A REVIEW OF THE ASSESSMENT OF THE WATER FOOTPRINT

Kirti Singh[1], Hans Pal[2]

[1]*Master of Technology Student, Environmental Engineering, IET, Lucknow*
[2]*Assistant Professor, Department of Civil Engineering, IET, Lucknow*

---***---

Abstract - *Water is a crucial part of our daily lives since it satisfies our basic necessities. There is a severe lack of water compared to previous years. Although freshwater renewal rates are limited, this study is based on basic ideas to focus on virtual water trade and the effects of countries externalising their water footprint using currently available methods such as Water Footprint Assessment, Life Cycle Assessment, and Environmentally Extended Input Output, and though freshwater renewal rates are limited, so focusing on the evolution of consumption, production, and trade patterns in connection to these constraints, as well as focusing more on supply chain thinking, which was previously unusual in water management, can assist enterprises and final consumers handle sustainable water use. This review considers water footprint methods and their benefits and drawbacks, but this new field and widespread adoption of the water footprint concept in society has sparked considerable debate about what the concept in a narrow sense and the research field in a broader sense can offer and what they cannot.*

Key Words: Water Footprint, Water Footprint Assessment, Life Cycle Assessment (LCA), Environmentally extended Input Output (EEIO).

1.INTRODUCTION

The water footprint considers a process's, product's, company's, or sector's direct and indirect water use, as well as water consumption and pollution over the whole production cycle, from the supply chain to the end-user. The water footprint can also be used to calculate the quantity of water needed to generate all of the goods and services used by an individual, a community, a nation, or all of mankind. The direct water footprint, which is the water used directly by persons, as well as the indirect water footprint, which is the sum of the water footprints of all things consumed, are also included. Following the success of the idea of considering water use along supply chains, it has gained traction after the introduction of the 'water footprint' concept by Hoekstra in 2002 (Hoekstra, 2003). The water footprint can be calculated in cubic metres per tonne of output, per hectare of agriculture, per unit of currency, and other functional units. The water footprint enables us to see how and why our limited freshwater resources are used and polluted. The consequences vary depending on when and where the water is consumed. If it originates from an area where water is already scarce, the ramifications can be severe, necessitating action.

1.1 Distinguishing between green, blue and grey Water Footprints.

Table1.1: Distinguishing between green, blue and grey water footprint

Green Water Footprints	Blue Water Footprint	Grey Water Footprint
The volume of water evapo-transpired through plants and soils is determined by the moisture in the soil. Agricultural processes were assessed.	Water volume originating from surface water or groundwater/baseflow. For irrigated water, evapotranspiration modelling is used, while for water withdrawals, a consumptive water coefficient is used.	The amount of water required to absorb waste flows. The nitrogen and phosphorus content of return flows were primarily assessed. The difference between the maximum allowed concentration and the natural concentration of the receiving water body is used to calculate the pollution load.

Fig- 1: Components of the Water Footprint (Arjen Y. Hoekstra et al.)

2. OBJECTIVES OF THE REVIEW

a) To study how human activities or specific products relate to issues of water scarcity and pollution.

b) To study how consumption, production, trade and specific products can become more sustainable from a water perspective.

c) Assess the sustainability, efficiency and equitability of water use: consumption and pollution.

3. METHADOLOGIES

Three main methodologies which have been used for regional or urban studies(Arjen Y. Hoekstra and Ashok Chapagain et al.):

1) Water Footprint Assessment (WFA) which tends to be employed at the product/commodity level;
2) Environmentally extended input-output (EEIO) which uses economic input output tables and thus considers sector level data;
3) Life cycle assessment (LCA) which realizes heavily on standardization and databases to estimate the environmental, including water and health impacts of products along their full life.

3.1 Water Footprint Assessment (WFA)

Hoekstra et al. give this method. The Water Footprint Assessment method has been most commonly used to estimate the Water Footprint associated with agricultural commodities, including livestock [10], due to the large share of global freshwater that goes into agricultural production, the interest in considering green water, and the ability to directly incorporate hydrologic modelling outputs.
Global hydrologic models are largely utilised to estimate product WFs in the WFA technique. CROPWAT, the Global Crop Water Model (GCWM), and the H08, among other models, have been employed [10], [2].

A product's water footprint can be calculated by looking at all components of its supply chain, or a specific activity or process within a long supply chain. Assessment of the life cycle is similar (LCA). The four phases of the Water Footprint Assessment are as follows:

I. Determining the scope and aims (Phase 1)

II. The second step is to calculate your water footprint (Phase 2)

III. Assessment of the Water Footprint's Long-Term Sustainability (Phase 3)

IV. Formulation of a Water Footprint Response IV (Phase 4)

According to ISO14040/44 standards, the four phases of WF assessment are comparable to those of an LCA research.

.

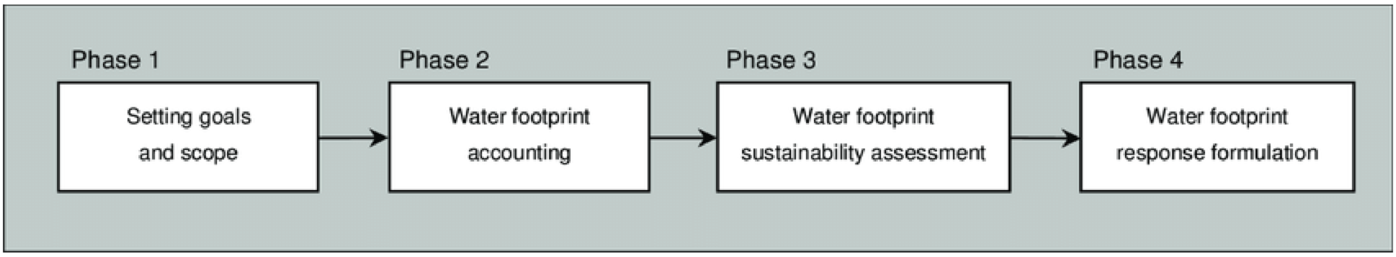

Fig -2: Four distinct phases in The Water Footprint Analysis (Arjen Y. Hoekstra et al.)

3.2 Environmentally Extended Input Output

By tracking monetary flows along the supply chain and connecting them to environmental consumption coefficients, the EEIO analysis examines the interdependencies between sectors. In the context of WF analysis, this means that EEIO allows for the calculation of the quantity of virtual water that is moved between two process nodes in the trade network, often in units of a water volume per dollar of commodity value. The amount of consumptive water utilised by each sector in the IO tables is required for this. The IO tables are used to calculate the value of economic transactions between sectors. Nobel Laureate Wassily Loentief pioneered the IO method to economic data. Since its inception, it has become a standard economic tool and is primarily used in assessing employment impact from investments across sectors[2],[10].

EEIO has been implemented at the regional (SRIO), interregional (IRIO), and multiregional levels (MRIO). Miller and Blair provide a comprehensive overview of the IO framework and its expansions. The method, like WFA, does not always suggest a specific scale of study; rather, the absence of data has determined the scope and bounds for which EEIO is most commonly used. MRIO analysis is utilised when accounting for numerous spatially separate regions, and data transfer or trade across sites is essential. As a result, MRIO is increasingly being used at the national level, where trade data is more readily available. [4],[10].

3.3 Life Cycle Assessment (LCA)

A life cycle assessment assesses industrial supply networks over the course of a product's entire life cycle, as well as the environmental implications that occur along the way. Freshwater consumption has just recently been evaluated using LCA across products and sectors. The invention, implementation, and maintenance of a standard for comparing the systematic human and environmental repercussions connected with the creation of products is a major focus of LCA. The International Organization for Standards (ISO) has laid down these guidelines (ISO). They support the construction of inventory databases that streamline the evaluation process as part of this standardisation. Ecoinvent, GaBi, and Quantis are some of the most often utilised databases. The latter two monitor freshwater consumption, whereas ecoivent monitors withdrawals at the moment. LCA research is aiming to standardise the quantification of water resource impacts, such as distinguishing between outflows and consumptive usage, and the effect of water degradation[10],[2].

The WFA, unlike the LCA, uses a macro approach to assess consequences and make overall sustainability recommendations. There is more information on the differences in these approaches elsewhere. In urban locations, LCA can be useful for determining the WF of individual items and commodities. Huang, for example, looked at how much water was consumed in Beijing for tomatoes, maize, and wheat, as well as consumed water for transportation, packing materials, and other farm inputs. To analyse the effects, they used a water stress index for each crop based on the source region, as well as a grey WF and aquatic eutrophication footprint to determine water degradation footprints. However, the scope of this study is limited to a particular product. Each product consumed and produced in the city will need to be examined in order to account for the city scale.
As a result, LCA is best used to analyse the long-term viability of particular, alternative products, rather than the entire metropolitan system, which is made up of many different economic sectors and products.

To solve multi-scale difficulties in metropolitan environments, hybrid approaches integrating LCA and EEIO are being developed. The publication of the ISO 14046 recommendations was a significant step toward more widespread use of LCA for WF analysis. The substantial reliance of LCA on standardised inventory databases may result in an undesirably homogenised and inadequately contextualised characterisation of water sustainability in metropolitan areas, where the capacity to incorporate and maximise the usage of local data is vital. This lack of subjective contextualization could be a significant constraint for urban water LCA studies aimed at informing planning and water supply decisions in a specific municipality.

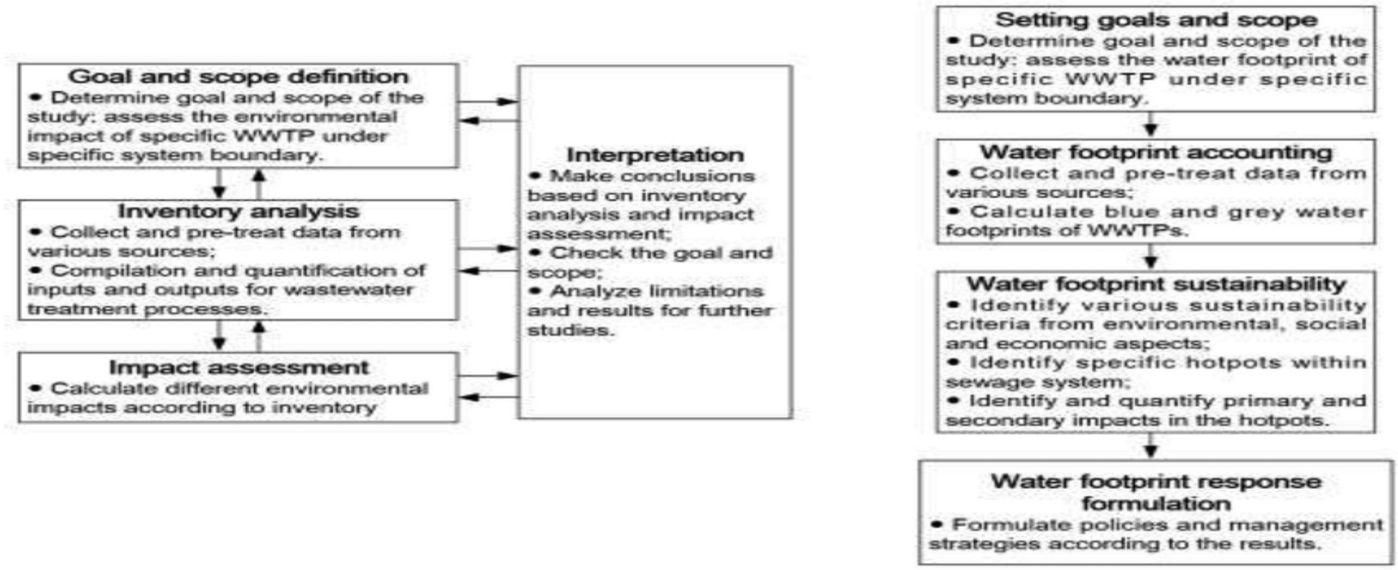

Chart 1: Differences between LCA Phases (left) and WFA Phases (right). (Jing Lon Hang , Kehua Chen)

4. COMPARISONS OF WATER FOOTPRINTS METHODS

Table 4.1: Comparisons between Water Footprint Methods

WF Method	Scale	Advantages	Disadvantages
Water Footprint Assessment(WFA)	Product level	WaterStat Database. Detailed analysis of agricultural products to give specific estimates of foods grown in certain regions. Dietary WF may be an easier communication tool. Partial supply chain assessment. Takes a system approach to evaluate sustainability.	Primarily uses national or state/ province level averages that do not show unique consumption patterns of the city.
Environmentally extended input- output (EEIO)	Sector level	Full supply chain assessment. Can identify hotspot sectors such as key water users, assess the water inter- dependency and efficiency of sectors, and identify "water multiplier" indicating the degree of virtual water recycling between sectors within the city. Can easily compare changes across time using IO tables.	Aggregation errors within each sector and disaggregation errors as IO tables are often not created at the urban scale. Primarily considers blue water
Life Cycle Assessment (LCA)	Product level	Full supply chain assessment. Explicit consideration of human and environmental impacts. Accounts for opportunity costs of water use. Assists business in evaluating supply chain water use and impacts.	Focus is on individual products. Difficult to account for all products within the city. Rely on databases that might be limited by the regional or product detail that is available. Inventory stage considers blue water.

5. CONCLUSIONS

The findings of this study, based on an examination of all current water footprint technologies, are divided into three parts: For starters, it provides a global perspective to efforts to comprehend patterns of water usage, pollution, and scarcity. It provides the path for analysing what may be done 'elsewhere' than locally to improve the sustainability and equality of water use by revealing indirect drivers of local water problems. Previously, water issues were assumed to be localised and solved locally, or at the very least within a river basin.

Second, WFA gives the way to analyse the most underlying driving force behind problems of water pollution and shortage, namely consumption. Water management has always centred on matching local water demands and supplies, taking into account both supply and demand management, but this approach is too narrow. The focus of water demand management is on reducing water needs per user rather than addressing the more fundamental question of for what final purposes water is being used, avoiding critical discussions such as water for food versus feed, water for food versus bio-energy, water for food versus forestry products, and water for producing domestic products versus export.

Third, WFA has introduced supply-chain thinking to water management, allowing new players to be included in the analysis. Whereas water management has traditionally focused on how governments can best govern the public resource water within catchments in the face of competing water users and interests, WFA highlights the importance of other actors (consumers, companies, and investors), many of whom appear to be unconnected to the catchment. WFA is novel for businesses in that it transfers the focus from internal operations to the supplier chain, from gross to net water abstraction, from gaining the "right to abstract" to measuring the actual sustainability of water use, and from meeting 'emission permits' to assessing the company's actual contribution to pollution. While WFA is rooted in discourses on globalisation and sustainability of footprints and supply-chains, the development of WFA has in turn also contributed to these larger fields of thinking. Water is a critical resource for future growth because of its critical position in our food and energy supply. Further advancements in WFA will require a better understanding of how different players can contribute to water governance models that incorporate important criteria such as environmental sustainability, social equity, economic efficiency, and supply security.

In this review, I've examined three methodologies, each of which has its own set of benefits, study area, and data requirements, as shown in table 3.2. The WF allows for benchmark and cross comparisons by using a standardised approach to detect water fluxes – both actual and virtual. It has highlighted the advantages and disadvantages of existing WF techniques.
As we enter into a new era of understanding the role of cities in the context of water scarcity, future studies should look into ways to apply the WF notion to assist decision-makers.

REFERENCES

[1] ARJEN, Y. HOEKSTRA; ASHOK K. CHAPAGAIN AND PIETER R. VAN OEL (2019), Progress in water footprint assessment: towards collective action in water governance, MDPI Journal, 2(8).

[2] ARJEN Y. HOEKSTRA;(2017): Water footprint assessment of a new research field, Springer link journal, pp. 3062-3073.

[3] ARJEN Y. HOEKSTRA; M.M. MEKONNEN: The water footprint of humanity, International Journal of Environmental Science, volume 109, pp. 3233-3256.

[4] CHAPAGAIN, A.K., HOEKSTRA, A.Y. SAVENIJE, H.H.G. AND GAUTAM, R. (2006): The water footprint of cotton consumption. An assessment of the impact of worldwide consumption of cotton products on water resources in the cotton producing countries. Ecological economic vol. 60, pp. 186-203.

[5] ERTUG ERCIN, A.Y. HOEKSTRA; Water footprint scenario for 2050: A global analysis, Environment international Journal, volume 64, pp. 61-82.

[6] HOEKSTRA, A.Y. CHAPAGAIN, A.K.; ALDAYA, M.M; MEKONNEN, M.M. (2011): The Water Footprint Assessment manual. Setting the global standard. London/ Washington: Earthscan, pp.1-155.

[7] JOEP F. SCHYNS and ARJEN Y. HOEKSTRA, (11th JUNE 2014) : The added value of Water Footprint Assessment for national water policy : A case study for morocco, International Journal, vol 9,pp- 1-55.

[8] MEKONNEN, M.M; HOEKSTRA, A.Y. (2011): National water footprints accounts. The green, blue and grey water footprint of productions and consumptions. Delft: United Nations Educational, scientific and cultural organizations- Institute for water education (UNESCO-IHE), International Journal, pp. 1577-2011.

[9] WEI CHEN; JINGLAN HONG; CHENGXIN WANG; LU SUN; TIANZUO ZHANG; YIJIE ZHAI; QUIA ZHANG (2021): Water footprint Assessment of gold refining: Case study based on Life cycle assessment, Ecological indicator journal, pp. 305-356.

[10] WILLA PATERSON; RICHARD RUSHFORTH; BENJAMIN L. RUDDELL; MEGAN KUMAR; JORGE GIRONAS (2015): Water footprint of cities: A Review and suggestions for future research, MDPI Journal, pp. 8461-8490.

BIOGRAPHIES

Kirti Singh is a Master of Technology student at the Institute of Engineering and Technology in Lucknow, Uttar Pradesh. studying Environmental Engineering in the Department of Civil Engineering.

Er. Hans Pal is working as Assistant Professor, Dept. of Civil Engineering in Institute of Engineering and Technology, Lucknow, Uttar Pradesh.