A Review of Water Footprint Assessment in Water Services

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Abstract— This paper presents the review of water footprint assessment in water services. Water footprint assessment (WFA) is the study of freshwater use, scarcity, and pollution in relation to consumption, production, and trade. All living things require water to grow and reproduce. Therefore, it must be managed in a sustainable manner to ensure the social, economic and environmental development of the current and future generations are not affected. Recently, water shortages are increasingly reported compromising the sustainability of several large cities and regions worldwide. Some regions for instance Malaysia is currently facing water scarcity problem despite it has high quantity of water resources and for the last two decades Malaysia experienced warming and rainfall irregularities, thus this might implicate the problem. As the increase in future water demand will be mainly due to increased industrial water demand, managing industrial water use is considered as a major option to relief foreseen water stress. Asia will need on average 65% more freshwater withdrawals for their industry and energy sectors by 2030 to meet the forecasted national economic growth rate. To date in current literature, formulating response options to reduce unsustainable WFs has been underemphasized. A large gap and thus research opportunity remains in understanding dynamics of proposed measures or policy recommendations that effectively reduce WFs. From the review, there are reveal how to conduct more water footprint assessment on the services as it is pertinent to assess the sustainability of water resources in a basin. Water stewardship and integrated river basin management engage a range of stakeholders in finding solutions which reduce wasteful water use and implement good water governance.

Keywords—Water Footprint; Water Supply; Water Resources Management; Industrial Sector

1. WATER RESOURCES-DEVELOPMENT LINKAGE

Water resources must be managed in a sustainable manner to ensure the social, economic and environmental development of the current and future generations are not affected. Due to strong water-development linkage, and as water is a common factor that cuts across all sectors of development, the sustainability of water resources can effectively provide an indication of sustainable development of a country. The demand for clean water is increased from year to year as population grows, as food production increases and also increases request from the industry for the production of products that require water supply apart from the demand during the wet and dry season too.

In many places around the world, water demand has far outstripped water supply particularly in seasons when supply is severely limited or in years of drought, or at times when demand is particularly high for large water-consuming sectors such as irrigation. A prolonged period without rainfall also reduce the amount of water available for industrial use in particular of textiles industries. Recently, water shortages are increasingly reported compromising the sustainability of several large cities and regions worldwide. Water resources shortage has given a negative impact on the development of a city and the basic lives of the residents, and it has become the main factor obstructing the development of a society [23]. This problem is significant in developing countries that are characterized by rapid population growth, high rates of urbanization, and management challenges. Moreover, water scarcity is currently staking a claim as a threat to the sustainability of large cities, especially in developing countries with limited resources. By 2025, about 1.8 billion people are expected to experience water scarcity, while two-thirds of the population will experience water stress [4]. Poor management of natural resources is the main contributor to the environment pollution, low resources-use efficiency and productivity. Natural resources management is one of the key panaceas for coordinating social–economic development and eco-environmental construction in catchments. To date in current literature, formulating response options to reduce unsustainable WFs has been underemphasized. A large gap—and thus research opportunity—remains in understanding dynamics of proposed measures or policy recommendations that effectively reduce WFs. For example, if response options are tested in a specific location or during a particular time period, how transferrable are they to other settings? How are we to address local impacts if the drivers are global? What if a "water" solution is found in changing trade policy or energy policy, or even in changing people's habits and diets? Or on a more practical level, which role can stakeholders play—water managers and direct users such as households, farmers, and industries, but also indirect stakeholders such as consumers, policy makers, and investors? [46].

Some regions for instance Malaysia is currently facing water scarcity problem despite it has high quantity of water resources and for the last two decades Malaysia experienced warming and rainfall irregularities, thus this might implicate the problem [36]. Moreover, The El Nino phenomenal has put Malaysia further to the risk of water scarcity [37]. In Malaysia, seven sectors have been identified as vulnerable to the impacts of climate change, i.e. agriculture, forestry, biodiversity, water resources, coastal and marine resources, public health and energy [23].

The key to mitigate water stress is improving water use efficiency, however the efficiency benefits will be highly compensated by the increased water demand caused by developed economy. As the increase in future water demand will be mainly due to increased industrial water demand, managing industrial water use is considered as a major option to relief foreseen water stress.

Water is used in most process industries for a wide range of applications. Industrial processes and systems using water are being subjected to increasingly stringent environmental regulations relating to the discharge of effluents. There is a growing demand for fresh water, which makes it precious in more and more countries very precious and in some parts of the world a crucial commodity. Industrial water demand is the amount of water used for cooling, processing and manufacturing operations, and power generation. It shares 22% of total water use globally but increasingly rapidly with economic development [26]. According to different scenarios, an increase of the industrial water demand up to 1,170 km^3 per annum till the year 2025 is expected on the global level, this would correspond to a share of this sector at the total water use of about 24 per cent [9]. The largest part of this projected increase in industrial water use will be realized in those developing countries with high economic growth rates, and especially by those which heavily rely on resource; intensive industries. To achieve sustainable, efficient, and equitable water use worldwide, there is need greater product transparency, international cooperation, WF ceilings per river basin, WF benchmarks for water-intensive commodities, water pricing schemes that reflect local water scarcity, and some agreement about equitable sharing of the limited available global water resources among different communities and nations [9].

The objective of this review is to opens up ways to analyze linkages between previously disconnected fields of study and that it offers a much broader perspective on how we can approach the solution of the water scarcity and pollution problems that people are facing in so many places today, in either direct or indirect ways.

1.1 INDUSTRIAL WATER DEMAND AND WATER STEWARDSHIP

The increasing industrial water demand will directly increase the competition with other sectors and might be contributed to the water stress in particular basin or region. The changes in industrial water demand due to industrial growth and technological advances influence the water consumption of the industrial itself. Besides, competition for water among water users increases the risk of localized conflicts and inequities in access to services. Plus, sharply companies should strive toward zero WF in industrial operations, which can be achieved through nullifying evaporation losses, full water recycling, and recapturing chemicals and heat from used water flows. The problem is not the fact that water is being used, but that it is not fully returned to the environment or not returned clean. The WF measures exactly that (the consumptive water use and the volume of water polluted) [10].

The author proposed to consider of some issues associates in industrial water demand which to consider for further study [33]:
 the impacts of climatic factors on water demand in different types of industries are required to assess in order to understand the mechanism of climate change impact on industrial water demand.
 The model developed in this study only considered average temperature as the climatic factor. Other climatic variables, namely maximum and minimum temperature and humidity. are required to consider for development of a more reliable model.
 It is also required to quantify the uncertainty in projected industrial water demand. Furthermore, more attention should be paid to industrial water demand management to mitigate water stress due to increase in industrial water demand.
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2.0 WATER FOOTPRINT APPROACH

Many countries are applying integrated water resources management at the basin level. However, management is still largely confined to the water sector, where it is well understood that water is essential to all life on the planet (human and other species) and to human livelihoods. However, it is recognized that decisions by people outside the water sector determine how water will be used, but the other sectors are seen as cross-cutting in water management. Since the catchment is recognized as an appropriate scale for natural resource planning and management, integrated water resources management (IWRM) at basin level has emerged as the major paradigm for managing natural resources. IWRM can be defined as the coordinated planning and management of land, water and other environmental resources for their equitable, efficient and sustainable use at the catchment scale. Water footprint puts forward as a tool for assisting policy development in the water sector by showing the extent of interdependence of individual countries on the water resources of other countries [19] and thus allowing countries to assess their national food security and develop environmental policy [17]. It has been suggested that water footprint can help governments understand the extent to which the size of their national water footprint is due to consumption patterns or inefficient production and thus to priorities policy actions such as changing consumption patterns or improving the water efficiency of production [43]; [12]; [42]. It has also been suggested as a means to assist corporations improve their efficiency of production and minimize water-related business risk by identifying any components of their supply chain which are [5].

Created in 2002 by Arjen Hoekstra, the water footprint is one of the family of environmental footprints that help us understand how our production and consumption choices are affecting natural resources. As population grows and the standard of living increases for many people, the water footprint tells us how much water is used each and every day in all our activities, such as for producing our food and clothes, and indicates the pressure we exert on our freshwater resources. Basically, the water footprint measures the amount of water used to produce each of the goods and services we use. The water footprint can also tell us how much water is being consumed by a particular country – or globally – in a specific river basin or from an aquifer.

The water footprint also helps us understand for what purposes our limited freshwater resources are being consumed and polluted [41]. The impact it has depends on where the water is taken from and when. If it comes from a place where water is already scarce, the consequences can be significant and require action. Broadly speaking, the goal of assessing WFs is to analyze how human activities or specific products relate to issues of water scarcity and pollution, and to see how consumption, production, trade, and specific products can become more sustainable from a water perspective [9]. In addition, considerable amount of literature has been published on WF, which are for crop production [30], crude palm oil [22], dairy products [17], steel production [16], cereal production [34], silk apparel [33] and sugarcane production [1]. In addition, WF has been used in reducing water footprints through healthy and reasonable changes in diet and imported products [14], potential technique to reduce the water footprint of microalgal biomass production for biofuel [18], and in determining the grey water footprints of U.S. thermoelectric power plants from 2010–2016 [5].

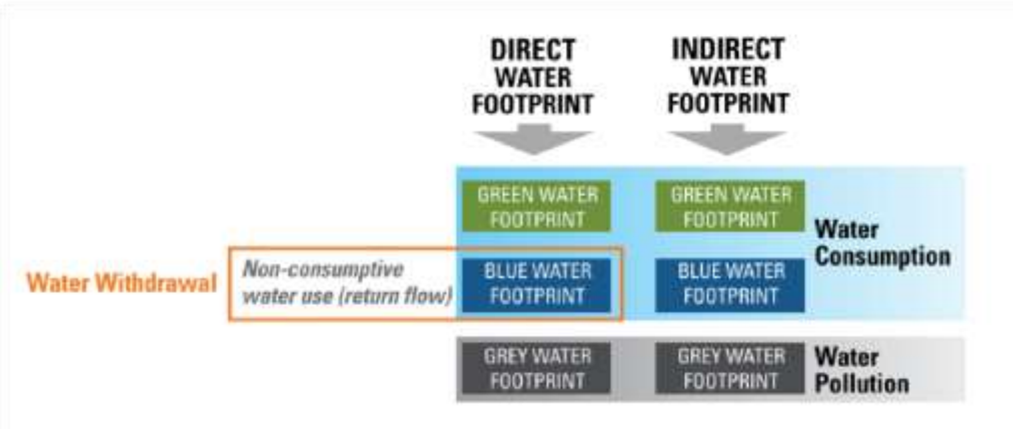

Figure 1: Components of Water Footprint

Meanwhile in industrial sector, WF has been applied in utilization of sustainable water resources on energy industry based in Hunan Province [31], water utilization and allocation in industrial sectors based on water footprint accounting in Dalian City, China [32], in assessing human and veterinary pharmaceuticals [27], wood for lumber, pulp, paper, fuel and firewood industry [20], and also in managing the implications from the high amount of industrial water use by plant infrastructure of coal-fired generation system [29]. Moreover, WF application also covered in the analysis techniques for sustainable water management in the brick-manufacturing industry [21], concrete industry [24], and selected polymers, polymer blends, composites, and biocomposites industry [13].

Until to this date, water footprint assessment was largely focused on the production and products and limited was on the services. Thus, it is time now to conduct more water footprint assessment on the services as it is pertinent to assess the sustainability of water resources in a basin. To achieve sustainable, efficient, and equitable water use worldwide, there is need greater product transparency, international cooperation, WF ceilings per river basin, WF benchmarks for water-intensive commodities, water pricing schemes that reflect local water scarcity, and some agreement about equitable sharing of the limited available global water resources among different communities and nations [9]. In recent years, review a paper by the Chinese government has issued many policies and standards on restrictions of freshwater appropriation, wastewater generation and discharge [25]. The development and popularization of freshwater saving concepts and wastewater treatment technologies are also very effective to reduce freshwater use and wastewater generations and discharge. However, there is still much work to do in order to achieve cleaner production goals. In order to alleviate freshwater scarcity and wastewater pollution, the government issued many policies and standards to restrict freshwater use and wastewater generation and discharge. Water stewardship is a collaborative and multi-stakeholder approach that aims to achieve social, environmental and economic benefits. By using Water Footprint Assessment, a company can ensure that all stakeholders are well informed and good river basin governance is developed.

Currently, the concern regarding the environmental sustainability of urban development, specifically the use of freshwater resources, has significantly increased due to population growth, which has increased water demand; this problem is exacerbated when combined with water scarcity. WF the urban water cycle includes water withdrawal from natural resources, water treatment to satisfy the required quality standards for different uses, water distribution, water consumption (drinking water, water for recreational activities, water for cleaning and irrigation of urban areas, water for agriculture and process water for industries), collection and transport of wastewater via sewer systems, and wastewater treatment [15]. The objective of their paper is to adopt the general WF methodology that considers both the blue and grey WFs to assess the water resource consumption of WWTPs. They analyzed the water footprint sustainability assessment for the WWTP, is important to formulate modifications for operational conditions to further reduce the water footprint. In that case, the application of $FeCl_3$ to achieve a greater total phosphorus removal efficiency resulted in a greater reduction in the grey water footprint. In addition to the energy savings, the sludge treatment practices should be further improved by optimizing the operational costs and also by reducing the blue water footprint.

The system boundary analysis method is proposed in this work to develop a common and feasible industry water footprint assessment methodology. The blue water (total WC) footprint and the grey water (water pollution) footprint are calculated separately to better understand the different water risks instead of the simple numerical sum of the two footprints. This leads to specific recommendations for reducing the risks. This work is expected to contribute to the development of industrial water footprint assessment methodologies [8]. In order to be transparent about the choices made when undertaking a water footprint assessment study, one will have to start by clearly setting the goals and scope of the study. A water footprint study can be undertaken for many different reasons. The diagram below provides a summary of the assessment process and identifies how the four phases work together in conducting a water footprint assessment [42].

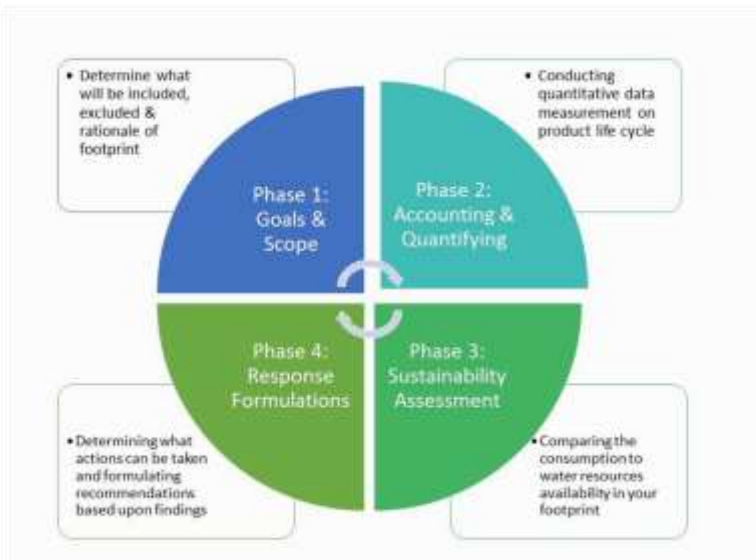

Figure 2: A full water footprint assessment consists of four distinct phases

Water allocation within basins depends largely on physical factors, i.e., climate, soils and altitude, but also on socioeconomic and policy characteristics, i.e., predominant economic activities, policies in place and measures to support specific economic sectors. Besides, regarding blue water, 7% of the consumption of annual precipitation is for human purposes, 0.05% is evaporated from the reservoir surface and 10.6% is left to the environment to sustain environmental flows and ground- water recharge, whereas 3.2% is stored in reservoirs at the end of the hydrological year [19].

The water footprint is highly important measurement since we entered the point of environmental conscience and ability to create alternative sources of energy that do not depend on water in general.

At the same time, an industry that surrounds us is energy and water-intensive, which means that it puts the pressure on water resources that are already scarce, they are contaminating freshwater and causing problems that organizations and nations should address as soon as possible. According to estimations, by 2030 under the current economic growth, the demand for water will increase by 40%, and that will overshadow the scarce supply.

3.0 DISCUSSION

Given the complex nature of the assessment process and the wide variety of potential stakeholders that can be engaged ranging from businesses to governments to farmers to investors to consumers the process can seem confusing at times. Water Footprint Assessment can be undertaken for diverse purposes. For example, it can be undertaken to:

- Support a specific business on achieving sustainable water management within their direct operations and supply chain
- Support governments and regulatory agencies on national/regional sustainable water allocations and management
- Define benchmarks for water consumption and water pollution for a specific sector of activity or production of a specific product
- Raise awareness on water sustainability issues related to water use

A Water Footprint Assessment can be tailored to meet the goals and scope of the study. The goal of the Water Footprint Assessment clarifies what you will do in the subsequent steps: accounting, sustainability assessment and response formulation. The scope of the assessment defines the spatial and temporal scale of the study, for example whether the focus will be global or within a single catchment, whether it will span one year or multiple years, whether it will include some or all of the value chain, address one product or a facility or an entire company [44]. Presently, Water Footprint (WF) Approach has been used to assess the sustainability of a product's chain globally but is lacking in the services sector. Thus, to introduce WF assessment as a technical approach to determine the sustainability of water supply management for the typical water supply treatment process (WSTP) used in Malaysia. Water supply is one of the pertinent services and most of WF accounting begins with data obtained from the water supply treatment plant. Therefore, the amount of WF will be accounted for each process of WSTP in order to determine the water utilization for the whole process according to blue, green and grey WF. Hence, the exact amount of water used in the process can be measured by applying this accounting method to assess the sustainability of water supply management in Malaysia. Therefore, the WF approach in assessing sustainability of WSTP could be implemented [47].

The water footprint concept, however, has a wider application. We can for example speak about the water footprint of a consumer by looking at the water footprints of the goods and services consumed or about the water footprint of a producer (business, manufacturer, service provider) by looking at the water footprint of the goods and services produced by the producer. Furthermore, the water footprint concept does not simply refer to a water volume only, like in the case of the term 'virtual water content' of a product. The water footprint is a multidimensional indicator, not only referring to a water volume used, but also making explicit where the water footprint is located, what source of water is used, and when the water is used. The additional information is crucial in order to assess the local impacts of the water footprint of a product [45]. Water footprint studies are available at all levels, from studies that consider how to reduce the water footprint in a crop field or industrial production unit to global-level studies. As the papers in the current collection show, methods to localize and quantify water footprint in the various steps of the supply chain of a product are improving; for many products particularly agricultural products, we understand how water footprint vary with climate, soil and production properties, and how water footprints can be reduced by changing policies and applying better technologies and practices [11].

For real decision making and policy at the regional and local levels, water footprints have limited use because too much critical information, like the opportunity cost of different water resources, their spatial and temporal dimensions, and the wider socioeconomic and environmental context, are currently missing from most applicable and assessments [4]. The scenario analysis revealed the existing opportunities for adopting integrated land water resources management to reallocate water productive uses, as well as to mitigate water degradation caused by soil erosion [19]. As many authors have pointed out, WFs need to be put in context to get meaning and water considerations need to be embedded in broader reflections. More useful than a simple numerical WF label would be a graded water label based on criteria such as: is the product's WF below a certain benchmark level and are most of the components of the product's WF in basins where the aggregate WF is below the maximum sustainable level. Similarly, governmental policies and corporate strategies can be informed based on a full WFA, not just based on one number. The Dutch Environmental Agency notes that instead of revealing their overall WF in their sustainability reports, companies would do better to report progress made in reducing the separate components of their WF in unsustainable hotspots [10].

4.0 CONCLUSIONS

To conclude, this review has found the water footprint assessment to be helpful to assess whether water use is environmentally sustainable, resource efficient and equitably allocated. Response strategies can range from investing in better metering to enable improved water management, to changes in practices or investments in technology that will reduce the water footprint at any step along the value chain. It may also be important to take action collectively with others to improve the long-term sustainability of water use at the catchment or river basin level. Water stewardship and integrated river basin management engage a range of stakeholders in finding solutions which reduce wasteful water use and implement good water governance. The rapid growths in population, urbanization, industrialization and irrigated agriculture have imposed growing pressure on the existing water resources. The public should therefore adopt the concept of sustainability in conserving water resources because water resources have shrunken further with the rising threats of dynamic climate and extreme weather. In response to climate extremes, RWH has emerged as one of the measures to enhance the resilience of human society towards water shortage problem.

Based on this Pahang River Basin case study, that paper further argues that the participation of local community needs to be strengthened from consultation level to the involvement level. This could be approached through joint management concept [26]. Obtaining good local data, however, remains difficult. Perhaps even more challenging is to improve our understanding of the interactions between actors along the supply chain, for instance: how can consumers motivate retailers and producers to reduce the water footprint of products in the hotspots along the product supply chain; how can companies influence suppliers through sustainable procurement strategies that include water criteria; how will water pricing affect final commodity prices and thus potentially influence consumer decisions; and how could the inclusion of water criteria in environmental product labels bring about sustainable water use along the supply chain [11].

The responsibility for cutting back on water consumption shouldn't just lie with consumers, of course. For people to be able to make informed decisions about which options to choose, businesses need to be transparent about their processes, and governments more forward-thinking when it comes to regulation**.** When information is available on the impacts of a certain article on the water system, consumers can make conscious choices about what they buy. And if governments were to bring in water-saving measures, businesses would be incentivised or perhaps even obligated, to introduce water-saving measures. The water footprint is the best framework that will help governments as well as organizations to create policies and to control the private sector as well as individual consumption and water usage so that the amount of freshwater can remain for people to consume.

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