all human's freshwater needs.

As economies develop and the population grows concentrated in certain regions, water demand increases rapidly, for this reason many regions face water scarcity challenges (Bodley, 2012). Besides, the impact of climate change will exacerbate water problems, because it will probably lead to greater variability in supply, floods and droughts in many countries (Intergovernmental Panel on Climate Change, 2008). Since it is expected that water scarcity will worsen in many parts of the world as a result of factors including urbanization and population growth, increasing food production, industrialization, water pollution and climate change (United Nations Global Compact, 2011); water management systems need to be more effective in addressing the challenges of water scarcity.

To understand and reduce the environmental impacts of concrete, requires a life cycle assessment (LCA) approach (Sanguinetti & Ortiz, 2014). Unlike cement production LCA, there are not many LCA on other raw materials for concrete production including aggregates, admixtures, supplementary cementitious materials (SCM), etc. Without a comprehensive assessment such as an LCA, it is not possible to understand the environmental implications of concrete and raw materials, or to compare concrete to other construction materials (Petek Gursel et al., 2014b).

This paper identifies potential water impacts due to concrete production. To identify opportunities to reduce potential impacts related to water and associated products and processes at different stages of the life cycle, the water footprint concept will be introduced. This concept applied to concrete production will be studied broadly for the purpose of this work. The identification of water related impacts in the cementitious materials industry contributes to sustainable construction.

2. Methodology

This paper outlines concrete production and potential water related impacts to better understand the general terms, related concepts and implications. The introduction of this paper demonstrates the importance and scale of the topic under study. After the methodology, the results are presented and discussed. First, the challenges regarding water resources are presented and analyzed. The water footprint concept is introduced based on the main references in the area. The water footprint assessment phases and the relation between water footprint and life cycle assessment are analyzed as well.

The importance of concrete production is also analyzed from a sustainability point of view. A literature review (Rowley & Slack, 2004) was carried to identify water related impacts presented in published studies. This study analyzes concrete production processes in a cradle to gate approach. That is, the processes within the concrete production plant. Energy production is not considered since this process is not under the control of the concrete producer. However, since energy production is an intensive water consumption process, an efficiency approach is recommended for the industry.

3. Results and discussion

To identify water related impacts in concrete production, the global challenges regarding such valuable resource must be understood as well as the methodologies to assess environmental impacts.

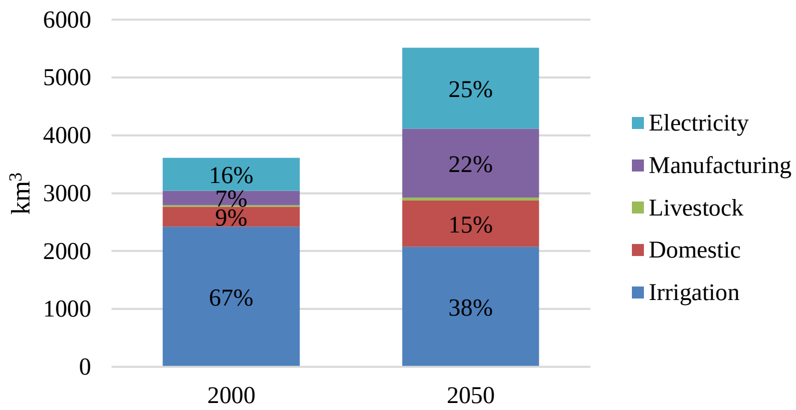
3.1. Challenges regarding water resources

In 2010 the United Nations (UN) declared water access a human right through the resolution A/RES/64/292 (United Nations, 2010). The problem with water is that it is unevenly distributed. In some regions there are large amounts of water and in others there is none. Furthermore, where there are large amounts of water, there could be other restrictions such as supply risk, environmental implications and vulnerability to supply restriction.

Water covers more than 70% of the earth's surface. However, oceans make up for 97% of the world's water, freshwater makes up for only 3%; yet only 0.5% is accessible (Gleick, 1993; USGS, 2016; World Business Council for Sustainable Development, 2009b). Sea water has high content of salts, therefore it cannot be used as drinking water nor as water for agriculture and industry uses due to its high salinity. The fact is that the amount of water we have is finite, and as population growth water demand will rise to produce more food and energy and to serve our communities.

In 2009, (Rockström et al., 2009) proposed a planetary boundary of 4000 km^3 per year for freshwater use. By that time, the status was estimated in 2600 km^3 per year. According to the United Nations World Water Development Report 2015 (United Nations Educational, Scientific and Cultural Organization, 2015), the global demand will increase from 3600 to 5500 km^3 approximately, between the years 2000 and 2050 (Figure 1), which would be crossing the mentioned planetary boundary. The biggest increase will be in manufacturing (~5 times) follow by electricity and domestic water use.

Figure 1 Global water demand in the years 2000 and 2050. Water demand for manufacturing is expected to increase approximately 5 times.



Source: Adapted from (United Nations Educational, Scientific and Cultural Organization, 2015).

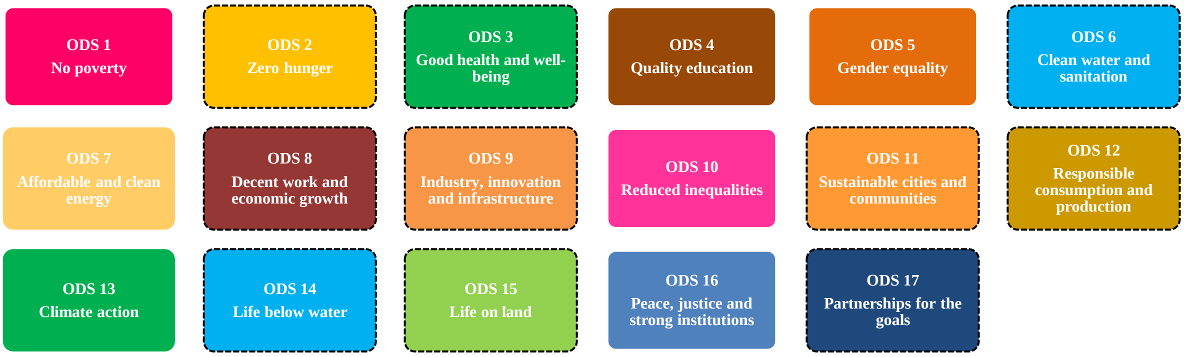
Access to freshwater is one of the biggest challenges that humanity faces. Both public and private sector entities need to think about water in the way that many think about other finite resources, such as oil and minerals. More than 2.1 billion people already lack access to clean water which causes diseases and other issues that impact social and economic development (United Nations, 2015c).

Even though there are large amounts of water globally, there are local water scarcity issues.

One issue is that due to the low cost of the water in some places, people tend to use it carelessly when we should be conserving it. Climate change further increase these issues with dry regions becoming drier and other regions flooding more often affecting specially the poorer and more vulnerable people.

The importance of water resources is reflected in many of the sustainable development goals adopted by the United Nation members in 2015 (Figure 2) (United Nations, 2015a). Clean water and sanitation and life below water are goals directly related to water availability and water quality. Zero hunger and good health and wellbeing are quite related to water as well. The decent work and economic growth and sustainable cities and communities' goals also depends on water efficiency. On the other hand, research on industry innovation and infrastructure, responsible consumption and production and partnerships, will contribute to achieving sustainable development.

Figure 2 United Nations Sustainable Development Goals for 2030. 9 out of 17 (marked) require action related to water efficiency to be achieved.



Source: Adapted from (United Nations, 2015a).

As there are many challenges regarding water resources, it is necessary to have tools to assess water use. The water footprint is presented as a concept that enables this assessment in order to reduce potential environmental impacts related to water.

3.2. The water footprint concept

(Allan, 1998) introduced the virtual water concept, which states that each product requires a greater volume of water in their production process besides the water that is incorporated. The concept refers to the hidden flow of water if food or other commodities are traded from one place to another.

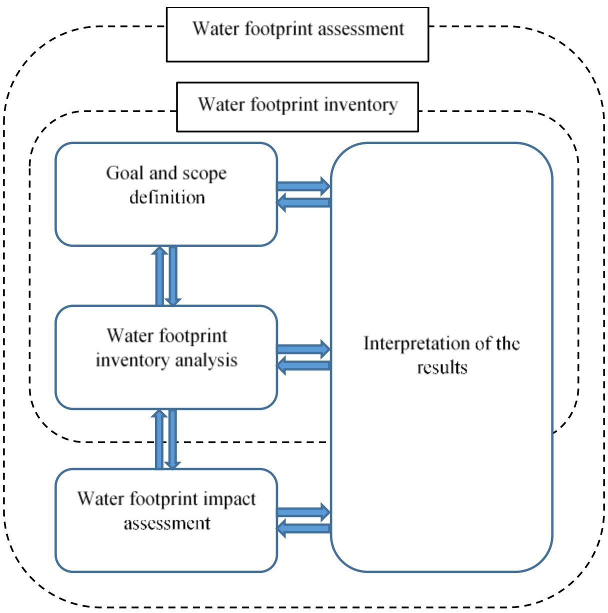
In 2002, (Hoekstra et al., 2009) introduces the concept of water footprint as the total fresh water used to produce goods and services consumed along the production and supply chain (Chapagain & Hoekstra, 2004). Later, the ISO 14046 standard defines the water footprint as a parameters that quantifies the potential environmental impacts related to water (Figure 3) (International Organization for Standardization, 2014). The water footprint is considered an extension of the LCA concept defined by the (International Organization for Standardization, 2006a, 2006b).

The calculation of the water footprint ends up being a complementary indicator to assess the environmental impacts of natural resources used by humanity. This indicator includes all process data involving water, "where," "when" and "how much", consumed or contaminated, considering the whole supply chain. In addition, the water footprint specifies the use of the water, the source and destination.

Because of the impending water crisis, it has been tried to apply the same measurement initiatives, mitigation, reduction and compensation designed for carbon emissions. However, in the case of water related environmental impacts, location becomes crucial when making impact analysis and implementing strategies.

The water footprint measure is extremely important worldwide due to the risks associated with future availability, scarcity and cost of this resource. Water footprint reporting is a useful tool that helps identifying water reduction opportunities, thus contributing to efficiency in water use for products and services as a response to the current water crisis in many regions of the world.

Figure 3 Water footprint assessment phases.



Source: Adapted from (International Organization for Standardization, 2006a, 2006b, 2014).

According to the ISO 14046 standard for water footprint (International Organization for Standardization, 2014), the water footprint assessment phases consist of definition of goal and scope, water footprint inventory analysis, water footprint impact assessment and interpretation of the results. These phases are iterative, this means that once the first analysis is finished, more analysis might be performed again or going back and forth between phases in order to refine the results.

The definition of the goal includes reasons for the study, intended applications -for instance if a comparison between products is needed-, target audience, if it is a standalone study or a part of a LCA, and objective of the study.

The scope should state the system under study and system boundaries in addition to the functional unit, time frame and location coverage, data quality, input and output cut-off criteria, unit processes and stages of the life cycle, chosen impact categories and impact assessment methodology. All relevant information that the analysis is expected to attend should be stated.

The water footprint inventory analysis phase consists of the compilation and quantification of water inputs and outputs. The volumes of water used in the different stages of the life cycle of a product or service are described in the inventory phase. The inventory includes water inputs and outputs per volume, source, destination and water quality throughout the life cycle. Water balances should be established as well.

There are two kinds of data for the water footprint inventory. Primary data that come directly from processes and installations of the organization and secondary data coming from literature, suppliers, life cycle inventory databases and other sources. Secondary data is often not representative of the reality of a specific case. Data quality should be representative, accurate, and precise and uncertainty should be assessed.

The ISO 14046 standard for water footprint (International Organization for Standardization, 2014) stresses that the water footprint is an impact and not a volume or an inventory. The total water volume is not enough to evaluate the water footprint, it is necessary to transform the water inventory into environmental impacts, so it can be reported as water footprint. As the water footprint is a local indicator, local water scarcity and water stress should be evaluated. The potential impact of water use is then evaluated by water scarcity indices or with more extensive impact assessment methods.

During the water footprint impact assessment phase, for each impact category, characterization factors that are specific to each flow are applied in order to estimate their potential impacts. Changes in both water volume and water quality can lead to local water impacts, which should be assessed.

There are multiple possibilities to represent and communicate the results -with a single impact indicator or as a group of them-. Interpretation of the results includes conclusions, assumptions and limitations for data and methodology, positive aspects and expert judgment by internal or external -independent of the water footprint assessment team- part or panel of interested parties.

LCA is a tool to measure the various environmental impacts caused by products along their lifespan (International Organization for Standardization, 2006a). A water footprint according to the ISO 14046 standard is the fraction of those impacts which are related to water (International Organization for Standardization, 2014). The concept of water footprint according to the ISO 14046 standard is based on life cycle thinking, this means accounting water consumption from the extraction of raw materials, through production, use, final treatment and recycling to disposal.

In the case of products, the water footprint is environmental impact of the total volume of water used to produce the product, summed over the various steps of the production chain. The water footprint assessment according to the ISO 14046 standard may be conducted and reported as a stand-alone or as part of a LCA (International Organization for Standardization, 2014).

In most LCA studies not related to agriculture, water consumption has been traditionally omitted (Canals et al., 2008; Cooney, 2009). Until approximately a decade ago, water consumption was not considered as a major problem by the LCA community. Today, water conservation, water footprint, and water management are taking an increasing importance in the sustainability agenda of many companies (Holcim, 2012; Lafarge, 2012a, 2014).

LCA as well as water footprint seeks for “hot spots” –activities with a significant contribution to the total potential impact attributed to the product - along the life cycle of the product. In the case of water footprint, it specifically seeks for activities where the water demand is high, and the water availability is low. Once these “hot spots” are identified, companies can implement water reduction strategies. Potential synergies exist between water footprint and LCA, since they rely on the same data for water accounting and impact assessment (Jefferies et al., 2012).

3.3. Concrete production and its accelerated demand

Due to current environmental issues such as climate change, engineers have the challenge of developing and working with more sustainable materials. Sustainability considers environmental, social and economic aspects of a product or service and is focused on allowing present generations to meet their needs without compromising the ability of the next generations to meet their own needs (Bruntland, G., 1987).

Concrete is the largest manufactured material in the world and, is the second most consumed substance, after water. It is made by simple components including aggregates, cement, water and small amounts of admixtures.

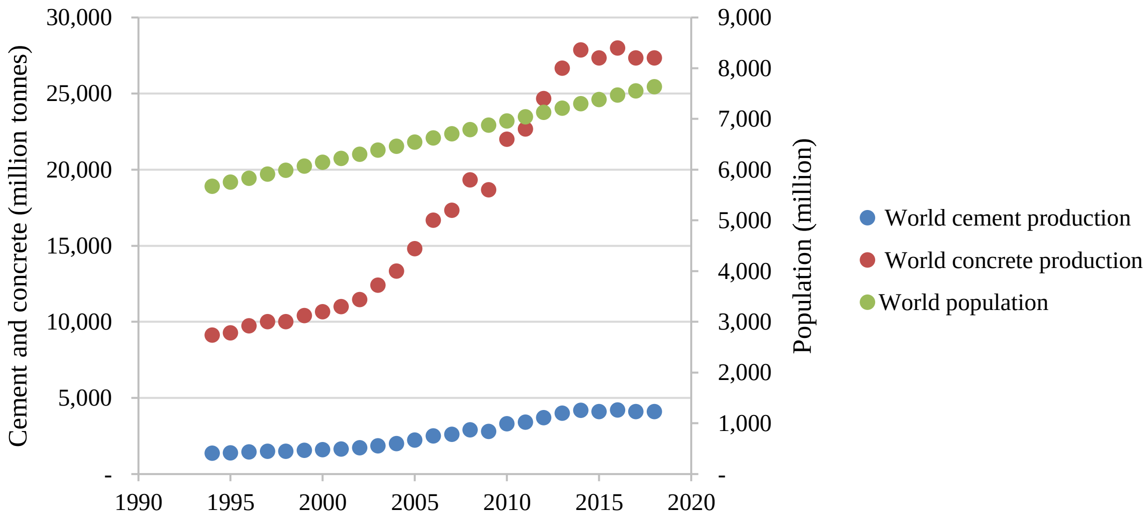
Concrete’s large demand is made possible because: it is based on abundant raw materials; has as low cost - a liter of concrete is cheaper than a liter of mineral water - making it affordable for billions of people in quantities large enough to make houses; it is easy to use, which allows untrained people to produce large, cast-in-place monolithic 3D strong and durable structures of large dimensions and diverse shapes, just mixing small particles without expensive equipment, and let it harden in the open environment; has a simplified logistics because water and aggregates, which make the bulk of it, can be locally produced. For these reasons concrete has enormous advantages compared to other construction materials.

Another advantage given by the use of concrete as construction material is that it allows to build a wide variety of structures. From single family houses easy and fast to build to large skyscrapers such as the Burj Khalifa in Dubai. Regarding infrastructure, concrete allows the construction of impressive dams such as the Hoover dam. The Panama Canal expansion is a great example of what can be done with concrete: an amazing 5 million m^3 concrete structure that allows the passage of the biggest chips between the Atlantic to the Pacific. Even more important than impressive structures, concrete allows the construction of hospitals, schools and social housing.

Concrete production has been improved and its demand have increase and is expected to increase until 2050. The yearly cement production -one of concrete’s main constituents- is more than 4 million t. This is equivalent to a per capita consumption higher than that of human food (Food and Agriculture Organization of the United Nations, 2013). Furthermore, the growing demand for larger and better built environment, may cause future production to surpass these values (Scrivener et al., 2018). From the cement production, it is estimated that approximately 50% goes to concrete production and the rest is divided into mortar production and other cementitious materials such as concrete blocks, tiles, etc.

The world population is expected to grow from 7 to 9 billion people between 2015 and 2050 (United Nations, 2015b). Figure 4 presents the increase of cement and concrete production compared to the increase in population growth. It is observed that the increase rate is higher than that of the world population. The need of housing and infrastructure will increase as well (Figure 5). This increase in population is happening mostly in urban areas where access to resources is already limited.

Figure 4 Cementitious materials production and population growth. The production of concrete is growing faster than population.



Source: Based on data from (USGS, 2019).

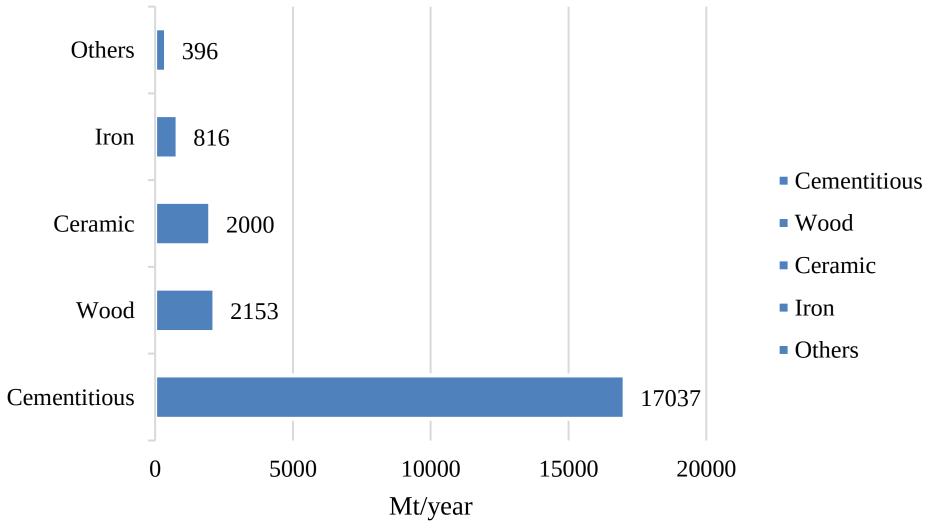
Concrete have been the foundation of the built environment and will continue to play the main role in meeting the demand for housing and infrastructure in order to have a more sustainable world. In Europe, most of the housing and infrastructure that is needed is already built contrary to emerging and developing countries such as Brazil, India and China. These countries are characterized for an expected population growth and a current deficit in housing and infrastructure in terms of quantity and quality. The World Bank states that 65% of the urban population in low-income lives in slums, >60% do not have access to sanitation, and 35% do not have a safe water supply (DataBank, 2019). Therefore concrete demand growth is and will continue to be concentrated in emerging and developing countries as the result of better quality of life requirements (Scrivener et al., 2018).

Figure 5 Housing and infrastructure renovation at Curundu, Panama (Loo Pinzón, 2016).

Source: (Loo Pinzón, 2016).

It is important to work on solutions to the global challenges that the increase in urban population poses. It is a fact that there are no other materials that could replace all concrete, due the large amount that is needed. Neither other materials can be casted and easily molded in 3D shape by unequipped and almost untrained people. Figure 6 presents the production of common construction materials such as iron, wood and others. It could be observed that the production of concrete fully surpasses the production of other contruction materials.

Figure 6 Production of common construction materials in Mt/year (Scrivener et al., 2018).



Source: Adapted from (Scrivener et al., 2018).

Since we cannot replace concrete, it is crucial to develop more sustainable ways to produce and use concrete, allowing to meet the social needs meanwhile reducing environmental impacts. To reduce environmental impact of concrete, it is essential to quantitatively measure them as presented in the next section.

3.4. Concrete LCA and water footprint: the gap

Most of the activities within the concrete life cycle, demand significant amounts of water. However, usually only water for mixing the concrete is measured. Sometimes even this water is not accurately measured since part of it comes from the aggregates; however, the producers do not know the exact amount. In the mixing, water is added until concrete gets the desire slump, as a result not always is the water for mixing the same as the water in the concrete mix design.

There are other activities that demand water for concrete production such as washing the trucks, washing the yard, etc. as well as to produce cement and the aggregates. There is also water for curing the concrete.

The cementitious materials industry already has some practices and available definitions regarding water footprint. Members of The Cement Sustainability Initiative (CSI) collect and disseminates primary data (World Business Council for Sustainable Development, 2014). However, there are still difficulties with these figures regarding measuring and reporting (Cemex, 2015; Holcim, 2015).

For the cementitious materials industry, measuring the water footprint is quite complex. There are many uncertainties, for example, there is no information on the origin of the water that comes with the aggregates, which can be from the quarry, or due to precipitation during transport and storage. Another challenge for instance is to measure water for curing concrete that depends on the environmental conditions and the type of application.

Water obtained from the public network is measured but the water losses in the public network are usually not considered and this could represent up to 30% of the water. However, the amounts of water extracted by companies from river, lakes or underground aquifers often are not as accurate.

It is also important to record and quantify the treatment and reuse of wastewater. This record is not only for the consolidation of the mass balance and environmental practices of rational use of water but also helps explaining the variation of the water footprint.

The concrete blocks modular life-cycle assessment project of the Brazilian Council for Sustainable Construction (CBCS) (John et al., 2014) was an interesting experience, where it was observed that almost no company measures its water consumption. Only the public water supply and water to the composition of the products are known.

A streamlined water footprint is necessary. To measure what is not known a solution would be to measure systematically at different points of the production process and even the wastewater generation (equipment, facilities, etc.). A recommended practice is to install measuring devices as they did in Lafarge installations (Lafarge, 2012b).

The results from the literature review in this paper shows that there are several water related aspects and impacts divided in water quantity such as water consumption and water quality such as acidification, eutrophication and ecotoxicity. The literature review also demonstrates that not all LCA studies on concrete include water related impacts. These LCA are more focus in energy and CO_2 emissions.

As shown in Table 1**Error! Reference source not found.**, most of the papers consider water in one way or another, which is a start. However, water is mostly considered as another inevitable component of the concrete mixing inventory. Scarcely is it discussed for any other function apart from direct use as mixing water.

Table 1 Potential water related impacts considered in the concrete LCA by published studies.

Reference	Water acidification	Freshwater	Marine	Freshwater	Marine ecotoxicity	Water consumption	Water depletion	Ecotoxicity	Emissions to surface	Emissions to ground
Comparative LCA of recycled and conventional concrete for structural applications (Knoeri et al., 2013)	*							*	*	*
Life Cycle Assessment of Completely Recyclable Concrete (de Schepper et al., 2014)	*	*		*	*					
Life Cycle Inventory analysis of a precast reinforced concrete shed for goods storage (Ingrao et al., 2014)										
LCA of recycled and conventional concretes designed using the Equivalent Mortar Volume and classic methods (Jiménez et al., 2015)	*	*		*	*					
Environmental evaluation of green concretes versus conventional concrete by means of LCA (Turk et al.,	*	*								

2015)								
Environmental evaluation of concrete made from recycled concrete aggregate implementing life cycle assessment (Serres et al., 2016)	*	*		*		*		
Comparative environmental life-cycle analysis of concretes using biomass and coal fly ashes as partial cement replacement material (Teixeira et al., 2016)	*	*						
A life-cycle approach to environmental, mechanical, and durability properties of “green” concrete mixes with rice husk ash (Gursel et al., 2016)	*							
A closed-loop life cycle assessment of recycled aggregate concrete utilization in China (Ding et al., 2016)								
Analysis of Environmental Impact for Concrete Using LCA by Varying the Recycling Components, the Compressive Strength and the Admixture Material Mixing (T. Kim et al., 2016)	*	*						
Environmental Impact Analysis of Acidification and Eutrophication Due to Emissions from the Production of Concrete (T. H. Kim & Chae, 2016)	*	*						
The Environmental Impact and Cost Analysis of Concrete Mixing Blast Furnace Slag Containing Titanium Gypsum and Sludge in South Korea (T. H. Kim et al., 2016)	*	*						
Environmental life cycle assessment of lightweight concrete to support recycled materials selection for sustainable design (Napolano et al., 2016)								
A comparative cradle-to-gate life cycle assessment of three concrete mix designs (Tait & Cheung, 2016)	*	*						*
Life cycle water inventory in concrete production—A review (Mack et al., 2016)						*		
Comparative life-cycle impact assessment of concrete manufacturing in Singapore (Gursel & Ostertag, 2017)	*		*	*	*			
Compared environmental and economic impact from cradle to gate of concrete with natural and recycled coarse aggregates (Braga et al., 2017)	*	*						
Concrete based on recycled aggregates – Recycling and environmental analysis: A case study of paris’ region	*	*		*		*		

(Fraj & Idir, 2017)								
Product-specific Life Cycle Assessment of ready mix concrete: Comparison between a recycled and an ordinary concrete (Kleijer et al., 2017)								
Environmental assessment of green concretes for structural use (s. Marinković et al. 2017)	*	*						
Life cycle assessment (LCA) of benchmark concrete products in Australia (Mohammadi & South, 2017)	*	*						
Influence of supplementary cementitious materials on the performance and environmental impacts of reactive magnesia cement concrete (Ruan & Unluer, 2017)	*							*
A study on environmental and economic impacts of using waste marble powder in concrete (Singh et al., 2017)							*	
Comparative process-based life-cycle assessment of bioconcrete and conventional concrete (Soleimani & Shahandashti, 2017)	*	*				*		*
Life cycle water inventory in concrete production—A review (Mack-Vergara & John, 2017)						*		
Consideration of strength and service life in cradle-to-gate life cycle assessment of self-compacting concrete in a maritime area: A study in the Brazilian context (Vieira et al., 2018)								
Comparative LCA of concrete with natural and recycled coarse aggregate in the New York City area (Yazdanbakhsh et al., 2018)	*	*						
Life cycle assessment of recycled concretes: A case study in southern Italy (Colangelo et al., 2018)	*	*						
Environmental impacts and mechanical properties of lightweight concrete containing bauxite residue (red mud) (Nikbin et al., 2018)								
Life cycle water inventory in concrete production—A review (Mack-Vergara & John, 2019)						*		

Water impacts are usually neglected. There is clearly a gap in the concrete life cycle water impacts assessment since no thorough publication on the water footprint area in concrete was found that would include water quantity as well as all water quality impacts.

4. Conclusions

Water is a basic need for all human activities. Furthermore, we need mostly freshwater which is not that abundant. Due to population growth, the demand for water will increase. On the other hand, the availability of water is compromised due to factors such as climate change. Therefore, there is a need for higher efficient in terms of water use.

The annual production of concrete is ~30 billion tonnes and is expected to increase until the year 2050. This means that several cubic meters of water will be used for the global concrete production. The high demand of concrete responds to housing and infrastructure needs from society. The concrete demand will take place mostly in developing countries such as Brazil, India and China, where water scarcity is a major problem specially in large cities. Since there is no replacement for concrete, it needs to be produced in the most efficient and sustainable way possible.

Despite the large amount of concrete production and water used for its production, the literature on water related impacts is limited, focusing primarily on energy and CO_2 emissions.

The water inventory and footprint methodologies are more complex than CO_2. For a water footprint assessment to be performed, it is needed to consider the location and period when the processes are happening. However, in the case of concrete production, the water inventory alone, also has great importance since it allows to identify where exactly in the production, we can reduce water and critical water sources.

An extensive study on water related impacts in concrete production from cradle to gate was performed. There are several water related aspects and impacts divided in water quantity such as water consumption and water quality such as acidification, eutrophication and ecotoxicity.

The study of concrete water related impacts is fundamental in order to propose and implement actions to improve water efficiency.

The results of this study are of interest to the research community as well as to the stakeholders of the cement and concrete industries who seek sustainability in their products.

The development of tools to diagnose problems inherent to water footprint calculation in cementitious materials industry and complemented by existing methodologies represent an interesting contribution to sustainable construction.

This work also aims to attract attention for future policy making seeking sustainable construction for an industry which provides space and infrastructure for many people.

Conflict of interest

The author declares no conflicts of interest in this paper.

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