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ENVIRONMENTAL ENGINEERING

Water footprint: An effective tool for the challenge of water sustainability

INGENIERÍA AMBIENTAL

Huella hídrica: Una herramienta eficaz para el desafío de la sostenibilidad del agua

Oscar I. Vargas-Pineda[1§], Juan M. Trujillo-González[1], Marco A. Torres-Mora[1]

[1]Grupo de Investigación Gestión Ambiental Sostenible GIGAS. Instituto de Ciencias Ambientales de la Orinoquia Colombiana ICAOC. Facultad de Ciencias Básicas e Ingeniería. Universidad de los Llanos. Villavicencio, Colombia.

[§]oscar.vargas@unillanos.edu.co, jtrujillo@unillanos.edu.co, marcotorres@unillanos.edu.co

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Abstract

Water is an indispensable liquid for subsisting as for the development of society. However, currently the availability of water refers to the world community, at the same time, to the physical and economic problems of the resource, reason why it is necessary that this resource has an efficient management of the way to satisfy the current needs, without compromising its use in the future. This article will present a conceptual analysis of the dynamics of the resource with the emphasis on scarcity, and the importance of integral management, around an indicator such as the water footprint, the view as an effective tool for decision making.

Keywords: *Basin, Water footprint, Water management, Water scarcity.*

Resumen

El agua es un líquido indispensable tanto para subsistir como para el desarrollo de la sociedad. No obstante, actualmente la disponibilidad de agua preocupa a la comunidad mundial por la intensa aparición de escenarios de escasez física y económica del recurso. Razón por la cual, es necesario que este recurso tenga una gestión eficiente, de tal manera que satisfaga las necesidades actuales, sin comprometer su uso en el futuro. Este artículo, presentará un análisis conceptual de la dinámica del recurso con énfasis en la escasez, y la importancia de la gestión integral, alrededor de un indicador como la huella hídrica, vista como una herramienta eficaz para la toma de decisiones.

Palabras clave: Cuenca hidrográfica, Escasez hídrica, Gestión del agua, Huella hídrica.

1. Introduction

Water is a limited natural resource used essentially for the subsistence of life and the development of society [(1)]. According to FAO, living things can survive in scenarios of extreme food shortages, but not in the face of a water resource shortage [(2)]. In this sense, water scarcity is one of the main concerns of leaders, academics and society in general. The demographic growth has generated an increase in the demand for water in quantity and quality for the direct use and production of food, fiber and other goods and services [(3,4)]. Nowadays, the prevailing economic development model tends to lead the water resource along unsustainable paths [(5)], and even when it is considered a finite resource [(6,7)], its rational use is not promoted [(8)]. Factors such as inefficient water use and current consumption habits hinder water sustainability and intensify socio-environmental conflicts in the territories [(9,10)]. According to the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) [(11)], about 2.1 billion people lack enough and potable water in their homes, and the concern is even greater considering that a 55% increase in water requirements in anthropic activities is expected for the year 2050 [(12)].

In Latin America, the situation is intensifying because countries have economic and technical limitations that make it difficult to have efficient basic supply and sanitation systems and have become fundamental factors that cause deterioration of surface and underground water resources close to urbanized centers of these countries [(13,14)]. Colombia is a country with abundant water supply, fifth in the world with greater water wealth [(15)]; However, in 2017, approximately 10% of the population did not have potable water supply systems or with minimum conditions for human use, just like wastewater improvement systems, they do not treat them in a 100 % [(16)], a situation that is caused by socio-cultural, political and limited technical capacity factors that hinder public investment [(17,18)]. On the other hand, climate change has modified rainfall regimes generating long and / or short periods that complicate the scenarios of water scarcity in the territory [(19, 20)].

Due to the above, it is necessary to have effective tools that facilitate decision making and improve water resource management [(21,22)], where it is necessary to consider demand / supply factors [(23)]. So, a relatively new indicator emerges, called the Water Footprint (WF), which was introduced by the Dutchman Arjen Hoekstra in 2002 [(24)], and which transcends mainly the term "virtual water" [(25, 26)]. In this way, the WF is defined as an indicator that determines the impact on the water resource, considering the consumption according to its use, which incorporates, within its methodology, aspects of sustainability, based on the natural supply of the resource, the economy and society [(27)]. The WF, quantifies the volume and, in addition, analyzes the pollutant load along the supply chain, especially applied in the study at the river basin level [(28, 29, 30)]. Finally, this article aims to analyze the concept of WF as an effective tool for decision-making in pursuit of water sustainability.

2. Methodology

The research that was conducted is exploratory, descriptive and analytical, taking into account that secondary information was collected from scientific articles and research reports available from sources such as databases (Science Direct and Springer) and academic search portals (Google scholar, Researchgate), which were selected and categorized according to the space-time approach of the water footprint indicator, with the purpose of performing a critical analysis of the conceptual application of the indicator and its contribution to the development of the sustainability in socio-economic activities, taking into account a integral approach of the components; *natural* which considers the implications of water use in the dynamics of ecosystems, *economic* that refers to the need for efficient use of water for its productivity and *social* that is associated with people's water use and resource competence with other sectors. This analysis contributes in the decision making regarding the integral management of the water resource [31, 32]. In such a way that perspectives and challenges are posed in subsequent investigations.

3. Development

It is necessary to emphasize that WF is an indicator of the use of fresh water, which refers not only to the direct use of water from a process of consuming and / or producing, but also to the indirect use of water [28]. In addition, WF is a multidimensional indicator of water use, which in addition to the type used, indicates the time and place where the resource is consumed [33]. WF is divided into three components, blue WF, green WF and gray WF. Thus, blue WF refers to the water that is consumed and / or incorporated into the process of surface and underground water sources, which has the characteristic of not returning to the source of collection or returning in a long period of time [34]. The green WF represents the water stored in the form of moisture in the soil from precipitation and which is mainly consumed by the water requirements of agricultural crops [35, 36]. Finally, the gray WF refers to the quality of the water resource. It represents the theoretical volume of water required by a water body to dilute a pollutant load to the limit values allowed by environmental authorities [37, 38].

3.1. Methodological proposals

The evaluation of WF has several proposed methods; Hoekstra [27], considers WF as the total consumption of fresh water that is required in a given process. Others, such as Deurer [39], propose analyzing the hydrological flows of both exits and storage changes with respect to WF. There are also those who propose the evaluation of the environmental impacts associated with the use of the resource [40]. Some others use the LCA product life cycle approach to address WF [41]. However, the two most relevant approaches to the evaluation of WF are: the first, which refers to the international guideline ISO 14046, which suggests the application of WF with an ACL approach [42], and the second, of greater application in the world, developed by the Water Footprint Network (WFN) that proposes the volumetric analysis of the use for water consumption [28] and develops a methodology for the evaluation of WF that considers the following four stages [27, 28]: *1. Establishing objectives and scope*, which aims to determine what type of WF, place and period of time to evaluate, taking into account the resources of the study. *2. Water footprint accounting*, refers to the collection of data and calculations of WF through the application of methodologies adjusted to the real context of the study [28, 43]. *3. Evaluation of sustainability of the water footprint*, to carry out a sustainability analysis, detailed studies are necessary and in parallel to the results of the WF, social and economic aspects in the territory where the study is generated. Among the environmental criteria are the flows and environmental requirements, which are essential to maintain the conditions of the aquatic and terrestrial ecosystems associated with water resources [28, 44]. *4. Formulation of response strategies*, it is the phase where the base information is compiled to make appropriate and most beneficial decisions about sustainable water management [28, 45].

3.2. Water footprint and its relationship with environment

The water footprint homologous to the ecological footprint, estimates the appropriation of natural water capital in a territory, with the purpose of meeting the needs of the population [46]. That is why, when assessing the WF, it is necessary to know the available water supply, taking into account that in order to conserve the natural balance, an ecological flow that ranges between 30 and 50% of the natural water supply must be considered [47].For this reason, the WF analysis is complemented with water stress indices and pollution level [33]. However, these indicators require greater verification, standardization and detail, because they do not integrate determining factors in water sustainability such as the appropriation of the resource, understood not only as the use of water, but the will of the different demanding actors of the resource in contributing to the conservation of water systems and establishing an equitable distribution of water [48, 27]. As with WF, which directly and indirectly links the use of water of the different anthropic activities in a river basin and its influence on the natural processes of the hydrological cycle, which are finally those that alter temporal and spatial conditions of the availability of the resource [49, 50]. Reason why, studies have been carried out at the basin level in India where an WF of 2.4 $x10^6$ m^3/km^2 was calculated [51], in China of 0.6 $x10^6$ m^3/km^2 [52], in Chile of 0.06 $x10^6$ m^3/km^2 [53] and Colombia of 0.18 $x10^6$ m^3/km^2 [54], these WF values are influenced by the spatio-temporal climate variability, so in this way, it is stated that the abundance of water does not necessarily guarantee the availability of water in the basins, but it does determine the importance of a redistribution of water based on anthropic activities and water supply available in the territories. Considering that quantifying the water consumed in quantity (blue WF and green WF) and quality (gray WF), of the strategic ecosystems in a given place and time, allows to generate important information to improve decision making in the water conservation and distribution that guarantees its sustainability [55, 56]. However, Li [52] ensures that the participation of multiple jurisdictions in the basins makes it difficult to organize these natural units, as evidenced in a study conducted in the Guadiana basin that is part of Portugal and Spain [57] or in the Nile river basin that is between Egypt and Ethiopia [58], where the distribution of the resource is hampered due to the water planning policies of each country and differences in water availability in the upper and lower basins.

3.3. Water footprint and its relationship with society

The water shortage due to the deterioration in its quality and / or limited supply available caused by the dry years, difficulties the development of industrial, agricultural and domestic activities [59, 60], and poses conflict scenarios, due to the use of water, of these sectors in a territory [61, 62]. The WF is an indicator that allows to evaluate the natural, economic and social sustainability of the water resource in a specific geographical area, and therefore, they play a fundamental role in the prevention and resolution of socio-environmental conflicts, associated with the use of the water resource [63, 64]. Delgado [65] suggests that the inclusion of this indicator, as a water management strategy, allows communities to associate the relevance of efficient use of water resources in their territories, which is why WF is being used worldwide to improve water management in the different anthropic activities, which require the resource [66, 67]. In addition, WF has been used in food safety studies as shown in Hong Kong where water use was evaluated according to the diets of the population with the purpose of determine critical or unsustainable diets, also, this study allowed to identify a decrease in per capita consumption of 355 to 326 l/day in two years by responsible consumption policies in this country [68].

3.4. Water footprint and its relationship with economy

In organizations and / or productive systems, the WF is an indicator that allows analyzing and evaluating the way in which goods and services are consumed, produced and sold, which demand water resources [69]. Studies have been carried out in agriculture; in rice crops such as in China, an WF of 1.76 m^3/kg [70] was calculated, in India of 0.980 m^3/kg [71] and Thailand of 2.60 m^3/kg [72], in this productive system the WF is determined by the supply of green water in the production area, the irrigation system, crop variety and agrochemicals applied. On the other hand, the livestock sector; as occurs in the production of fish in Colombia where it can range between 6.19 and 19.85 m^3/kg of fish depending on the variety [73], while in cattle farming for milk production for example in Colombia an WF of 1.9 m^3/l is estimated [74] and in Ireland of 0.7 m^3/l [75], the WF in these productions is highly influenced by the gray water that these productions generate, and the indirect consumption of water in the production of pastures for the feeding of the animals. Finally in the manufacturing industry; as for example in the production of cement an WF 2.2 m^3/kg [76] was calculated, in wines of 1.84 m^3/l [77] and gazpachos of 0.58 m^3/l [78], in this sector it is inferred that the processes of Transformation of the final product does not provide a high consumption of water, but the WF focuses mainly on the raw materials that are required to generate these products. Also, the need to ensure greater management of wastewater because gray WF is a critical point in the production of this sector. In order to ensure that the investors can identify and assess the risks associated with critical points of water use in the supply chain, and can determine the impact that it generates on water resources, product development and make decisions to reduce it [27, 33, 79]. In addition, Vargas-Pineda [80] ensures that guaranteeing an optimal supply of water in quantity and quality, to the production processes, allows the productive sectors to be competitive, because they generate economic sustainability.

4. Conclusions

The Water Footprint is a determining indicator for decision-making in the face of comprehensive water management in a territory with anthropic intervention, because it allows dimensioning the impact caused by the use of water from human activities in a given territory and in a specific period of time, also recognizing the importance of strategic ecosystems, as the main suppliers of water resources. In addition, when evaluating the Water Footprint, from the perceptive of consumption, critical points can be identified and actions generated where different sectors with common water interests are involved, to guarantee the conservation and equitable distribution of the resource, mainly at the level of river basin.

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