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Review

Life cycle water inventory in concrete production—A review

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ABSTRACT

High water consumption and wastewater generation in the concrete industry have become very important environmental issues; however, water inventory data for concrete production and its raw materials are limited and inconsistent. The water use for different components (aggregates and cement) and processes in concrete production cradle-to-gate were identified along with water inventory figures. A large dispersion was found. The aim of this paper is to review the various water inventory methodologies and understand their implications on the water inventory figures in concrete's life cycle to understand the wide dispersion of the inventory data that was found in the literature. The implications of the various methodologies on water inventory figures were tested in a hypothetical concrete production scenario. Our case scenario shows that methodology can give results that differed by a factor of approximately 3–4. Available data on water consumption should be use very carefully by LCA practitioners and the industry decision makers. This study concludes that there is a need for unification of the water inventory methodologies in order to have data that is actually comparable. Understanding the water inventory methodologies will result in more detailed and clarified water inventory and consequently a more thorough impact assessment will be possible. The results 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.

Contents

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1. Introduction

The water footprint concept was introduced by Hoekstra in 2002 (Hoekstra et al., 2009). This concept is defined as "the total volume of fresh water that is used, directly or indirectly, to produce the product" (Hoekstra et al., 2011). In 2014 the first ISO standard for Water Footprint was published; this standard defines the water footprint as "metrics that quantify the potential environmental impacts related to water" (International Organization for Standardization, 2014). Water related environmental impacts are of great concern because water scarcity is expected to worsen in many parts of the world due to urban population growth (Bodley, 2012), industrialization, and climate change (Holcim, 2010; Intergovernmental Panel On Climate Change, 2008; United Nations Global Compact, 2011; World Business Council for Sustainable Development, 2014a, 2012, 2009a). Today, water conservation, water footprints, and water management are of increasing importance in the sustainability agenda of many organizations (BASF, 2014; Holcim, 2012; Hu et al., 2016; Lafarge, 2014, 2012).

Water use can be classified as consumptive -water that is withdrawn from one source and discharged into a different source or not returned, such as water integrated into a product or evaporated- or degradative which entails changes in water quality (Ridoutt and Pfister, 2012; Pfister et al., 2015). Water consumptive and degradative use lead to a modification of resources availability which translates into environmental impacts of concern affecting human health, ecosystem quality, and resources (Curran, 2012).

The environmental impact assessment of water resources results from the numbers coming from a water inventory, pondered with local conditions such as local water scarcity and local water quality, precipitation and hydrological characteristics, and climatic characteristics (International Organization for Standardization, 2014; O'Brien et al., 2009; Pfister et al., 2009; World Business Council for Sustainable Development, 2012). As stated in (Pfister et al., 2015), regionalized water inventory, impact assessment and uncertainties represent quite a challenge. For instance, data from the Ecoinvent database do not include location on the watershed level or temporal aspects which is needed for impact assessment. Compared to CO_2 contribution to global warming, water environmental impact assessment is not yet a clear established topic and its application to concrete industry is limited. This may be due to the fact that CO_2 emissions have a global scale while water use related impacts are local, therefore more data is needed for water impact assessment.

From an environmental point of view, water impact assessment is crucial. Nevertheless, since water impact assessment depends on local conditions, the water inventory becomes relevant when it comes to comparison between companies or products at a global scale. Water inventory will allow to compare water that is used for the production process without considering local factors.

Available data related to cement and concrete life cycle is mostly concerned with CO_2 emissions and energy consumption (Amato, 2013; Hasanbeigi et al., 2012; US EPA, 2010; Van Oss and Padovani, 2003; World Business Council for Sustainable Development, 2009b; Worrell et al., 2001). For these aspects, large worldwide datasets are available (World Business Council for Sustainable Development, 2009b). Data coming from different sources are coherent and the reasons for the differences between sources are rather well understood. This allows the industry and its clients to take measures to minimize the associated environmental impacts. Although concrete production requires large amounts of water (Henry and Kato, 2014), the available inventory data associated with water is scarce and presents large dispersion of up to one order of magnitude (Cemex, 2015, 2013, 2012; Holcim, 2015, 2014, 2013, 2012; Lafarge, 2012) rendering impossible for the industry to act based on it. Explanation for such large differences are not immediately understood. Reasons for this may include different inventory criteria, technological routes as well as local conditions, such as rain regime. However, the exact contribution of each factor is not clear. The Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD), a group of the major cement producers with 15 plus years of inventory of CO_2 emissions and energy, introduced in 2013 (World Business Council for Sustainable Development, 2014a) a customized version of the WBCSD Global Water Tool (GWT) first launched in 2007. Despite the group effort, only three companies managed to publish data in their environmental reports. Values presented were sometimes 10–20 times lower than available inventory data from life cycle assessment (LCA) studies. In revised past values; time series presented sometimes 30% shifts, which is unexpected in average values of large international operations. This picture has a stark contrast with the coherence of data from CO_2 and energy inventory coming from both, companies' inventories and LCA databases. The fact that large, well organized and experienced companies have problems mastering water inventory, is worrisome. To allow the data to be used in the decision-making process of both industry and clients, a better understanding of the underlying reasons of such variation in water inventory published data is needed.

In general data on water use have been inconsistently reported and in some cases -for instance in the concrete industry-, water data for essential activities are neglected (Pfister et al., 2015). The concretes life cycle includes many activities in addition to concrete mixing as can be seen in Fig. 1. This research presents the sum of the available water inventory figures from literature since water consumption data on concrete production life cycle is not only scarce but also scatter on different references such as scientific papers, sustainability reports, etc.

The aim of this paper is to review the various water inventory methodologies and understand their implications on the water inventory figures in concrete's life cycle from cradle-to-gate. Understanding the water inventory methodologies will results in more detailed and clarified water inventory and consequently a more thorough impact assessment will be possible (Pfister et al., 2015). This work is our first step in establishing actions to improve water use efficiency in concrete production by defining its water footprint which is our forthcoming objective.

2. Methodology

In Fig. 1 we present the concrete's life cycle from cradle to grave for a better understanding of the water use in the different phases. The scope of the study is cradle to gate. This research covers not only concrete but also aggregates and cement production. Chemical admixtures production is not covered since there is a large variety and many possible production lines. However, as presented in Fig. 1 there is water in the production of admixtures which is one of the components of concrete. In a more specific study and where