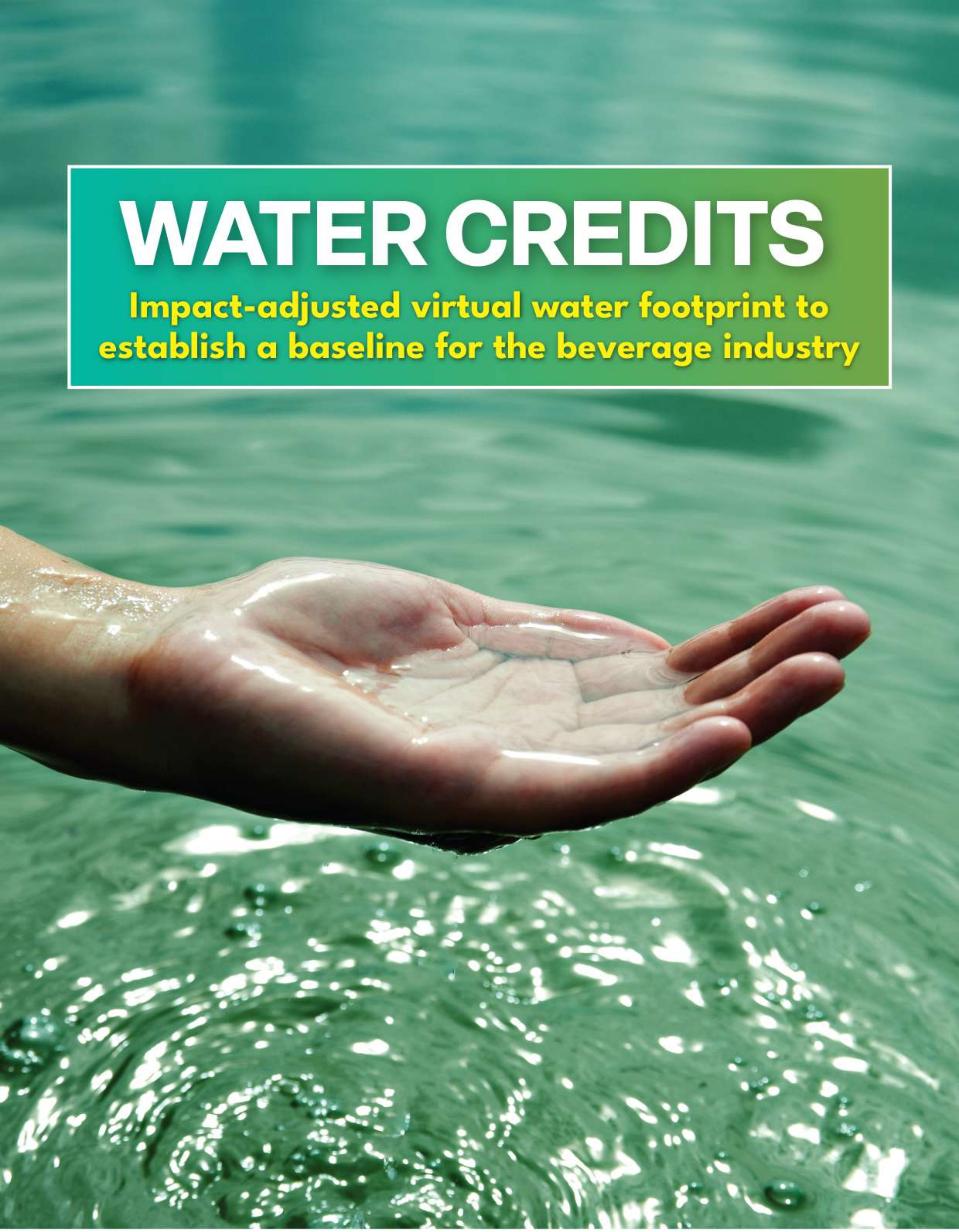
WATER CREDITS

Impact-adjusted virtual water footprint to establish a baseline for the beverage industry



Project led by

IPCA Centre for Waste Management and Research
TERI School of Advanced Studies

WATER CREDITS

Impact-adjusted virtual water footprint to establish a baseline for the beverage industry

A study for bottled water and soda production units

Project Team :

Principal Investigator (PI) - Prof Dr. Arun Kansal

Technical Expert - Dr. Sherly MA

Team Members :

Dr. Fawzia Tarannum

Dr. Gopal Sarangi

Devendra N Nimbokar

Dr. Atul Kumar

Garima Kaushik

Illustrated by - Achintya Malviya (achintya.sketch@gmail.com)

Designed by - Darshana S Kumar (darshanakumar0@gmail.com)

WATER CREDITS

Impact-adjusted virtual water footprint to establish baseline for the beverage industry.

May 2024

ABOUT

THE REPORT

The ensuing pressures on water demand and supply call for immediate measures, not only focused on the conventional strategies related to supply augmentation and demand management but also using new fiscal and regulatory measures for water arrogation, allocation, and even rationing. Industries can drive change as they have capital, skills, and access to technologies. The sustainability of businesses depends on the sustainability of water resources, a combined outcome of the water intensity of all activities in the region.

Social and political factors are anticipated to favour the priority water allocation to agriculture and the domestic sector. Hence, businesses will have to leapfrog from conventional methods of water estimation based on physical water withdrawals (abstraction) to include consumptive and indirect water use embedded in their material flows. Return flows from the industry, such as grey water or harvested rainwater, impact the overall water footprint of the industry or a product (negatively in the case of grey water and positively for return flow from production and harvested rainwater).

This report is an outcome of the **industry - academia research collaboration between Bisleri International Private Limited (BIPL) and TERI School of Advanced Studies (TERI SAS) aimed at developing a methodology and estimating the water footprint (WF) of a production unit and impact-adjusted water footprint (IA-WF) on the watershed where the production unit is located.** The water footprint of a production unit helps in product benchmarking, product labelling, and comparing the water performance of the unit with that of its peer group in the same sector. However, from the ecological considerations, this information alone may not be sufficient since, unlike carbon footprint, the impact of water footprint is local. The IA-WF informs about the effects of the production unit on the background hydrology of the watershed where it is located.

The larger objective of this collaborative research includes reviewing national and international policies and practices in water trading, water credit and fiscal instruments. It also entails developing a generic methodology for estimating footprints following the work of Hoekstra and Chapagain et al., NITI Aayog guidelines on water neutrality for Indian industries and many other works in the literature during the past decade.

The WF of a production unit comprises an operational WF (within the factory boundary) and a supply chain WF (outside the factory boundary and possibly outside the watershed- partly or wholly). Operational WF further comprises product - and manufacturing-process-related and overhead water consumption (administrative building, shared facilities like canteen, garden, etc.). Supply chain WF includes embodied water in product ingredients and packaging materials. The supply chain also has an overhead WF from energy usage, embodied water in building construction, etc. This research considers only energy to estimate the supply chain overhead WF. The WF itself consists of green (rainwater), blue (surface and groundwater stock) and grey (pollution). Analysis has been done on an Excel-based toolkit.

This report presents estimates of WF and IA-WF of two sites of similar products and manufacturing processes of BIPL. One site is Kamshet, and the other is Sahibabad, belonging to water-sufficient and deficit regions, respectively. An annual estimate of the WF for each site has been done for Nov 2022-Oct 2023.

The IA-WF proposed under this research is a new contribution to generate meaningful discussions and guidance for policymakers on water security and sustainability. Even though the national water policy documents have repeatedly recognised water resource planning at the watershed level, the data related to water demand, pollution and several related parameters are often collected and aggregated at administrative boundaries, thus making it difficult for watershed-based planning unless extensive primary monitoring is carried out.

The study team has attempted to collate the input data for IA-WF through an extensive literature search on the watershed where production units (Sahibabad and Kamshet Plants) are located along with reasonable assumptions.

The results presented in the report are valuable for the following reasons:

1. It illustrates the robust methodological tool for policymakers and industries for water sustainable planning and resource appropriation.
2. It presents how IA-WF informs different The results presented in the report are valuable for the following reasons:
1. It illustrates the robust methodological tool for policymakers and industries for water sustainable planning and resource appropriation.
2. It presents how IA-WF informs different perspectives compared to stand-alone production unit WF.
3. Comparing two production units, one located in a stressful region and the other in a comfortable region, reveals the need for local considerations for a green credit regime.
4. The information will pave the way for industries and governments to plan water monitoring programmes.
5. Historically, new concepts started with the illustration of methodology through literature-based assessment (as seen in the carbon footprint case). Progressively, estimates improve with input data quality from researchers and stakeholders.

TABLE OF

CONTENTS

CHAPTER 01

Introduction

India's water resources are under tremendous pressure, and the country is currently experiencing a water-stress scenario. Estimates reveal that India may become a water-scarce country by 2050. Geographically, 54% of the area is already experiencing high to extremely high-water stress. In this context, water credit (WC) can be used as an instrument to improve water availability, optimal production, and use of water through water resources development and conservation within a river basin or watershed. LiFE (Livelihoods, Food Security, and Environment) framework by FAO (2022) focuses on the development and environmental programs to address issues related to livelihoods, food security, and environmental sustainability in a

holistic manner.
Hence, any water crediting efforts should support livelihoods and environment conservation through collaborative programs.

The industrial virtual water footprint measures the amount of water used in industries' production of goods and services. **Virtual water** (VW) is defined as the amount of water used to produce and transform raw materials into products, while the **water footprint (WF)** is the amount of virtual water plus the water used to deliver the product to the consumer (Velázquez et al., 2011). This means virtual water is embedded in a commodity used to produce, package, and ship the product to the consumer. The water footprint is the total water consumption

Sharing a common source of water

measured at the consumer or geography or location level. There has been significant emphasis on water footprint assessment by business units as there has been an increasing realisation that water consumption and water pollution by industries could be one of the reasons for water scarcity. Hence, the emphasis is laid on sustainable water management by industries both in the direct operation and in the supply chain of the industrial production processes. In this study, we limit our scope to virtual water as we are dealing with water needed for product manufacturing and assembly processes.

Water credits or water trading are essentially a market mechanism to incentivize companies to reduce their water usage and improve the water use efficiency and productivity and create positive environmental impacts. The mechanism entails a trading mechanism where companies that use less water than they are allocated can sell their unused water credits to other companies that need more water. The virtual water of a product (i.e., a commodity, good or service) refers to the volume of freshwater used to produce the product, measured at the place where the product is actually produced (Hoekstra et al., 2011; Hoekstra and Chapagain, 2007). The use of virtual water credits can help to reduce overall water usage and promote sustainable practices (Angara and Saripalle, 2022; Ravi Shankar and Jayasri, 2015).

This project is an Industry-Academia research collaboration that aims at developing a methodological framework for impact-adjusted water footprint that considers water credits and trading, water sustainability-based product labelling, and thus focuses on a science-policy interface.

1.1 Objectives of the study

The specific objectives of the project are:

a. State of the art review of national and international policies and practices in the fields of water trading, water credit and fiscal instruments for the same.
b. Develop a methodological framework to estimate water footprint of a production unit and impact-adjusted water footprint.
c. Apply, test, and estimate water footprint of two production units of Bisleri International Private Limited (BIPL) in different locations.

Accordingly, the assigned tasks are mentioned below:

Task 1: Review of national and international policies and practices on water trading, water credit and fiscal instruments for the same.

Task 2: Develop a generic methodology to estimate the water footprint of a product/ production unit and impact-adjusted water footprint.

Task 3: Demonstration of the proposed methodology on two case sites of BIPL.

1.2 Scope of study

The project aims at two aspects, namely, impact-adjusted water footprint estimation of a production unit and water credit. This calls for a science-policy interface as shown in Figure 1.1 in which the first component focuses on developing a generic framework to assess water consumption/pollution by the production unit, while the second component deals with

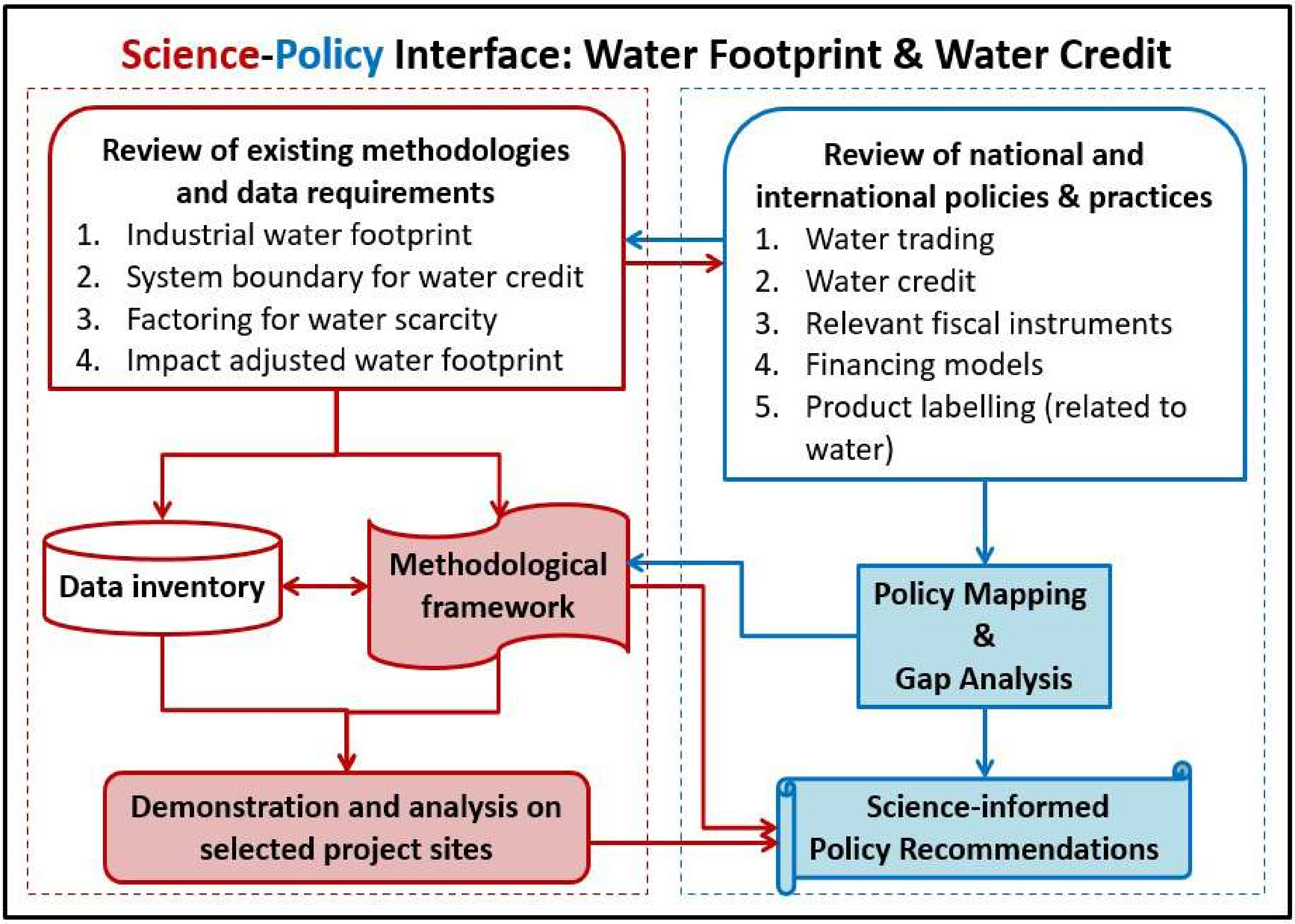


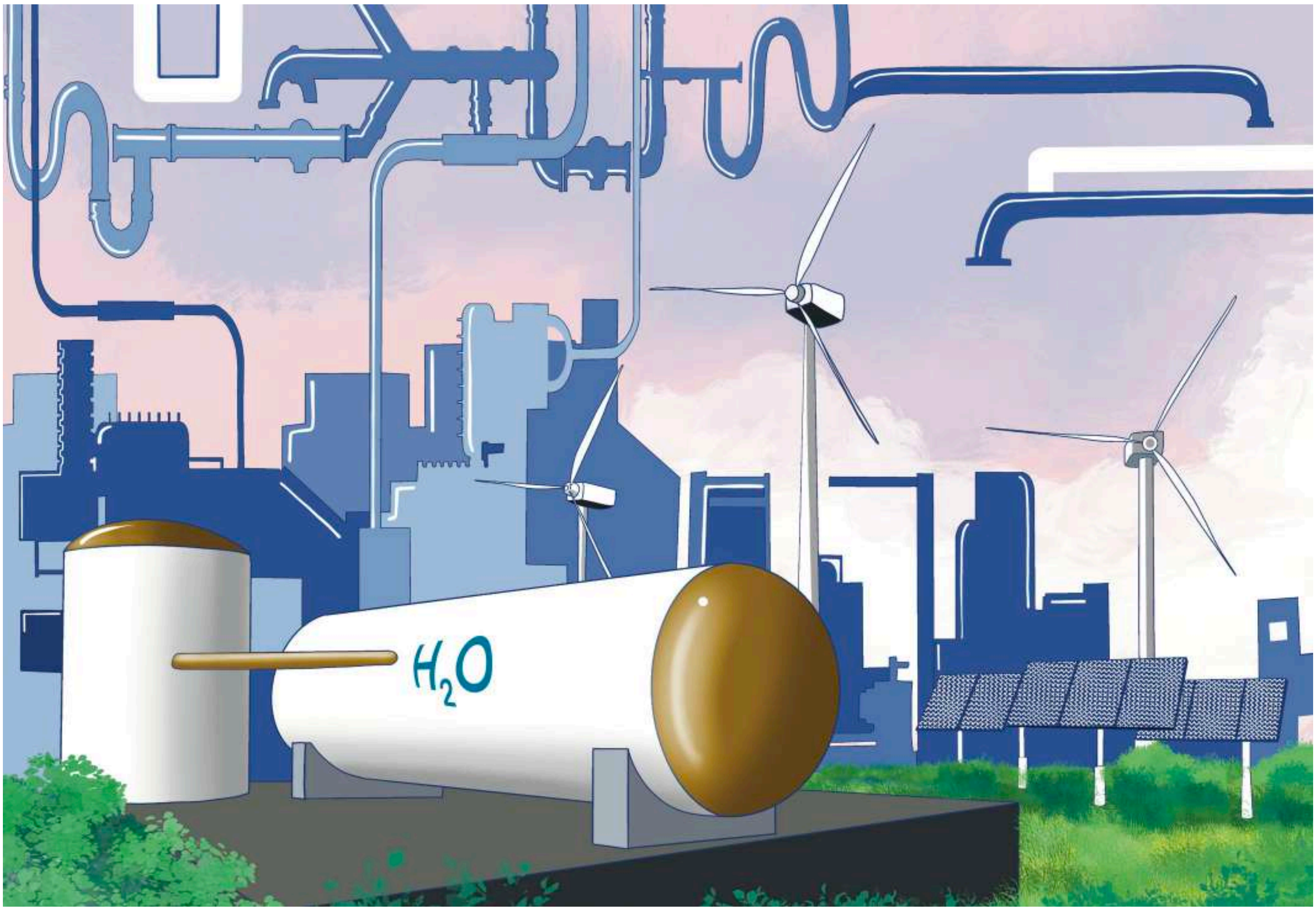
***Figure 1.1**: Overall methodological framework of the study.*

the relevant policies and practices for the successful implementation of water credit at watershed/ catchment level.

Both science and policy components interact at various levels so that a holistic and integrated approach can yield the most desirable outcomes. The various outputs of the project include: a novel methodological framework, application of the framework for two case sites, policy mapping and gap analysis, and finally the science-informed policy recommendations.

CHAPTER 02

Review of Water Footprint in the Context of a Production Unit



It has been reported that water consumption by industries is increasing over time and is often linked to the growth in GDP of a country. Apart from agricultural and domestic use of water in India, industrial use of water has 8% share, which constitutes about 500 billion cubic meters of water used annually.

It is very crucial to know how much groundwater resources are consumed and polluted over the production process, which is highly valuable for effective planning, management and sustenance of water resources by policy makers (Hoekstra and Chapagain, 2008). Importantly, water footprint mapping and assessment has been employed as an effective water management across sector. In industries, the **water footprint** (WF) is the total volume of fresh water used (both consumed and polluted) to produce the product, calculated across all stages of manufacturing process (Hoekstra and Chapagain, 2008; NITI Aayog, 2023a) directly involved by the production unit. This water footprint can be expressed as the sum of the water footprints of the process steps taken to produce the product. The WF can be measured and expressed per day, month or year depending on the level of information needed (Hoekstra, 2009). A few examples are water volume per unit of mass (litre/kg or m^3/t of products) if weight is chosen as a quantity indicator. Also, water volume per piece of the product or number of pieces is measured (Kakad and Pachkor, 2021). This could be used as a strategic tool for mitigating the associated business risks with the water consumption and use.

Water footprint estimation of a business unit is different from water audit as the latter is a management tool that focuses on quantifying and improving water use efficiency within a specific system, while a water footprint is a broader assessment that evaluates the environmental impact of water use associated with products and processes.

Water audits are typically conducted for operational improvements, while water footprints are used to understand and mitigate the environmental consequences of water consumption and pollution. While both concepts are related to water management, a water audit is focused on quantifying all the flows of water in a system to understand its usage, reduce losses, and improve conservation.

A water footprint, on the other hand, is focused on capturing the volume of freshwater used directly or indirectly to produce a product or service and identifying opportunities for reducing the water footprint. Water footprint is multidimensional capturing not only the water volume used in the production process, but also it traces the location of water footprint, source of water uses and stages of water use compared to a single dimensional aspect of water audit.

The uses of water footprint estimation can be grouped under three broad themes:
(i) a tool for assisting water resources management and dealing with water scarcity;
(ii) a means of consumer empowerment; and
(iii) a way of promoting equity in the use of global water resources (Chenoweth et al., 2014).

Recent discussion on water footprint is made in connection with virtual water. While the virtual water concept was developed by T. Allan in 1993 and conceptualised as the amount of fresh water used for the production of goods and services, whereas it is non-existent in the final product, whereas water footprint as developed by Hoekstra in 2002 is more broad in scope and entails the entire volume of water (including the virtual water) required in reference to a time unit by particular type of user, say companies (Schubert, 2011).

The difference between water audit, virtual water and water footprint is not that straightforward, rather subtle in nature and often blurred. However, the broad relationship between these aspects of water assessment is presented in the below graph (Figure 2.1).

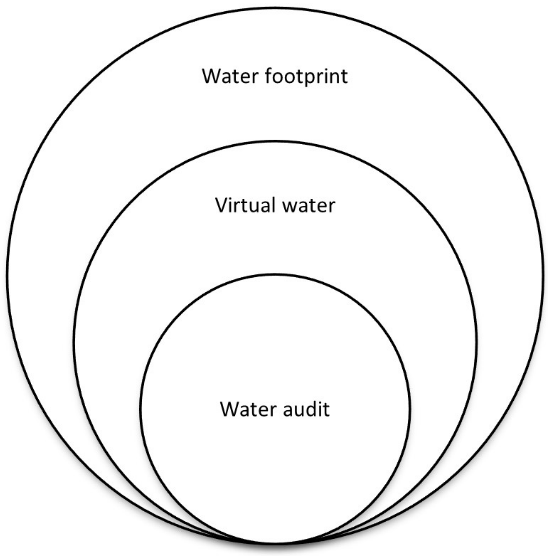


Figure 2.1: *Water audit, virtual water, and water footprint study.*

2.1 Approaches to Water Footprint Estimation

Estimating water footprints involves assessing the total volume of freshwater used to produce goods, considering both direct and indirect water use. Here, direct water use refers to the water used (consumed/polluted) in the product and processes, while the indirect water use refers to water used or embedded in the allied activities in kitchen, gardening, transportation etc, which are largely invisible. In this context, virtual water footprint is different than an indirect water use as the former sums up water embedded in the product through both production processes and allied activities (Nydrioti and Grigoropoulou, 2022). Water footprint is estimated and classified based on the quality parameters of water such as consumptive and degradative water use. Consumptive water footprint estimation rests on green and blue categorisation, whereas degradative water footprint estimations rely on grey water (Hoekstra, 2017). Different approaches have been developed to estimate water footprints, ranging from simple to complex methodologies. The two major categories are top-down and bottom-up approaches. The former approach is widely used in global and national scale estimation, while the latter is applicable for industrial products and services (Fang et al., 2014; Feng et al., 2011; Hoekstra, 2009; Hoekstra et al., 2011; van Oel et al., 2009). A detailed study on the water footprint estimation in agriculture for India has been conducted by (Kampman, 2007) that considers a comprehensive assessments at State-level for various crops.

The emphasis is laid in this report on the bottom-up methods in estimating the water footprints. The most used bottom-up methods of water footprint estimation are mentioned below in Figure 2.2.

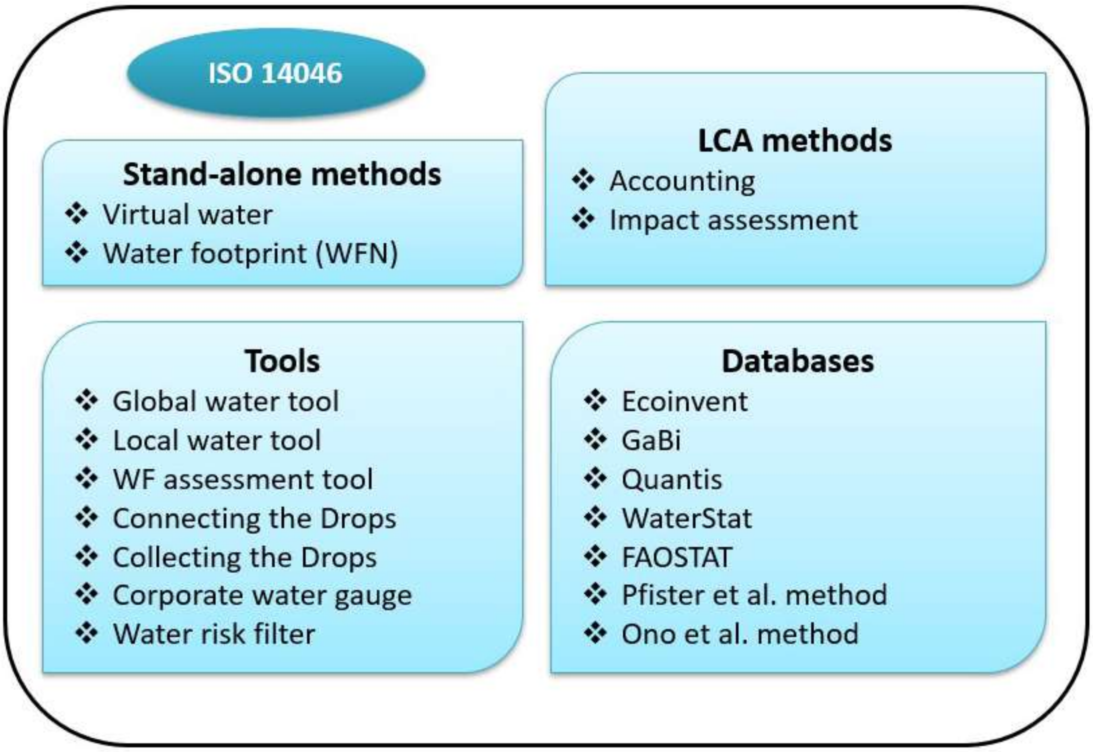


Figure 2.2: *Water footprint methods, databases, and tools based on bottom-up approach.*

2.1.1 Stand-alone methods

Stand-alone methods like Virtual Water (Allan, 1998) and the Water Footprint as defined by the WaterStat Database (Hoekstra et al., 2011) enable the analysis of water use throughout products' or organizations' supply chains.

a. Virtual water

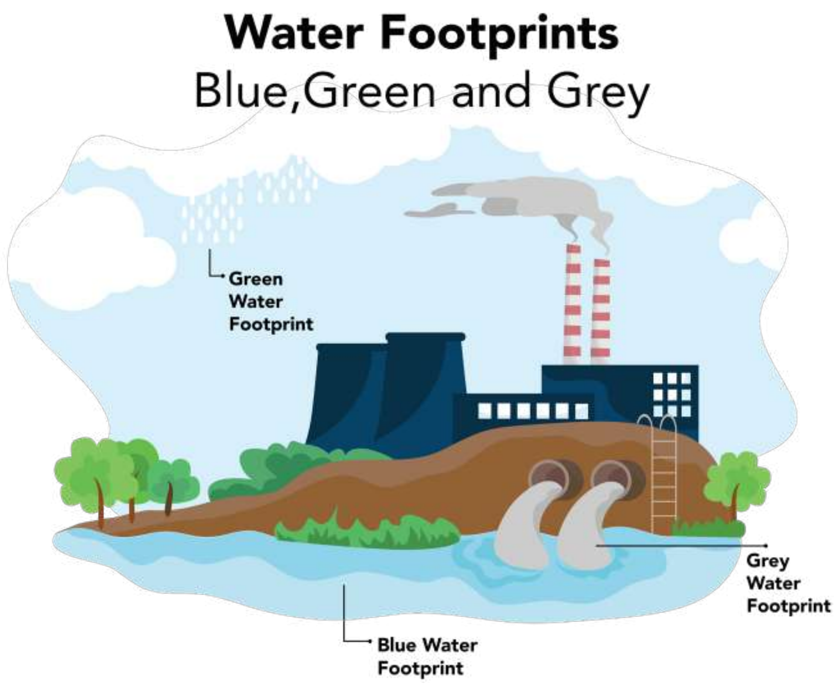
The water that is used in the production process of an agricultural or industrial product is called the 'virtual water' contained in the product. Virtual water is divided into three categories: green, blue, and grey water as follows:

- *Green water footprint:* Water from precipitation that is stored in the root zone of the soil and evaporated, transpired, or incorporated by plants. It is particularly relevant for agricultural, horticultural and forestry products (Hoekstra et al., 2011). However, within an industrial production unit, green WF may not be significant as agricultural production is not directly involved (Gu et al., 2014).
- *Blue water footprint:* water derived from surface or groundwater resources that is evaporated, incorporated into a product, or taken from one body of water and returned to another, or returned at a later time. Irrigated agriculture, industry, and domestic water use can have blue water footprint (Lamastra et al., 2014).
- *Grey water footprint:* volume of polluted water that associates with the production of goods and services. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards allowed by environmental authorities (Mekonnen and Hoekstra, 2011)

Hence, virtual water can be presented as follows:

$$V_{Total} = V_{Green} + V_{Blue} + V_{Grey} \quad \text{--(2.1)}$$

(Total Virtual Water = Virtual green footprint + Virtual blue footprint + Virtual Grey footprint).



Water Footprint

b. Water footprint network

The water footprint according to Hoekstra (Hoekstra and Hung, 2002) was introduced in 2002 and relies on the virtual water concept, but additionally includes spatial and temporal information (Water Footprint Network, 2023). Accordingly, the quantitative water footprint of a product is the same value as its virtual water content. Furthermore, water footprints were calculated for individuals, organizations, or nations by multiplying all products and materials consumed with their respective virtual water content and by adding the direct water consumption of the person, organization, or nation.

2.1.2 LCA-based method

LCA is a comprehensive approach that evaluates the environmental impacts of a product or process throughout its entire life cycle. It considers direct and indirect water use, along with other environmental factors, such as energy consumption and emissions. LCA provides a holistic view but can be data-intensive and complex (Boulay et al., 2018; Cai et al., 2022; Hoekstra et al., 2011; Mikosch et al., 2021). Assessing water use in Life Cycle Assessment (LCA) is important for understanding the environmental impact of products, processes, or systems. There are several methods and approaches to assess water use in LCA, and the choice of method depends on the specific goals of the assessment and the availability of data.

The Water Footprint Network has developed a methodology that categorizes water footprints into three components: blue (surface and groundwater consumption), green (rainwater consumption), and grey (water pollution).

This approach allows for a more nuanced analysis of water use impacts (Al-Bahouh et al., 2021; Hoekstra et al., 2011; Lovarelli et al., 2018).

The choice of method depends on the context, available data, and the level of detail required for the assessment. Often, a combination of approaches is used to provide a more robust understanding of water footprints. The main differing perspective between the WFN and LCA-based approach seems to relate to the fact that LCA aims to account for environmental impacts through water scarcity approach, while the WFN aims to account for water productivity of global fresh water as a limited resource (Hoekstra et al., 2011). The ISO 14046 (ISO, 2014) provides a standardized framework for conducting water footprint assessments, allowing organizations to assess and manage their water use more effectively and make informed decisions to reduce their overall environmental impact related to water resources. It is commonly used by the companies, governments, industries and other organizations to better understand and address their water-related sustainability challenges. The choice of the method also depends on the available data and the objective of the study.

The whole framework of WF estimation has four steps:

1. Setting goals and scope,
2. Water footprint accounting,
3. Water footprint sustainability assessment, and
4. Water footprint response formulation (Hoekstra et al., 2011).

Table 2.1 shows the estimated water footprints of beverages and aerated drinks as reported in the literature. Different methodological approaches were used in these studies.

Source	Product	Water footprint	Remark
(Coca-Cola and Nature Conservancy, 2010; Kuo et al., 2015)	0.5L Coca-Cola beverage in Netherlands	Green-15L; Blue-1L; Grey-12L; Total–28L	Uncertainty in estimation due to changes in processes and geographical conditions is not explicitly mentioned.
	1kg sugar from sugar beets in Europe	Green-375L, Blue-54L, Grey-128L; Total-557L	
	1L Simply Orange sourced from Florida	Green- 386L, Blue- 154L, Grey-100L; Total-640L	
	1L Simply Orange sourced from both Florida and Brazil	Green- 407L, Blue- 127L, Grey-117L; Total-651L	
	1L Minute Maid sourced in Florida and Costa Rica	Green- 319L, Blue- 115L, Grey-84L; Total-518L	
(Jeswani and Azapagic, 2011)	1GJ of corn-ethanol across 12 countries	Green: 0.0-96.5L, Blue: 0.4-163.3L; Grey: Not calculated	Under estimation of total WF due to non-inclusion of grey WF.
(Ercin et al., 2012)	1L of soy milk	Green: 276.4L, Blue: 11L, Grey: 9.6L, Total: 296.9L	Both operational and supply chain water footprints are mentioned though no uncertainty estimation.

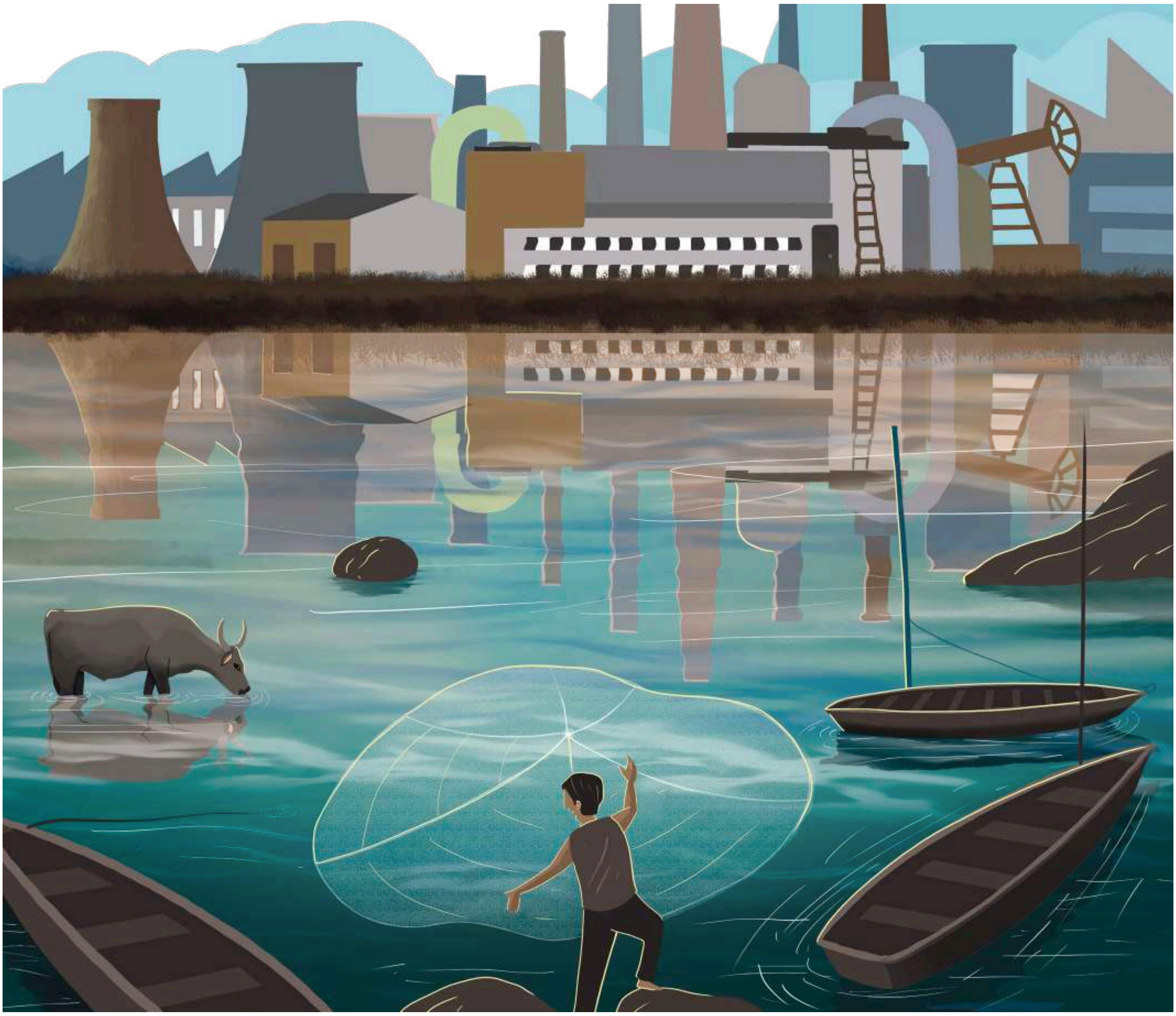
Table 2.1. *Water footprints of list of beverages and aerated drinks.*

2.2. Water Footprint of a Business

It is a complex exercise to assess the water footprint of a business. Estimating the water footprint for a business becomes imperative, given the risks faced by the companies. In fact, water crisis has been identified as one of top ten business risks by World Economic Forum (WEF) to be encountered by the corporate sector globally.

Even NITI Aayog (NITI Aayog, 2023) recognises that water will accentuate the financial risks for the business in India. These risks are more pronounced by sectors like beverages which are heavily dependent on water as their key input. The water footprint of a business is defined as the total volume of freshwater that is used directly or indirectly to run and support the business. The business water footprint consists of two components: the **operational water use** (direct water use) and **the water use in the supply chain** (indirect water use). The operational (or direct) water footprint of a business is the volume of freshwater consumed or polluted due to the business's own operations or direct water use. The supply chain (or indirect) water footprint of a business is the volume of freshwater consumed or polluted to produce all the goods that form the inputs of production of the business. Instead of the term **'business water footprint'** one can also use the terms **'corporate water footprint'** or **'organizational water footprint'** (Hoekstra et al., 2011). The operational water footprint assessment would aid industries to enhance the operational water use efficiency and minimise the water waste by adopting water saving techniques, whereas the indirect or supply chain water footprint assessment maps the water used in the supply chain of the industrial products and identifies the associated risks and sustainability of the business.

A product water footprint is the total volume of freshwater consumed, directly and indirectly, to produce a product.



Water footprint

A full water footprint assessment considers the impacts of this water consumption on local watersheds, as well as appropriate response strategies to minimize those impacts (Coca-Cola and Nature Conservancy, 2010). However, accounting for the water footprints of the ingredients and packaging materials of a business is debatable as the water use efficiency of the processes involved in their manufacturing by another business unit is not within the scope of a business unit.

As shown in Figure 2.3, the business water footprint consists of two components: **the operational water use** (direct water use) and the water use in the **supply chain** (indirect water use). The **operational** (or direct) water footprint of a business is the volume of freshwater consumed or polluted due to the business's own operations. The supply chain (or indirect) water footprint of a business is the volume of freshwater consumed or polluted to produce all the goods and services that form the inputs of production of the business. The overhead water footprint refers to freshwater use that in first instance cannot be fully associated with the production of the specific product considered but refers to freshwater use that associates with supporting activities and materials used in the business, which produces not just this specific product but other products as well. The **overhead water footprint** of a business has to be distributed over the various business products, which is done based on the relative value per product. The overhead water footprint includes, for example, the freshwater use in the toilets and kitchen of a factory and the freshwater use behind the concrete and steel used in the factory and machineries (Ercin et al., 2011).

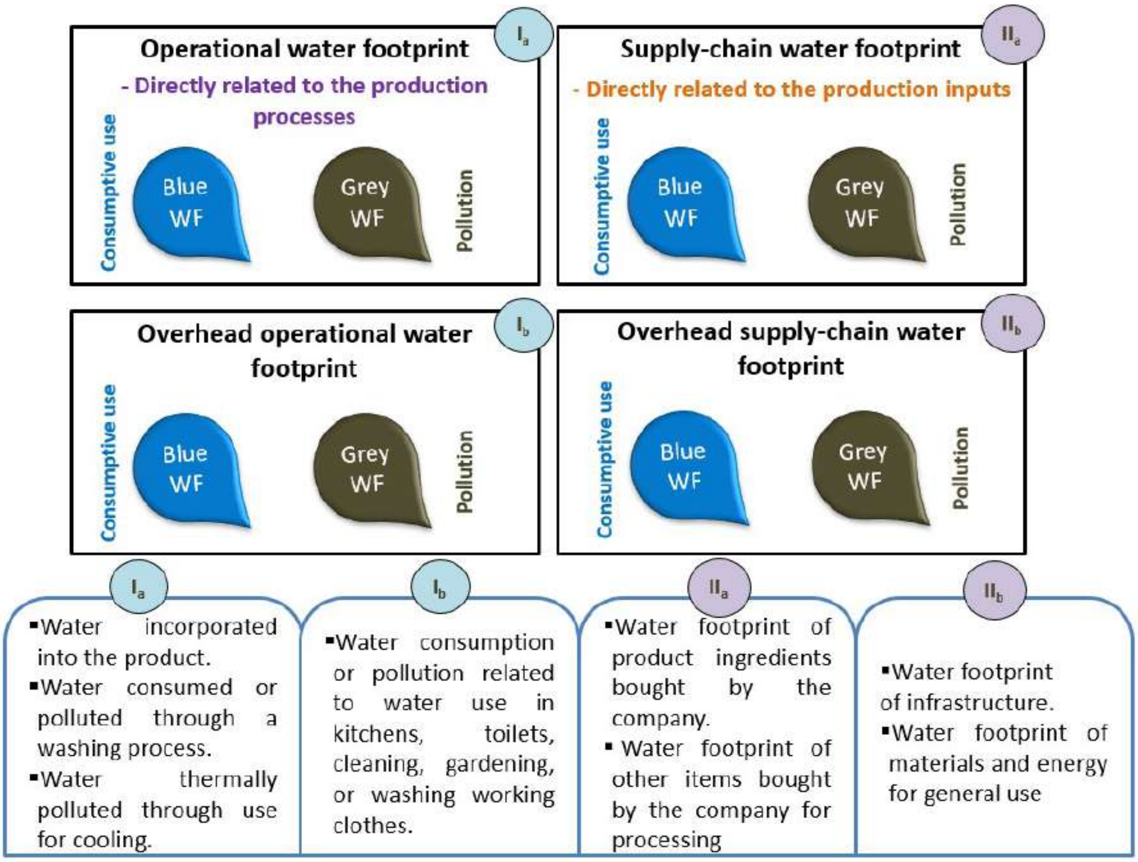


Figure 2.3: *Components of water footprint of a business*

Thus, the water footprint of a business unit (WF, volume/time) is calculated by adding the operational water footprint of the business unit (WF_O) and its supply-chain water footprint (WF_S):

$$WF = WF_O + WF_S \quad \text{---(2.2)}$$

2.2.1 Operational water footprint

Both components in Equation (2.2) consist of a water footprint that can be directly associated with the production of the product in the business unit and an overhead water footprint. The operational water footprint is equal to the consumptive water use and the water pollution that can be associated with the operations of the business:

$$WF_O = WF_{O,\ inp} + WF_{O,\ overhead} \quad \text{---(2.3)}$$

2.2.2 Supply-chain water footprint

The supply-chain water footprint can be estimated as the sum of consumptive water use by the inputs and the water pollution that can be associated with the supply chain of the business:

$$WF_S = WF_{S,\ inputs} + WF_{S,\ overhead} \quad \text{---(2.4)}$$

If there are different input products 'i' originating from different sources x, the supply-chain water footprint of a business unit is calculated as:

$$WF_S = \sum_x \left[\sum_i \left(WF_{prod}[x,i] \times I[x,i] \right) \right] \quad \text{---(2.5)}$$

in which WF_S represents the supply-chain water footprint of the business unit (volume/quantity), $WF_{prod}[x,i]$ the water footprint of input product i from source x, (volume/unit of product) and I[x,i] the volume of input product i from source x into the business unit (product units/time).

2.3 System Boundary for Water Footprint Estimation

Given the typologies of water footprints associated with the industrial production, setting the boundary conditions becomes crucial for robust estimation of water footprints. Hence, assessing the water footprint of a business, the system boundary of the business should be clearly delineated and defined. It should be possible to schematize the business into a system that is clearly distinguished from its environment and where inputs and outputs are well-known (Hoekstra et al., 2011). The system boundary should be different for: 1) Water footprint of the production unit, and 2) Impact assessment of water footprint of the production unit that includes any water conservation within the watershed along with the level of water scarcity and quality.

2.3.1 System boundary for production unit's water footprint

System boundary can be referred to as a set of criteria specifying which unit processes are part of a product system or the activities of a production unit, while cut-off criteria is a specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study (ISO, 2014). Since the water footprint of a production unit is different from that of its product, the two aspects are to be considered

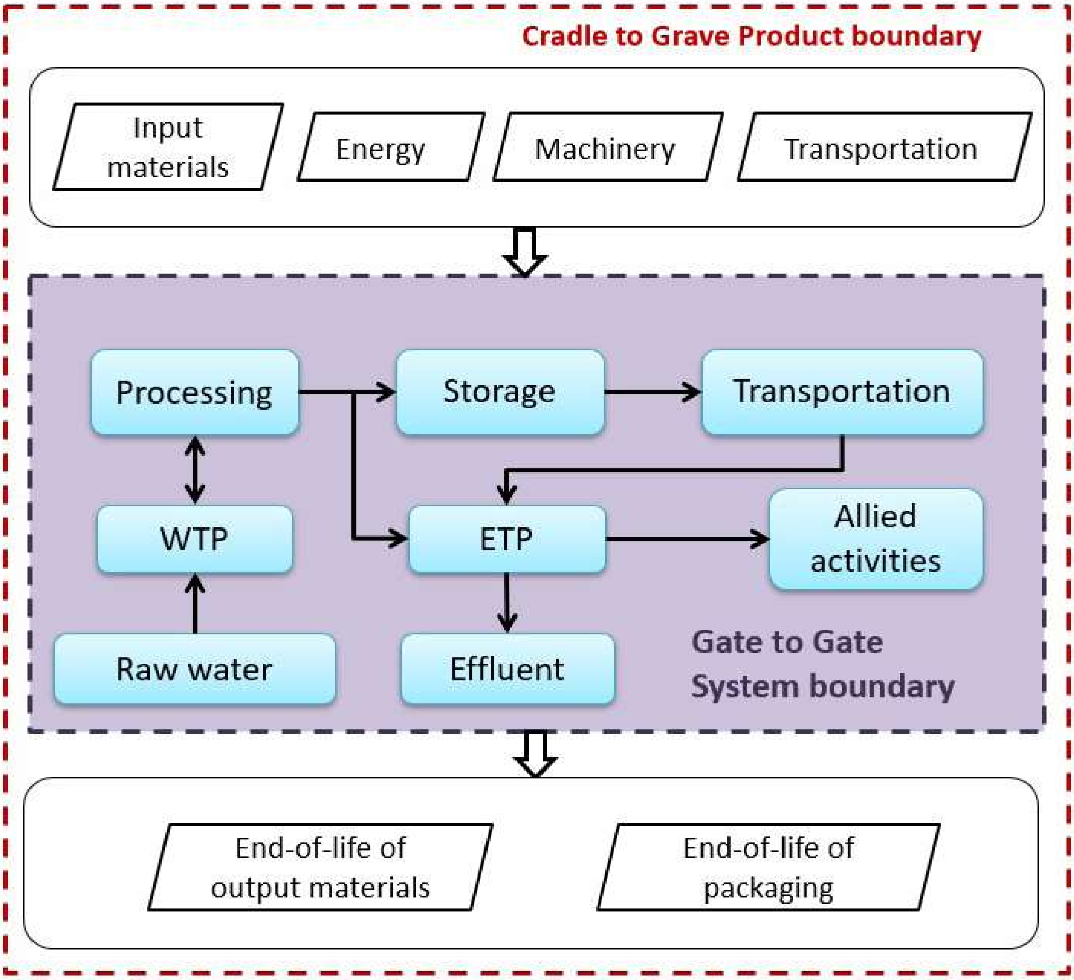


Figure 2.4: *Conceptualisation of 'Gate to Gate system boundary' for a production unit*

separately as shown in Figure 2.4 where the system boundary for the business unit can be considered as 'Gate to Gate' rather than 'Cradle to Grave' or 'Gate to Grave' for a product.

2.3.2 System boundary for impact assessment of the production unit

As shown in Figure 2.5 and 2.6 the point at which a company is extracting water or discharging wastewater defines a 'point of origin' from which a contributing watershed can be delineated upstream of this point. The 'area of influence' depicts the boundary within which potential ecological and social cumulative impacts should be assessed. While this example depicts a watershed-based assessment, similar logic can be applied to water extractions from an aquifer or lake (Coca-Cola and Nature Conservancy, 2010).

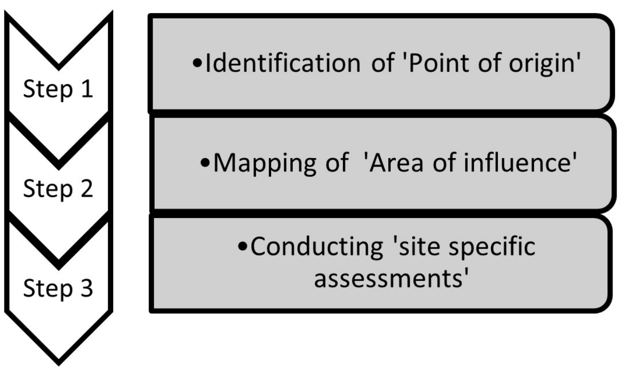


Figure 2.5: *Stages approach in impact assessment of a production unit*

In the identified local watershed, three possible indicators are examined, depending upon which water sources are influenced by the company's water consumption and pollution discharge: 1) historical changes in river flow; 2) changes in lake or aquifer levels; and 3) violations of water quality standards. Those watersheds that appear to be adversely impacted based on these indicators will require further analysis to determine appropriate response strategies. The third step involves a site-specific assessment of not only water quantity and quality impacts, but also ecological and social impacts (Coca-Cola and Nature Conservancy, 2010).

Thus, in the context of an impact-adjusted water footprint estimation, the catchment area within which the production unit is located needs to be considered as the system boundary exclusively for water conservation measures (Hoekstra et al., 2011). However, the water footprint estimation can be performed considering the production unit as the boundary.

2.4. Sustainability Assessment of Water Footprint

Based on Hoekstra et al. (2011), the sustainability assessment of water footprint involves three dimensions, namely environmental, economic and social (Figure 2.7):

a. Environmental sustainability

Water quality should remain within certain limits, and as an indicator of what these limits are, ambient water quality standards can be considered for the region. In addition, river and groundwater flows should remain within certain limits compared to natural run-off, in order to maintain river and groundwater-dependent ecosystems and the livelihoods of the people that depend on those ecosystems.

In the case of rivers, the environmental flow requirements form boundaries for run-off alteration, comparable to the way in which water quality standards form boundaries for pollution.

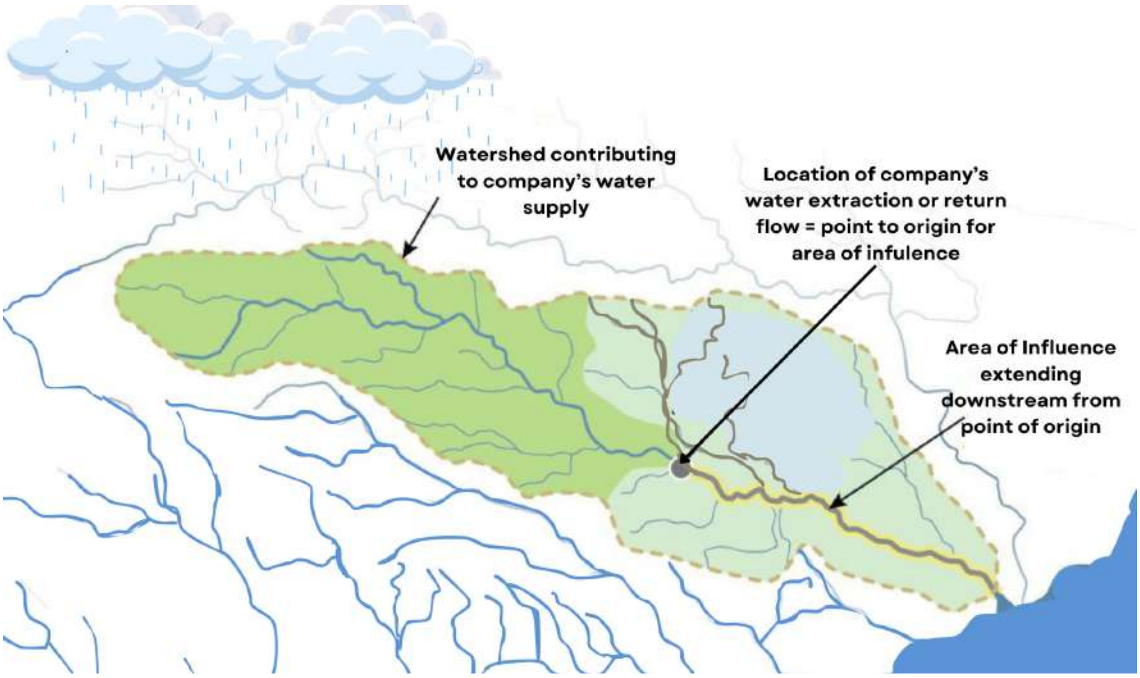


Figure 2.6: *Conceptual Diagram of Impact Assessment Boundaries (Image source: Coca-Cola and Nature Conservancy, 2010)*

b. Social sustainability

A minimum allocation of available freshwater needs to be kept for the basic human needs. It means a minimum domestic water supply for drinking, washing, and cooking and a minimum allocation of water to food production to secure a sufficient level of food supply to all.

This criterion implies that only the fraction of available freshwater supply that remains after subtraction of environmental water needs and water requirements to sustain basic human needs can be allocated to luxury goods. A minimum domestic water supply for drinking, washing, and cooking needs to be guaranteed at the catchment or river basin level.

costs and a scarcity rent. If this is not the case, the water footprint is unsustainable.

The sustainability of the water footprints of a production unit can be assessed through the water footprints of a) unit processes and b) products. When the details of water audit report are available, the various unit processes can be evaluated against industry standards to assess their sustainability. Also, assessments of the products can be used to see the processes that are responsible for the unsustainable components in the business water footprint and to identify in which catchments these processes are located. Thus, sustainability assessment calls for an impact-adjusted water footprint estimation.

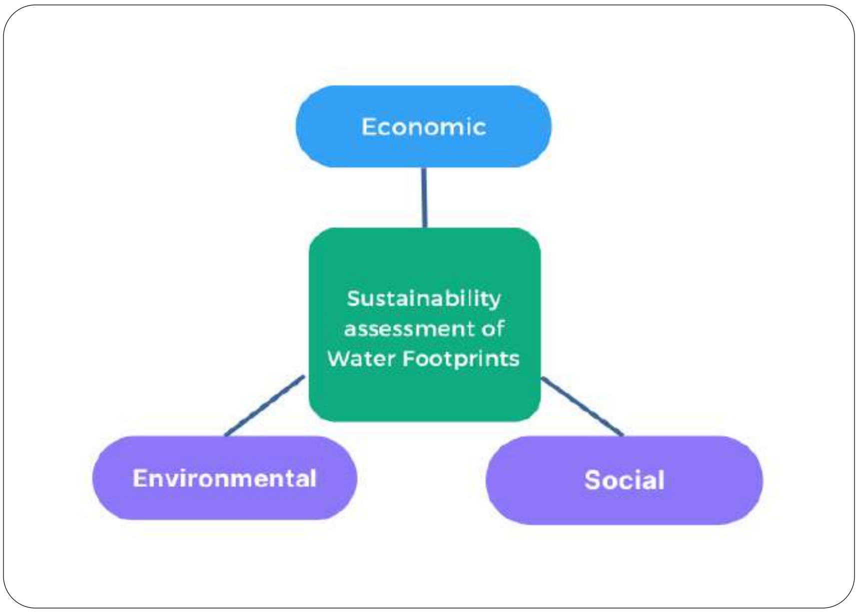


Figure 2.7: *Dimensions of water footprint sustainability*

c. Economic sustainability

Water needs to be allocated and used in an economically efficient way. The benefits of a (green, blue, or grey) water footprint that results from using water for a certain purpose should outweigh the full cost associated with this water footprint, including externalities, opportunity

2.5 Impact-Adjusted Water Footprint

Industries are more sensitive to wastewater than agricultural sectors. The environmental impact of industrial processes is the key to properly assessing the corresponding water footprints and water risk. Often, capturing these impacts are quite cumbersome and demanding on data.

With respect to the suitability of the different methods for assessing the impacts of water use, arguably the approaches which only assess the quantity of the water used provide only part of the information due to exclusion of grey water footprint. The environmental impacts of water consumption will be different depending on the level of water scarcity of the area even if the quantity used is the same for a particular product. Therefore, the volumetric water footprint could be misleading as it does not account for the environmental impacts of water consumption (Ridoutt et al., 2010; Ridoutt and Pfister, 2010).

Problems get amplified when water footprint strives to show water consumption and pollution in industries simultaneously. This essentially involves capturing both backward and forward impacts based on the defined system boundary.

Current problems in water footprint methodologies may result in underestimation of industrial water footprints; hence, processes should be improved (Jeswani and Azapagic, 2011).

Current grey water footprint method cannot be applied to evaluate the impact of wastewater discharge on local water pressure. The methodology using grey water footprint should be improved by considering the quality, quantity, and time effects (Gu et al., 2014).

Impact-oriented footprints are used to minimize the impacts of water use on human health, ecosystems, and freshwater resources. Recent studies integrate pollution and scarcity within water footprint impact assessment framework (Chenoweth et al., 2014; Coca-Cola and Nature Conservancy, 2010; Pierrat et al., 2023). AWARE (Available Water Remaining) method developed by the European Commission (Boulay et al., 2018) is a water use midpoint indicator representing the relative Available WAter REmaining per area in a watershed, after the demand of humans and aquatic ecosystems has been met. The efforts towards positive impacts through water resources developmental activities can be rewarded in terms of water credits that can mitigate the impact of water scarcity and pollution.

2.5.1 Negative impacts – *Water scarcity & pollution*

The methodology for estimating the industrial virtual water footprint involves calculating the amount of freshwater consumed and the impact on local ecosystems and pollution generated during production. Jeswani and Azapagic (2011) assess the impact of water footprints using multiple methods based on water-use-to-availability ratio, namely, eco-scarcity method (Frischknecht and Jungbluth, 2009), The Llorenç Milà i Canals et al. approach (Milà i Canals et al., 2009), and The Pfister et al. approach (Pfister et al., 2009). The study finds that the results vary so much due to diverse geographical and catchment characteristics. Pierrat et al. (2023) consider **water resource footprint (WRF)** to model the impacts of freshwater stress, i.e., pollution and scarcity, on water resource availability. WRF distinguishes the pollution deprivation potential (PDP) from the **scarcity deprivation potential (SDP).** The WRF associated with a water user is a fraction of the monthly PDP and SDP calculated at the watershed scale, and this fraction corresponds to the user's contributions to water scarcity and water quality degradation. A scarcity weighting factor (ws) can be used to calculate the SDP of a specific business unit (user), which is calculated as the ratio of the user's water consumption by the total sectoral demand. The pollution weighting factor (wp) is proportional to the user's emissions and the severity of the pollution compared to the quality requirements. It is calculated as the product of the ratios between the user's emissions by the total emissions, and the pollutant's concentration exceedance by the sum of all pollutants' concentration exceedances. Therefore, the operational form of WRF can be described as the sum of weighted PDP and SDP of the production unit aggregated at monthly scale (Pierrat et al., 2023).

2.5.2 Positive impacts – *Water neutrality*

Water neutrality has a crucial role in reducing the impact of water footprint and aims at reducing an activity's water footprint as much as reasonably possible while offsetting the negative externalities of the remaining water footprint (Hoekstra and Chapagain, 2008). 'Water Neutral' may not only imply that freshwater use is reduced to zero, but rather that the negative economic, social, and environmental externalities are reduced to a large extent and that the remaining impacts are fully compensated (NITI Aayog, 2023a).

Water credits refer to a system where

individuals, businesses, or communities can earn or purchase credits for sustainable water use or conservation practices. These credits can then be traded, sold, or redeemed to support water-related projects, infrastructure, or initiatives (Gonzales et al., 2017).

Water credits deal with the transaction between water deficit and water surplus entities within a basin. However, the **virtual trade of water credits** can happen across basins. Water credit represents a fixed quantum of water that is conserved or generated. It is almost a mirror image of the concept of carbon credits. However, unlike carbon credits, the spatial limits for transactions are confined to hydrological boundaries — that is, river basin or watershed (Sarkar and Tigala, 2023) as discussed in subsection 2.3.2.

For example, multiple industries can offset their impact by buying water credits from municipalities that are fund-crunched to finance large-scale floodwater harvesting or wastewater treatment projects that conserve freshwater resources at a city level and promote wastewater reuse.

More details on water neutrality are provided in Section 3.1, while the management strategy for water credits is explained in Section 3.2.

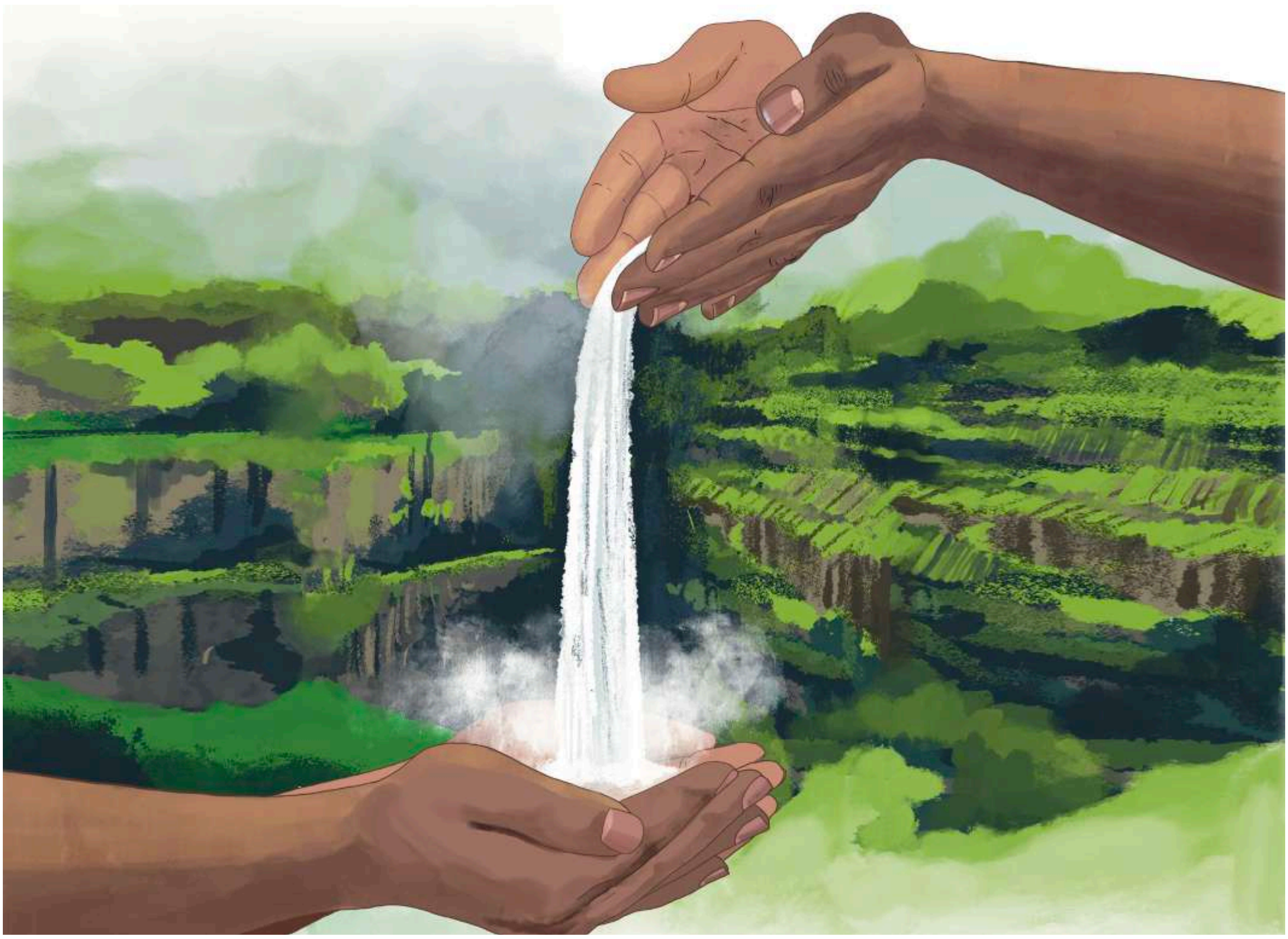
CHAPTER 03

Review of Water Neutrality, Water Credits, Water Trading and Water Footprint Reduction Strategies

In this section, various aspects of water credits are reviewed, namely, objectives of water credit, water trades, and national schemes for water credits through water footprint reduction, fiscal instruments and financing models, and sustainability product labelling for water credits.

3.1 Water Neutrality

According to (NITI Aayog, 2023a), water neutrality can be defined as total freshwater consumption that consists of direct freshwater and estimated indirect or virtual water use as a part of water critical supply chains, applicable as on current date referred to as the date on which the evaluation is done, should either be less than or equal to all the quantifiable (and verifiable) water savings achieved through strategies undertaken as well as to be further (and futuristically) executed towards improving operational water use efficiencies, water conservation efforts as shown in Figure 3.1. Hence, water neutrality has both temporal as well as spatial dimension. Operational efficiency, operational sustainability, and supply-chain systems, all inclusive, form elements of estimating credits and debits towards defining water status (i.e., water neutral, water positive, and water negative). What differentiates water positive from just saving water is the focus on areas where water security is a problem and overcompensating for consumption in those places. Once companies have identified areas where water scarcity is an issue, they then look for ways to cut back on water and make up for what they are using (Schupak, A., 2021).



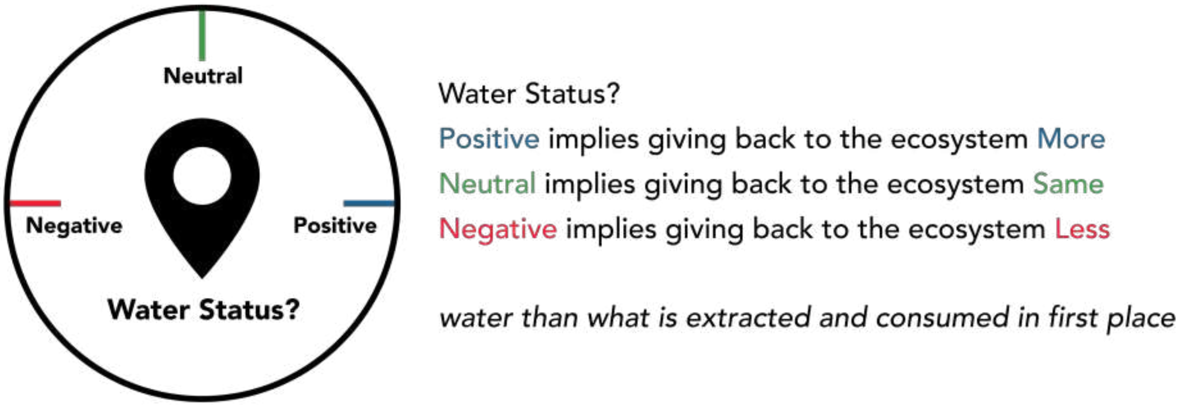


Figure 3.1: *Concept of water neutrality (Source: NITI Aayog, 2023a)*

Through water neutrality a system of accountability and responsibility for water footprint of the industry is established such that there is a transparency of all the water usages of the system as shown in Figure 3.2.

Water used for conservation in watersheds should be of the quality which is at least similar or preferably better than the quality of water of the ecosystem that receives it. Only then will it be used for calculations of water status. All interventions which do not measure quality as a function of conservation effort or strategy undertaken will not be used for calculation of water status.

Total current offset should be less than or equal to all quantifiable and verifiable water savings currently and futuristically achieved in water stressed watersheds (plant's as well as its supply watersheds (plant's as well as its supply

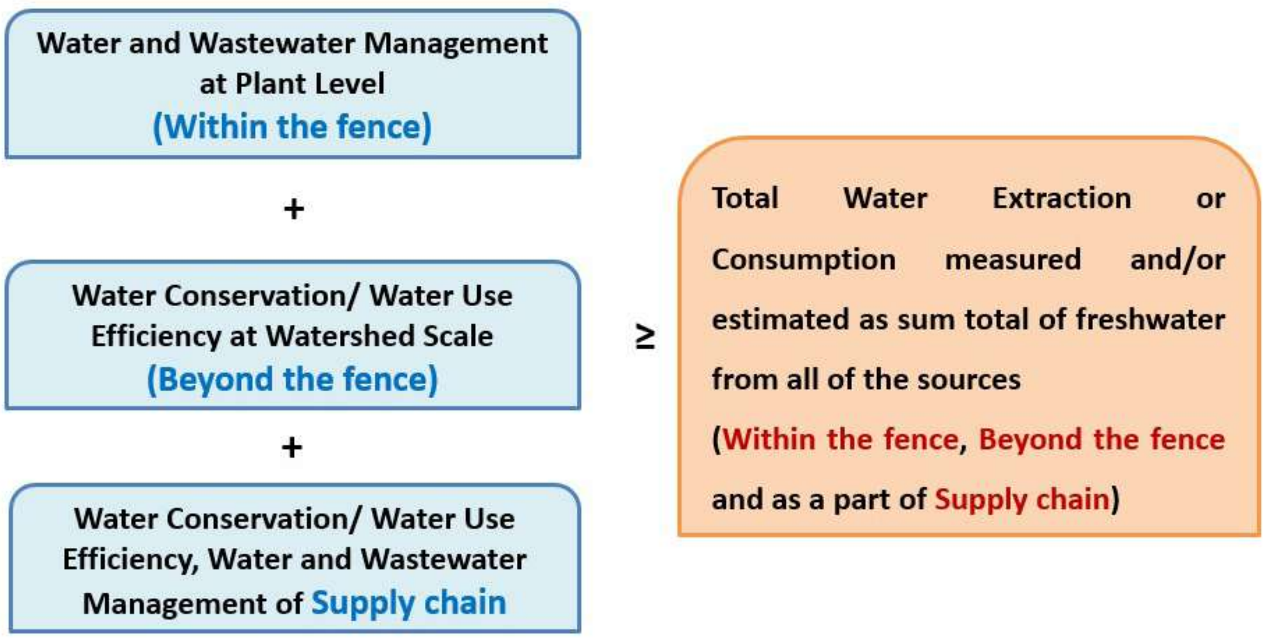


Figure 3.2: *Components of water neutrality based on NITI Aayog*

chains') through further and future improvement in operational water use in the plant and its supply chains. The equation aims to capture the components of "space" (defined as 'x' and "time" defined as 't') and in a mathematical form, it can be expressed as follows:

$$
\begin{aligned}
&\left[\sum_{t}^{t+1}\begin{pmatrix}\text{water and wastewater}\\ \text{management at plant level}\\ \text{(operational efficiency)}\end{pmatrix}_{x_1,t+1} + \sum_{t=0}^{t}\begin{pmatrix}\text{water conservation}\\ \text{in plant's watershed}\end{pmatrix}_{x_1,t}\right.\\
&\quad + \sum_{t}^{t+1}\begin{pmatrix}\text{additional water conservation}\\ \text{in plant's watershed}\end{pmatrix}_{x_1,t+1}\\
&\quad + \sum_{0}^{t}\begin{pmatrix}\text{water conservation}\\ \text{in supply chain's watershed}\end{pmatrix}_{x_{n(n\neq 1)},t+1}\\
&\quad + \sum_{t}^{t+1}\begin{pmatrix}\text{additional water conservation}\\ \text{in supply chain's watershed}\end{pmatrix}_{x_{n(n\neq 1)},t+1}\\
&\quad \left. + \sum_{t}^{t+1}\begin{pmatrix}\text{additional water and wastewater}\\ \text{management at plant level in}\\ \text{supply chains}\\ \text{(operational efficiency)}\end{pmatrix}_{x_{n(n\neq 1)},t+1}\right]\\
&\geq \left[\Sigma_0^t\begin{pmatrix}\text{Direct fresh water withdrawals or use or consumption}\\ \text{in the plant as well as in the supply chain}\end{pmatrix}_{x_1,t} + \right.\\
&\left.\Sigma_0^t\begin{pmatrix}\text{Additional estimation of direct fresh water withdrawals}\\ \text{or use or consumption in the plant as well as}\\ \text{in the supply chain (near future expansion)}\end{pmatrix}_{x_1,t+1}\right] \qquad (3.1)
\end{aligned}
$$

----(3.1)

where,

x1 = plant's watershed or plant's location; xn = supply chain watersheds or supply chain locations; t = time step (i.e., current date on which water status evaluation is conducted), and t+1 = future time step (since certain intervention that the plant chooses to undertake could be futuristic in nature in order to achieve status of neutrality or positivity).

In such a case certification could be offered as provisionally valid for a certain time period basis the written commitment provided by the plant for undertaken futuristic interventions (NITI Aayog, 2023a).

3.2 Water Credits – Management Strategy

The UN GEMS/Water Program uses a similar concept called the **'Green Water Credits'** and is implementing this in countries like China, Kenya, and Morocco. This project incentivizes upstream farmers to undertake green water management practices to reduce runoffs, boost groundwater recharge, and curb sedimentation in reservoirs. Downstream, the public and private beneficiaries have created an investment fund to address the gap between the farmers' initial investment and the realization of benefits by the end-users downstream (ISRIC, 2006; UNDESA, 2013).

The Ministry of Environment, Forest and Climate Change (MOEFCC), Government of India has notified green credits as a competitive market-based mechanism, wherein water credit is identified as a component of tradeable item. Specific emphasis is laid on private sector

ndustries and companies. Amongst sectors identified as part of green credit eligible sectors, water based green credits are chosen as an important sector too. Following set of specific objectives (MOEFCC, 2023) are spelt out as the key purpose of green credit in India:

1. Develop standards and associated Measurement, Reporting and Verification mechanisms.
2. Equivalence of Green Credits generated from each identified activity.
3. Establish Knowledge and Data platform.
4. Establish linkages with other National and International registries.

Water based green credit will primarily be earned through the following three activities.

1. Water conservation
2. Water harvesting/water use efficiency, and
3. Treatment/reuse of wastewater

and multiple ways through which water credits can be earned.

a. Water saving technologies

Implementing water-efficient technologies and practices is a key step. This might include using water-saving equipment and optimizing production processes. By reducing water consumption, an industry can earn water credits (The Statesman, 2023).

b. Water trading

Industries can participate in water trading markets, and these markets allow companies to buy and sell water credits based on their water usage and conservation efforts. This can be a way to incentivize water efficiency. NITI Aayog has been studying the feasibility of water trading in India and has proposed allowing trading of treated wastewater to incentivize and encourage efficient use of water (NITI Aayog, 2023b).

Punjab Groundwater Extraction and Conservation Directions, 2023, *which have come into effect from 1 February 2023, allow users to opt for implementation of a water conservation scheme with the approval of the Authority, either within the unit or outside. For every cubic meter (1,000L) of water conserved, the user will earn a rebate equal to Rs 2.50. The maximum rebate available to a unit will depend on the zone in which the unit is located and the volume of groundwater being extracted by the unit (The Statesman, 2023).*

c. Water offset programs

Industries can participate in water offset programs, which involves compensating for water usage by funding or implementing water-saving projects in the local community or watershed. These efforts can earn water credits (NITI Aayog, 2023a).

d. Water quality improvement

Improving water quality in industrial processes is not only a regulatory requirement but also a crucial step toward achieving water-positive status. It protects ecosystems, public health, and the reputation of the industry while contributing to the sustainable management of water resources.

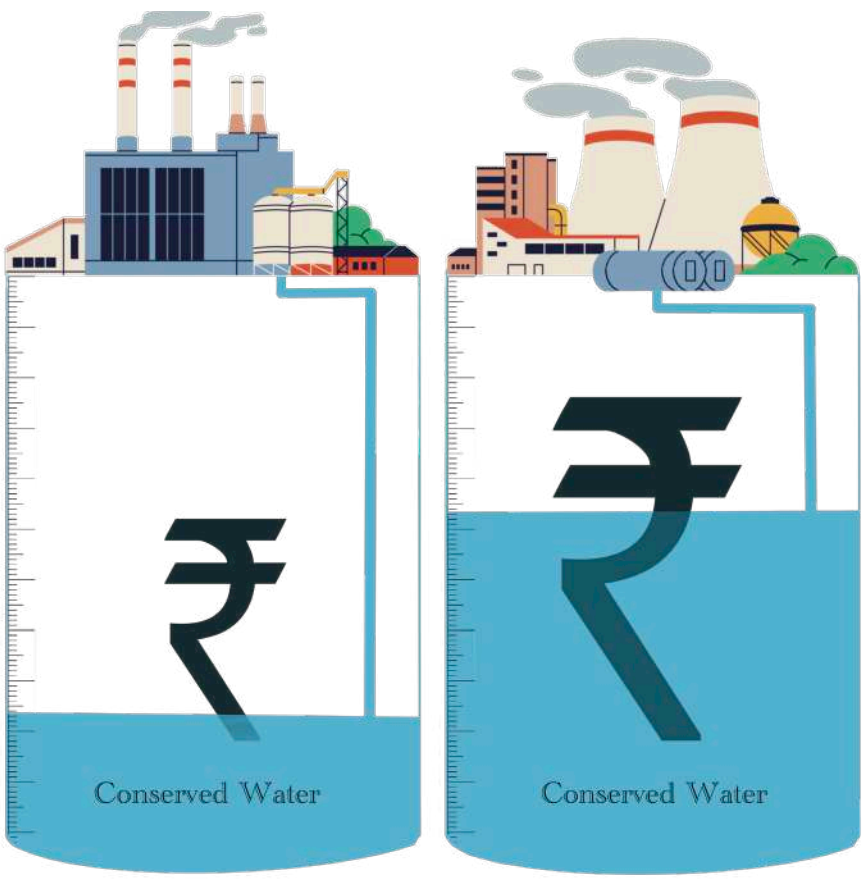
3.2.1 Fiscal instruments for water credits

Fiscal instruments for water credits refer to the use of various fiscal and financial mechanisms or incentives to promote the conservation and efficient use of water resources. They can be used to incentivize companies to reduce their water usage and promote sustainable water management practices. Water credits, in this context, would involve assigning a certain value or credit to the saved or conserved water, encouraging individuals, businesses, or governments to adopt water-saving practices.

As per UNEP (Young, 2015), in water sector, fiscal instruments are used to influence:

- The demand for goods and services, including demand for access to water;
- Private investment, including investment in the water supply and associated technologies;
- Private savings, including water that is stored for later periods and money put aside to assist during periods of drought;
- The distribution of income (e.g. providing access to water at subsidized prices).

A few fiscal instruments that are either existing or can be implemented include: a) Pricing, b) Trading, c) Cooperation, and d) Risk Management Schemes (Delacámara et al., 2013; Mario Gómez and Leflaive, 2015).



a. Water Pricing

Various water tariff models have been prevailing across countries. Table 3.1 presents the broad water tariff models and structures.

Tariff structure	Cost recovery	Economic efficiency	Equity	Affordability
Fixed charge	**Adequate** Provides stable cash flow if set at appropriate level	**Poor** Does not send a message about the cost of additional water	**Poor** People who use large quantities of water pay the same as those who use little	**Adequate** If differentiated by having different tariffs depending on ability to pay
Uniform volumetric charge	**Good** If set at appropriate level. Moreover, adjust automatically to changing consumption	**Good** If set at or near marginal cost of water	**Good** People pay how much they actually use	**Average** However, it is possible to differentiate set of consumers by geographical/ social barriers
Increasing block tariff	**Good** Only if the size of the blocks is well designed	**Good** If water is sold at marginal cost or near to marginal cost	**Average** Normally people do not pay according to the costs their water use imposes on the utility	**Poor** Penalise poor families with large households and/or shared connections
Decreasing block tariff	**Good** But only if the sizes of the blocks are well designed	**Good** If water is sold at marginal cost or near to marginal cost (applicable only when there is no water scarcity)	**Poor** People do not pay according to the costs their water use imposes on the utility	**Poor** This would only facilitate higher consumption categories with better affordability and that goes against the category with less affordability

Table 3.1: *Evaluation of Tariff Models*

There are multiple factors that can be considered for water pricing as mentioned in Table 3.2

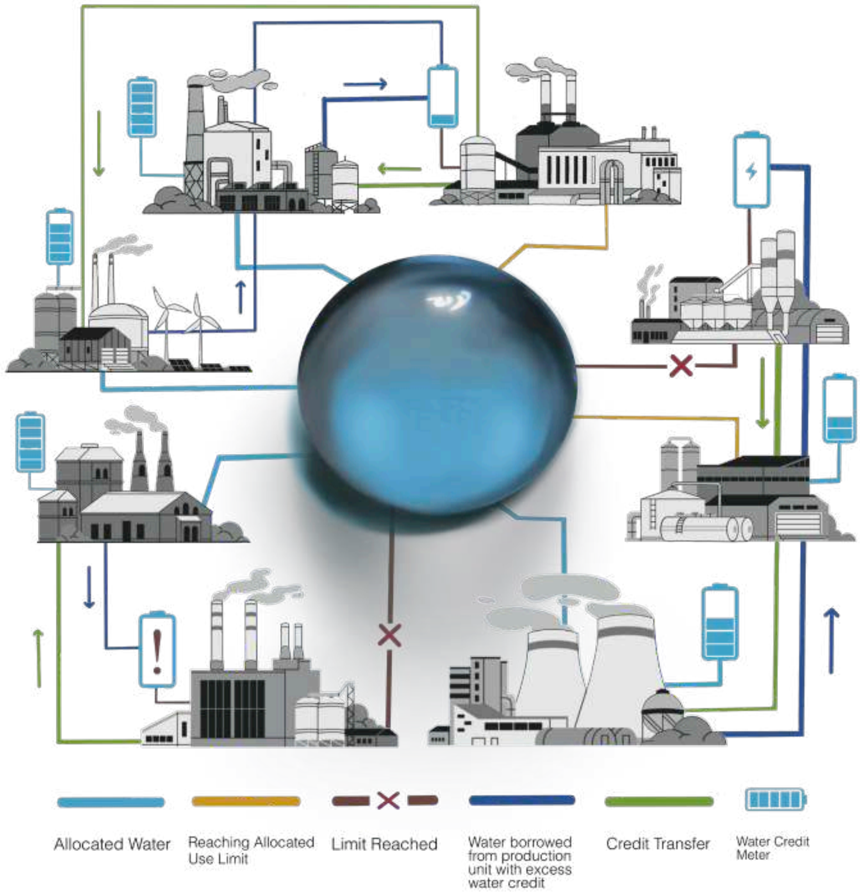
Existing	Can be implemented
1) Fixed charges: *designed to recover some or all the costs associated with connecting to a water main, irrigation system and sewage system, associated with the on-going provision of services, such as administrative overheads and the reading of meters, and associated with the cost of building and maintaining infrastructure, including dams, pipes, pumps and also the costs of protecting catchments, etc.* ***2) Variable charges:*** *associated with the volume of water used and/ or the area over which water is applied, and associated with transactions, such as the sale of a water entitlement or allocation and relocation to another property.*	***1) Impact Fees:*** *Local governments can impose impact fees on developments that require substantial water usage. These fees could be reduced if developers implement water-saving technologies or practices in their projects.* ***2) Water footprint tax:*** *This involves taxing products and activities based on their water consumption throughout their lifecycle. Products with higher water footprints would have higher taxes, encouraging consumers and producers to opt for water-efficient alternatives.* ***3) Water Resource Tax:*** *Governments can impose taxes on the extraction or use of water resources. These taxes can help generate revenue for water management and conservation efforts.* ***Pollution Tax:*** *Taxes on industrial or agricultural pollutants can encourage businesses to reduce their water pollution, which can lead to cleaner water sources.*

Table 3.2: *Various types for water pricing methods*

b. Water trading

Like carbon trading systems, water trading involves allocating a certain amount of tradable water permits to different entities. Entities that use water efficiently and have excess credits can sell them to those that need more water credits due to higher usage. This creates a market-driven approach to water conservation. Establish platforms where water users can buy and sell water credits, allowing those with excess credits to profit and incentivizing efficient water use. The various programs that can be implemented include:

- **Cap-and-Trade Programs:** Set a limit (cap) on total water consumption in a region, and then issue tradable water consumption allowances.



Participants that consume less water can sell their unused allowances to those who exceed their allocated limit.

- Tradable pollution rights designed to maintain water quality
- **Water Efficiency Certificates:** Introduce a certification system for water-efficient practices. Individuals or businesses that achieve higher levels of water efficiency could receive certificates that lead to benefits such as tax breaks or lower water tariffs.

c. Cooperation

The various programs that can be implemented include:

- Water Footprint Labelling: Like nutritional labels on food products, water footprint labelling on consumer products can raise awareness about the water usage associated with manufacturing and encourage consumers to choose products with lower water footprints.
- Land Use Planning and Zoning: Integrate water conservation requirements into land use planning and zoning regulations. This could include requirements for green spaces, permeable surfaces, and water-efficient landscaping.

d. Schemes

The various risk management schemes include subsidies, grants and donations that can be implemented are:

- Landscape Conversion Subsidies: Offering subsidies for converting traditional lawns to water-efficient landscaping, native plant gardens, or xeriscapes can help reduce outdoor water usage.

- **Subsidies for Efficient Technologies:** Governments can provide subsidies or tax incentives to individuals or businesses that invest in water-efficient technologies such as low-flow faucets, efficient irrigation systems, and rainwater harvesting systems.
- **Water tax credits:** Under Section 80-IA (Income Tax Department, 2011), the government of India offers income tax deduction for infrastructure development projects that includes water supply and treatment. This option offers tax credits to individuals or businesses that are engaged in the business of developing or operating and maintaining of water supply projects, water treatment systems, irrigation projects, sanitation and sewerage systems etc.
- **Water Efficiency Rebates**: Governments or utility companies can offer rebates to customers who invest in water-saving technologies or practices. For instance, homeowners who install low-flow toilets, rainwater harvesting systems, or water-efficient landscaping could receive a rebate on their water bills.
- **Water Conservation Grants:** Governments can offer grants to businesses, communities, or individuals that propose innovative and effective water-saving projects. This can stimulate the development and adoption of new technologies and practices.
- **Water Certification Programs:** Creating a certification program for water-efficient products, services, or practices can incentivize consumers to choose options that conserve water. Businesses achieving certification could receive benefits like tax breaks or marketing advantages.
- **Green Bonds:** Governments or organizations can issue green bonds to finance water conservation projects. These bonds specifically fund projects that have a positive environmental impact, such as water-efficient infrastructure development or restoration of water ecosystems.
- **Deposit-Refund Systems:** Like bottle deposit systems, consumers could pay a deposit on water-intensive products, and they receive a refund when they return the product for recycling. This encourages responsible consumption and recycling.
- **Rainwater Harvesting Incentives:** Provide financial incentives to individuals or businesses that implement rainwater harvesting systems, which can reduce the strain on traditional water sources.

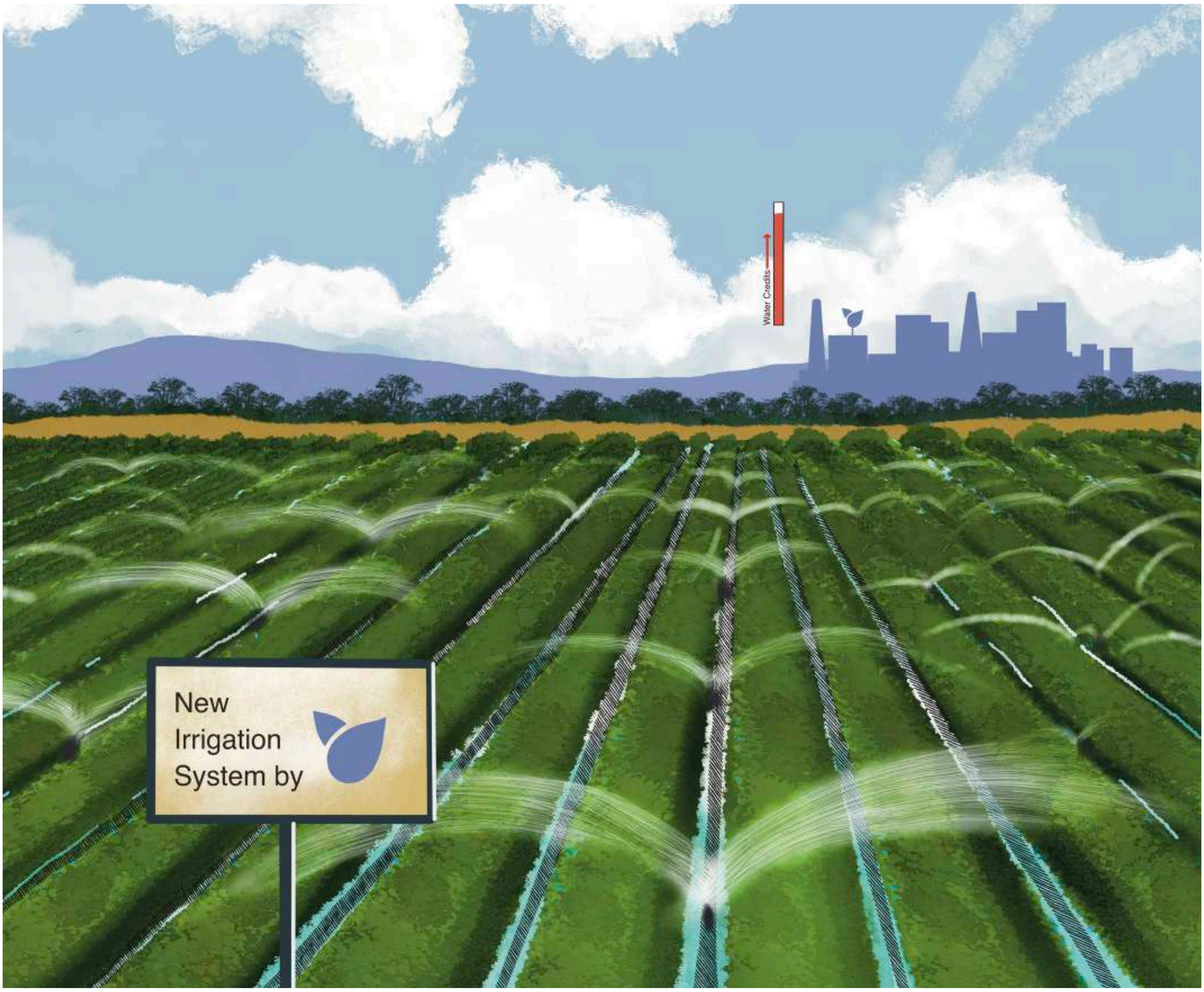
These fiscal instruments are examples of how economic incentives and regulations can be used to promote water conservation and sustainable water management practices. The specific instrument chosen would depend on the context, regulatory framework, and goals of the jurisdiction implementing them. The effectiveness of these fiscal instruments depends on various factors including the regulatory environment, public awareness, and local context. It is important to carefully design and implement these instruments to ensure that they achieve the desired outcomes of water conservation while also being fair and equitable.

3.2.2 Financing models for water credits

Financing models for water credits can vary depending on the specific context and goals of the program. Here are a few potential financing models:

a. Pay-for-Performance Contracts: This model involves a contract between a water user (individual or entity) and a water management organization. The user commits to certain water conservation actions, and in return, they receive water credits. These credits can then be monetized by selling them to others who need to offset their water use or by redeeming them for financial incentives or discounts on water bills (water.org, 2023).

b. Cap-and-Trade System: Similar to carbon emissions trading, a cap-and-trade system sets a limit (cap) on total water consumption within a specific region. Water users who consume less than their allocated share can sell their excess credits to users who exceed their limits. This creates a market for water credits and provides financial incentives for efficient water use (Derouin, 2018) as shown in Figure 3.3.



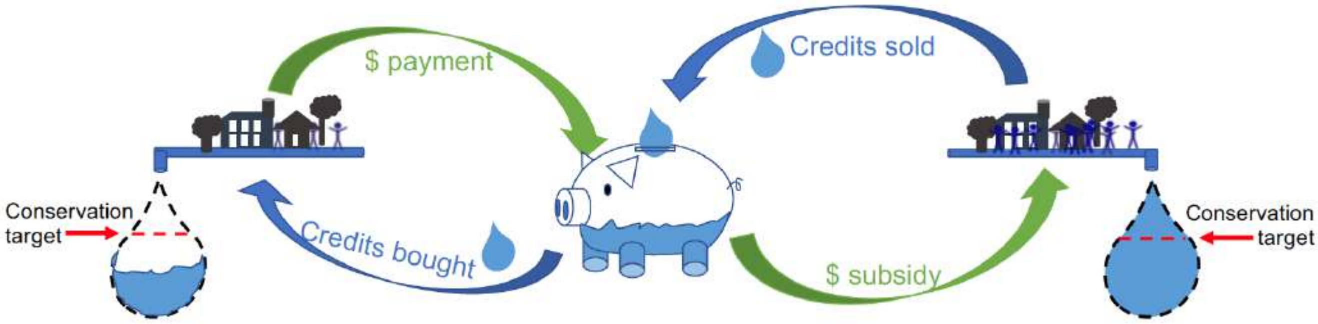


Figure 3.3: *Conceptual diagram of a water conservation trading scheme (Source: Stanford University)*

c. Water Offset Programs: Businesses or individuals can voluntarily invest in water offset programs to balance their water footprint. They purchase water credits to support water-saving projects such as restoring watersheds, implementing efficient irrigation systems, or upgrading water infrastructure in underserved communities (Mason and Plantinga, 2013; Woodward et al., 2016).

d. Public-Private Partnerships (PPPs): Governments or municipalities partner with private entities to develop and manage water-related projects. Private entities invest in these projects in exchange for water credits that can be redeemed over time or sold to interested parties (Lima et al., 2021).

e. Water Bonds: Issuing green or water bonds is a way to finance water conservation projects. Investors purchase these bonds, and the funds raised are used to implement initiatives that generate water credits. As the projects succeed, the credits are generated and can be sold or traded. These projects can involve improving water infrastructure, ensuring clean and safe drinking water, managing water scarcity, restoring watersheds, and implementing sustainable water use practices. Water Bonds aim to address the global challenges of water scarcity and pollution by providing a way to finance projects that contribute to better water resource management. Governments issue these bonds as a way to raise funds for these critical water-related projects. Investors who purchase water bonds are essentially lending money to the government, which the government promises to repay with interest over a specified period.

The specifics of water bonds can vary from one jurisdiction to another, but they generally work like other types of municipal bonds. Based on OECD, some key points about water bonds are explained in Table 3.3.

f. Crowdfunding and Community Investments: Community-based financing can be used to fund local water projects. Individuals or groups can invest in these projects in exchange for water credits, providing a tangible return on their investment while supporting sustainable water management (World Bank, 2013).

g. Micro-financing and Microcredit: In areas with limited access to traditional financing, micro-financing institutions can offer small loans for water conservation projects. As the projects yield water savings, participants earn credits that can be used to repay the loans or provide additional benefits (water.org, 2023). Institutions like SIDBI can play a vital role.

Factors	Key Points
Purpose	To address various water-related needs- water quality, expanding water supply infrastructure, managing stormwater, and enhancing water conservation.
Financing	To finance projects that benefit the community's water supply and related infrastructure.
Interest Rates	Vary based on factors such as the creditworthiness of the issuing government and prevailing market conditions.
Repayment	Governments that issue water bonds commit to repaying the bondholders over a specific period, typically through periodic interest payments and the eventual return of the principal amount.
Investor Base	Relatively safe investments, attracting investors who seek stable returns while contributing to essential community projects.
Environmental and Social Impact	Contribute to environmental sustainability by supporting projects that improve water quality, reduce pollution, and enhance conservation efforts.
Credit Ratings	Ratings can impact attractiveness to investors as higher credit ratings often result in lower interest rates for bond issuance.
Regulation	Subject to regulations and oversight by relevant government bodies.

Table 3.3: *Key features of water bonds as per OECD (Kaminker, 2015)*

h. Corporate Social Responsibility (CSR) Initiatives: Companies may choose to invest in water credits as part of their CSR efforts. They could purchase credits to offset their water use or support water conservation projects in communities where they operate (Pawlowska et al., 2021).

It is important to note that the success of any financing model for water credits depends on factors such as regulatory frameworks, market demand, stakeholder engagement, and the availability of accurate water measurement and monitoring systems. Additionally, water credit programs should prioritize equitable access to clean water and ensure that local communities and vulnerable populations benefit from such initiatives.

3.2.3 Product labelling for water credits

As mentioned in Section 3.2.1 (c), water footprint labelling aims to provide consumers, businesses, and policymakers with information about the amount of water embedded in a product's lifecycle. This information helps raise awareness about the water consumption associated with different products and allows consumers to make more informed choices based on environmental considerations (Grunert et al., 2014; Nydrioti and Grigoropoulou, 2022).

Water Stewardship emphasizes collective accountability and action to ensure that water resources are managed responsibly, sustainably, and equitably. Water stewardships and certifications can play a critical role in sustainable water management as can be seen through the India Water Stewardship Network as part of Alliance for Water Stewardship (India Water Stewardship Network, 2016), European Water Stewardship (European Water Partnership, 2012), and TRUE Certification (Green Business Certification, 2020) ensures that the product has been manufactured in a zero-waste plant.

The labelling process involves calculating the water footprint of a product using established methodologies and standards, such as those developed by the Water Footprint Network. The water footprint is often expressed in litres or cubic meters of water per unit of product (e.g., per kilogram or per litre). The labelling can include information about the product's "blue" water footprint (surface and groundwater consumption), "green" water footprint (rainwater consumption), and "grey" water footprint (pollution generated due to water use) (ISO, 2014).

Water footprint labels can be placed on product packaging, similar to nutritional labels, or provided through online platforms and information systems. The goal is to help consumers make more sustainable choices by selecting products with lower water footprints. Additionally, companies can use water footprint labelling as part of their corporate social responsibility efforts to promote transparency and environmentally responsible practices. It is worth noting that water footprint labelling can provide valuable information, though it may face challenges related to data accuracy, consistency in calculation methodologies, and consumer understanding. However, as sustainability and environmental concerns become more prominent, initiatives like water footprint labelling contribute to fostering more responsible consumption patterns and promoting resource-efficient production practices (Manson and Epps, 2014; Nydrioti and Grigoropoulou, 2022).

The Unified Water Label is European wide initiative by companies involved in the bathroom industry. It is a smart tool that provides a means to identify water using products with a common label that offers clear, concise and easy to understand messaging about water energy usage (Unified Water Label Association, 2017). Based on IWA's report on international water efficiency product labelling (IWA, 2019), implementation of water footprint labelling can involve the following steps:

1. **Assessment and Standards:** Establishing a standardized methodology to calculate the water footprint of different products. This would involve assessing the direct and indirect water usage across the supply chain, including water used in production, processing, transportation, and disposal.

2. **Database Creation:** Compiling a comprehensive database of water footprint values for various products commonly consumed in India. This would require collaboration between government agencies, industries, and environmental organizations to collect relevant data.

3. **Labelling Scheme:** Designing a clear and easy-to-understand labelling scheme that can be displayed on product packaging. This label could provide information about the product's water footprint in terms of litres or gallons of water used in its production.

4. **Consumer Awareness:** Launching public awareness campaigns to educate consumers about the importance of water footprint labelling and how to interpret the labels. This could involve media campaigns, workshops, and educational materials.

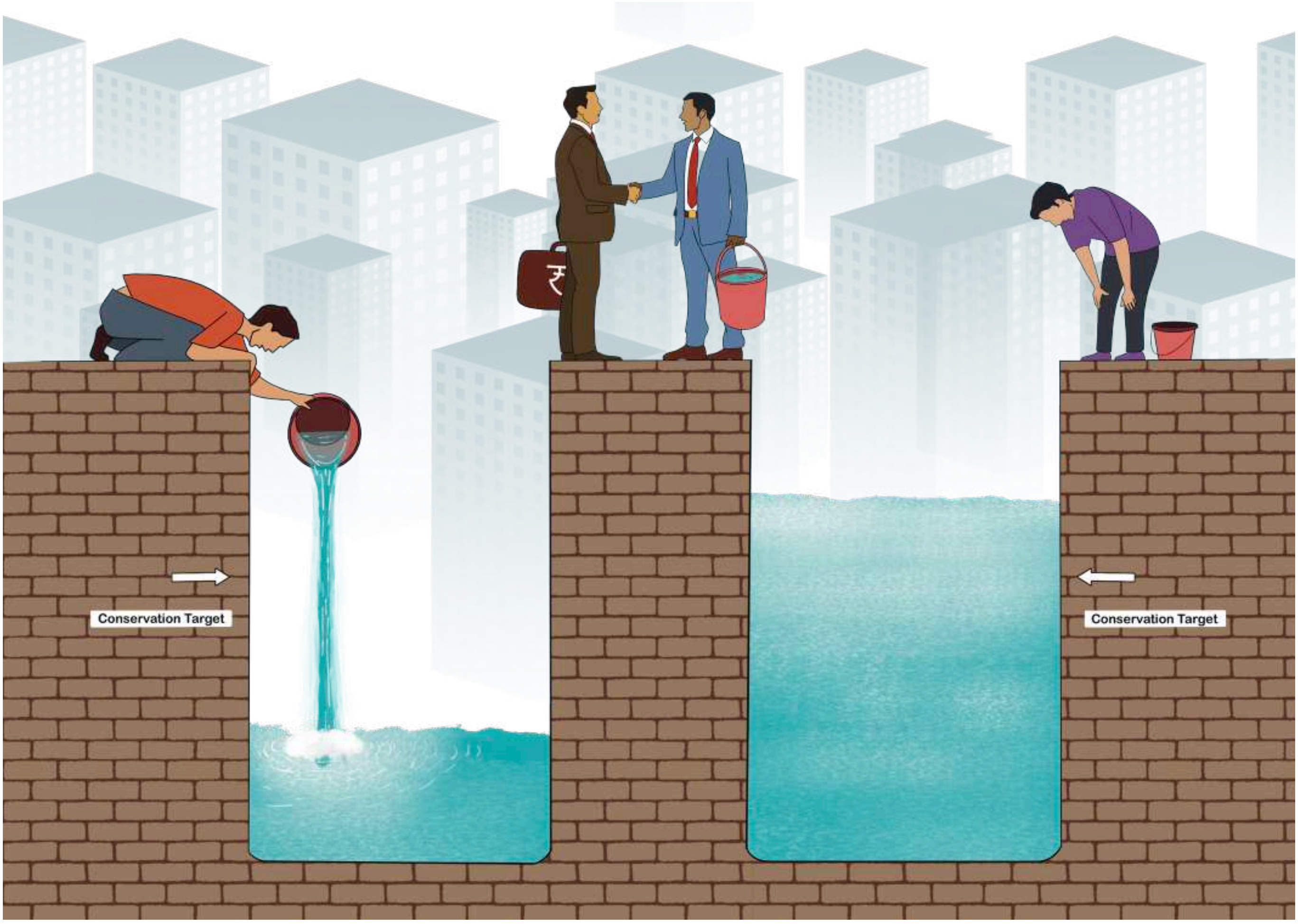
5. **Industry Collaboration:** Collaborating with industries to encourage the adoption of water-efficient practices and technologies to reduce the water footprint of their products.

6. **Government Support:** Government support in terms of policies, incentives, and regulations could play a significant role in promoting water footprint labelling. This could include providing incentives for companies that adopt sustainable water practices and making water footprint labelling mandatory for certain products.

3.3 Water trading

Water trading is a market-based approach that allows the buying and selling of water rights or allocations between individuals, organizations, or entities. It is commonly used to allocate and manage water resources more efficiently. This system creates a dynamic platform where the demand and supply of water are calibrated, encouraging stakeholders to utilize water judiciously while discouraging wasteful practices (Honey-Rosés, 2009). By placing a monetary value on water or bolstering water resource management, this approach incentivizes stakeholders to optimize water usage, leading to improved water efficiency in agriculture, industry, and domestic consumption, also empowering farmers to adapt to changing climate patterns, as they can sell excess water during times of abundance or purchase water when facing scarcity (World Bank, 2022).

Water trading is a complex issue influenced by factors such as water scarcity, legal frameworks, cultural values, and environmental concerns. Therefore, policies and practices can change significantly over time and may differ at various



administrative levels within a country (Debaere and Konar, 2022). It is important to note that water trading can have both positive and negative consequences, depending on how it is implemented and regulated. Issues like water rights, environmental protection, and social equity often come into play in designing water trading policies. Water is typically traded as either temporary water allocations or short-term access and permanent water entitlements or long-term access (Wheeler et al., 2014).

Countries or regions endowed with abundant water resources can support water-scarce regions by exporting virtual water through the trade of goods and commodities, fostering cooperation in times of shared water challenges. Water trading can be both direct and virtual water based on the product being traded. In the direct trade, water becomes the commodity, while in virtual trade water is embedded within the product and its processes (Zhang et al., 2019). Water trading policies vary significantly from one country to another, reflecting the unique challenges and priorities each nation faces in managing its water resources.

A few success stories in water trading include (Sarkar and Tigala, 2023):

The Murray-Darling Basin, Australia (MDBA, Government of Australia)

MDB is Australia's largest and most important river system, covering over 1 sq.km and spanning multiple states. It plays a crucial role in supplying water for agriculture, urban areas, and environmental sustainability. Water trading in this basin is regulated and governed by policies and institutions designed to ensure efficient and sustainable water allocation.

Water Trading Markets: *With well-established water trading markets, water entitlement holders buy, sell, or lease their water rights. Water trading can occur within and between different regions of the basin.*

Water Accounting and Measurement: *Water authorities in the basin closely monitor water flows, allocations, and trade transactions to maintain transparency and fairness.*

Environmental Water Holdings: *A portion of water entitlements and allocations in the basin is dedicated to environmental water holdings. These holdings are used to support and maintain the health of the river ecosystem, including wetlands, bird habitats, and native fish populations.*

Water Resource Plans and Regulations: *Each state within the Murray-Darling Basin has developed water resource plans that outline how water resources are managed and allocated. These plans are designed to balance the needs of agriculture, the environment, and other users. Regulations and rules governing water trading are implemented to ensure that water is used sustainably and that market activities are fair and transparent.*

Challenges and Concerns: *Water trading in the Murray-Darling Basin has faced challenges, including concerns about over-extraction, environmental degradation, and the social and economic impacts on rural communities. Balancing the competing interests of various stakeholders remains a complex issue.*

The Chicago Mercantile Exchange (CME Group)

In 2020, the CME Group announced plans to launch a water futures market in cooperation with NASDAQ and several partners, making it the first major U.S. exchange to offer futures contracts tied to water prices. This development marked a significant step in the financialization of water resources. The futures contracts are aimed at helping users manage water price risks and gain exposure to the water market. Water users, including agricultural producers and municipalities, can use these futures contracts to hedge against the risk of price fluctuations in water markets, especially in regions facing water scarcity or drought conditions.

Futures markets can help establish transparent and standardized prices for water, improving price discovery mechanisms in the water market. Investors interested in water-related assets can gain exposure to the water market through these futures contracts, potentially creating new investment opportunities.

Nasdaq Veles California Water Index: *This Index, created in partnership with Veles Water and WestWater Research, is designed to provide price transparency and price discovery in the California water market. It is based on the volume-weighted average price of water rights transactions in California's five largest and most actively traded water markets.*

Regulatory Framework: *The launch of water futures involves regulatory considerations, as water rights and usage are subject to complex regulatory frameworks at the state and local levels. The CME Group and its partners worked closely with regulators to ensure compliance with relevant laws and regulations.*

Environmental and Ethical Concerns: *The introduction of water futures has sparked debates and concerns. Some critics argue that water is a fundamental human right and should not be treated as a commodity. There are also concerns about the potential for speculative trading in water futures and the impact on water availability and affordability, especially in drought-prone regions.*

Water Quality Trading of USEPA (USEPA, 2023)

Water Quality Trading (WQT) is a market-based approach to improving water quality, particularly in impaired or polluted water bodies, that is supported by the United States Environmental Protection Agency (USEPA). The goal of water quality trading programs is to provide flexibility and cost-effectiveness in achieving specific water quality goals or standards, such as reducing nutrient pollution (e.g., nitrogen and phosphorus) in rivers, lakes, and estuaries. The USEPA promotes water quality trading as a tool to achieve environmental benefits in a more cost-effective manner. By allowing sources to find the most cost-efficient way to reduce pollution, it aims to encourage innovation and technology adoption. USEPA provides guidance and support for states and regions interested in developing water quality trading programs. The agency encourages innovation and the use of market-based approaches to meet environmental goals while addressing these challenges.

Pollutant Credits: *In a water quality trading program, pollutant credits are created and traded. These credits represent a specific amount of pollution reduction achieved by one entity (e.g., a wastewater treatment plant) that can be sold to another entity needing to offset its own pollution.*

Basin-Wide Approach: *Water quality trading often takes a basin-wide or watershed approach. This means that trading can occur among various sources of pollution (e.g., agricultural runoff, industrial discharges, wastewater treatment plants) within a specific geographic area.*

Credit Generation: *Entities that reduce pollution below their regulatory requirements can generate credits. These credits can then be sold to other entities that are unable to meet their pollution reduction goals or regulatory limits through traditional means.*

Regulatory Framework: *Water quality trading operates within a regulatory framework established by the USEPA and state environmental agencies. It typically involves the development of Total Maximum Daily Loads (TMDLs) or similar regulatory mechanisms that set pollution reduction targets for specific water bodies.*

Compliance Assurance: *Regulatory agencies oversee the trading program to ensure compliance with environmental regulations and the integrity of credit transactions.*

Challenges and Concerns: *Ensuring that trades lead to real and additional pollution reductions, while protecting vulnerable communities and ensuring equitable outcomes become a challenge. Monitoring and enforcement are crucial to prevent credit 'double counting' and addressing non-point source pollution can be more challenging to quantify and regulate.*

3.3.1 Policy framework for water trading

Policy framework for water trading is context-specific and should be tailored to the unique needs, challenges, and objectives of the region or jurisdiction. It requires careful consideration of social, economic, and environmental factors to strike a balance between economic development and sustainable water resource management. The specific policies and regulations governing water trading can vary significantly depending on the region and the specific goals of the water management authority. Figure 3.4 depicts an approach to policy framework for water trading.

a. Legal Framework:

- Establish a legal framework that defines water rights, ownership, and the conditions under which water can be traded.
- Define the scope of water trading (e.g., surface water, groundwater, or both).
- Determine whether water rights are permanent or temporary, and how they can be transferred.
- Require water users to register their trades and report them to a regulatory authority.
- Establish a centralized registry or database to track water trades and water rights ownership

b. Water Allocation:

- Set rules for allocating water rights, including initial allocations and subsequent adjustments.
- Establish a clear and transparent process for issuing and managing water licenses or permits.

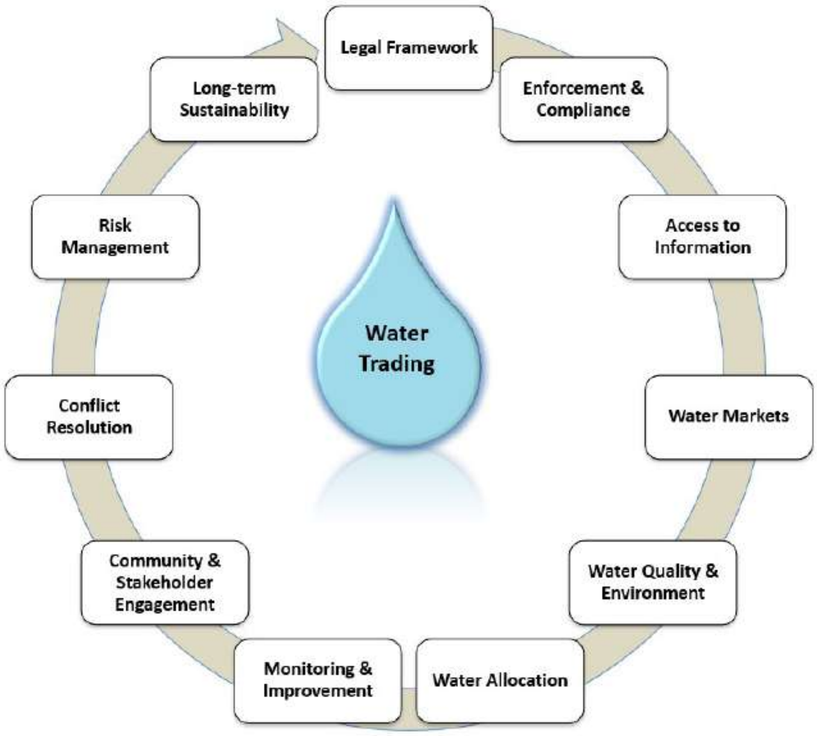


Figure 3.4: *Integrated approach to policy framework for water trading*

c. Water Market:

- Determine the type of water trading market (e.g., spot market, long-term contracts, or both).
- Establish trading rules, including pricing mechanisms (e.g., auctions, negotiated prices, or regulated prices).

d. Water Quality and Environmental Considerations:

- Include safeguards to protect water quality and the environment. Water trading should not lead to over-extraction or pollution.
- Implement mechanisms for monitoring and enforcing water quality standards.
- Allocate water for environmental purposes, such as maintaining minimum flow levels in rivers and protecting ecosystems.
- Develop mechanisms to allocate water for these purposes while allowing for trading.

e. Transparency and Information Access:

- Ensure that information about water availability, pricing, and trading is accessible to all stakeholders.
- Promote transparency in water trading to build trust among participants.

f. Community and Stakeholder Engagement:

- Involve local communities and stakeholders in the development and review of water trading policies.
- Address concerns about equity and social impacts, particularly on marginalized communities.

g. Enforcement and Compliance:

- Establish penalties for non-compliance with water trading rules and regulations.

h. Review and Adaptation:

- Regularly review and update water trading policies to adapt to changing environmental, social, and economic conditions.

- Incorporate feedback from stakeholders to improve the effectiveness of water trading mechanisms.

i. Conflict Resolution:

- Develop mechanisms for resolving disputes and conflicts related to water trading.
- Establish a regulatory body or authority to oversee and mediate disputes.
- Address issues related to water trading across different regions or countries, including harmonizing regulations and resolving conflicts.

j. Risk Management:

- Consider strategies for managing risks associated with water trading, such as droughts, price fluctuations, or market manipulation.

k. Long-Term Sustainability:

- Ensure that water trading policies promote the sustainable use of water resources, taking into account long-term availability and climate change impacts. It is important to note that the specific policies and regulations for water trading can vary widely depending on the local context and the goals of water resource management. Therefore, this policy mapping should be adapted to the specific needs and conditions of the region in question. Additionally, water trading policies should always prioritize the sustainable and equitable use of water resources to ensure they meet the needs of all stakeholders.

There are multiple prospects of water trading along with a set of challenges as mentioned in Table 3.4.

Table 3.4: *Opportunities and challenges in water trading*

Opportunities		Challenges	
Efficient Resource Allocation	By allowing more water to its highest value uses, it can lead to increased agricultural productivity, economic growth, and overall resource optimization.	**Equity Concerns**	Water trading can raise concerns about equity and social justice, as it might result in certain water users (often smaller or less economically powerful entities) being disadvantaged by higher prices or restricted access to water resources.

Opportunities		Challenges	
Flexibility	By adjusting the water use based on the changing needs of users, weather conditions, and economic considerations, it allows farmers to respond to market demands and varying water availability.	**Speculation**	The introduction of market forces can attract speculators who buy water rights solely for the purpose of selling them at a higher price in the future, potentially driving up water prices without contributing to the productive use of water.
Incentive for Conservation	In water-scarce areas, water trading can incentivize water users to use water more efficiently and conserve it to sell any surplus on the market, thus promoting water conservation and sustainable management.	**Local Disruption**	Water trading might lead to the movement of water away from rural communities, affecting local economies and livelihoods. This can result in the depopulation of rural areas and related social and cultural challenges.
Drought Resilience	Help mitigate the impacts of drought by enabling water users to access water from other regions that might have a surplus, reducing the negative effects of water scarcity on agriculture and other industries.	**Fragmented Management**	Water trading can complicate water resource management, especially if water basins cross administrative boundaries or involve multiple stakeholders with differing priorities.
Market-Based Pricing	Introduces market-based pricing mechanisms, which can help reflect the true value of water. This can lead to more accurate pricing that reflects scarcity and encourages responsible use.	**Environmental Risks**	If not well-regulated, water trading could lead to over-extraction of water from sensitive ecosystems, causing environmental degradation and impacting aquatic habitats.

Opportunities		Challenges	
Environmental Benefits	Some water trading systems incorporate environmental considerations, ensuring that a certain portion of water allocations remains dedicated to maintaining ecosystem health, particularly in sensitive areas like wetlands or rivers.	**Lack of Public Input**	Water trading systems might not always incorporate sufficient public input, potentially excluding marginalized communities or environmental advocates from decision-making processes.
		Complex Implementation	Establishing effective water trading systems requires robust legal, regulatory, and institutional frameworks, as well as reliable data on water availability and use. Implementation challenges can be significant.

In practice, the success or failure of water trading depends on the specific context, the regulatory framework in place, and the willingness to address potential challenges while maximizing the benefits for both water users and the environment.

3.3.2 Virtual water trading

Virtual water trading is a concept related to the global distribution of water resources. It is not the physical trading of water itself but rather the idea that when a country or region exports water-intensive goods (such as crops or industrial products), it is essentially 'virtually' exporting the water that was used to produce those goods. The virtual water trade can be evaluated using two factors, namely, virtual water dependency and virtual water trade intensity. The concept of virtual water helps to understand the water consumption to produce different goods and services. This understanding and the knowledge can help to the best use of scarce water resource to produce the goods and services especially in the water scarce regions, semi-arid and arid areas. The specific advantages of virtual water trading are explained below:

a. **Water-Scarce Regions:** Virtual water trade is particularly relevant for regions that are water-scarce but heavily rely on agricultural or industrial products that require abundant water. They can save their own water resources by importing virtual water instead of producing these goods domestically.

b. **Global Water Efficiency:** Virtual water trade can contribute to global water efficiency by allowing countries to specialize in producing goods that are water-intensive in regions where water is abundant. This reduces the overall strain on water resources.

c. **Economic and Environmental Impact:** Virtual water trade can have economic and environmental implications. It can boost a country's economy by focusing on high-value exports; however, it may also lead to over-exploitation of water resources in some regions or environmental degradation without proper regulations.

3.4 Water Trading – Indian scenario

Water management and trading are complex issues that involve various aspects including legal, environmental, social, and economic considerations. While water trading has different facets, one aspect of it is in terms of virtual water trading amongst countries. India is one of the major virtual water exporters to other countries with value of virtual water export of around 18 billion cubic meters through export of rice to other countries (Nishad and Kumar, 2021). This water export has brought tremendous pressure on water resources of the country leading to serious threat to food security and the negative impact on development of economy and other sectors.

According to NITI Aayog (2023b), though it may not be advisable to introduce full-fledged water trading in India for various socio-economic reasons, trading of treated wastewater among industrial users can be tried. The main stakeholders include water consuming industries irrespective of the volume of water consumed, agriculturists, municipal/residential users, the suppliers of treated wastewater, and a government regulatory agency.

The Indian government and various state governments have been working on different aspects of water management and allocation. However, ***India has multiple comprehensive national water trading policy in place.***

Here are some key policy provisions related to water trading policies in India:

1. **National Water Policy 2002:** The National Water Policy 2002, though, does not explicitly mention about water trading, but it proposes some kind of a framework for water trading in future. In particular, Section 11.6, Section 12.3 and Section 13 talks about role of private sector in water management and emphasized the need for public-private partnerships.
2. **National Water Policy, 2012:** The National Water Policy (NWP), 2012 provides guidelines for water management in India. It emphasizes the need for efficient water use, equitable distribution, conservation of water resources, and reduction of water footprints by the industrial users, inter alia. In particular, Section 11.6 and 12.3 assigns the importance of private sector and public-private partnership in management of water. However, NWP does not explicitly address water trading (Ministry of Water Resources, 2012).
3. **Draft National Water Framework Bill, 2016:** Again, like other policies, though the draft Bill does not explicitly mention about the water trading, however,

- It emphasizes the importance of private sector and public-private partnership in provisioning of water.
- specific emphasis is laid of Section 25 on the imperatives to reduce the water footprint by the industrial water users.

4. **Wastewater Trading Mechanism for industries, 2023:** As per NITI Aayog (2023b), there should be a defined entitlement of water use for the industries in every basin. Industries must be restricted from un-regulated extraction of freshwater. They should in fact **recycle the water to the maximum extent possible and must use the treated wastewater**. The quantity of extractable fresh water will be limited to such quantity which is essential to meet the water demand beyond recycling and use of treated wastewater.
5. **Water Reuse Certificates (WRCs) trading model:** WRC (Figure 3.5) is a market-based mechanism with tradable economic instrument which was conceptualized by '2030 Water Resources Group' (2030 WRG). This encourages bulk users to meet their regulatory requirements by overcoming the geographical constraints of reclaimed water market. Under the WRC trading system, an independent implementation agency

shall register water users across sectors including municipal/residential, industrial and agricultural sectors, and set individual targets for water reuse. These targets shall be user-specific and shall depend on the respective current water withdrawal from the environment and industrial best practices, and each WRC is equivalent to a certain quantity reused. Each trading phase of WRCs may continue for a specified period, say for 3 years. The first year involves establishing the baseline for the respective user followed by target year where the users adopt measures to achieve their targets, and the final year is when the performance is assessed to issue WRCs and allow trading among the users (NITI Aayog, 2023b).

Whichever industrial unit can save water can trade it with other industrial units or for peri-urban agriculture or for municipal/ residential uses. Trading between industrial units could be on monetary terms. However, water given for agriculture will earn water-points to industries.

6. **Water Markets:** While there is no national policy, a few states have explored water trading mechanisms through groundwater markets (Pathak, 2023).

7. **Industrial water pricing:** Appropriate pricing and tariffs on water use can support sustainable use of groundwater through borewells.

8. **'Draft Methodology for Water Harvesting based Green Credit:** GoI has recently notified the methodology to generate green credits through water harvesting in select set of districts in India. The details regarding the water harvesting structures, site location, the minimum size and storage capacity for water conservations are provided in this document. This would act as a step ahead in enhancing the water use efficiency and reducing the water footprint of the region.

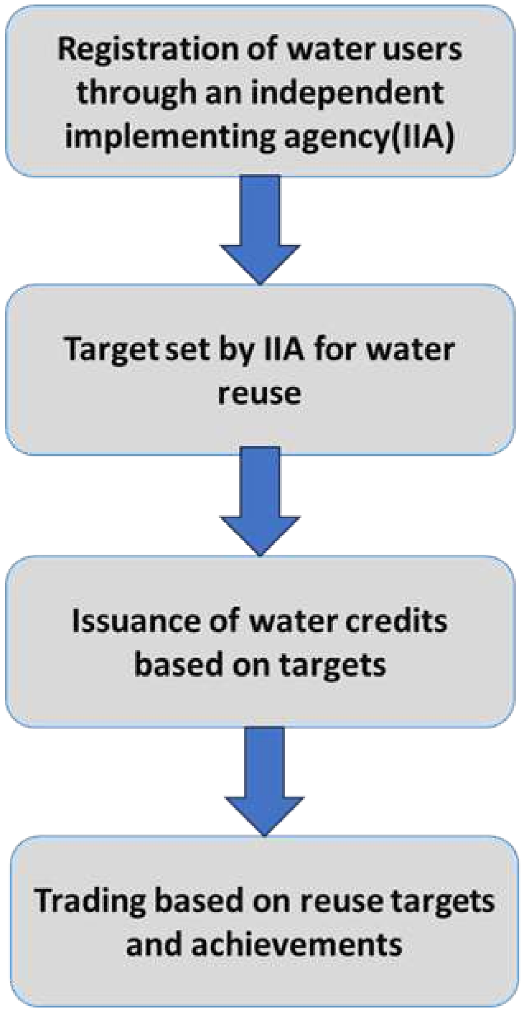


***Figure 3.5:** Water Reuse Certificates (WRC) trading model*

3.4.1 Groundwater trading in India

In many areas of India, groundwater levels have been depleting rapidly due to over-extraction. While surface water in India is under the control of the state governments. Some states, namely, Gujarat, Maharashtra, Haryana, Rajasthan, Tamil Nadu and Telangana have started considering policies to regulate and manage groundwater, which may include provisions for trading groundwater rights. The primary goal of groundwater trading policies is to promote efficient and sustainable use of groundwater resources while reducing over-extraction and encouraging conservation. However, this concept is not applied at national level, while some regions in India have experimented with water markets, where farmers or industries can buy and sell water rights. These markets are usually localized and not widespread, and they often operate informally. Here is a set of examples from different states where ground water market is present.

a. **Gujarat:** Sardar Sarovar Narmada Nigam Limited (SSNNL): Ground water market in the state of Gujarat is quite old and often upheld as 'Model' for other states. In fact, the Gujarat State Water Policy 2015 also talks about water trading (Section 3.9.3.8), though explicitly. One such recent example is the pilot water trading programme of SSNNL. The SSNNL introduced a pilot project for groundwater trading in 2018 in the Sabarkantha district. Farmers with unused groundwater rights could sell them to other farmers facing water shortages. The project aimed to promote efficient water use and reduce over-extraction.

b. **Maharashtra:** State Groundwater Authority (SGWA): Groundwater management and policies in Maharashtra are typically overseen by the Maharashtra Groundwater (Development and Management) Act, 2009. The State Groundwater Authority (SGWA) and the District-Level Committees play crucial roles in implementing groundwater regulations and policies. Section 8(5) prohibits selling of ground water without prior permission of District Authority. Besides, Maharashtra State Water Policy 2019 talks about industrial water management (Section 9.3). Besides, the MWRRA Act 2005 mention that it is the function of the Authority to decide the criteria for trading of water entitlements (Section 11 (i))

c. **Haryana:** The Bhakra Beas Management Board (BBMB): In Haryana, the BBMB has been involved in the regulation of groundwater trading. They implemented a system where farmers could buy and sell groundwater usage rights, helping to manage water resources more effectively.

d. **Rajasthan:** Jaipur and Nagpur: In some parts of Rajasthan, informal groundwater trading has been happening for years, with farmers sharing and selling water resources among themselves. However, this has led to concerns about equitable access and sustainability.

e. **Tamil Nadu:** Ramanathapuram: The district of Ramanathapuram in Tamil Nadu has also experimented with groundwater trading. In this region, over-extraction of groundwater has led to seawater intrusion, making it essential to manage groundwater resources more efficiently. The Ramanathapuram model involves the government regulating the sale and purchase of groundwater rights.

f. **Telangana:** Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB): In Hyderabad, the HMWSSB introduced a pilot project in 2020 that allows industries and businesses to buy and sell treated wastewater. This initiative indirectly impacts groundwater trading, as it reduces the dependency on groundwater for industrial purposes.

g. **Uttar Pradesh:** There exists some kind of informal water trading market in the Western UP, where buying and selling of water is determined through the running cost of water extraction. However, this is largely informed, not regulated by the state regulatory agencies.

Implementing water trading policies in India faces challenges such as social equity concerns, lack of comprehensive data on water availability and usage, administrative hurdles, and differing priorities among states.

3.4.2 Challenges to water trading in India

The implementation of water trading faces numerous challenges in India:

a. **Equity and social justice:** Equity and social justice concerns often arise because water is a vital resource, and unrestricted trading could lead to disparities in access (Acharya, 2023).

b. **Lack of Infrastructure:** India lacks the necessary infrastructure for water trading, such as robust water metering system, reliable data on water availability, and efficient water pricing mechanisms (Frost & Sullivan, 2016).

c. **Regulatory Framework:** There is currently no regulatory framework in place for water trading in India. Water trading policies need to navigate India's complex legal framework, including existing laws related to water rights and river basin management. The government needs to establish clear guidelines and regulations to ensure that water trading is conducted in a transparent and fair manner[11].

d. **Environmental Concerns:** Water trading policies need to consider ecological sustainability. Excessive water extraction and trading can harm ecosystems, and therefore, any policy must strike a balance between economic needs and environmental preservation.

e. **Political Will:** The success of water trading in India will depend on the political will of the government to implement it effectively. The government needs to work with all stakeholders, including farmers and civil society organizations, to ensure that their concerns are addressed.

3.5 Water Pricing in India

Water pricing is increasingly becoming an important tool for optimal utilization of water. The need for water pricing has been stated in the Central Ground Water Authority Guideline (CWGA) Guideline declared by GoI in 2020. Section 5.0 explicitly talks about water abstraction charges for various categories of water users such as residential consumers, industries, mining infrastructure projects including MSME sector.

Besides, water pricing is also being implemented varyingly in various states and has received importance in the state policies. The pricing mechanisms differ across states, though there exist some degree of similarities. Some water pricing principles as highlighted in various state water policies are explained below.

a. **Gujarat:** The Gujarat State Water Policy, 2015 explicitly mentions water pricing as an important strategy for water conservation and efficient water utilization. Section 3.9.3.1 speaks about pricing of water. While it talks of prevalence of fair pricing for various sectors, the decision of the pricing of water is expected to be decided by independent Statutory Gujarat Water Regulatory Authority. The policy also prescribes that the water charges will be based on volumetric basis and shall be designed on the principles of differential pricing.

b. **Maharashtra:** The Maharashtra State Water Policy 2019 (Section 17) talks about water charges for the purpose of regulating water use and enhancing efficiency. It says that the tariff will be determined by the Maharashtra Water Resources Regulatory

Authority (MWRRA). It also proposes the tariff determination process to gradually move from the norma based recurring expenses to cost reflective tariffs. The tariff for water will be based on volumetric basis. It also mentions the role of the private sector in water management (Section 18).

c. **Haryana:** The Haryana Water Resources (Conservation, Regulation and Management) Authority Act 2020, in Section 18 talks about tariffs for bulk water and treated water. The tariff principle shall be based on economy, efficiency, equity and sustainability. It shall be based on volumetric measurement of water.

d. **Rajasthan:** The Water Resources Vision 2045 talks about pricing of water based on scarcity value of water. It lays emphasis on increasing water rates for sustainable development of water sector.

e. **Uttar Pradesh:** The Water Tariff Rules of 2022 provides details of the water tariffs in the state. It shall be based on the total area of the land. Uttar Pradesh State Water Policy, 2020 (Draft) also highlights the details of water pricing in Section 11. It talks about fair pricing, determination on the basis on volumetric basis, and implementation of differential pricing.

f. **Punjab:** The Punjab Water Resources (Management and Regulation) Act, 2020 also has provisions of water pricing in Section 17. It mentions that tariff shall be based on economy, efficiency, equity and sustainability. Pricing principle would be based on volumetric basis and differential pricing principle will be implemented.

3.6 National policies on water footprint reduction

Though, there do not exist any direct policy on water footprints, however, there exist multiple policy provisions that are relevant to water footprint reduction. Here is an effort made to capture those policy provisions (both direct and indirect) and other guidelines. Though, the most important policy from the water footprint point of view i.e. National Water Framework Bill, 2016 is still at its draft stage, we traced several other policies to understand the implications of such policies for water footprint reduction.

3.6.1 National Water Policy 1987

Historically tracing, the National Water Policy is the first water related policy in the country which talks about the importance of water use efficiency and water conservation, though it does not explicitly mention water footprint reduction. In particular, Section 1.6 talks about efficiency in water utilization and the importance of conservation for industrial use of water. Section 11 mentions water tariffs and prescribes the need for estimating the scarcity value of water. Section 15 speaks about efficiency in water utilization through conservation consciousness through mechanisms of incentives and disincentives.

3.6.2 National Water Policy 2002

This policy is a review and update of National Water Policy 1987. Again, though the Policy does not directly speak about water footprint reduction, it has other indirect provisions having implications for water footprint reduction. Section 1.8 mentions the need for efficiency in water utilization and importance of conservation for industrial use of water. Section 11 talks about introducing the private sector for bringing in the corporate management and improving service efficiency and accountability to users. Section 16.1 and Section 16.2 assigns importance to efficiency in water utilization and water conservation.

3.6.3 Model Water Bill to Regulate and Control the Development and Management of Ground Water, 2005

The policy does explicitly mention about the water footprint, however, the provisions related to regulation and management of ground water in the country. It mentions the need for permission to extract ground water in the notified areas. Along with this a few other provisions indirectly speak about controlling water use and hence contributing to the reduction of water footprints in the country.

However, the report released by the Comptroller and Auditor General (CAG) report released in 2021 states that close to 20 states have enacted the laws related to management of ground water based on the above model bill and 4 states have implemented it so far.

3.6.4 National Water Policy, 2012

Though the policy has been a decade old now, the policy laid specific emphasis on demand management and water use efficiency in Section 6. For promoting and inculcating the habit of efficient use of water, the policy prescribes for the use and development of water footprints and water audits.

In addition, it also talks about use of water balancing and water accounting as measures to improve the water use efficiency. Section 6.2 talks about analysis of water footprints for the industrial water use. It says "6.2 The project appraisal and environment impact assessment for water uses, particularly for industrial projects, should, inter-alia, include the analysis of the water footprints for the use". Besides, Section 7 dwells on the pricing of water as a mechanism for efficient use and conservation of water.

3.6.5 Draft National Water Framework Bill, 2016

The Bill clearly stated the water footprint in relation to water use by industries and connotes the water footprint in terms of both direct use of water and water embodied in the goods and services used by industries and others. Section 10 talks about binding national water footprint standards and prescribes that all categories of water users shall strive to reduce their water footprints. More specific emphasis is laid of Section 25 which specifies the imperatives to reduce the water footprint by the industrial water users.

The Section 25: Industrial Water Management of the bill deals with water footprint reduction in industries as follows (MoWR RD&GR, 2016):

1. All industrial units shall make every possible attempt to reduce their water footprint over time.
2. All companies using large volumes of water (beyond a limit to be specified by the Appropriate Government) shall be required to transparently state their water footprint in their Annual Reports, including information, such as, water utilisation per unit produce, effluent discharge details, rainwater harvested, water reuse details and fresh water consumption. They shall also include the outline of a plan to reduce their water footprint over time and a statement of where they have reached every year in the attainment of these goals.

The negative impact of industrial plants in drought prone regions

3. Industries with high intensity of water use should not be located in regions prone to water stress or in drought prone regions.
4. Industries in water short regions shall be allowed to either withdraw only the make-up water or have an obligation to return treated effluent to a specified standard back to the hydrologic system.
5. Pricing of water for industry shall include efficiency costs and capital charges.
6. Incentives shall be implemented to encourage recovery of industrial pollutants including recycling and reuse that are otherwise capital intensive.
7. There shall be prohibitive penalties to discourage profligate use, with denial of water supply services beyond a threshold, as may be prescribed by the appropriate government." A summary of the policy evolution around water footprints is captured in the Figure 3.6.

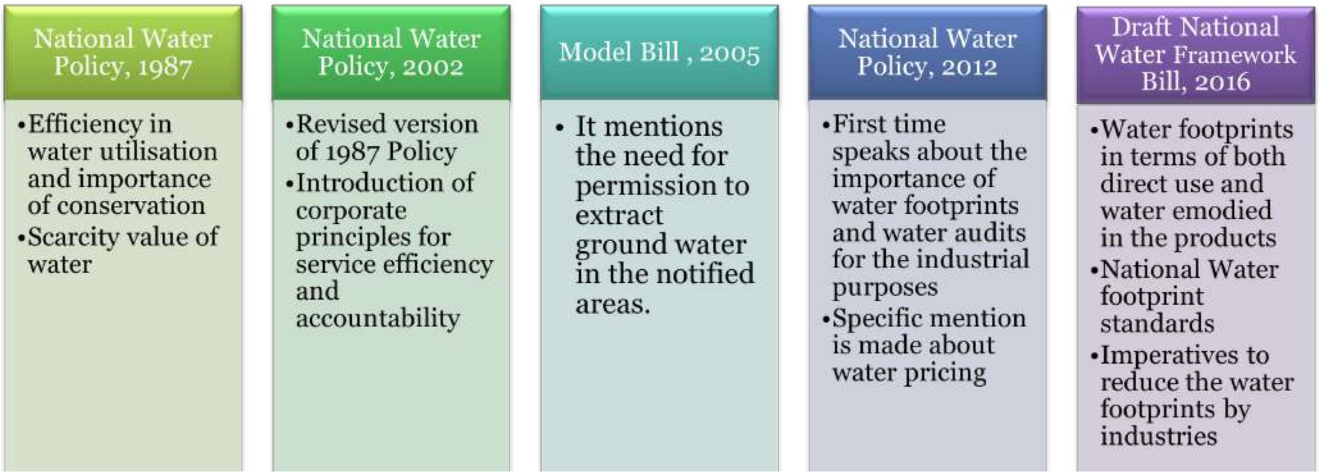


Figure 3.6: *Policy mapping of water footprints in India.*

It can be observed that for the first time, the importance of water footprint is highlighted in the National Water Policy 2012, which further get strengthened in Draft Bill 2016.

Besides, various state water policies also have provisions for water footprints. A select list is presented in Table 3.5.

State Policy	Key Points	Relevant Sections
Gujarat State Water Policy, 2015	Talks about water footprints and water auditing	Section 3.4
Maharashtra State Water Policy, 2019	Mentions the need for reducing water footprints Need to public Annual Water Reports	Section 9.3 (1) Section 16 (5)
Haryana Water Resources (Conservation, Regulation and Management) Authority Act 2020	Talks about bulk water entitlements for industrial and commercial water supply, inter alia	Section 10
Uttar Pradesh State Water Policy, 2020 (Draft)	It speaks about water footprints and water auditing. EIA for water projects involves assessment of water footprints	Section 10.2 Section 10.4

Table 3.5: *Water footprint in state water policies*

3.6.6 Water use efficiency & recycling to reduce water footprint

Many flagship programmes of both State and Central governments focus on improving water use efficiency and encourage recycling as shown in Table 3.6

The government of India has launched multiple schemes to combat water stress at national level (Ministry of Jal Shakti, 2021) as mentioned below:

- National Water Mission has launched another campaign **"Catch the Rain"** with the tag line "Catch the rain, where it falls, when it falls" to nudge the States and all stakeholders to create Rain Water Harvesting Structures (RWHS) suitable to the climatic conditions and sub-soil strata, with people's active participation, before the onset of monsoon to ensure storage of rainwater.
- **Ministry of Jal Shakti launched Jal Shakti Abhiyan-I (JSA-I)**, a campaign for water conservation and water security, in 256 water-stressed districts of the country. Under JSA-I, officers, groundwater experts and scientists from the Government of India have worked with State and District officials in these water-

Name	Features
National Water Mission 2009*	To increase water, use efficiency by 20%.
National Water Policy (2012)	To emphasize the efficient use of water resources and promotes water conservation and recycling.
Jal Shakti Abhiyan (Water Power Campaign), 2019	To improve water conservation and water security in various parts of the country, focusing on water-stressed districts.
National Mission for Clean Ganga (Namami Gange), 2014	To focus on the clean-up and rejuvenation of the Ganga River, aiming to reduce pollution and improve water quality.
Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), 2015	To enhance water use efficiency in agriculture by focusing on precision irrigation, micro-irrigation, and water-saving technologies.
Urban Water Policy framework, 2019	To manage water supply and wastewater treatment to ensure sustainable water usage in cities.

Table 3.6: *Select national policies with focus on water use efficiency and recycling.*

stressed districts of the country to promote water conservation and water resource management by focusing on accelerated implementation of five target interventions, viz, water conservation & rainwater harvesting, renovation of traditional and other water bodies/tanks, reuse and recharge of bore wells, water shed development and intensive afforestation.

- **AMRUT 2.0** aims to promote circular economy of water through development of City Water Balance Plan for each city focusing on recycle/reuse of treated sewage, rejuvenation of water bodies and water conservation.
- CGWB have taken up **artificial recharge** work in select Aspirational Districts in the year 2018 and completed the same in 2020. Appropriate structures were constructed to harvest the runoff water in streams for storage at suitable locations for augmenting recharge of the ground water. The structures constructed included check dams, percolation tanks, subsurface barrier, recharge wells and recharge shafts.

3.7 Designing of Water Credit Systems: Can experience in Carbon Credit provide the needed direction?

While operational characterization of water market and carbon market are different, both these market-based instruments are aimed at enhancing the use and efficiency of resources varyingly and offer flexibility to the parties to optimize from their actions in resource use. Carbon market, while is intended to reduce the cost of emissions reduction by offering flexible mechanisms for trading across participants, water credit could effectively deal with the efficient use of water through trading associated with incentive structures either financially or in other modes. In fact, carbon credit's primary emphasis is to curtail the emission at the lowest cost, whereas water credit is designed for the optimal use of water, leading to water conservation and efficient use.

Just like carbon market which operates in two different scales i.e. at project scale (e.g. CDM Market) and at national/sectoral scale (such as cap and trade mechanism), water market could also be visualized both at the project scale (may be at a basin level) and at the national/sectoral scale (through cap and trade mechanism). Similarly, just like carbon market, water credit systems could possibly have two different regulatory designs such as compliance market and voluntary markets. It may also happen that the market will start as a voluntary market and over time converted into a compliance form of market.

However, water as a good has a very different character compared to carbon. The importance of water for sustenance of life and human wellbeing is paramount both individually as well as collectively, whereas carbon market is intended to address the problem of global commons and largely collective level.

Hence, the market designing, regulatory modalities, and the market structure has to take that into these heterogenous character of water market while comparing vis-à-vis carbon market. Considering the differences, here are a set of key lessons that could possibly be used for designing water markets drawing from the existing carbon market operations and modalities, primarily for industrial purposes.

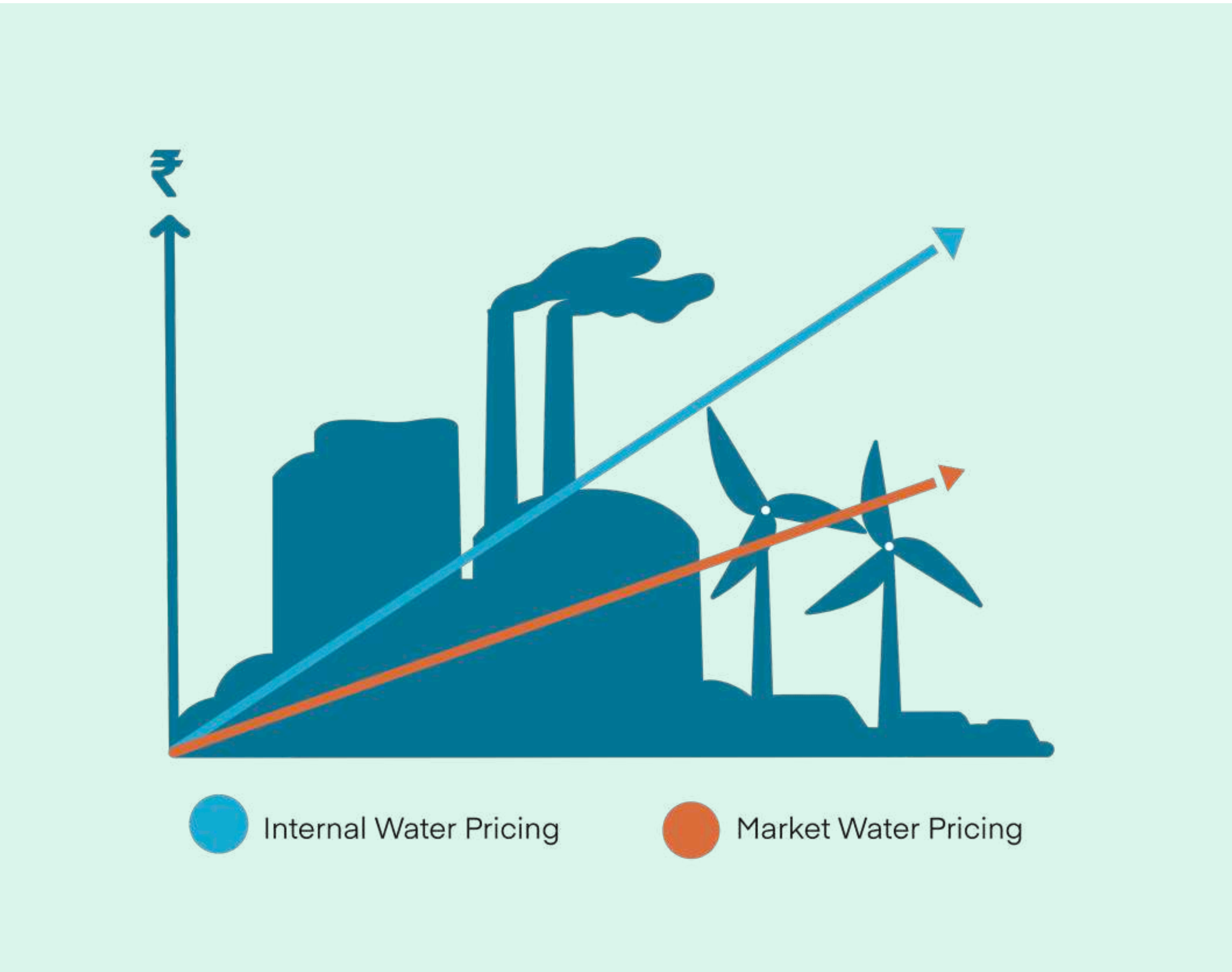
Given that there has been lot of emphasis on virtual water in the water accounting process to measure the water footprint of industrial products, which essentially captures the water use and water embedded in the products considering the product life cycle, water trading shall consider an approach which considers the virtual water embedded in such products. This could possibly be designed in line with the scope 3 emissions while estimating the GHG emission profile of industries to manage the carbon emission footprint of industries. Scope 3 emission essentially captures the emissions by companies (not within the company's scope 1 and scope 2) and largely associated with the emissions associated with the value chain or supply chain of goods and services procured by the company. A similar approach could be followed for estimation of water footprints embedded in the indirect or value chain products of industries. The detailed methodology used for the estimation for scope 3 emissions could possibly be helpful for estimating the indirect water footprint and virtual water footprint associated with the supply chain of the products. A base line approach is usually followed for targeting the emission reduction from industries of different types, following a robust scientific target setting through Science Based Target Initiatives (SBTi). A similar approach could be developed for estimating the water footprints and reducing the same. It is also need of the hour to develop a standardized approach for estimating the water footprint of industries of different sizes and mechanisms for converting the same into water credits.

Another important lesson could be setting up Internal water pricing (IWP) similar to internal carbon pricing (ICP) for industries. The IWP would help industries in many ways. Importantly, it would aid industries to plan the required investments in water in advance to minimize the future risks of water scarcity.

Importantly, the internal water pricing would be built based on determination of shadow pricing and scarcity value of water. IWP will also help industries in providing direction for the efficient use of water and enhancing their environmental performance.

Besides, just like carbon market, effective designing of market requires creating the string architecture of regulatory authority for governing such a market. The regulatory authority could plan a sequential and gradual evolution of the 'water market' considering the robustness of the market structure.

There is a need to plan both the demand augmentation for such credits and supply



push for such credits in the designing of the market over different phases of market growth. The 'cap and trade' kind of a market could possibly be created for the select set of water intensive industries. It would also be important to deliberate on the compliance and voluntary nature of the market structure. Importantly, the kind of water to be traded and trading participants are important considerations for robust and efficient water market designing. While carbon market operates by defining a unit widely acceptable globally, similar robust approach of defining a unit could be helpful. Given the fact that countries across the world are increasingly conscious about the carbon footprint and water footprint of the products being traded globally, it is crucial to create a market structure considering such global implications of water use and efficiency.

A schematic capturing various aspects of the proposed water trading market is presented in Figure 3.7.

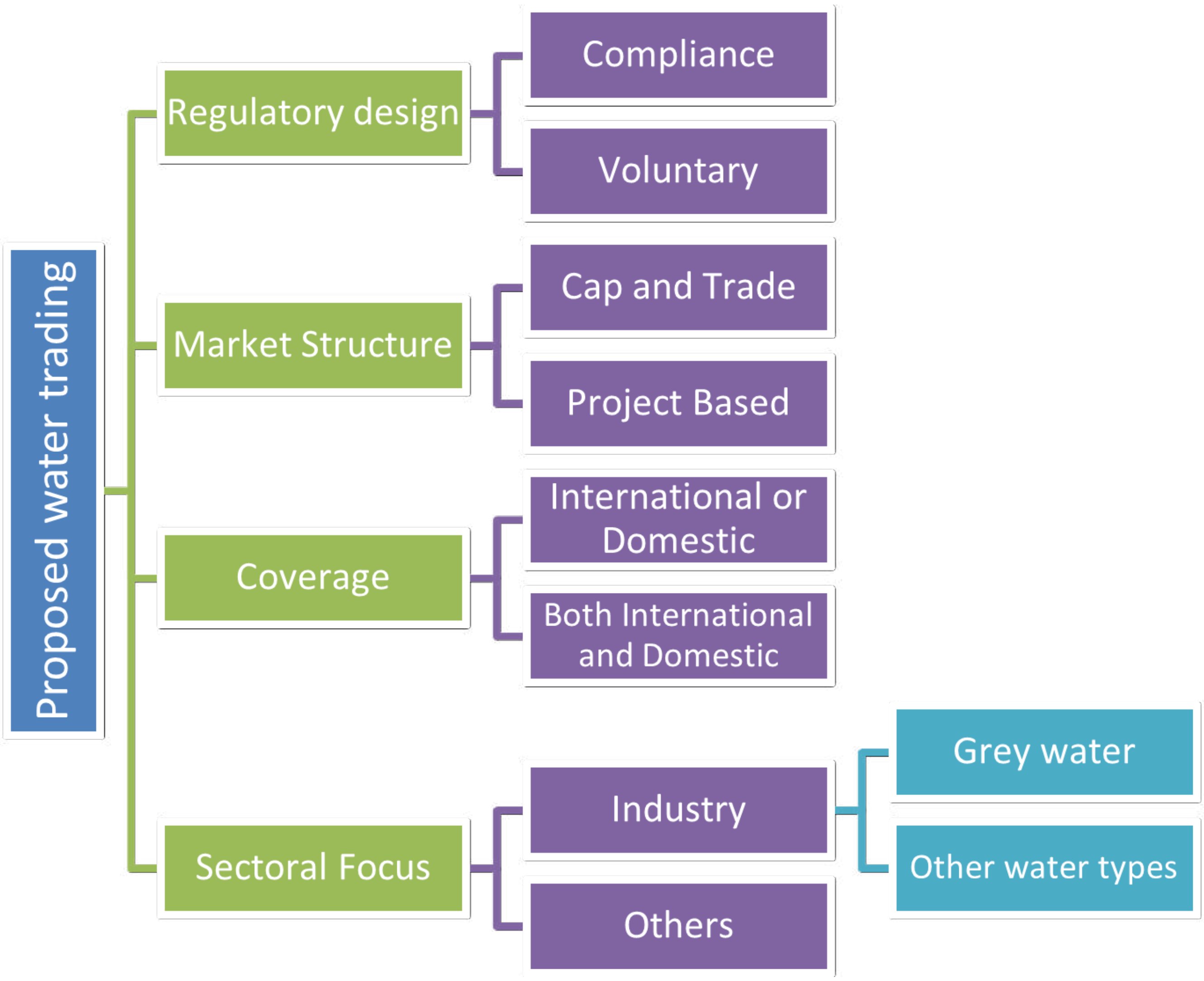


Figure 3.7: *Water trading market mechanism*

3.8 Policy Summary

Above sections assessed policies, legislations, regulations governing the water sector in India, considering the stated project goals and study objectives. While assessing the policies, we examined policies not only pronounced at the federal scale but also declared at the sub-national scale. This becomes important considering the constitutional provision of water as a state list, though central government plays an important role in governing the water resources of the country. Hence, key policy elements are drawn and analyzed considering the focused areas of this report such as water trading, water pricing, water footprint analysis and water use efficiency and recycling and considering the governance framework of water policy making in India. One of the important considerations is about rationale behind designing of water policies in the country and forces behind such design and modifications introduced in the water policy making in India. Water policy making in India appears to be the resultant of both top-down and bottom-up forces. While global climate change considerations and emphasis to use water efficiently drive the water policy making in the country, bottom-up domestic forces equally hold importance in India as the country is one of the water deprived countries and increasingly facing water related stresses and other associated challenges. Hence, policy evolution does manifest the changes happening globally as well as domestically. Policy assessment also reveals that that there has been a policy evolution over time with greater recognition and emphasis on managerial aspects of water resources considering the increasing scarcity of water resources on the one had while increasing demand for water by all sectors. This temporal mapping of the policies reveals several interesting aspects as presented in the Figure 3.8.

- **Water trading:** Though India does not have explicit policy for trading of water, it can be elicited from the policy mapping that the need and imperatives for trading has been recognized in the National Water Policy 2002 as a modality to allocate water in future. This has been further amplified with emphasis on the role of Public-Private Partnership (PPP)

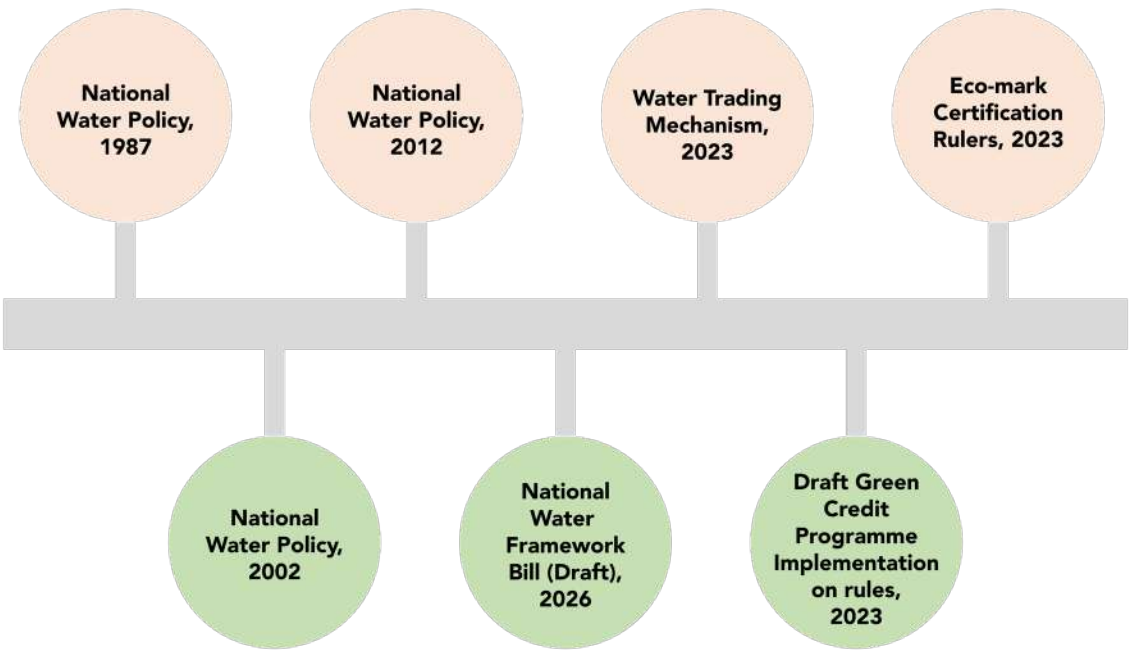


Figure 3.8: *Water policies in India*

in the National WaterPolicy, 2012 as well as in the Draft National Water Framework Bill, 2016. However, trading got a boost with the NITI Aayog's (2023b) proposal to trade wastewater amongst industries as one step forward in the direction of water trading in the country. It appears from the policy mapping on water trading that there has been an incremental approach towards introducing trading as a mechanism for effective water management. The sectoral focus is on industries as accounting of water becomes manageable with industry as an actor.

Another important aspect of water trading is associated with the ground water trading in India, which has evolved in a patchy and sporadic manner. Ground water trading in India is associated with ownership structure of ground water which is privately owned and managed largely, and hence offers an opportune platform for them to trade water to mobilize funds. These markets operate locally and largely in informal mode and present in a few states like Gujarat, Maharashtra, Haryana, Rajasthan, Tamil Nadu, and Telangana. Considering the market structure, states have come up with regulatory mechanisms to have control over such market. However, a national level mechanism is yet to evolve.

- **Water Pricing:** Another important policy aspect is to assess how the water pricing is recognized in the policy gamut. Water pricing is increasingly becoming an important tool for optimal utilization of water in various states and has received importance in the state policies. It is drawn from the assessment of policies that though there is a heterogeneity in pricing structure of water across sectors, it is primarily based volumetric basis and differential pricing for different sectors.

- **Water footprint:** The third important policy aspect which is examined in this study is about 'carbon footprint'. It is gleaned from the analysis of policies that there has been an incremental approach in recognition of this element of water footprint in the policy. While 1987 policy does not mention anything about water footprint, National Water Policy 2002 speaks implicitly about water conservation and efficiency in water utilization. It also talks about introducing the private sector for bringing in corporate management and improving service efficiency and accountability to users. It talks about use of water balancing and water accounting as measures to improve the water use efficiency. However, the explicit mention of water footprint is presented in the Draft National Water Framework Bill, 2016. It, for the first time, talks about National Footprint Standards. However, state policies are increasingly recognising the imperatives to assess the water footprint for efficient and effective use of water. States such as Gujarat, Maharashtra, Haryana and Uttar Pradesh have explicitly mentioned about estimating the water footprints for their states.

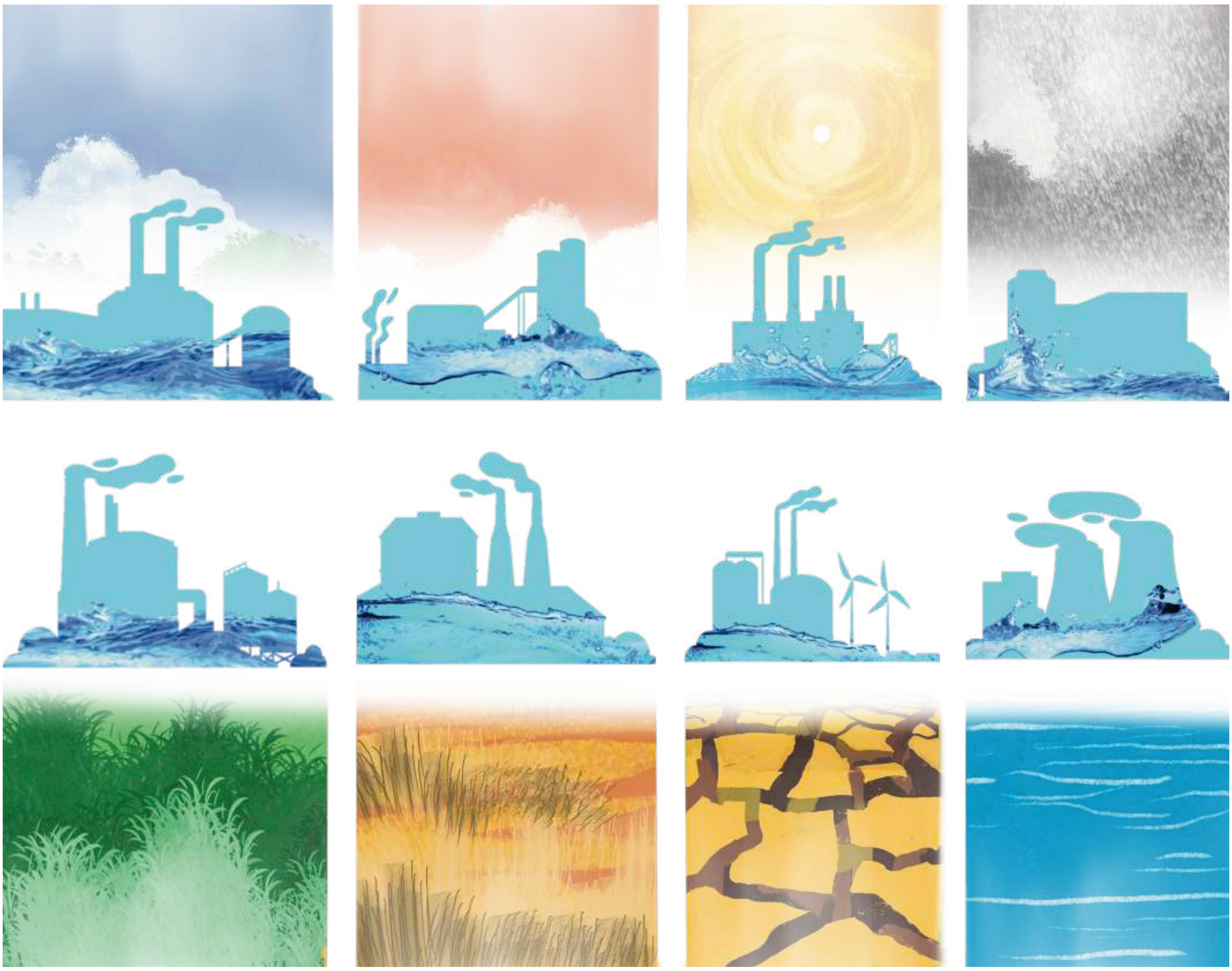
CHAPTER 04

Methodology

According to Hoekstra and Chapagain (2008), the water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. The green water footprint refers to the global green water resources (rainwater) consumed to produce the goods and services. The blue water footprint refers to the global blue water resources (surface water and ground water) consumed to produce the goods and services. 'Consumption' refers here to 'evaporation' or 'incorporation into the product'. It does not include water that is withdrawn but returns to the system from where it was withdrawn. The grey water footprint is the volume of polluted water that associates with the production of goods and services (Ercin et al., 2011).

4.1 Water footprint of a business unit

A business may have multiple production units at different locations. For the purpose of water footprint accounting, it is often useful to distinguish between different business units as the individual units are likely to operate under different conditions and derive their inputs from different places. In such a case, it is useful to do water footprint accounting per business unit first and aggregate the business unit accounts later on into an account for the business as a whole. When a business is large and heterogeneous



(different locations, different products), it is advised to schematize the business into some major business units and each major unit into a number of minor units again. In this way the business can be schematized as a system with subsystems at a number of levels. Later on the water footprint accounts at the lowest level can be aggregated to accounts at the second-lowest level, and so on, up to the level of the business as a whole (Hoekstra et al., 2011).

As shown in Figure 4.1 the business water footprint consists of two components: **the operational water use** (direct water use) and **the water use in the supply chain** (indirect water use). The **operational** (or direct) water footprint of a business is the volume of freshwater consumed or polluted due to the business's own operations. The **supply chain** (or indirect) water footprint of a business is the volume of freshwater consumed or polluted to produce all the goods and services that form the inputs of production of the business. The **overhead water footprint** refers to freshwater use that in first instance cannot be fully associated with the production of the specific product considered but refers to freshwater use that associates with supporting activities and materials used in the business, which produces not just this specific product but other products as well. The overhead water footprint of a business has to be distributed over the various business products, which is done based on the relative value per product. The overhead water footprint includes, for example, the freshwater use in the toilets and kitchen of a factory and the freshwater use behind the concrete and steel used in the factory and machineries (Ercin et al., 2011).

As shown in Figure 4.1, the water footprint of a business unit (WF_{unit}, volume/time) is calculated by adding the operational water footprint of the

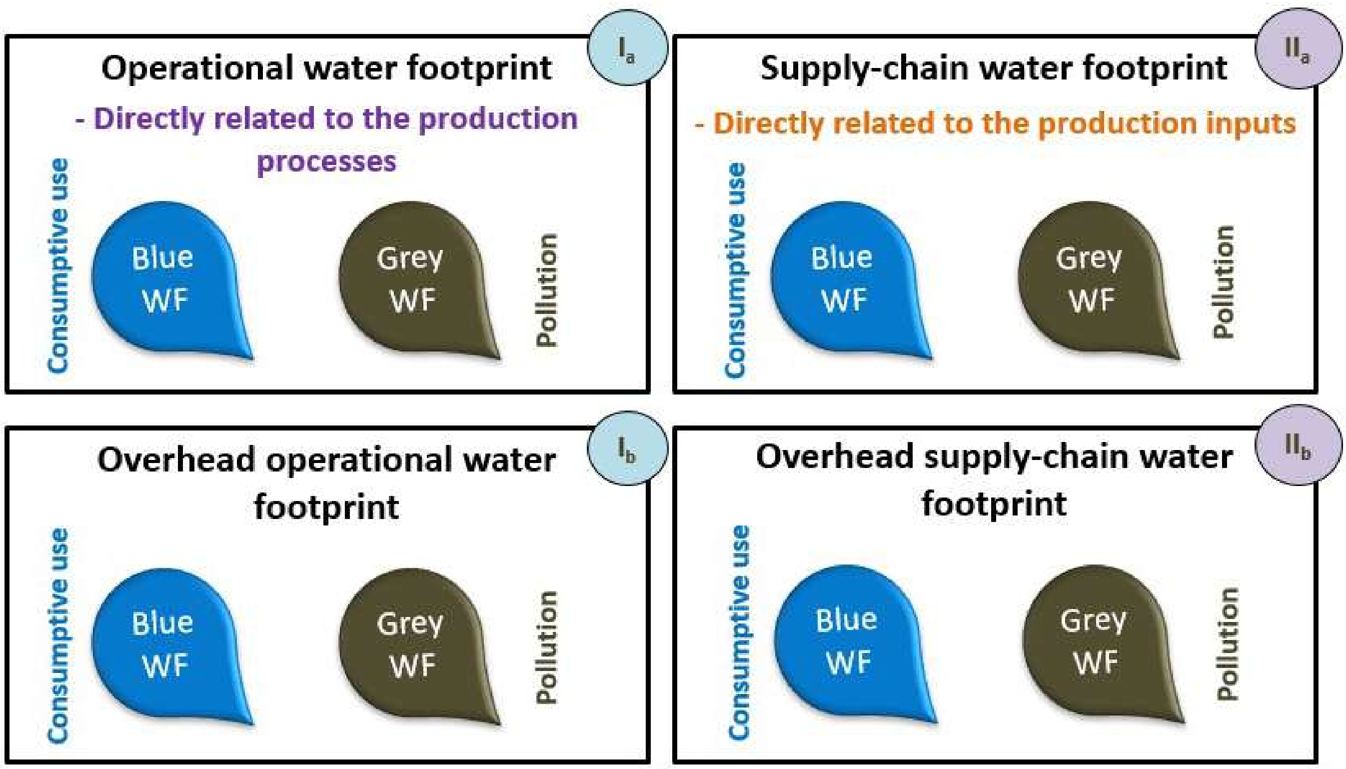


Figure 4.1: *Components of water footprint of a business*

business unit (WF_O) and its supply-chain water footprint (WF_S):

$$WF_{unit} = WF_O + WF_S \quad \text{.......... (4.1)}$$

4.1.1 Operational water footprint

Both components in Eqn (4.1) consist of a water footprint that can be directly associated with the production of the product in the business unit and an overhead water footprint. The operational water footprint is equal to the consumptive water use and the water pollution that can be associated with the operations of the business:

$$WF_O = WF_{O,\ inputs} + WF_{O,\ overhead} \quad \text{.......... (4.2)}$$

Based on, Figure 4.1 there are four components mentioned as Ia, Ib, IIa and IIb as follows:

(Ia) ***Operational water footprint directly associated with the production of the product,*** $WF_{O,\ inputs}$

It has the following components:

a. Water incorporated into the product as an ingredient ***(Blue WF)***

b. Water consumed (i.e. not returned to the water system from where it was withdrawn) during the production process (during bottling process, washing, cleaning, filling, labeling and packing) ***(Blue WF)***

c. Water polluted (thermally/chemically) as a result of the production process ***(Grey WF)***

(Ib) ***Overhead Operational Water Footprint,*** $WF_{O,\ overhead}$

The overhead operational water footprint is the water consumed or polluted as a result of:

a. Water consumed by employees (drinking water) ***(Blue WF)***

b. Water consumed in toilets and kitchen ***(Blue WF)***

c. Water consumed due to cleaning activities in the factory ***(Blue WF)***

d. Water polluted due to use in toilets and kitchen ***(Grey WF)***

e. Water polluted due to cleaning activities in the factory ***(Grey WF)***

f. Water consumed in gardening ***(Blue WF)***

A beverage unit may produce a number of different beverage products; hence, only a fraction of the total overhead water footprint is attributed to each beverage product, based on the ratio of the annual value related to the production of this specific product to the annual value of all products produced in the factory.

4.1.2 Supply-chain water footprint

The supply-chain water footprint can be estimated as the sum of consumptive water use by the inputs and the water pollution that can be associated with the operations:

$$WF_S = WF_{S,\ inputs} + WF_{S,\ overhead} \quad \text{.......... (4.3)}$$

(IIa) ***Supply-chain water footprint related to the product inputs,*** $WF_{S,\ inputs}$

The supply-chain water footprint related to product inputs consists of the following components:

a. Water footprint of transportation of product ingredients ***(Blue WF)/ (Grey WF)***

b. Water footprint of transportation of other inputs used in production (bottle, cap, labelling materials, packing materials) ***(Blue WF)/ (Grey WF)***

(IIb) *Overhead supply-chain water footprint,* $WF_{S,\ overhead}$

The overhead supply-chain water footprint originates from all goods and services used in the factory that are not directly used in or for the production process of one particular product produced in the factory ***(Blue WF)/ (Grey WF)***.

Goods that can be considered for the calculation of the overhead supply-chain water footprint include:

a. Energy for heating and power

b. Transportation: Vehicles and fuel

4.1.3 Grey Water Footprint

Though it is easier to differentiate the components of grey water footprint within operational water footprint, it possesses challenges in quantifying the footprint for each component individually. For example, in an industry, it poses challenges in estimating the water quality at every stage of wastewater generation rather it is feasible to sample the outlet discharge. Hence, a few assumptions are considered for estimating the grey water footprint as follows:

a. The water quality of wastewater generated at different stages of the production or other activities shall be same as that of the effluent discharge of the unit.

b. The pollution dilution factor shall be considered based on the ambient water quality requirement specified for the respective water sources, namely, surface water, groundwater and inter-basin water transfer.

c. The effluent discharge shall be assumed to be returning into the same source. Hence, the total outlet discharge shall be allocated to the sources based on their proportion to the water abstraction by the production unit.

The estimation of grey WF per year can be performed as follows:

$$WF_{Grey} = \sum_{m} \max_{p} \left[\frac{q^{m}_{unit,i} * r^{m}_{unit,p,i} - A^{m}_{unit,i} * C^{m}_{nat,p,i}}{C_{lim,p,i} - C^{m}_{nat,p,i}} \right] \qquad \text{.......... (4.4)}$$

Where;

WF_{Grey} : Grey water footprint (m^3/year),

m,p,i : Month, pollutant, and water source, respectively,

$q^{m}_{unit,i}$: Average wastewater discharge by the unit in month 'm' into source 'i' (m^3/month),

$r^{m}_{unit,p,i}$: Average concentration of pollutant 'p' released by the unit in month 'm' into source 'i' (g/m^3),

$A^{m}_{unit,i}$: Average amount of water abstracted by the unit in month 'm' from source 'i',

$C^{m}_{nat,p,i}$: Natural ambient concentration of pollutant 'p' in source 'i' in month 'm', and

$C_{lim,p,i}$: Permissible ambient concentration of pollutant 'p' in source 'i'.

When $C_{lim,p,i} < C^{m}_{nat,p,i}$, then $C_{lim,p,i} - C^{m}_{nat,p,i} = 1$.

Assumptions:
It is assumed that industry discharge into the same source from where it is abstracting water. In practice it may be possible that Industry abstract from one source and discharge wastewater into another source. For example, an industry may abstract ground water but discharge wastewater onto surface water or on land. In such cases, according to our assumption $C^{m}_{nat,p,i}$ and $C_{lim,p,i}$ shall have values for the source from where the industry is abstracting water.

4.2 Impact-adjusted water footprint estimation

As explained in Section 2.5, impacts can be both negative (water scarcity and water pollution) and positive (water credits earned through various water resources developmental activities). Hence the impact-adjusted water footprint can be estimated as the aggregate of both negative and positive impacts, wherein higher positive impacts can lead to either water neutral or water-positive.

4.2.1 Negative impacts – water scarcity & pollution

The various sectors considered to assess negative impacts within the watershed due to water demand include domestic, industrial and agriculture. Based on Pierrat et al. (2023), this study considers ***water resource footprint (WRF)*** to model the impacts of freshwater stress, i.e., pollution through *pollution deprivation potential (PDP)* and *scarcity through scarcity deprivation potential (SDP)* on water resource availability. The WRF associated with a business unit can be a fraction of the monthly PDP and SDP calculated at the watershed scale aggregated for a year, and this fraction corresponds to the user's contributions to water scarcity and water quality degradation.

A **scarcity weighting factor (ws)** can be used to calculate the SDP of a specific business unit (user), which is calculated as the ratio of the unit's water consumption by the total sectoral demand.

The **pollution weighting factor (wp)** is proportional to the unit's effluent emissions and the severity of the pollution compared to the quality requirements. The water quality is considered to be insufficient when the environmental concentration of at least one pollutant exceeds the limit of the sectoral water quality requirement. If the quality is insufficient, the PDP of a sector is equal to the water demand of that sector scaled by the water availability in the watershed. It is calculated as the product of the ratios between the unit's emissions by the total emissions, and the pollutant's concentration exceedance by the sum of all pollutants' concentration exceedances.

Therefore, the *operational form of WRF* can be described as:

$$WRF^{unit} = \sum_{m,j} \left(wp_j^{m,unit} PDP_j^m + ws_j^{m,unit} SDP_j^m \right) \quad m = 1, \ldots, 12 \;\&\; j = 1, .\ 4 \quad \text{.......... } \mathbf{(4.5)}$$

where

WRF^{unit} : Annual water resource footprint of the production unit (m^3),

PDP_j^m : Pollution deprivation potential in source j (surface water, harvested rain water, ground water and interbasin transfer) in month m (m^3),

SDP_j^m : Scarcity deprivation potential in source j in month m (m^3), and

$wp_j^{m,\,unit}$, $ws_j^{m,\,unit}$: Pollution and scarcity weighting factors of the production unit in month m for source j (expressed as a unit less ratio between 0 and 1).

a. Factoring for pollution:

Here, $wp_j^{m,unit}$, the pollution weighting factor of the production unit is given by:

$$wp_j^{m,unit} = \sum_p \left(\frac{r_p^{m,unit}}{\sum_{user} r_p^{m,user}} \cdot \frac{q_{j,p}^m \left(1 - \frac{c_{\lim j,p}}{c_{user,p}^m}\right)}{\sum_{user} q_{j,p}^m \left(1 - \frac{c_{\lim j,p}}{c_{user,p}^m}\right)} \right) \quad \text{.......... } \mathbf{(4.6)}$$

$$m = 1, \ldots, 12 \;\&\; j = 1, \ldots, 4$$

where

$c^{m}_{user,p}$: Environmental concentration of pollutant p in month m for each user,

$c_{lim\,j,p}$: Concentration limit for pollutant p expressed as ambient water quality of source j,

$q^{m}_{j,p}$: Water functionality for quality parameter p of the sectoral requirement of the unit from source j. It is a Boolean equal to 1 if $C^{m}_{user,p} \geq C_{lim\,j,p}$ and 0 otherwise,

$r_p^{m,unit}$: Emission of substance p from the production unit in month m (in kg/month),

$r_p^{m,\,user}$: Emission of substance p from each user (including the production unit) within the watershed in month m (in kg/month).

Therefore, the pollution weighting factor (wp_j^m) is a dimensionless ratio between 0 and 1. It is null if the water quality is sufficient to attend the requirements of sector j or if the production unit does not emit any chemical p. It gives higher weight to the unit whose emissions of chemicals are high and to chemical p exceedingly largely the concentration limits. Here, the toxicity of chemicals is indirectly accounted through the concentration limit exceedance weighting because concentration limits are usually meant to protect human health.

PDP_j^m, the pollution deprivation potential or the contribution of the production unit to PDP is given by:

$$PDP_j^{m,unit} = wp_j^{m,unit} * PDP_j^m \quad \text{.......... (4.7)}$$

and PDP can be written as:

$$PDP_j^m = s_j^m . \sum\nolimits_{user} q_j^{m,user} . WC_j^{m,user} \quad \text{.......... (4.8)}$$

where

$q_j^{m,user}$: Water functionality of month m for the quality requirements of source j based on sector of the user (0 or 1). When the water available does not meet the quality requirements for use by sector j, $q_j^m = 1$.

$WC_j^{m,user}$: Estimated water demand of each user (1 to n) in month m and source j (expressed in m³),

s_j^m : Ratio of water availability to demand in month m for source j (ratio between 0 and 1),

$$s_j^m = \begin{cases} \dfrac{A_j^m}{\sum_{user} WC_j^{m,user}} & for\ 0 \leq \dfrac{A_j^m}{\sum_{user} WC_j^{m,user}} \leq 1 \\ 1 & otherwise \end{cases} \quad \text{.......... (4.9)}$$

Here, A^m is the water availability in month m (expressed in m³). It is assumed that the blue water consumption is an estimate for the demand.

When $q_j^m=1$, the deprivation from source j, i.e., PDP_j^m is equal to the total blue water consumption of the sector regardless of the existence of scarcity issues. Therefore, the maximum value of PDP is limited to the total blue water consumption in the watershed. The contribution of production unit to PDP_j^m is proportional to its emissions of chemical p in the quality requirement for sector j.

b. Factoring for water scarcity:

The scarcity-induced deprivation or SDP is defined only when the water available in the environment i.e., the surface water, groundwater, and green water availability, is lower than the total demand in the watershed. When there is a shortage, the SDP quantifies the fraction of the sectorial water demand that is not attended due to the water shortage.

Scarcity-induced deprivation occurs when the water body meets the quality requirements of sector j but there is a water shortage. The water shortage is equal to the difference between the water demand (estimated as water consumption) and the water availability. We assume that all water users would be equally affected by water shortages. Therefore, the monthly scarcity-induced deprivation of the watershed for source j (SDP_j^m) is:

$$SDP_j^m = \begin{cases} (1 - s_j^m). \sum_{user} (1 - q_j^{m,user}). WC_j^{m,user} & 0 \leq s < 1 \\ 0 & s \geq 1 \end{cases} \quad \text{.......... (4.10)}$$

SDP can be calculated separately for surface water and groundwater because the availability of each water source is different. The blue water availability is the total blue water available i.e. water in the river, lakes, reservoirs and groundwater storage (expressed in m^3). It is possible to only consider the renewable part of water availability, so that, SDP>0 includes the risk of long-term groundwater depletion, but probably overestimates short-term scarcity.

In the case, the monthly runoff (i.e. surface water recharge) and groundwater recharge can be an estimate of renewable blue water.

The contribution of the production unit to SDP is proportional to its water consumption compared to the total water consumption. The scarcity weighting factor is defined by $WSC_j^{m,unit}$ (dimensionless) so that the sum of the scarcity weighting factors for all users in a given month m for a given source j is equal to 1. It can once again be disaggregated for each water source, when surface water and groundwater SDP are calculated.

$$ws_j^{m,unit} = \frac{WC_j^{m,unit}}{\sum_{j,user} WC_j^{m,user}} \quad \text{.......... (4.11)}$$

Therefore, the monthly water scarcity deprivation potential of source j due to the production unit n is given by:

$$SDP_j^{m,unit} = ws_j^{m,unit} . SDP_j^m \quad \text{.......... (4.12)}$$

and local body officials (Indian Cement Review, 2020). The efforts to become water positive or neutral can be grouped under three categories as mentioned in *Section 3.1*.

4.2.2. Positive impacts – Water credits

As explained in the concept of water neutrality, all activities that are directly relevant for water credits can be considered towards impact adjustment of water footprint. Water neutrality programmes include water storage, rainwater harvesting, groundwater level recharging, recycling of wastewater, availability of potable water to the communities, setting up of check dams and water storage facilities. Most of these initiatives need the involvement of the community

a. Water trading

ndustries can participate in water trading markets, and these markets allow companies to buy and sell water credits based on their water usage and conservation efforts. This can be a way to incentivize water efficiency.

b. Water offset programs

Industries can participate in water offset programs, which involves compensating for water usage by funding or implementing water-saving projects in the local community or watershed. These efforts can earn water credits (NITI Aayog, 2023a).

c. Water quality improvement

Improving water quality in industrial processes is not only a regulatory requirement but also a crucial step toward achieving water-positive status. It protects ecosystems, public health, and the reputation of the industry while contributing to the sustainable management of water resources.

Estimating water usage and determining water credits for industries involves a complex process that depends on various factors including the type of industry, its location, water source availability, and local regulations.

The steps involved are:

a. **Quantify Water Savings:** For each water reduction measure, estimate the amount of water savings achieved. This can be done through water flow measurements, calculations, or engineering assessments.

b. **Calculate Water Credits:** Determine the water savings achieved by subtracting the current water consumption (post-implementation) from the baseline water consumption (pre-implementation).

c. **Assign a Water Credit Value:** Assign a value or unit to the calculated water savings. This could be in cubic meters, gallons, or any other relevant unit. The value should reflect the reduction in water usage achieved.

d. **Calculate Total Water Credits:** Sum up the water credits from all the implemented measures to calculate the total water credits for water footprint reduction.

Depending on the context and goals, one may choose to have the water reduction and credits verified and certified by a third-party organization or a relevant certifying body. This can add credibility to the production units after reduction efforts. It is important to create a comprehensive report that details the water reduction measures, calculations, and the total water credits achieved. This report can be used for internal tracking, external reporting, and for showcasing sustainability achievements. Also, prepare a plan on how the water credits will be utilized. This could involve offsetting water usage fees, meeting sustainability targets, or earning recognition and incentives for water stewardship. Moreover, one needs to keep monitoring water usage and periodically recalculate water credits as new measures are implemented or as conditions change. It is crucial for a business unit to continuously seek opportunities for further water footprint reduction.

4.2.3 Impact-adjusted water footprint

Finally, the impact-adjusted water footprint (WF_{adj}) can be expressed as:

$$WF_{adj} = WF_{unit} + WRF_{unit} - \sum water\ credits \quad \text{...... (4.13)}$$

Where

WRF_{unit} : Annual water resource footprint of the unit adjusted for scarcity and pollution

$\sum water\ credits$: Aggregate water credits earned by the production unit through various water credit programmes factored annually.

4.2.4 Assumptions and limitations of the methodology

Multiple stressors can have synergistic or antagonist effects on freshwater organisms, which can change impacts on ecosystems significantly (Reid et al., 2019):

- Over-exploitation of groundwater can result in quality degradation (Gejl et al., 2018).
- Stream flow reduction can concentrate pollutants in the environment (smaller volume of the exposure medium) and increase their residence time.
- More research is needed to enable modelling and integration of such multi-stressor mutual interactions in the footprint calculations.
- The assessment assumes additivity of the impacts, as is typically done in the LCIA framework (Hauschild, 2005).

4.3 General data requirements

The data requirements can be classified into two types based on the method of water footprint estimation as follows:

4.3.1 Data inventory – Business water footprint

Creating a data inventory for water footprint estimation in a beverage business unit is essential for assessing and managing water use and its associated impacts. Water consumption of the business's operations including temporal pattern at Daily/Weekly/Monthly as suitable and can be of two types:

a) Direct Water Use: Water uses within the business premises, such as for drinking, sanitation, landscaping, and industrial processes; and

b) Indirect Water Use: Water uses in the production of goods and services that includes fuel use for electricity generation and transportation. Table 4.1 shows a comprehensive list of data categories in a data inventory.

By compiling and regularly updating this

data inventory, a beverage business unit can effectively assess its water footprint, identify areas for improvement, and implement sustainable water management practices. This data can also be valuable for sustainability reporting and demonstrating corporate responsibility.

Also, it is very important to clearly state the assumptions made in the collection, validation, and analysis, and document in the report

4.3.2 Data inventory – Impact-adjusted water footprint

a. System boundary: Delineation of the region of influence as per Subsection 2.3.2 for the impact assessment.

- Locations of water use and discharge.
- Monthly changes in water flows, water withdrawal and release or changes in water quality, where relevant
- Emissions to water, and soil that impact water quality

b. Water scarcity within the system boundary: From primary and secondary data.

- **Water scarcity index:** Published data on water scarcity from secondary sources
- **Water stress assessment:** The indicators can be changes in drainage, stream flow, groundwater flow or water evaporation that arise from land use change, land management activities and other forms of water interception, where relevant to the

Sl. No.	Particular	Item	Details
Direct Water Use			
1	Water Supply	Source & volume	Municipal water supply/groundwater/surface water/ rainwater harvesting (Daily/Weekly/Monthly as suitable)
		Quality	TDS, BOD, and COD etc.
		WTP	Capacity and level of treatment
		Recycle	Quantity and quality
		Reuse	Quantity and quality
2	Production Volume	Type	Different types of products
		Product wise volume	No. of bottles per product for different sizes
		Product wise quantity	Quantity per bottle size foreach product
3	Production Process	Stages of production	Raw material preparation/brewing/ packaging etc.
		Stage wise water consumption	Water use in each stage/process
		Stage wise water use efficiency	Water use efficiency of each stage/process
4	Wastewater and Effluent	Quantity	Volume generated daily/monthly
		Composition and quality	Various compounds and water quality parameters
		ETP	Capacity and level of treatment
Indirect Water Use			
5	Other water use within the unit	Kitchen	Water consumption in kitchen
		Wastewater from kitchen	Quantity and quality of wastewater from kitchen
		Washroom	Average rate of water consumed
		Gardening	Rate of reused water and fresh water
6	Packaging materials	Type and quantity	Quantity of different packaging materials used
		Water footprint of each material	Water footprint associated with production of each packaging material
7	Energy and Fuel use	Energy consumption	Energy units spent per production volume
		Water footprint of energy	Water footprint associated with energy production & consumption
		Energy efficiency	Efficiency of water-related equipment and systems that rely on energy (e.g., pumps, cooling systems).
		Indirect water use Water footprint of energy	Water footprint associated with energy production & consumption
		Energy efficiency	Efficiency of water-related equipment and systems that rely on energy (e.g., pumps, cooling systems).

Table 4.1: *Data inventory of water use of a production unit.*

scope and the boundary of the study being undertaken.

c. Water credit relevant activities: The details on various activities related to water conservation, water treatment or water supply projects can be gathered.

- **Type of water interventions:** The interventions shall include water conservation, drought mitigation, water treatment, water supply, water protection etc.
- **Impact of the interventions:** The impact may be assessed in terms of the quantity of water conserved or wastewater treated to designated water use quality.

d. Weather and Climate Data:

- Collect historical weather data for your location.
- Correlate weather patterns with water usage to identify seasonal variations.

e. Water Quality Testing:

- Regularly monitor the quality of incoming water sources.
- Analyze the composition of wastewater and treated effluent.
- Ensure compliance with local water quality regulations.

f. Employee and Operational Practices:

- Gather information on employee training related to water conservation.
- Document water-saving initiatives or best practices implemented within the facility.

g. External Benchmarks and Industry Standards:

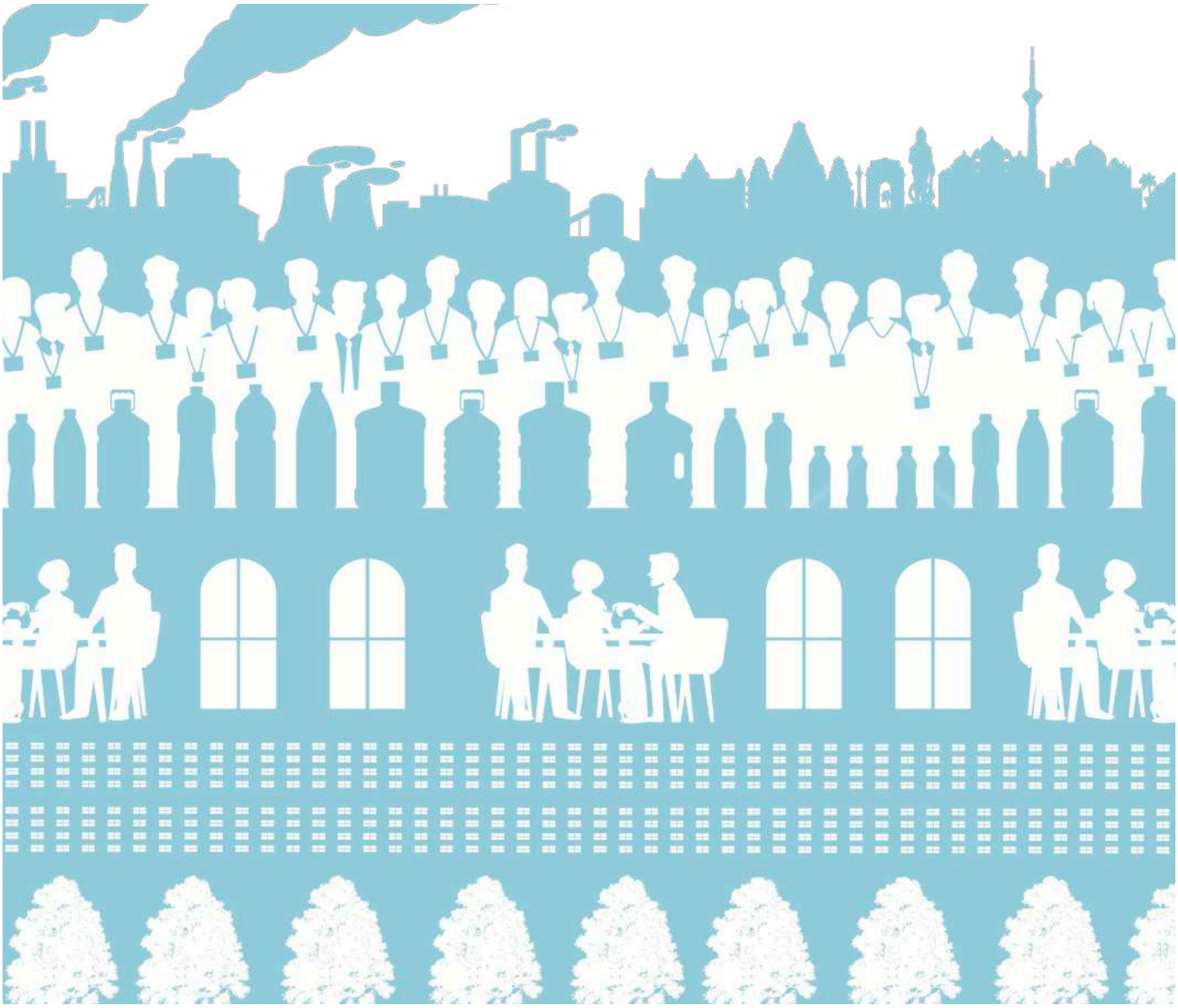
- Compare your water footprint data with industry benchmarks and standards for similar beverage businesses.

h. Financial Data:

- Analyze the cost associated with water supply, treatment, and wastewater management.

CHAPTER 05

Impact-adjusted Water Footprint Toolkit



Generally, the water footprint estimation by industries considers only physical water flows through water audits. This approach may pose issues in sustainable water management of the watershed based on the level of water scarcity and pollution. With an impact assessment framework that focuses on water scarcity and pollution, the role of each stakeholder within the watershed can be assessed and the authorities can urge them to take appropriate actions. In such situations, users within a watershed can be encouraged to reduce their water footprints through earning water credits using various water conservation and development activities. Hence, this toolkit aims at implementing a proposed methodology of impact-adjusted water footprint estimation that considers the impact of water scarcity, water pollution and water credits of a production unit.

The toolkit is an excel-based macro tool that provides the annual impact-adjusted water footprint of a production unit. The toolkit consists of input dataset, parameters, water circuit diagram of the production unit, calculations, and outputs.

5.1 Description of the Toolkit

The toolkit has multiple tabs that are shown in the 'Introduction' page as shown in Figure 5.1.

Impact - Adjusted Water Footprint Calculator for a Beverage Unit		
Index Page		
Sl.No.	Sheet Name	Details
Inputs		
1	Input - General	General and energy consumption details of the production unit
2	Input - Materials & Processes	Details of ingredients and processes
3	Input - Impact Assessment	Details of watershed water scarcity, pollution and water credits
Data & Calculation		
4	Data Inventory	Estimated WF of ingredients, packaging materials and others
5	Annexure	Details on selected parameters and limits
6	Impact Calculation	Calculation of impact due to water scarcity and pollution
7	Units	Standard units considered in the estimation
Water Circuit Diagram (WCD)		
8	Kamshet - Casestudy	WCD of Kamshet plant
Outputs		
9	Outputs	Outputs of WF calculation

Figure 5.1: *Index page of the impact-adjusted water footprint estimation toolkit*

5.2 Input-General

This section has three subsections, namely: A) General information, B) People and premises, and C) Annual energy consumption. The screenshots are shown in the Figure 5.2.

Impact-adjusted Water Footprint Calculator for a Beverage Unit

I. General Information

A. Production Unit related Information

1) **Name of the Product Unit:** Bisleri International Private Limited, Sahibabad

2) **Location:** 19/1, A, Sahibabad Industrial Area Site 4, Ghaziabad, Uttar Pradesh, 201010

Geographical Coordinates: 28°38´45.5″N Latitude and 77°19´24.2″E Longitude

3) **Type of Products and Annual Production (ton):** Packaged drinking water (Annual Production, in KL): 250 ml PET (21717.13), 500 ml PET (8461.36), 1 litre PET 53789.82), 2 litre PET (18545.63), 300 ml Glass Bottle (206.58), 750 ml Glass Bottle (161.95) Club Soda (Annual Production, in KL): 600 ml PET 3167.81), 750 ml PET (10673.64)

B. People and Premises

This section is mainly about the overhead water footprint of your production unit. Employees who use tap water, and areas that are cleaned with water. Food used in the canteen causes an indirect water footprint.

1) **Ann. Average Daily Employees:** 360

2) **Canteen facility** (Yes/No): Yes

3) **Total Area of the Premises** (m^2): 6700.83

4) **Area of Lawn/Garden** (m^2): 810.81

5) **Area of paved surfaces (m^2):** 5890.83

6) **Total Rooftop area of the Builings (m^2):** 5404.83

C. Annual Energy Consumption

Energy is well-known for its carbon footprint. But the use of energy leaves a water footprint too. Please enter the fuel used for machines and vehicles, and the electricity that bought from the local utility company.

1) **Annual petroleum based fuel consumed** (kilo litre/year): 63.8

2) **Annual coal consumed** (ton/year): 0

3) **Annual electricity consumption (Other than wind and solar)** (kwh): 6613290

4) **Annual solar/wind electricity consumption** (kwh): 107527

Data Inventory Details

WF of Energy Consumed

Excel formula

Enter 0 for solar/wind electricity WF.

Item	Quantity	Green WF (m^3/un	Blue WF (m^3/unit	Grey WF (m3/u	Green W	Blue W	Grey WF	Total W
Petroleum	63.8	0	0.0003	0	0	0.01914	0	0.01914
Coal	0	0	0	0	0	0	0	0
Electricity (other than solar and wind)	6613290	0	0.016	0	0	105813	0	105812.64
Solar/wind electricity	107527	0	0	0	0	0	0	0
				Total	0	105813	0	105812.66

Figure 5.2: *Input-General tab details*

5.3 Input-Materials and Processes

This tab requires the input related to: A) ingredients of the products by the production unit, B) Packaging materials, and 3) Unit processes involved as shown in Figure 5.3.

Impact-adjusted Water Footprint Calculator for a Beverage Unit

II. Materials and Processes related Information

A. Ingredients

Link to Data Inventory

Enter volume of water used as ingredient in the products (m^3/year)

Rainwater harvested:

Blue water consumed:

1) Refer to **Data Inventory** tab for global values of some of the ingredients.
2) You shall modfiy first 5 columns of table manually.

Ingredient	Quantity (ton/year)	Green WF per ton	Blue WF per ton	Grey WF per ton
Calcium Chloride	1.9	0	1.64	31.26
Magnesium Sulphate	6.95	0	0.12	2.28
Potassium Bicarbonate	2.175	0	3.13	59.47
Sodium Carbonate	0.18	0	1.37	26.13
Sodium Hydroxide	1.40	0	1.31	24.89
Cartridge Ink, Wash & Makeup Sol.	0.42	0	1.56	29.64
CO2 Sustain	0.02	0	0.26	4.94
CO2 Gas	197.34	0	0.26	4.94

Total

B. Packaging Materials

1) Refer to **Data Inventory** tab for global values of some of the packaging materials.
2) You shall modfiy first 4 columns of table manually.

Material	Quantity (ton/year)	Green WF per ton	Blue WF per ton	Grey WF per ton
Preform PET	2907.233415	0	41	225
Preform Recycled PET	0.04896	0	7	225
Glass Bottles	232.1	0	7	1568
Labels-PP	45.27	0	19	225
Shrink Film	360.11	0	31	225
Carton	289.56	369	0	180
Handles of 2 ltr PET Bottle	23.64	0	19	225
Cap (Glass Bottle)	1.67	0	4.21	145
Cap (PET Bottle)-HDPE	266.60	0	19	225
Hotmelt Glue	4.40	0	0	0
Taperoll	9.85	0	19	225
				Total

C. Unit Processes

1. Refer to the water audit report for the water circuit diagram of the production unit to enter all unit processes.
2. Enter values in KLD

Process	Harvested RW use	Blue water WF	Water polluted (KLD)
Sand Filtration	0	0	0
Activated Carbon Filtration	0	0	0
Ultra Filtration	0	0	0
Micro Filtration	0	0	0
Backwashing	0	0	10
Primary RO	0	0	0
Secondary RO	0	0	0
Bottling & Packaging	0	319.8	0
Cooling Tower	0	3.6	0
Toilets & Kitchen	0	0	1.8
CO2 Cylinder Washing	0	0	0
ETP	0	0	0
STP	0	0	0
Gardening	0	38.2	0
Total	**0**	**361.6**	**11.8**

Figure 5.3: *Input-Material and Processes tab of the toolkit*

5.4 Input-Impact Assessment

Impact assessment input data involves: A) Water scarcity data – Quantity and quality of monthly water availability, and source-wise monthly water demand, B) Water pollution data that includes monthly discharge and quality parameters, and C) Water credit details of the business unit as shown in Figure 5.4.

III. Environmental Impact related Information

Instructions:
1. The first user details entered shall be that of own business unit.
2. Click on 'Add User' button to pre-fill the tables of water scaricty and water pollution simultaneously. Please DO NOT delete all rows together and run the macro as it will show error.
3. ALWAYS maintain same number of users in both the tables in the SAME ORDER.

A. Water Scarcity Data

A1. Quantity and Quality of Monthly Available Water at Watershed

[Enter the details of sourcewise monthly water available here]

Sl.NO.	Source	January	February	March	April	May	June	July	August	September	October	November	December
1	Surface water availability (m3)	0	0	0	0	0	0	0	0	0	0	0	0
2	Surface water BOD (mg/l O2)	0	0	0	0	0	0	0	0	0	0	0	0
3	Surface water TDS (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
4	Surface water TSS (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
5	Groundwater availability (m3)	27689	27689	27689	27689	27689	27689	27689	27689	27689	27689	27689	27689
6	Groundwater BOD (mg/l O2)	0	0	0	0	0	0	0	0	0	0	0	0
7	Groundwater TDS (ppm)	610.48	610.48	610.48	610.48	643.85	643.85	643.85	643.85	606.9	606.9	606.9	606.9
8	Groundwater TSS (ppm)	31	31	31	31	31	31	31	31	31	31	31	31
9	Precipitation (m3)	17300.0051	5652.65454	0	0	10630.404	7205.27904	51978.56432	8010.579622	40312.51161	27697.49813	0	0
10	Interbasin transfer availability (m3)	0	0	0	0	0	0	0	0	0	0	0	0
11	Interbasin transfer BOD (mg/l O2)	0	0	0	0	0	0	0	0	0	0	0	0
12	Interbasin transfer TDS (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
13	Interbasin transfer TSS (ppm)	0	0	0	0	0	0	0	0	0	0	0	0

A2. Sourcewise Monthly Water Demand

1. 'Add User Details' button simultaneously updates the below table (Water Pollution) also.
2. Please make sure that the no.of users in both tables is same.

Add User Details | Delete A User

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Surface Water (m3)		0	0	0	0	0	0	0	0	0	0	0
Domestic	Sahibabad	Groundwater (m3)	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6
Domestic	Sahibabad	Rainwater harvested (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Domestic	Sahibabad	Interbasin transfer (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Surface Water (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Groundwater (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Rainwater harvested (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Interbasin transfer (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Surface Water (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Groundwater (m3)	12092	12347	12313	10589	10982	10834	11007	10681	10545	11115	13124	11298
Industrial	BIPL	Rainwater harvested (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Interbasin transfer (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	Others	Surface Water (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	Others	Groundwater (m3)	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00
Industrial	Others	Rainwater harvested (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	Others	Interbasin transfer (m3)	0	0	0	0	0	0	0	0	0	0	0	0

B. Water Pollution Data

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Monthly Discharge (m3)	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6
Domestic	Sahibabad	Biochemical Oxygen Demand (COD), mg/l O2	120	120	120	120	120	120	120	120	120	120	120	120
Domestic	Sahibabad	Total Suspended Solids (ppm)	343	343	343	343	343	343	343	343	343	343	343	343
Domestic	Sahibabad	Total Dissolved Solids (ppm)	3280	3370	3280	3370	3450	3500	3690	3700	3700	3690	3450	3370
Agriculture	Sahibabad1	Monthly Discharge (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Biochemical Oxygen Demand (COD), mg/l O2	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Total Suspended Solids (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Total Dissolved Solids (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Monthly Discharge (m3)	354	354	354	354	354	354	354	354	354	354	354	354
Industrial	BIPL	Biochemical Oxygen Demand (COD), mg/l O2	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65
Industrial	BIPL	Total Suspended Solids (ppm)	5	5	5	5	5	5	5	5	5	5	5	5
Industrial	BIPL	Total Dissolved Solids (ppm)	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854
Industrial	Others	Monthly Discharge (m3)	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	24897.75	24897.75
Industrial	Others	Biochemical Oxygen Demand (COD), mg/l O2	172	172	172	172	172	172	172	172	172	172	172	172
Industrial	Others	Total Suspended Solids (ppm)	160	160	160	160	160	160	160	160	160	160	160	160
Industrial	Others	Total Dissolved Solids (ppm)	3280	3370	3280	3370	3450	3500	3690	3700	3700	3690	3450	3370

B. Water Pollution Data

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Monthly Discharge (m3)	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6
Domestic	Sahibabad	Biochemical Oxygen Demand (COD), mg/l O2	120	120	120	120	120	120	120	120	120	120	120	120
Domestic	Sahibabad	Total Suspended Solids (ppm)	343	343	343	343	343	343	343	343	343	343	343	343
Domestic	Sahibabad	Total Dissolved Solids (ppm)	3280	3370	3280	3370	3450	3500	3690	3700	3700	3690	3450	3370
Agriculture	Sahibabad1	Monthly Discharge (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Biochemical Oxygen Demand (COD), mg/l O2	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Total Suspended Solids (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Total Dissolved Solids (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Monthly Discharge (m3)	354	354	354	354	354	354	354	354	354	354	354	354
Industrial	BIPL	Biochemical Oxygen Demand (COD), mg/l O2	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65
Industrial	BIPL	Total Suspended Solids (ppm)	5	5	5	5	5	5	5	5	5	5	5	5
Industrial	BIPL	Total Dissolved Solids (ppm)	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854
Industrial	Others	Monthly Discharge (m3)	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	22533.00	24897.75	24897.75
Industrial	Others	Biochemical Oxygen Demand (COD), mg/l O2	172	172	172	172	172	172	172	172	172	172	172	172
Industrial	Others	Total Suspended Solids (ppm)	160	160	160	160	160	160	160	160	160	160	160	160
Industrial	Others	Total Dissolved Solids (ppm)	3280	3370	3280	3370	3450	3500	3690	3700	3700	3690	3450	3370

C. Water Credit Details of the Business Unit

1) Enter values with respect to base line data for each subactivity ONLY.

Sl.No.	Activities	Quantity (m3/year)
1	**Water trading**	**0**
1.1	Water credits through markets	0
2	**Water offset programs**	**107914**
2.1	Water recharge - RWH, Groundwater recharge	107914
2.2	Water credits earned through water conservation project funding	0
3	**Water quality improvement**	**0**
3.1	Water credits earned through improved water quality in industrial processes (through Kg of pollutant reduced per year w.r.t baseline)	0

Total water credits earned (m3/year)	**107914**

Figure 5.4: *Input-Impact Assessment tab of the toolkit*

5.5 Calculation-Impact

This tab contains all calculations carried out to assess the impact due to water scarcity and water pollution using the input data collected through 'Input-Impact Assessment' tab. The two sub sections considered are: A) Factoring for water pollution and 2) Factoring for water scarcity as shown in Figure 5.5.

Calculation of Impact of Water Scarcity and Pollution

1) Click the 'Run' buttons to update the details as per Input-Impact Assessment tab.
2) No inputs shall be entered and no changes to the equations shall be made.
3) Verify the details shown and for any changes, modify in the input sheet of Impact Assessment

1. Pre-fill water pollution data | 3. Pollution Weights
2. Pre-fill water scarcity data | 4. Final Parameters

Excel formula
Macro code

A. Factoring for Water Pollution

A.1 Biochemical Oxygen Demand (COD), mg/l O2

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Biochemical Oxygen Demand (COD), mg/l O2	120	120	120	120	120	120	120	120	120	120	120	120
Agriculture	Sahibabad1	Biochemical Oxygen Demand (COD), mg/l O2	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Biochemical Oxygen Demand (COD), mg/l O2	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65
Industrial	Others	Biochemical Oxygen Demand (COD), mg/l O2	172	172	172	172	172	172	172	172	172	172	172	172

A.2 Total Suspended Solids (ppm)

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Total Suspended Solids (ppm)	343	343	343	343	343	343	343	343	343	343	343	343
Agriculture	Sahibabad1	Total Suspended Solids (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Total Suspended Solids (ppm)	5	5	5	5	5	5	5	5	5	5	5	5
Industrial	Others	Total Suspended Solids (ppm)	160	160	160	160	160	160	160	160	160	160	160	160

A.3 Total Dissolved Solids (ppm)

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Total Dissolved Solids (ppm)	3280	3370	3280	3370	3450	3500	3690	3700	3700	3690	3450	3370
Agriculture	Sahibabad1	Total Dissolved Solids (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Total Dissolved Solids (ppm)	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854	9854
Industrial	Others	Total Dissolved Solids (ppm)	3280	3370	3280	3370	3450	3500	3690	3700	3700	3690	3450	3370

A.4 Monthly Discharge (m3)

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Monthly Discharge (m3)	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6
Agriculture	Sahibabad1	Monthly Discharge (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Monthly Discharge (m3)	354	354	354	354	354	354	354	354	354	354	354	354
Industrial	Others	Monthly Discharge (m3)	22533	22533	22533	22533	22533	22533	22533	22533	22533	22533	24897.75	24897.75

B. Factoring for Water Scarcity

Water Demand Data

B.1 Surface Water (m3)

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Surface Water (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Surface Water (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Surface Water (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	Others	Surface Water (m3)	0	0	0	0	0	0	0	0	0	0	0	0

B.2 Groundwater (m3)

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Groundwater (m3)	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6	6716.6
Agriculture	Sahibabad1	Groundwater (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Groundwater (m3)	12092.3145	12346.74	12313.161	10589.0085	10981.6245	10834.3935	11007.4545	10680.705	10545.0975	11114.649	13124.223	11298.042
Industrial	Others	Groundwater (m3)	22533	22533	22533	22533	22533	22533	22533	22533	22533	22533	22533	22533

B.3 Rainwater harvested (m3)

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Rainwater harvested (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Rainwater harvested (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Rainwater harvested (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	Others	Rainwater harvested (m3)	0	0	0	0	0	0	0	0	0	0	0	0

B.4 Interbasin transfer (m3)

Sector	User	Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Domestic	Sahibabad	Interbasin transfer (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	Sahibabad1	Interbasin transfer (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	BIPL	Interbasin transfer (m3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	Others	Interbasin transfer (m3)	0	0	0	0	0	0	0	0	0	0	0	0

Figure 5.5: *Calculation-Impact tab of the toolkit*

5.6 Outputs

The outputs tab displays a summary of component wise both blue and grey water footprints, namely: A) Operational water footprint, B) Supply chain water footprint, C) Water footprint impacts on watershed, D) Water replenished or conserved and E) Summary of impact-adjusted water footprint. The details are shown in Figure 5.6.

Outputs of Impact adjusted Water Footprint Calculation (Annual)

Please DO NOT change any values here.

A. Operational water footprint

1)	***Operational green and blue water footprint directly associated with production***	**361.6**	m^3
1.1	Rainwater incorporated into the product as an ingredient	0	
1.2	Rainwater consumed during the production process	0	
1.3	Blue water incorporated into the product as an ingredient	0	
1.4	Blue water consumed during the production process	361.6	

Green WF	0
Blue WF	361.6

2)	***Overhead green and blue operational water footprint***	**7212**	m^3
2.1	Rainwater consumed by employees (drinking water)	0	
2.2	Rainwater consumed in toilets and kitchen	0	
2.3	Rainwater consumed due to cleaning activities in the factory	0	
2.4	Rainwater consumed in gardening	0	
2.5	Blue water consumed by employees (drinking water)	336	
2.6	Blue water consumed in toilets and kitchen	1440	
2.7	Blue water consumed due to cleaning activities in the factory	108	
2.8	Blue water consumed in gardening	5328	
3)	***Operational Grey water footprint***	**3951**	m^3

Green WF	0
Blue WF	7212
Total WF	11524

B. Supply Chain Water Footprint

4)	***Supply-chain water footprint related to the products***	**1475858.637**	m^3
4.1	Water footprint of product ingredients - Green WF	0	
4.2	Water footprint of packaging materials - Green WF	106846.2411	
4.3	Water footprint of product ingredients - Blue WF	64.809997	
4.4	Water footprint of packaging materials - Blue WF	138553.7019	
4.5	Water footprint of product ingredients - Grey WF	1231.597943	
4.6	Water footprint of packaging materials - Grey WF	1229162.286	

Green WF	106846.241
Blue WF	138618.512
Grey WF	1230393.88
Total WF	1475858.64

5)	***Overhead supply-chain water footprint***	**105812.6591**	m^3
5.1	Energy for heating and power- Green WF	0	
5.2	Energy for heating and power- Blue WF	105812.6591	
5.3	Energy for heating and power- Grey WF	0	

Green WF	0
Blue WF	105812.659
Grey WF	0
Total WF	105812.659

C. Water Footprint Impacts on Watershed

6)	***Pollution impact within watershed***	**0.0**	m^3
6.1	Surface water Pollution	0.0	
6.2	Groundwater Pollution	0.0	
6.3	Interbasin transfer water Pollution	0.0	
7)	***Water scarcity impact within watershed***	**43774.8**	m^3
7.1	Surface water Scarcity	0.0	
7.2	Groundwater Scarcity	43774.8	
7.3	Interbasin transfer water Scarcity	0.0	

D. Water Credits Earned

8)	***Total water credits earned***	**107914**	m^3
8.1	Water trading	0	
8.2	Water offset programs	107914	
8.3	Water credits earned through improved water quality in industrial processes	0	

E. Summary of Outputs			
I.	Total estimated water footprint (A+B)	1593195.54	m^3
	Green WF	106846.2411	
	Blue WF	252004.7711	
	Grey WF	1234345	
II.	Impact adjusted water footprint (A+B+C-D)	1529056.4	m^3

Figure 5.6: *Output tab of the toolkit*

5.7 Other details

Apart from the tabs mentioned in the previous sections, additional details needed to perform calculations are provided in tabs- Data inventory, Annexure 1, Water circuit diagram and Units.

5.8 Conclusion

The excel-based macro tool is tailored to include as many user-defined inputs as possible so that the template is more generic. A user with basic knowledge of MS Office can use this excel to estimate water footprint for their production unit. To our knowledge, this is the first attempt at a toolkit that integrates an impact assessment framework.

CHAPTER 06

Input data for water footprint of BIPL production units

6.1 Details of BIPL production units

The first unit for the water footprint analysis is Bisleri International Private Limited (BIPL), Sahibabad, located in the Ghaziabad district of Uttar Pradesh at a latitude of 28°38′45.5″N and longitude of 77°19′24.2″E. The plant is in the Delhi-NCR region and less than 1 km from the Anand Vihar (i.e., the eastern border of Delhi). The second unit for water footprint analysis is Bisleri International Private Limited (BIPL), Kamshet, located in Mundhavare village of Mawal taluka of Pune district in Maharashtra. It geographically lies between 18°45′24.66″ to 18°45′29.16″N latitudes and 73°31′14.82″ to 73°31′23.17″ E longitude.

The annual average daily employees in BIPL Sahibabad and Kamshet were 360 and 140, respectively. The total area of the BIPL Sahibabad unit is 11,310.76 m^2, out of which 5,531.52 m^2 is paved surface (i.e., including the covered roof, footpath, and road) and 810.81 m^2 is the green area (garden/lawn). The total rooftop area of the building is 5,404.83 m^2. The total area of the BIPL Kamshet unit is 6,015 m^2, out of which 3,252 m^2 is paved surface (i.e., including the covered roof, footpath, and road) and 929 m^2 is the green area (garden/lawn), and 2,973 m^2 is rooftop area.

The assessment year for the water footprint analysis for both units is considered from November 2022 to October 2023. All the primary water footprint-related data and subsequent calculations from both units are from the period.

6.2 Production volume

Packaged drinking water and club soda is produced in both the units. In BIPL Sahibabad, packaged drinking water is made in two different packaging types: polyethene terephthalate (PET) and glass bottles, while club soda is only produced in PET packaging. BIPL Kamshet only uses pet packaging for drinking water and club soda. The total production volume (in kL) for both the units for different pack sizes of packaged drinking water and club soda is shown in Table 6.1. Based on the annual production data of individual pack sizes of both the units, 319.8 KLD and 196.2 KLD of product water were packed in

Product	Total production* (in KL) from Nov 22 - Oct 23	
	Sahibabad	Kamshet
Packaged Water	1,02,882	60,888
Soda	13,841	10,741

**Values are round-off*

Table 6.1: *Annual production of packaged drinking water and club soda*

6.3 Water Use

Due to the miscellaneous use of water, such as for drinking, kitchen, gardening, toilets and utilities, the water footprint comes under the overhead operational water footprint. The water source for the products and various other activities in both units is predominantly groundwater. In BIPL Sahibabad, the water source is two borewells, and there isn't any system for directly utilising harvested rainwater for products or other activities. Rainwater harvesting systems are available in the unit only for groundwater recharge. So, the only water source is two borewells, which cumulatively extracted an average of 375 KLD of groundwater. The groundwater is used for production, utility, drinking, washrooms, and kitchens.

In BIPL Kamshet, 18% of the daily water needs are extracted from the two in-house borewells, 37% from open wells located in the premise and the rest are sourced from tankers. Additionally, there is a tank in the Kamshet unit to store the rooftop rainwater during the monsoon season. So, 278 m^3/month and 275 m^3/month of rainwater was harvested in the monsoon months of August and September 2023, respectively, in the entire assessment period. Since the volume of harvested rainwater was less, it is assumed that all the harvested rainwater was utilised as product water. Apart from harvested rainwater, **265 KLD** of groundwater is used for production, utility, drinking, washrooms, and kitchens.

6.3.1 Drinking water consumption

In BIPL Sahibabad, water from the product water storage tank is used for both drinking purposes as well as in the cooling tower. The monthly average meter reading showed 135 m^3/month of water consumed for drinking water and in the cooling tower. To estimate the volume of water utilised only for drinking purposes, the average water consumption was assumed to be 2 litre/capita/day. Therefore, considering the annual average daily employee of 360 and the average daily visitors (including sales personnel, truck drivers and others) of 100, the total drinking water consumption was 920 litres/day, equivalent to **28 m^3/month.**

In BIPL Kamshet, packaged water from the production line is used for drinking. On average, 13.6 m^3/month of water is consumed by employees and visitors for drinking purposes. In this unit, ultra-filtration permeate water is used in the cooling tower.

6.3.2 Water consumption in toilets and kitchen

Water is used for handwashing, cleaning, and flushing in toilets and washrooms. In Sahibabad, raw water is used in offices, washrooms, and kitchens. The wastewater from office washrooms is discharged into the drain, whereas the wastewater from workers' washrooms and kitchens goes to the sewage treatment plant (STP). The STP-treated water is utilised for toilet flushing in workers' washrooms. In the kitchen, raw water is used for washing/cleaning and purified water for cooking. As per the annual water flow meter reading average, the water consumption was 4 KLD, equivalent to 120 m^3/month in toilets, washrooms, and kitchens. In Kamshet till July 2023, raw water was used in the toilets and washrooms for flushing, handwashing, and cleaning. After July 2023, reject water from secondary RO is used for toilet flushing. Thus, the average raw water consumption in toilets and washrooms was 120 m^3/month during the assessment period. In the Kamshet unit, the kitchen is unavailable, i.e., only the outside cooked food is served. Thus, there is zero water consumption in the canteen.

6.3.3 Water consumption due to cleaning activities in the factory

In BIPL Sahibabad, the estimate provided by the housekeeping staff, an average of 300 litres/day of raw water is consumed for cleaning activities, equivalent to 9 m^3/month. Similarly, in BIPL Kamshet, the water for cleaning is taken from the washroom tap. It was assumed that 10 m^3/month of water was consumed for cleaning activities in Kamshet for the same assessment period.

6.3.4 Water consumption due to gardening

In BIPL Sahibabad and BIPL Kamshet, treated water from production units and sewage is used for gardening and flushing of toilets.

6.4 Wastewater generation

Wastewater in BIPL is generated from direct and indirect water use. Direct water uses in product manufacturing cause wastewater generation predominantly from RO reject, whereas indirect water uses in various overhead operations such as toilets, washrooms, kitchens, and cleaning cause indirect wastewater generation.

6.4.1 Wastewater generation due to use in toilets and kitchen

In BIPL Sahibabad, raw water is used in washrooms and kitchens. However, the washrooms available for the workers utilise STP-treated water for flushing. It was assumed that all the raw water used in the toilets, bathrooms and kitchen gets converted to wastewater, as there is no specific flow meter to measure the volume of wastewater generation. As 4 KLD of water is utilised for these activities, the waste generation is also assumed to be 4 KLD, equivalent to 120 m^3/month. As per the data, the Kamshet unit generates 270 m^3/month of wastewater from toilets and kitchens.

6.4.2 Wastewater generation due to leaning activities

The wastewater generation due to cleaning activities in BIPL Sahibabad and BIPL Kamshet is about 9 m^3/month and 10 m^3/month, respectively.

6.5 Energy consumption

Although energy is mainly responsible for the carbon footprint of any industry, the use of different forms of power also has a water footprint. In both units, diesel is used to run gensets. The diesel consumed in Sahibabad and Kamshet units was **63.8 kL** and **61.7 kL** per year, respectively. Regarding grid-based electricity (other than wind or solar), the annual consumption in Sahibabad and Kamshet units was **66,13,290 kWh** and **50,03,045 kWh**, respectively. Additionally, the Sahibabad unit has a system for electricity generation from solar energy. The annual electricity consumption from solar energy was **1,07,527 kWh.**

6.6 Ingredients and chemicals required for manufacturing of products

Packaged drinking water and club soda are produced in both units. Product water is the main ingredient, followed by minerals, chemicals, and carbon dioxide, which are used to manufacture the main product in both units. In BIPL Sahibabad, only groundwater is used in the product, whereas in Kamshet, harvested rainwater during the monsoon season is also used apart from the groundwater. The volume of blue water incorporated in the product in Sahibabad and Kamshet units was **1,16,727 m^3/year** and **71,060**

m^3**/year**, respectively. Further, in BIPL Kamshet, **553** m^3**/year** of harvested rainwater was used as raw water in production.

Minerals are added in the packaged drinking water, whereas CO_2 is added into the club soda. Further, certain chemicals, such as printing ink, cleaning solutions, etc., are consumed in secondary packaging. Since the printing ink and its makeup solutions are water-based solvents, the density for the ink cartridge, makeup and wash solution has been assumed to be 1000 kg/m^3. The quantity of chemicals and other ingredients consumed in both units during the assessment period is provided in Table 6.2.

Ingredients	Quantity (ton/year)	
	Sahibabad	Kamshet
Calcium Chloride	1.90	2.77
Magnesium Sulphate	6.95	2.99
Potassium Bicarbonate	2.17	0.83
Sodium Carbonate	0.18	-
Sodium Hydroxide	1.40	0.12
Cartridge Ink, Wash & Makeup Sol.	0.42	0.58
CO_2 Sustain	0.02	0.18
CO_2 Gas	197.34	159.57

Table 6.2: *Quantity of chemicals and ingredients consumed in Sahibabad and Kamshet from November 2022 to October 2023*

6.7 Details of packaging materials

The packaging materials include PET preforms, glass bottles, caps, labels, cartons, and shrink film of different sizes and weights based on the pack size. In Sahibabad, recycled PET was used in September 2023 on a trial basis for 1 litre of packaged drinking water. Although there are different varieties of cartons and shrink films, such as plain, printed, etc., used for packaging, it is believed that printed and plain cartons will not have significant differences in the water footprint, like the case of shrink films and other similar type of packaging materials. Pallets are an essential material used to carry product cases and other raw materials from one place to another inside the factory premises. However, due to its high durability, it was informed that no new pallets were purchased during the entire assessment period. The details of different packaging materials consumed of various pack sizes were collected from both the units of BIPL, and their consolidated weight is provided for the entire assessment period in Table 6.3.

Ingredients	Quantity (ton/year)	
	Sahibabad	Kamshet
Preform PET	2,907.23	1,732.01
Preform Recycled PET	0.05	-
Cap (PET Bottle)	266.60	181.77
Hotmelt Glue	4.40	2.97
Labels	45.27	37.38
Handles of 2 litre PET Bottle	23.64	2.24
Shrink Film	360.11	260.12
Glass Bottles	232.10	-
Cap (Glass Bottle)	1.67	-
Carton	289.56	11.83
Tape roll	9.85	0.24

Table 6.3: *Packaging materials consumption in both units*

6.8 Details of water consumption and pollution in various unit processes

The water beverage industry mainly depends on extracted water from groundwater, harvested rainwater, or surface water. The raw water goes through a series of treatment processes before being packaged for distribution. Further, some overhead processes go simultaneously inside the factory premise to execute various operational processes. The details of water consumed (due to incorporation into the product or evaporation) and wastewater from different unit processes of Sahibabad and Kamshet units are provided in Table 6.4. As the backwashing of different filters is regularly carried out, the sludge deposition is not significant in the backwash recovery tank. As per the details obtained from both the units, 10 KLD and 20 KLD of water are wasted/polluted in Sahibabad and Kamshet, respectively; due to backwashing, the backwash sludge with water is drained into the sewer. The bottling and packaging unit processes consumed 319.8 KLD and 196.2 KLD as product water in Sahibabad and Kamshet, respectively. Water is consumed (evaporated) in the cooling tower to circulate the water to cool down machinery such as blow moulding and compressors. The cooling tower in BIPL Sahibabad utilises water from a product water storage tank, whereas in the Kamshet, it is from an ultrafiltration storage tank. The water consumed in the cooling towers of Sahibabad and Kamshet was 3.6 KLD and 10 KLD, respectively. BIPL Sahibabad has two types of washrooms and toilets, one for office employees and the other for workers. The wastewater from workers' washrooms and toilets is treated in STP and recycled for toilet flushing, whereas the wastewater of 1.8 KLD from office washrooms is discharged into the drain. The wastewater from the toilets and kitchen of BIPL Kamshet is treated in STP and utilised for gardening, thus nil consumption and wastage. CO2 cylinders require continuous showers to prevent freezing. The water from the CO2 cylinders washing area is used for gardening. There is no specific flow meter to measure the volume of water utilised

Process	Sahibabad		Kamshet	
	Water consumed (KLD)*	Wastewater (KLD)	Water consumed (KLD)*	Wastewater (KLD)
Backwashing	0.00	10.00	0.00	20.00
Bottling & Packaging	319.80	0.00	196.20	0.00
Cooling Tower	3.60	0.00	10.00	0.00
Toilets & Kitchen	0.00	1.80	0.00	0.00
CO_2 Cylinder Washing	0.00	0.00	0.00	12.00
STP	0.00	0.00	0.00	14.00
Gardening	38.20	0.00	10.00	0.00

**Water consumed is due to evaporation or incorporation into the product*

Table 6.4: *Water consumed and polluted in various units processes in both units of BIPL*

for CO_2 cylinder washing. The officials informed that, on average, 12 KLD of water is used in both units. There is no effluent treatment plant (ETP) in Kamshet, whereas in Sahibabad, all the ETP-treated water was utilised internally for gardening purposes. Similarly, the sewage treatment plant (STP) treated water in Sahibabad gets utilised in gardening and workers' toilet flushing. In contrast, in Kamshet, some STP-treated water is used for gardening (10 KLD), and the remaining is discharged into the drain (14 KLD). Both the units have in-house gardens, which consume 38.2 KLD and 10 KLD of water, respectively. There could be a slight mismatch between the water extraction and the water consumption or pollution due to calibration/ measurement errors.

6.9 Source-wise monthly water demand

All the water demand in BIPL Sahibabad is fulfilled with groundwater from the two borewells in the factory premises. In BIPL Kamshet, the groundwater is extracted from two borewells, one open well inside the factory premises and around 45% of the total water demand through tankers. The Kamshet unit also uses the harvested rainwater in the monsoon months for production. The details of monthly water demand from various sources in both units are provided in Table 6.5.

6.10 Water pollution details

The wastewater from production processes, utilities, and domestic uses at both units is treated in ETP and STP before discharging into the municipal sewer. The ETP available at the plant treats the secondary RO reject, and ETP-treated water is used for gardening. An STP treats the wastewater from workers' washrooms and kitchens. The water pollution data is taken from the quarterly monitoring report by NABL-accredited labs available with BIPL. The average data of quarterly monitoring reports is considered for the entire assessment period.

Sources	Monthly water demand (m^3) in BIPL Sahibabad											
	Nov 22	Dec 22	Jan 23	Feb 23	Mar 23	Apr 23	May 23	Jun 23	July 23	Aug 23	Sept 23	Oct 23
Groundwater	13,124	11,298	12,092	12,313	10,589	10,982	12,092	10,834	11,007	10,681	10,545	11,115
Monthly water demand (m^3) in BIPL Kamshet												
Groundwater	11,722	9,380	7,109	7,670	8,563	8,962	9,345	8,007	4,765	6,196	6,196	8,819
Harvested rainwater	-	-	-	-	-	-	-	-	-	278	275	-

Table 6.5: *Source-wise monthly water demand in Sahibabad and Kamshet*

6.11 Details of rainwater harvesting

In BIPL Sahibabad, there are two rainwater harvesting recharge pits inside the factory premise and 7 ponds located in the villages of Uttar Pradesh. Check dams and rainwater harvesting recharge pits are available in BIPL Kamshet.

The details of rainwater harvesting in both units are provided in Table 6.6.

Type	Sahibabad (m^3/year)	Kamshet (m^3/year)
Rainwater harvesting	1,07,914	26,141

Table 6.6: *Details of rainwater harvesting*

CHAPTER 07

Literature-based data inventory of the water footprint of materials

Stages of making a Bisleri Bottle

7.1 Water footprint of materials reported in literature

Packaging materials include PET bottles, glass bottles, caps, labels, handles, shrink film, cartons, tape rolls, glue, etc. PET bottles are the most important packaging materials from a water footprint perspective. PET bottles are made from PET resins, a petroleum-based compound of terephthalic acid and ethylene glycol. The PET resins are then melted to form a test tube-shaped and cap-threaded structure called 'preform'. These PET preforms are then blown into the shape of bottles in the blow moulding machine. Thus, PET resin production and its conversion into bottles cause a water footprint. Similarly, PET bottle caps, labels, and shrink film are petroleum-based materials. The materials for PET bottle caps and handles are of High-Density Polyethylene (HDPE) and labels are polypropylene (PP), whereas shrink film is made from Low Density Polyethene (LDPE). The raw materials of these petroleum-based materials contribute less to the blue water footprint due to low freshwater consumption and zero green footprint due to the absence of rainwater use. However, the manufacturing process generates a lot of waste, which needs to be diluted before being discharged into the environment.

Ercin et al. (2011) conducted an extensive water footprint accounting of the beverage industry. The data related to the green and grey water footprint of PET preform, caps, labels, handles and shrink film are taken from Ercin et al. (2011). Whereas the data for blue water footprint for all the packaging materials has been estimated using Hoekstra et al. (2012) v1.04 methods using the Ecoinvent library process available in the life cycle assessment (LCA) software (SimaPro) for PET granulate production applicable for the global scenario. Similarly, the blue water footprint for recycled PET preforms, labels, handles, shrink film and caps are estimated using the Ecoinvent library processes. Glass bottles have a high grey water footprint as the process effluent of glass manufacturing contains high concentrations of heavy metals, suspended solids, and other pollutants. The water footprint of transparent packaging glass production has been estimated using the Ecoinvent library process applicable to global glass production. The blue and grey water footprint comes out to be 7 m^3/ton and 1568 m3/ton, respectively, considering the grey water footprint to be 224 times the blue water footprint for glass production based on a similar study conducted in the Netherlands (Leenes et al., 2017)

The closure/cap of the glass packaged drinking water bottles is made from tinplated steel (TERI, 2022) Due to the unavailability of reliable data, the water footprint data for steel production has been considered for the tinplated steel closure/ cap. The blue water footprint of steelmaking has been taken from Tata Steel's water accounting report, while the grey water footprint has been taken from Gu et al. (2015). The paperboard carton production is again water-intensive, generally manufactured from forest wood; thus, there is zero blue water footprint, assuming all the water requirements were met from rainwater. The green and grey footprint data for paperboard

Materials	Green WF (m³/ton)	Blue WF (m³/ton)	Grey WF (m³/ton)
Preform PET	0	41[a]	225[b]
Preform Recycled PET	0	7[c]	225[b]
Glass Bottles	0	7[d]	1568[d]
Labels-PP	0	19[e]	225[b]
Shrink Film - PE	0	31f	225[b]
Carton	369[b]	0	180[b]
Handles of 2 litre PET Bottle	0	19[e]	225[b]
Cap (Glass Bottle)	0	4.21[g]	145[h]
Cap (PET Bottle) - PP	0	19[e]	225[b]
Hotmelt Glue	0	0	0
Tape roll - PP	0	19[e]	225[b]

Table 7.1: *Water footprint (green, blue & grey) of packaging materials*

[a]https://v391.ecoquery.ecoinvent.org/Details/PDF/cdaf4313-0a0c-4713-afd2-cccaae020dab/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[b]https://v391.ecoquery.ecoinvent.org/Details/PDF/7b35ca1d-12cf-4fce-8a39-8e54df55387c/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[c]https://v391.ecoquery.ecoinvent.org/Details/PDF/9893a3aa-4c9c-42bf-b3de-c4e6ada68626/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[d]https://v391.ecoquery.ecoinvent.org/Details/PDF/b6b91e87-7a7e-4e2b-a6ab-d1daf0b22ec1/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[e]https://v391.ecoquery.ecoinvent.org/Details/PDF/544320af-d938-4cfd-9b92-c4d82fbe74ae/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[f]https://v391.ecoquery.ecoinvent.org/Details/PDF/e550a620-f09e-4be4-b97a-0b59bb76b336/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[g]https://v391.ecoquery.ecoinvent.org/Details/PDF/eb4702c7-1971-4599-8352-deedf420ea57/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[h]https://v391.ecoquery.ecoinvent.org/Details/PDF/7c949b6c-a141-4e77-adfb-ebb300131239/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

carton production has been taken from Ercin et al. (2011). The water footprint of various packaging materials is shown in Table 7.1.

A. Water footprint of ingredients

The main ingredient in the drinking water beverage industry is the product water. For club soda, the other primary ingredient is CO_2 gas. However, various unit processes also require some chemicals (mainly minerals for packaged drinking water). The water footprint is estimated using the library processes for these ingredients from the Ecoinvent database valid for Indian conditions (Table 7.2). It is assumed that the industrial production process for these ingredients does not consume any rainwater, resulting in zero green water footprint. Further, as the water incorporated into these chemicals is very little (as the products are mainly dried), it has been assumed that out of the total water footprint, only 5% is blue, and the remaining 95% is grey. Therefore, the values obtained from the estimation of the Ecoinvent process for these ingredients have been apportioned into blue and grey water footprints in the ratio of 5% to 95%, respectively.

B. Water footprint of energy consumed

The electricity supply in Sahibabad and Pune is from Northern and Western grids, respectively. As per the recent report of the Ministry of Coal and Central Electricity Authority, Government of India, 57% of the total power generation in India is through fossil fuels (primarily coal) and the rest, 43%, from non-fossil sources (Ministry of Power, Government of India, 2023). To evaluate the water footprint of electricity consumed in BIPL Sahibabad and Kamshet units, the electricity mix of the northern and western grids has been considered. The water footprint (in m^3/kWh) has been estimated and shown in Table 7.3 based on the processes available from the Ecoinvent database for medium voltage electricity mix for the northern and western grids. The water

Materials	Green WF (m^3/ton)	Blue WF (m^3/ton)	Grey WF (m^3/ton)
Calcium Chloride	0	1.64[a]	31.26[a]
Magnesium Sulphate	0	0.12[b]	2.28[b]
Potassium Bicarbonate	0	3.13[c]	59.47[c]
Sodium Carbonate	0	1.37[d]	26.13[d]
Sodium Hydroxide	0	1.31[e]	24.89[e]
Cartridge Ink, Wash & Makeup Sol	0	1.56[f]	29.64[f]
CO2 Sustain	0	0.26[g]	4.94[g]
CO2 Gas	0	0.26[g]	4.94[g]

Table 7.2: *Water footprint of chemicals and other ingredient*

footprint of diesel consumption in the electric genset has been estimated using the Ecoinvent database. In BIPL Sahibabad, there are solar panels to harness solar energy. Although photovoltaic solar panels require periodic cleaning, the quantity of water needed for cleaning is much less. Thus, solar-based energy has zero water footprint. Further, it has been assumed that there is nil green and grey water footprint due to the use of various sources of energy and electricity in both the units of BIPL.

Items	Green WF (m^3/unit)	Blue WF (m^3/unit)		Grey WF (m^3/unit)
		Sahibabad	Kamshet	
Diesel	0	0.0003[a]	0.0003[a]	0
Electricity (other than solar and wind)	0	0.016[b]	0.011[c]	0
Solar/wind electricity	0	0	0	0

Table 7.3: *Water footprint of various sources of energy*

[a]https://v391.ecoquery.ecoinvent.org/Details/PDF/adbc3f12-ae19-49e4-b310-a3e78adff5c4/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[b]https://v391.ecoquery.ecoinvent.org/Details/PDF/42b98c78-3f98-4fcb-bff8-7fa5d866d98f/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

[c]https: //v391.ecoquery.ecoinvent.org/Details/PDF/726ae6ec-3330-4804-b627-a8964bbd9ee1/290c1f85-4cc4-4fa1-b0c8-2cb7f4276dce

CHAPTER 08

Description of BIPL watersheds and input data for impact-adjusted water footprint

Water filtration unit at BIPL

The water footprint of a production unit helps in product benchmarking, product labelling, and comparing the water performance of the unit with that of its peer group in the same sector. However, from the ecological considerations, this information alone may not be sufficient since, unlike carbon footprint, the impact of water footprint is local. Impact-adjusted water footprint (IA-WF) informs about the effects of the production unit on the background hydrology of the watershed where it is located. Chapter 2-5 of this report explains the rationale, utility, and methodology for estimating IA-WF.

The concept of IA-WF is new and proposed under this research to generate meaningful discussions and guidance for policymakers on water security and sustainability. The committee of the expert consultative group of this research project, in their mid-term review in October 2023 in Mumbai, expressed the immense utility of this concept but flagged the challenges of the data availability. Even though the national water policy documents have repeatedly recognised water resource planning at the watershed level, the data related to water demand, pollution and several related parameters are often collected and aggregated at administrative boundaries, thus making it difficult for watershed-based planning unless extensive primary monitoring is carried out.

We have attempted to collate the input data for IA-WF methodology through an extensive literature search. Despite these efforts, there are gaps in the required data, which we tried to fill by using reasonable assumptions. The estimates are not claimed to be the best estimates, but they are the 'next-best' estimates. We could not obtain data that conforms to the period of this assessment study (i.e., November 2022 to October 2023). Further, seasonal variations of many input parameters are not available in the public domain. Even though this research presents the next-best estimates, the results are still valuable for the following reasons:

1. It illustrates the robust methodological tool for policymakers and industries for water sustainable planning and resource appropriation.
2. It presents how IA-WF informs different perspectives compared to stand-alone production unit WF.
3. Comparing two production units, one located in a stressful region and the other in a comfortable region, reveals the need for local considerations for a based green credit regime.
4. The information will pave the way for industries and governments to plan water monitoring programmes.
5. Historically, new concepts in sustainability discourse started with the illustration of methodology and through the literature assessment (as seen in the case of IPCC's first to sixth assessment report). Progressively, input data quality improves as it triggers the interest of researchers and stakeholders, and estimations improve over time.

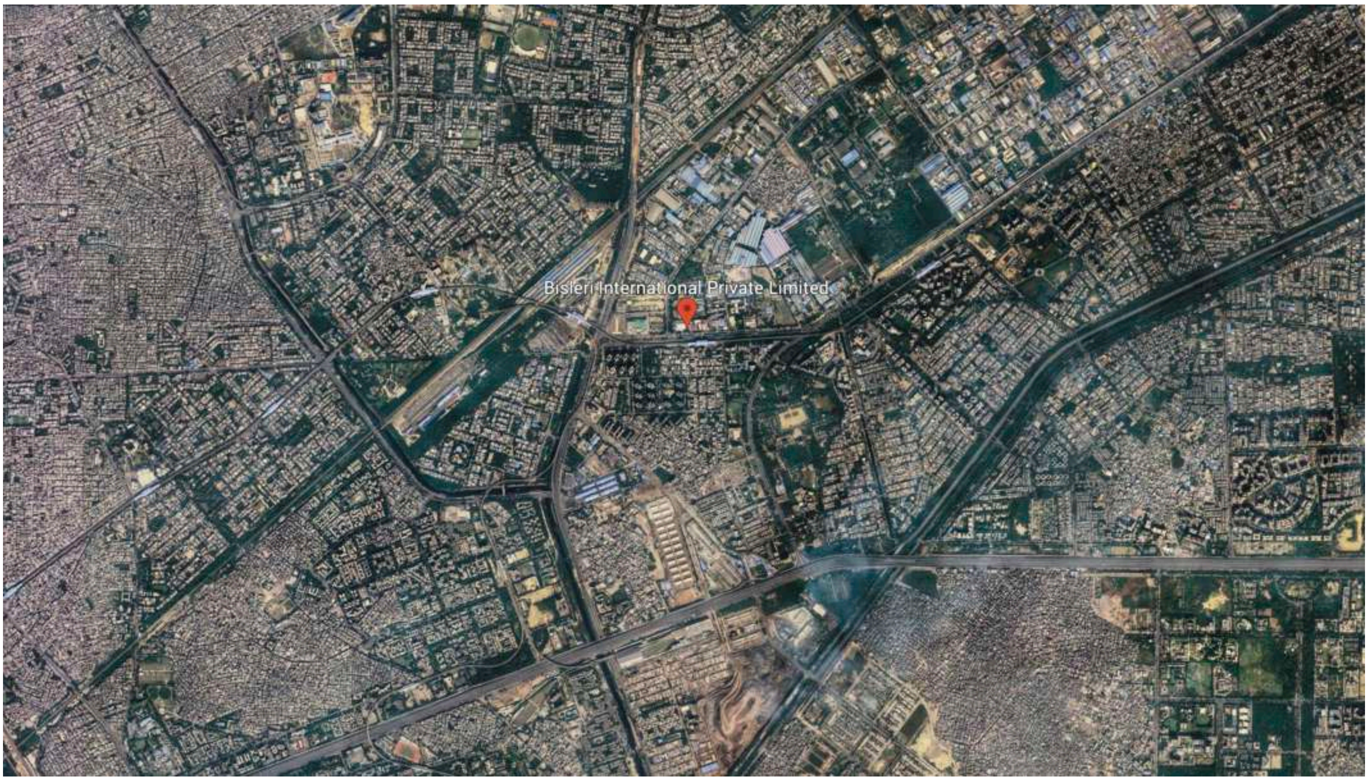
8.1 Background information of studies BIPL production units

8.1.1 Sahibabad

Sahibabad is a significant industrial area located within the city of Ghaziabad. It is situated in the western part of Ghaziabad. The region is well-connected to Delhi and other parts of the National Capital Region (NCR) via road networks like National Highway 9 (NH9) and various arterial roads. The population of Sahibabad has been steadily growing due to its industrial and commercial development, and some estimates suggest that it was 1,35,096 in 2020 with a population density of 12,798 people per square kilometre (GeoIQ). Sahibabad is known as an essential industrial hub within Ghaziabad. It houses numerous manufacturing units, factories, and industrial zones, contributing significantly to the regional economy. Industries in Sahibabad encompass many sectors, including steel, textiles, chemicals, pharmaceuticals, engineering goods, and more. Due to its strategic location, the area has also witnessed growth in the service sector, including logistics and warehousing.

The Hindon River flows through Ghaziabad and is one of the major rivers in the region. However, the river has degraded over the years due to pollution from industrial effluents and untreated sewage. The Upper Ganga Canal is a significant water body passing through Ghaziabad. It is an offshoot of the Ganges River and serves as a water source for irrigation and domestic use. There are several smaller ponds scattered across different parts of Ghaziabad. Some of these water bodies have historical significance and were traditionally used for irrigation and other purposes. However, urban development and pollution have affected their condition.

Ghaziabad is part of the National Capital Region (NCR) and has become an important industrial, commercial, and educational hub. It is strategically located in the western part of Uttar



Aerial view of BIPL Sahibabad unit

Pradesh, bordered by the districts of Meerut, Bulandshahar, Hapur, and Gautam Buddha Nagar. The process of industrialisation in Ghaziabad commenced during the 1960s when land acquisition initiatives were initiated under the supervision of the Uttar Pradesh administration. Over subsequent years, the trend persisted with multiple government notifications facilitating

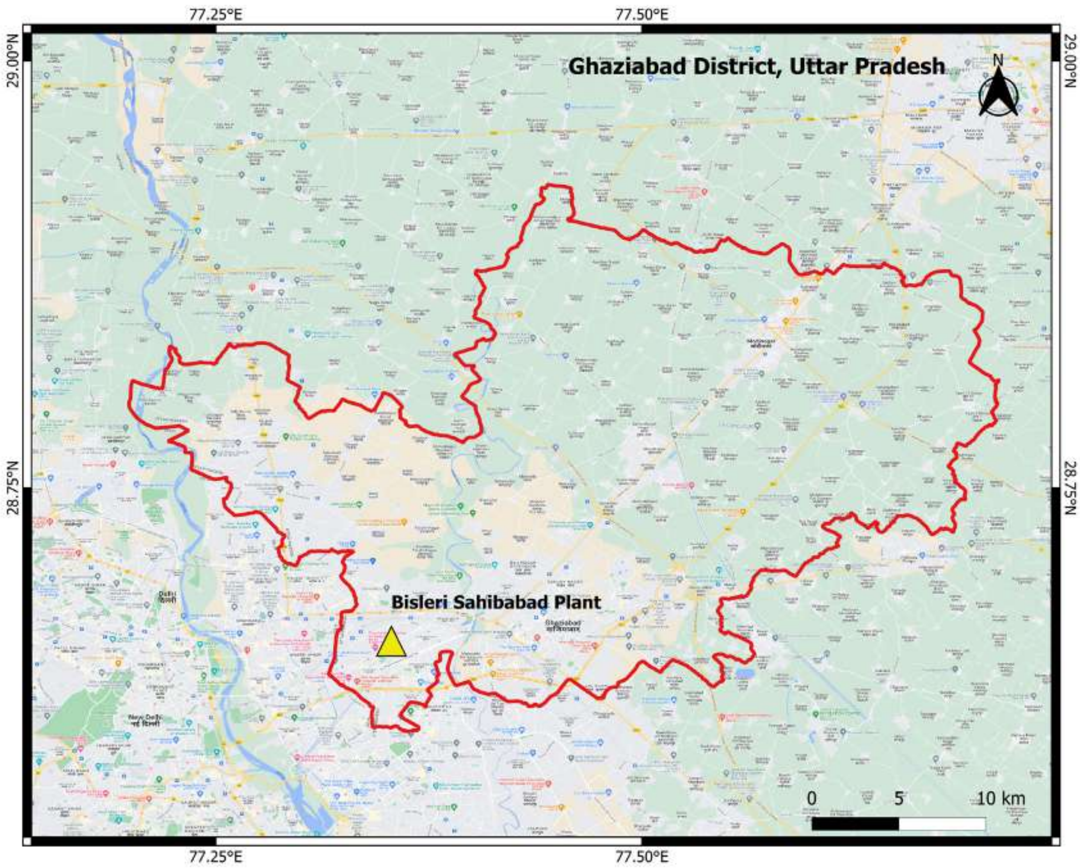


Figure 8.1: *BIPL Plant in Sahibabad in Ghaziabad District*

the acquisition of agricultural land from various villages. The acquired land falls under the Uttar Pradesh Industrial Development Corporation (UPSIDC) jurisdiction and encompasses expansive industrial estates like Sahibabad, Loni, and Meerut Road.

The built-up category encompasses urban and peri-urban areas, covering 158.11 square kilometres, which accounts for 17.18% of the entire area. Present-day urban expansion is noticeable along both banks of the Hindon River in the southern and southwestern regions of the Ghaziabad district. Additionally, urban development is scattered along the national highways in the northern parts of the area.

Agricultural practices include cropping seasons such as kharif, rabi, and zaid, with farming fields covering 296.04 square kilometres, constituting 32.16% of the total area. Other notable land classifications comprise fallow or barren land (388.31 sq. km - 42.19%), forested areas (62.47 sq. km - 6.79%), water bodies like canals, ponds, and reservoirs (11.64 sq. km - 1.26%), and the river itself covering an area of 3.85 sq. km (0.42%) (Tyagi and Sarma, 2021).

8.1.2 Kamshet

Kamshet is a village situated in Mawal taluka of Pune district. According to the 2011 Census, the total population of Kamshet was 828.8 (Indian Village Directory). Pune District is in the western region of Maharashtra in India. Thane District bounds it to the northwest, Raigad District to the

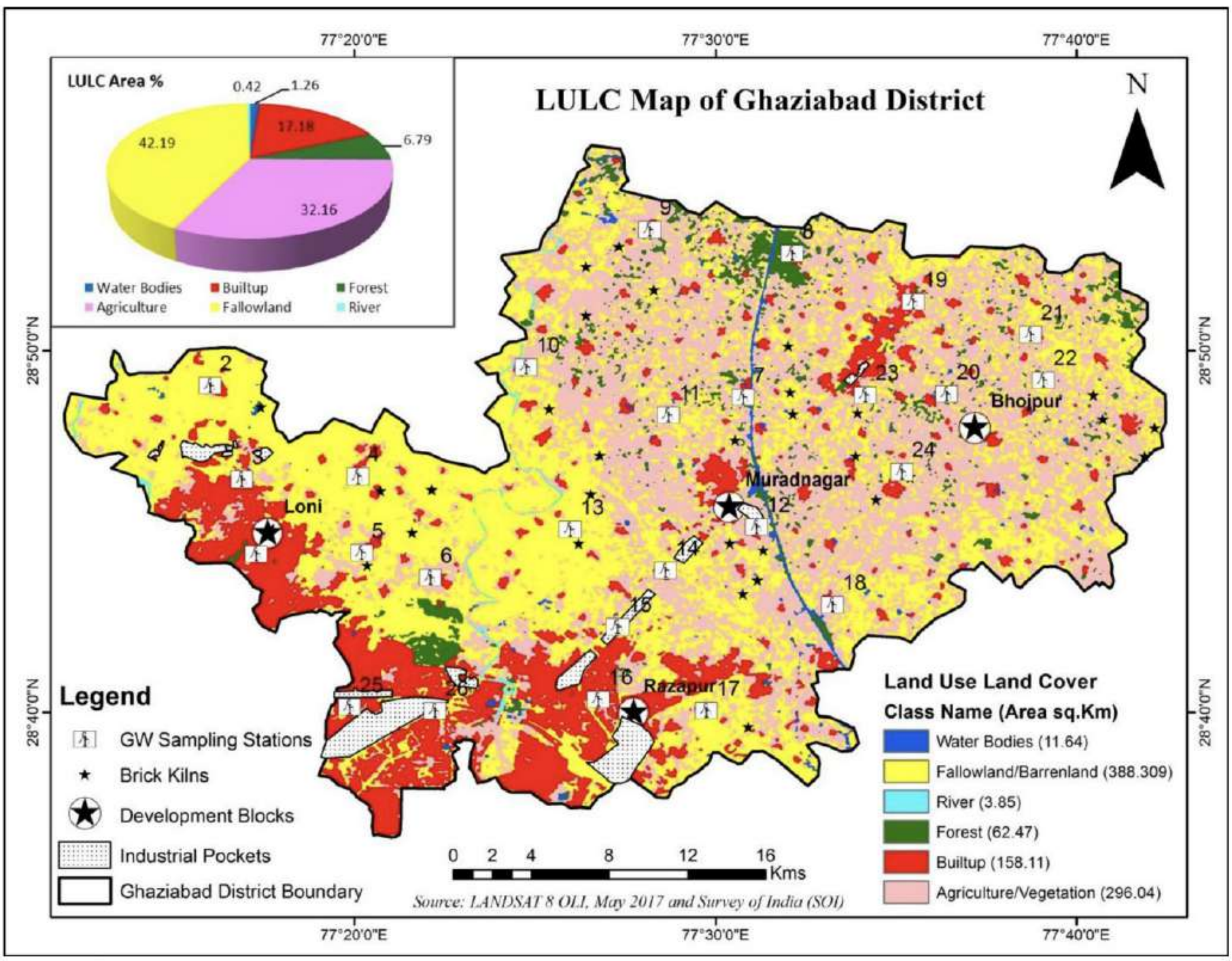


Figure 8.2: *Land use land cover (LULC) map of Ghaziabad district*

Aerial view of BIPL Kamshet unit

west, Satara District to the south, Solapur District to the southeast, and Ahmednagar District to the north and northeast. Pune district lies in the Western Ghats or Sahyadri mountain range, extending onto the Deccan Plateau on the east. Pune district is located between 17.5° to 19.2° North latitude and 73.2° to 75.1° East Longitude. Pune is 560m (1,837 ft) above sea level on the western margin of the Deccan plateau. It is situated on the leeward side of the Sahyadri mountain range (the Western Ghats). The district receives rainfall from the SW monsoon. Pune has a tropical wet and dry climate with average temperatures ranging between 20°C to 28°C. The two city talukas are the Pune City Taluka and the Pimpri Chinchwad City Taluka.

Pune City Taluka has an area of 331.26 km^2 and is administered by the Pune Municipal Corporation. It also has three cantonment boards: Pune, Dehu Road, and Khadki. Pimpri-Chinchwad City Taluka covers an area of 181 km^2 and is regulated by Pimpri Chinchwad Municipal Corporation (PCMC). Two main rivers serve the Pune city—Mutha and Mula rivers. These rivers originate in the Sahyadri ranges and traverse across Pune. The two rivers further meet, and upon their confluence, Mula–Mutha River is formed, draining itself into the Bhima River and ultimately into the Krishna River. Khadakwasla dam on the Mutha River is the primary source of water supply to

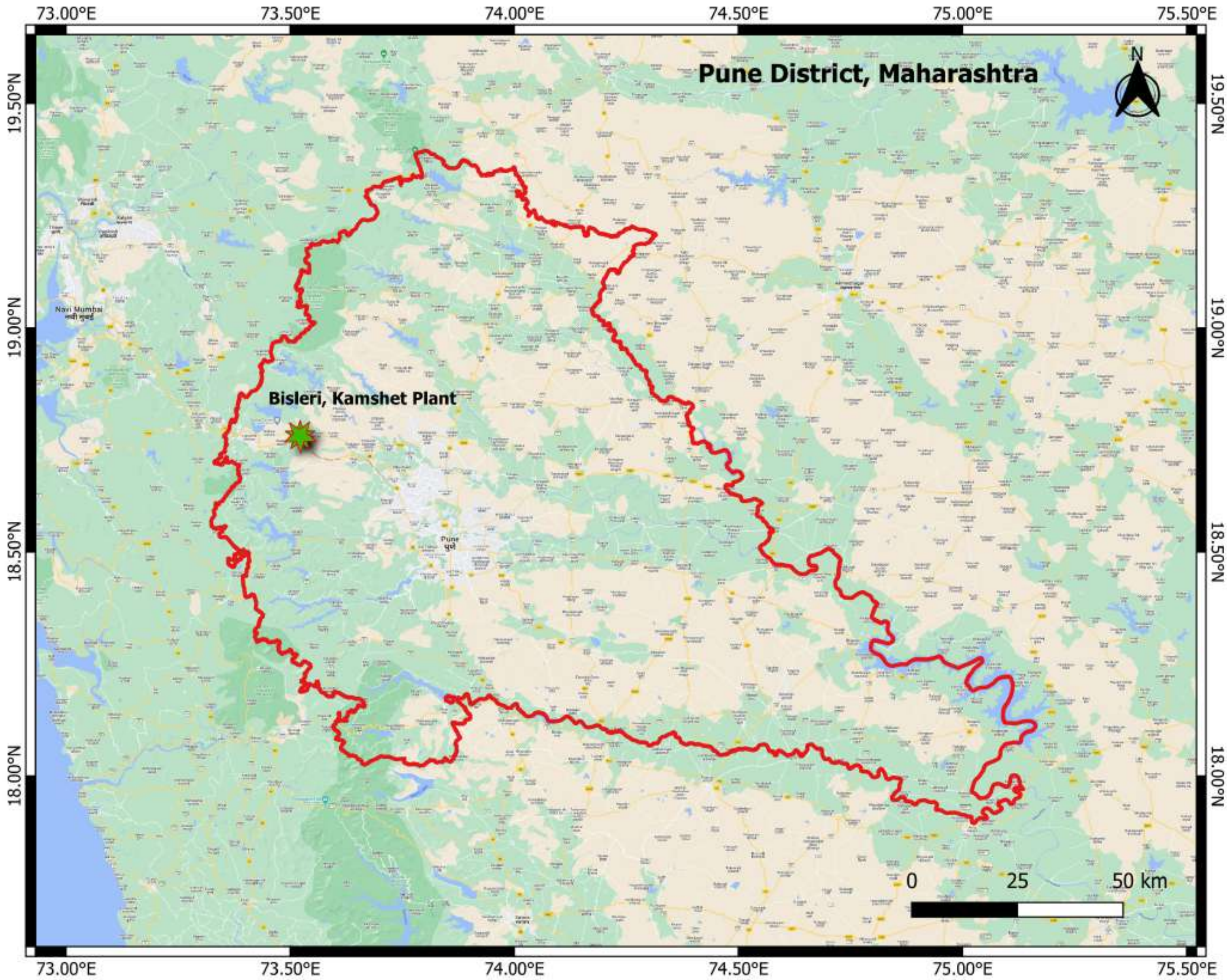


Figure 8.3: *BIPL Plant in Kamshet in Pune District*

Pune city and the cantonment areas (TERI, 2021).

The PCMC River serves the Pavana area, which originates south of Lonavala from the Western Ghats. It flows across Dehu, Chinchwad, Pimpri, and Dapodi before confluence with the Mula River in Pune. Pavana Dam, located 35 km from Pimpri Chinchwad, is the sole water source for the PCMC area.

The land cover analysis carried out by the European Space Agency (Zanaga et al., 2022) in the upper Bhima sub-basin unveiled that agriculture and grassland collectively dominate the landscape, accounting for approximately 79% of the area. This is followed by built-up regions covering 11% and tree cover at 5%. Similarly, an earlier study by Samal and Gedam (2015) in the same region yielded comparable findings. Forested regions are predominantly situated in the hilly areas of the northern Western Ghats, while extensive agricultural lands are primarily distributed in the eastern plains of the Deccan plateau. Grasslands, on the other hand, are prevalent on the western hill slopes, acting as a transitional zone between densely forested steep slopes in the west and agricultural plains in the east. Moreover, surface water bodies such as dam reservoirs are concentrated in the western part of the sub-basin, which receives higher rainfall.

The landscape in this area has been undergoing continuous changes, mainly accelerated in

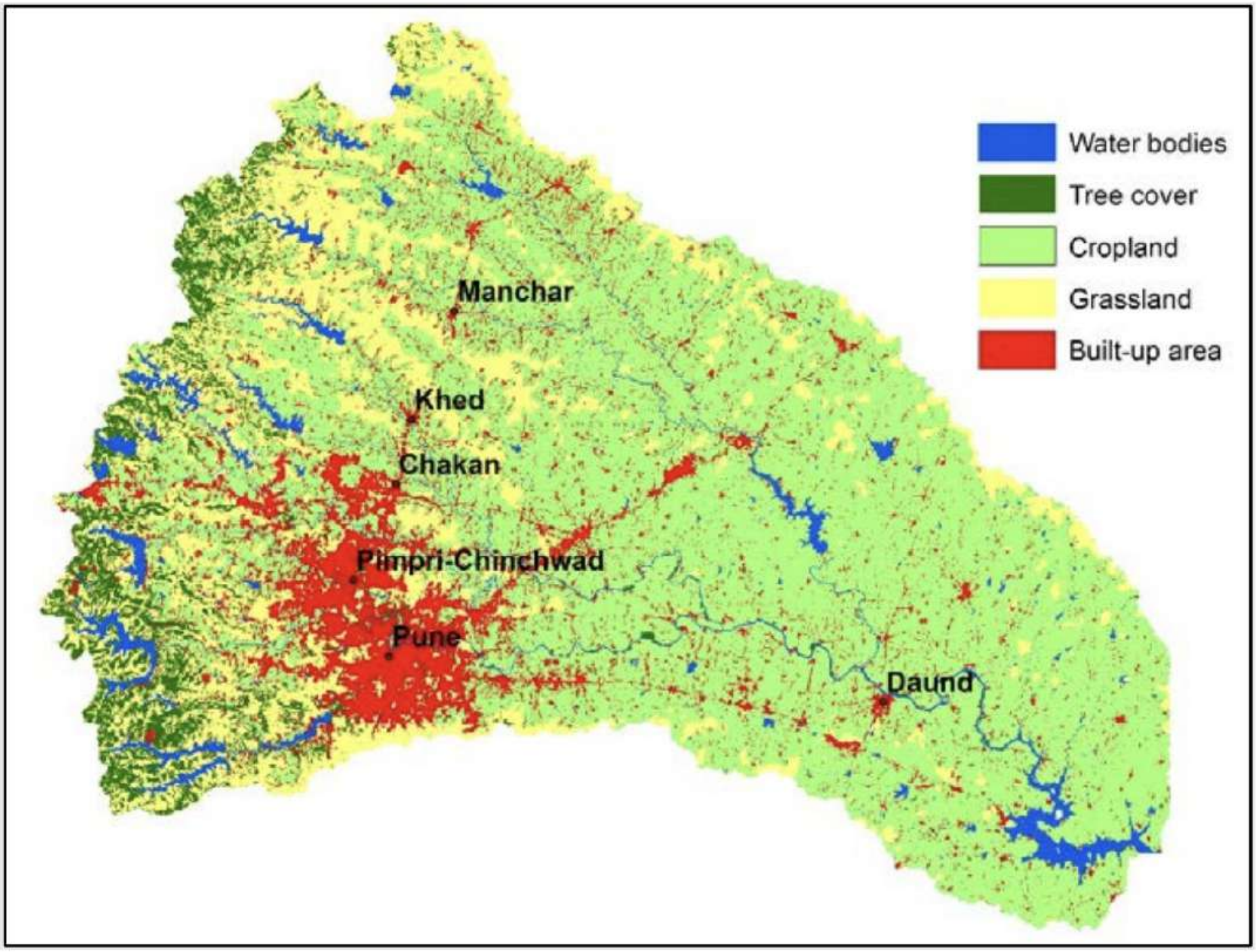


Figure 8.4: *Land use Land cover (LULC) map of the study area*
Source: Zanaga et al. (2022)

recent times due to various human activities, chiefly centred around Pune city (Semal and Gedam, 2021). Pune, a rapidly expanding urban centre in the sub-basin, is a hub for urbanisation activities. The built-up area is primarily concentrated within the Pune urban agglomeration, encompassing Pune city and the Pimpri-Chinchwad town situated northwest. There has been a noticeable increase in built-up areas encircling the city and following significant transportation networks, such as national highways, from the 1990s to 2010, as noted by Samal & Gedam (2015). Pimpri-Chinchwad and Chakan represent burgeoning industrial zones in Pune's outskirts, housing numerous industries, particularly automobile manufacturing units.

Like other Indian cities, Pune and its adjacent areas are experiencing rapid economic growth, unchecked urban sprawl, and population expansion mainly due to migration (Butsch et al., 2017). This swift urbanisation significantly impacts natural resources and the overall ecology across the broader geographical region in the sub-basin (Samal & Gedam, 2012). For instance, escalating built-up areas and impermeable surfaces have increased surface run-off and decreased infiltration, potentially causing flash floods during heavy rains (Shukla et al., 2014a). Studies have also highlighted adverse effects on surface water quality due to pollution from urbanisation and industrialisation (Shukla et al., 2014b).

8.2 Methodology for data collection

The data required for assessing the water footprint of the BIPL plant was collected through a detailed review of peer-reviewed articles and reports by the government, think tanks and other research institutions. Watershed and micro watershed delineation was first carried out to explore the possibility of assessing the surface and groundwater availability, inter-basin transfer and precipitation in the catchment of the BIPL plants in the two locations. Wherever data was unavailable through secondary sources at the watershed level, the taluka/district level data has been used as an estimate for the micro-watershed of the plants.

8.2.1 Watershed delineation

A watershed refers to an area of land where all the water that falls and drains off it or flows through it converges to a single point, such as a stream, river, lake, or ocean. It's a geographic area collecting and channelling water towards a standard outlet. The boundary of a watershed is determined by the land's topography, such as hills, mountains, and valleys, which direct the flow of water.

Within a larger watershed, smaller subdivisions can be known as micro watersheds. Micro watersheds are smaller-scale drainage areas within the larger watershed. They consist of smaller streams, tributaries, and land areas that

contribute water to a particular localised point, usually a smaller river or stream within the larger watershed.

Micro watersheds are essential for more detailed analysis and management of water resources within a specific region. Understanding micro watersheds helps assess local hydrological patterns, erosion control, and land use planning. It also helps implement more targeted conservation and management practices to address specific issues within these smaller drainage areas.

The watershed and micro watershed delineation were carried out in QGIS using the digital elevation model (DEM) maps from USGS for both Sahibabad and Kamshet locations to assess the water availability at the watershed/micro watershed level.

The steps involved in watershed delineation are as follows:

1. **Download DEM data from USGS**
   Visit the USGS Earth Explorer or other sources to download Digital Elevation Model (DEM) data for your area of interest.

2. **Import DEM into QGIS**
   Open QGIS. Go to Layer > Add Layer > Add Raster Layer and select the downloaded DEM file.

3. **Check CRS (Coordinate Reference System**
   Ensure that the DEM and any other added layers use the same CRS. Right-click on the layer > Properties > Source to confirm and reproject if needed.

4. **Prepare the DEM (if necessary)**
   If the DEM has missing data or depressions, you might want to preprocess it using tools like "Fill Sinks" or "Remove Sinks" available in the QGIS processing toolbox.

5. **Enable Hydrology Tools**
   Go to Plugins > Manage and Install Plugins and search for and install the "Processing" plugin if it's not already installed. Activate the processing toolbox from Processing > Toolbox.

6. **Perform Watershed Delineation**

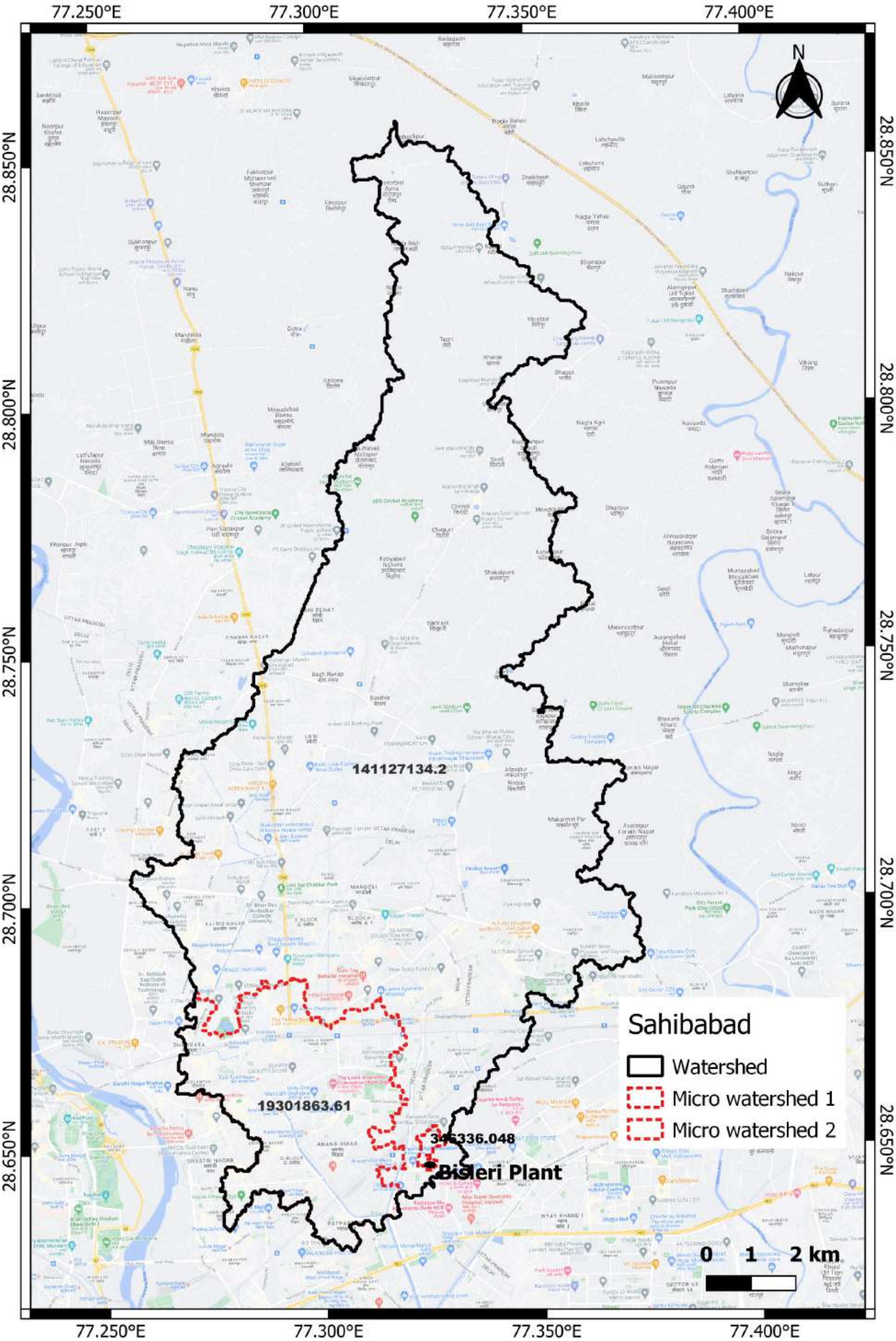


Figure 8.5: Watershed and Micro Watershed of Sahibabad

Sahibabad

Sahibabad lies in the Vasundhara Zone of Ghaziabad. The total area of the zone is approximately 38 sq km. The total area of the watershed, as shown in Figure 8.5, within which Sahibabad is located, is 141.13 sq km. Within the watershed is only the Ghazipur drain, which carries wastewater from the city. The Hindon River does not fall in the Sahibabad watershed.

However, the micro watershed of the BIPL Plant in Sahibabad, as shown in Figure 8.6, has an area of 0.35 sq km and no visible surface water body. This signifies that the water needs in the region are primarily met from the groundwater.

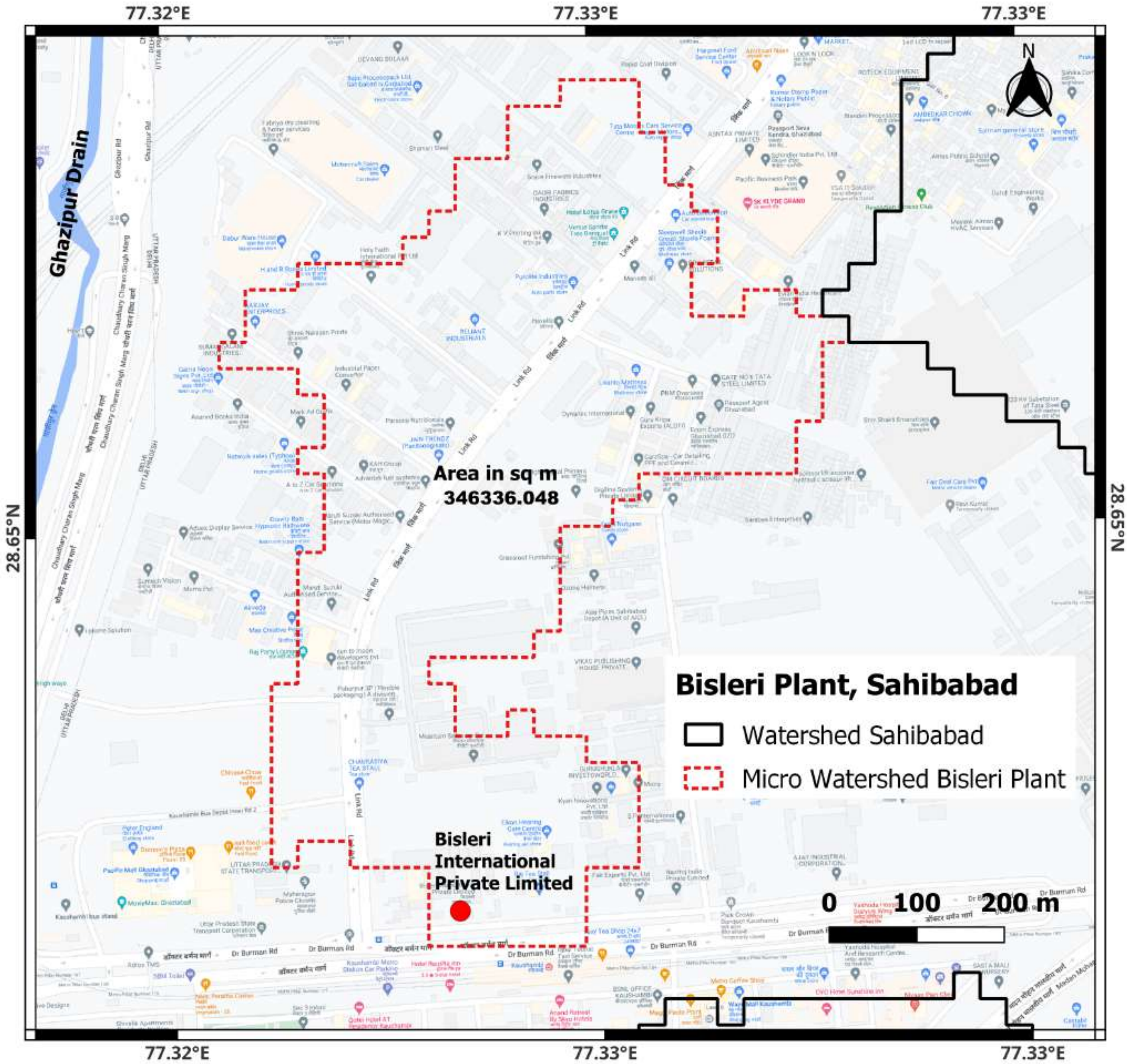


Figure 8.6: *Micro Watershed, BIPL Plant, Sahibabad*

Kamshet

The total area of the watershed within which Kamshet is located, as shown in Figure 8.7, is 982.54 sq km. The watershed is part of the Upper Bhima Basin and has several lakes and dams. The major river passing through the watershed is Indrayani.

The micro watershed of the Bisleri Plant in Kamshet, as shown in Figure 8.8, has an area of 10.41 sq km. River Indrayani passes through the watershed of the Bisleri plant in Kamshet. Indrayani River originates at Kurvande, near Lonavla in the Sahyadri ranges and meets the Bhima River at Tulapur. It flows through Kamshet, Talegaon, Dehu, Pimpri-Chinchwad and Alandi while meeting the Bhima River at Tulapur. It is one of the major tributaries of the Bhima River, which covers the area around Pune. There is a hydroelectric dam called Valvan Dam on the Indrayani at Kamshet. The river is non-perennial, and the steady flow is attributed to the release of water from the Kamshet dam. Fed by rain, it flows east from there to meet the Bhima River (MPCB, 2019).

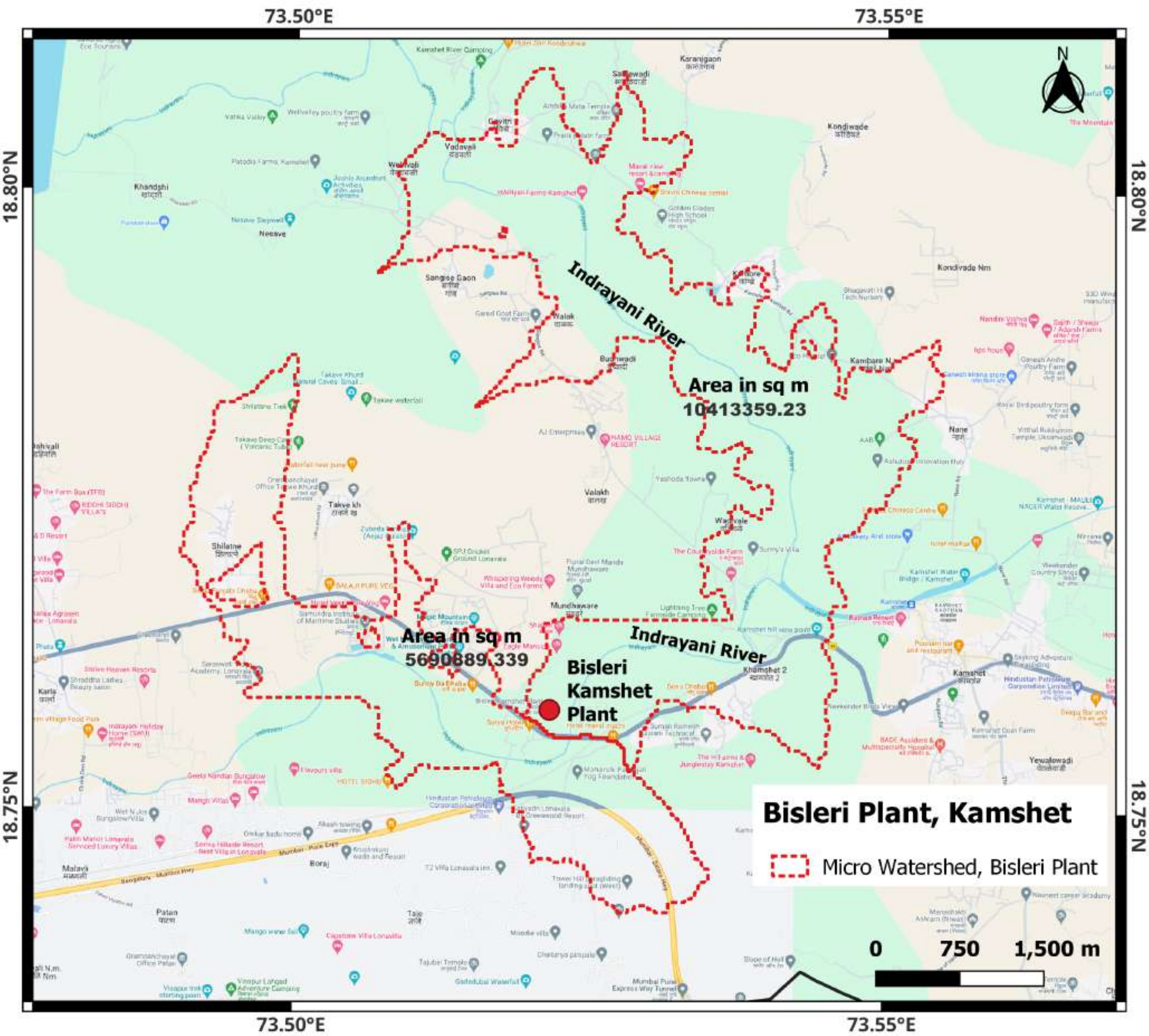


Figure 8.7: *Watershed and Micro Watershed, Kamshet*

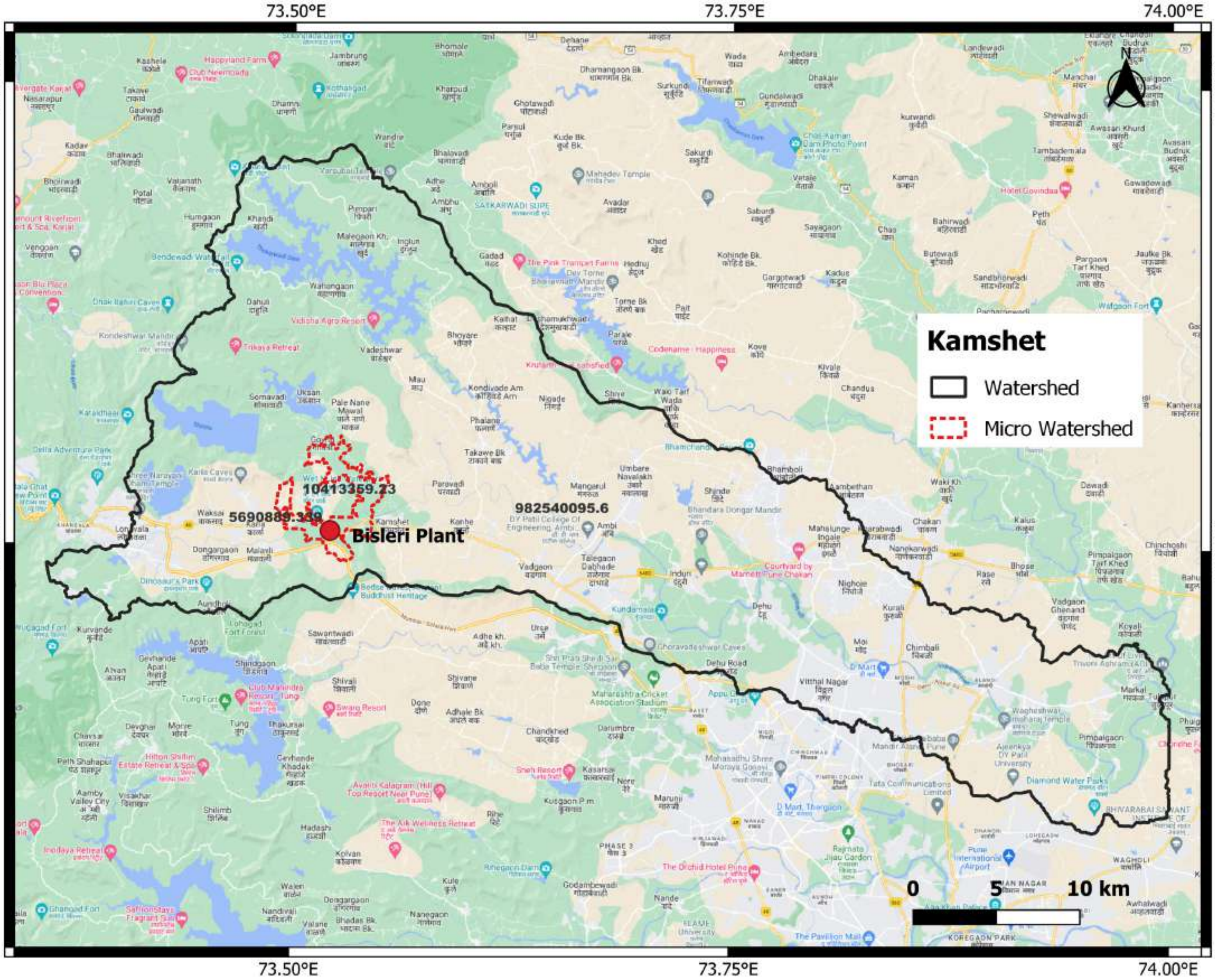


Figure 8.8: *Micro Watershed, BIPL, Kamshet*

8.2.2 Status of water resources Sahibabad

Figure 8.8 indicates the absence of a surface water body within the micro-watershed of the BIPL unit. Consequently, there exists no inter-basin transfer. Industrial, domestic, and agricultural demands predominantly rely on groundwater resources. To assess groundwater availability in this watershed, the research "A Review of Groundwater Status and Problems due to Industrial Pollution: Case Study of Ghaziabad City" was referred to (Khan et al., 2022). According to this research, the city's underground water movement comprises a three-layered aquifer system, reaching a total depth of 450 meters below ground level (mbgl). The initial aquifer layer spans depths of 125 mbgl, extending to 200 mbgl in the northern district, while the western part of the city houses shallow bedrock, resulting in thinner aquifer layers. In the Trans Hindon area, the aquifer material consists of medium to coarse-grained sand. Groundwater yielding capacity ranges between 1000 and 2500 litres per minute (lpm).

The unconsolidated sediments contain pore spaces saturated with groundwater, establishing the "zone of saturation." Pre-monsoon, typically in May, the water level fluctuates between 1.70–24.60 mbgl, drawn from an unconfined aquifer. Conversely, around November, water levels range from 2.20–23.37 mbgl (post-monsoon). Deeper aquifers exhibit groundwater depths varying from 3.04 to 16.37 mbgl. The estimated groundwater availability for Ghaziabad shall be used as an estimate for the micro-watershed's groundwater availability, as shown in Table 8.1.

To enhance the effective planning and regulation of groundwater resources, the Central Ground

Sr. No.	Blocks	Existing Gross Ground Water Draft. For All Uses (in ha.m)	Net Ground Water Availability (in ha.m)	Annual Ground Water Recharge (in ha.m)	Net Ground Water Availablity for Future Irrigation Development (in ha.m)	Stage of Ground Water Development (in %)	Category of Block
1	Bhajpur	8,453.72	11,336.3	11,964.53	2,759.71	74.38	Safe
2	Dhaulano	7,578.5	12,507.55	13,165.85	4,774.86	60.59	Safe
3	Garhmukteshwar	10,168.18	16,456.99	18,285.54	6,165.98	61.79	Safe
4	Hapur	14,003.64	15,965.94	17,739.93	1,879.13	87.71	Semi-Critical
5	Loni	5,548.47	7,366.9	8,185.45	1,425.95	75.32	Semi-Critical
6	Murad Nagar	7,355.34	11,259.77	12,510.86	3,747.72	65.32	Safe
7	Rajapur	5,935.95	10,032.02	11,146.68	3,925.35	59.17	Safe
8	Simbhaoli	11,449.75	13,208.06	14,675.62	1,670.88	86.69	Safe
	Total	70,493.55	98,163.53	1,07,674.46	26,349.5	71.81	

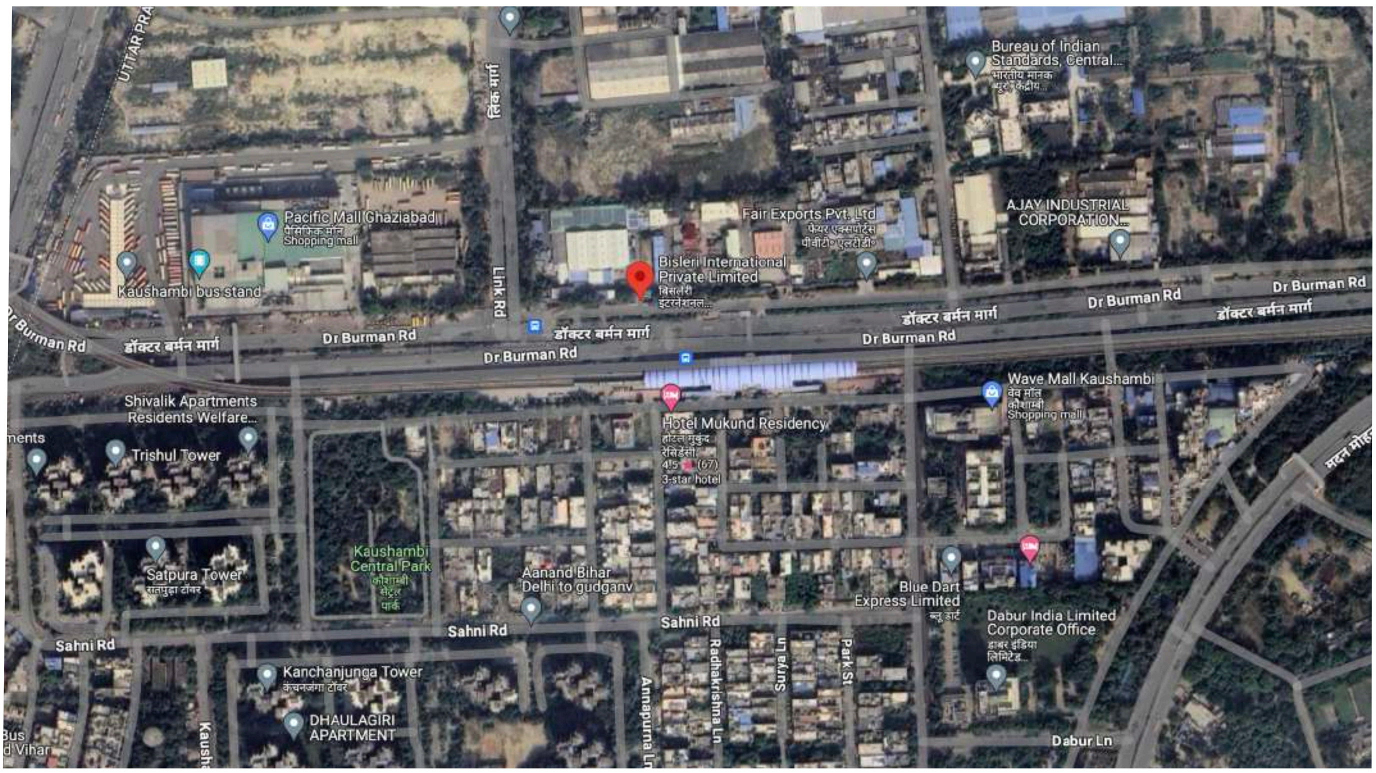
(Source: Groundwater Brochure of Ghaziabad District, U.P. 2009)

Table 8.1: *Block-wise groundwater resource, Ghaziabad district*

Water Board (CGWB) and the Ground Water Department (GWD) under the Government of Uttar Pradesh collaborated to assess the Dynamic Ground Water Resources across 836 evaluation units, comprising 826 blocks and ten urban areas. This estimation was conducted using the GEC-2015 methodology, as suggested by the Ground Water Estimation Committee formed by the Government of India. The report evaluates explicitly the Dynamic Ground Water Resources of Uttar Pradesh State, focusing on the base year 2019-20 (as of March 2020) (Ground Water Department, U.P and CGWB, 2021) . According to the report, Ghaziabad district's total annual extractable groundwater resource is 395.37 MCM (Million Cubic Meters). The current yearly groundwater extraction in the district for irrigation is 370 MCM, for the industry is unknown, and for domestic use is 8.06 MCM. Thus, the balance of 17.31 MCM could be by ndustries. Given that most of the industries are located in the Sahibabad region in Ghaziabad, we assume the total water consumed by all industries in the Sahibabad region to be 80% of the total water used by the industries. Hence, the water consumed annually by industries is assumed to be 13.85MCM.

Kamshet

Kamshet is in the Maval Taluk (1130 sqkm in area) (Indian Village Directory) in the upper Bhima basin, as shown in Figure 8.9. A detailed assessment was conducted for the basin in 2018 by the Water Resources Department of Maharashtra (Government of Maharashtra, Upper Bhima Sub basin draft report). The annual rainfall in the region ranges from 415mm to 4240mm, with an average of 688 mm. The maximum rainfall occurs in the Maval taluka of the Pune district, and the minimum rainfall occurs in the Parner taluka of Ahmednagar district. Indrayani and Pawana are the two tributaries of the Bhima River that pass through Maval. However, only Indrayani, a non-perennial river, passes through the micro-watershed of the BIPL, Kamshet.



Geographical image of Bisleri Sahibabad Plant

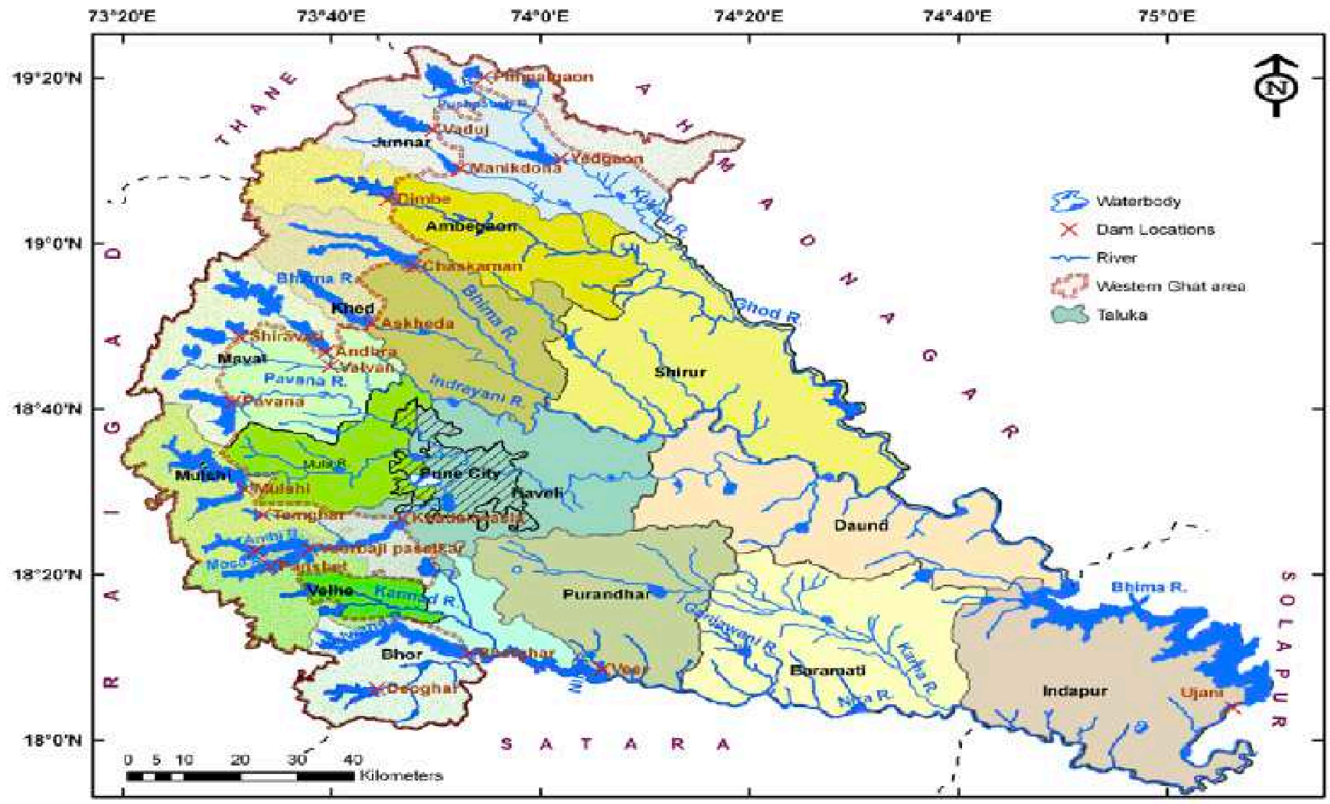


Table 8.9: *Upper Bhima Basin, Maharashtra*

The assumption for surface and groundwater availability and demand for the Sahibabad plant are as follows:

- *The surface water availability is considered as 0 since there is no river/lake available in the micro watershed of the plant.*
- *The groundwater availability in Ghaziabad district (Area=1034 sq km) is considered for quantifying the water availability in the micro watershed (Area =0.35sq km) of BIPL Sahibabad.*
- *The data provided by the Central Ground Water Board (CGWB) and the Ground Water Department (GWD) under the Government of Uttar Pradesh given in the report on effective planning and regulation of groundwater resources focusing on the base year 2019-20 (as of March 2020) is used for assuming the values.*
- *According to the report, Ghaziabad district's total annual extractable groundwater resource is 395.37 MCM (Million Cubic Meters). The current yearly groundwater extraction in the district for irrigation is 370 MCM, and for domestic use is 8.06 MCM.*

- *The balance of 17.31 MCM is assumed to be extracted annually by the industries. Given that most of the industries are located in Sahibabad region in Ghaziabad, we assume the total water consumed by all industries in the Sahibabad region to be 80% of the total water being used by the industries in the district. Hence the water consumed annually by industries in Sahibabad region is assumed to be 13.85MCM. Since the micro-watershed forms a small part of Sahibabad city, assuming the water demand by industries in the micro-watershed to be approximately 3% of the water demand of Sahibabad.*
- *Since the area is mainly industrial, for the purpose of estimation, the annual domestic water consumption for the micro watershed may be considered as 1% of the total water use for domestic use in the district which is 8.06 MCM.*
- *The water demand being met by rainwater harvesting is considered as 0.*

A situational analysis of the Upper Bhima sub-basin in the context of the Water-Food-Biodiversity Nexus was conducted by IISER in association with SOPPECOM and IIASA in 2023 (Kanade et al., 2023).

The Upper Bhima Basin has an area of 46,000 sq km. The region primarily comprises Deccan volcanic traps in its geological composition. These basalts possess minimal porosity, and the potential of groundwater resources relies on various factors such as weathering, geomorphological attributes, and geological features (Kulkarni, et al., 2002). Groundwater in basalt generally exists under unconfined to semi-confined conditions. In the Pune district, the primary aquifers are the Alluvium and Basalt aquifers, from which groundwater is typically extracted. Dug wells with larger or narrow diameters and bore wells are groundwater sources.

The shallow Aquifer (alluvium), typically accessed by dug wells, ranges from 9 to 30 meters, with water levels between 2.1 to 25.0 meters below ground level (BGL) and yields varying from 10 to 100 cubic meters per day. On the other hand, the deeper Aquifer, tapped by bore wells, spans depths of 50 to 180 meters BGL, with water levels between 6 to 45 meters BGL (Ministry of Jal Shakti, Government of India, 2019). The water table fluctuates from 480 meters above mean sea level (AMSL) in the southeast to about 700 meters AMSL in the northwest.

The total available groundwater in the Upper Bhima basin amounts to 3440 million Cubic Meters (MCM). Of this, Pune district has an accurate groundwater availability of 1720 MCM, of which the utilisable groundwater, which is 70% of the availability, is 1192 MCM (Central Ground Water Board, 2022). However, the actual groundwater use is 1287 MCM, suggesting there suggesting there is no scope for future groundwater development in the basin (ISWP, 2018) (Government of Maharashtra, Upper Bhima Sub basin draft report). The estimated water balance for the Upper Bhima Basin is shown in the Table 8.2.

Available Water Source	Average	65% dependability	75% dependability
Surface Water	7,349	6,616	5,424
Ground Water	1,400	1,400	1,400
Total water availability	8,749	8,016	6,824
Total Storage Capacity available for various uses	3,800		
Water use			
Domestic	346	346	346
Industrial	279	279	279
Agriculture	1,989	1,989	1,989
Evaporation	260	260	260
Total Water Use	2,874	2,874	2,874
Surplus Deficit	5,875	5,142	3,950

Table 8.2: *Estimated water balance for upper Bhima Basin (in Million Cubic Meters (MCM).* *(Source: IWSP 2018)*

The assumptions for estimating the surface and groundwater availability for Kamshet plant are as follows:

1. *The Water Resources Department report of the Maharashtra Government, 2018 and the Central Ground Water Report on Aquifer Mapping and Management of Ground Water Resources of Pune District, 2018 have been used for estimating the values of the surface and groundwater availability, respectively, for the Kamshet plant.*
2. *Since secondary data was only available for the Upper Bhima Basin and Pune District, the Pune district data has been used as an estimate of surface water availability and the Maval Taluka data for groundwater availability in the plant's watershed.*
3. *Maval Taluka occupies approximately 2.5% of the total area of the Upper Bhima Basin and 7.2% of the area of Pune district. Wherever the exact values were not available, estimations have been taken proportionately to calculate the water demand.*
4. *The following values have been considered for the surface and groundwater availability and demand in Maval Taluka:*
   - *Annual Surface water availability: 2.5% of 7349 MCM= 183 MCM*
   - *Annual Groundwater availability: 89.52 MCM*
   - *Annual Groundwater withdrawal for irrigation: 14.52 MCM*
   - *Annual Groundwater withdrawal for domestic and industrial use:3.84 MCM*
   - *Annual Surface water withdrawal for irrigation [(2.5% of 1989 MCM) – groundwater withdrawal]: 35.2 MCM*
   - *Annual Surface water withdrawal for domestic and industrial use [{2.5% of (346+279) MCM} – groundwater withdrawal]: 11.8 MCM*
5. *Since the plant lies in the industrial area it is assumed that the Industrial water use is twice the domestic water use in the area i.e 8 MCM for industry and 4 MCM for domestic from the surface water. Likewise, we assume 2.6 MCM for industry and 1.3 MCM for domestic use from groundwater.*
6. *The micro watershed of BIPL Kamshet is approximately 1% of the Maval Taluka.*

8.2.3 Status of water quality Groundwater quality, Sahibabad

Multiple literature was referred to for understanding the groundwater quality in the watershed of the BIPL Sahibabad. According to the study, "Assessment of groundwater quality from Sahibabad to Modinagar Meerut Uttar Pradesh, India" (Ruhela et al. 2022) using the water quality index by the average values of physicochemical characteristics (All the values are in mg/l except pH) are shown in Table 8.3.

S.No.	Parameter	Murad Nagar	Sahibabad	Modi Nagar
1	pH	8.82	8.69	8.10
2	Total; Alkalinity	346	476	530
3	Total Hardness	785	876	786
4	Ca^{++}	550	560	510
5	Mg^{++}	231	328	279
6	Na^{+}	66.80	120.80	138.80
7	K^{+}	230.40	240.50	230.80
8	Cl^{-}	575.46	580.75	556.25
9	SO_4^{--}	242.1	235	231
10	NO_3^{-}	2.90	5.70	6.50
11	F^{-}	1.88	3.80	4.20
12	Total Dissolved Solid	2458	3780	2380
13	Electrical Conductivity	778	870	1875

Table 8.3: *Groundwater quality in Sahibabad (Source: Ruhela et.al. 2022)*

Values of groundwater quality reported in another study by published titled "Groundwater Quality Analysis using WQI for Sahibabad (UP)" (Deoli and Nauni, 2021) are shown in Table 8.4.

Test	Acceptance limit	S1	S2	S3	S4	S5	S6	S7	S8	S9	10
pH	6.5 - 8.5	6.94	6.92	7.60	7.11	6.88	7.55	7.26	7.05	7.30	7.82
Conductivity ($\mu s\ cm^{-1}$)	500	470	1240	490	450	310	180	420	110	330	510
Turbidity (NTU)	300	4.50	0.73	0.68	1.49	1.96	1.60	0.62	3.20	0.75	1.25
Residual Chlorine ($mg\ l^{-1}$)	1	0	0	0	0	0	0	0	0	0	0
TDS ($mg\ l^{-1}$)	250	288	729	670	150	190	605	251	188	105	425
Chloride ($mg\ l^{-1}$)	0.2	130	140	170	60	280	220	110	380	310	70
Fluoride ($mg\ l^{-1}$)	5	0	0	0	0	0	0	0	0	0	0

Table 8.4: *Physicochemical parameters of groundwater samples*

Parameters	Summer (May 2017)				Post Monsoon (October 2017)				Winter (January 2018)				BIS (2012)	
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	DL	PL
pH	7.22	7.9	7.5	0.16	6.9	8.3	7.53	0.33	7	8.1	7.52	0.26	6.5	8.5
EC	408	2,920	1043.8	612.4	392	3,460	964.9	624.54	326	2,370	731.96	449.33	-	a1500
TDS	105	2,675	643.85	509.15	205	2,410	606.9	575.61	260.3	2,322	610.48	443.52	500	2000
TH	148	640	309.2	117.1	124	720	316.3	126.9	160	672	321.2	128.3	200	600
Ca^{2+}	36.87	153.9	68.25	24.91	11.22	155.51	52.35	33.78	32.06	134.67	63.02	27.59	75	200
Mg^{2+}	13.66	95.65	33.97	17.96	12.69	81.01	45.31	16.44	17.57	81.98	40.02	17.45	30	100
Na^{+}	21.18	528.77	160.45	106.77	16.37	696.55	134.79	146.28	14.59	573.5	144.41	154.15	-	200
K^{+}	9.27	55.94	17.91	9.65	6.83	39.36	14.96	8.37	10.89	45.47	18.46	7.96	-	12
HCO_3^-	190	530	363.08	87.21	220	690	401.2	96.5	220	580	383.1	88.4	200	600
Cl^-	7.1	1,053.64	123.76	224.41	1.42	1080.62	106.61	229.74	14.2	1,420	219.12	292.12	250	1000
F^-	0.12	1.55	0.58	0.41	0.42	1.98	1.02	0.4	0.11	1.38	0.59	0.33	1	1.5
SO_4^{2-}	19.23	179.51	55.12	47.16	6.79	177.9	46.69	43.53	11.36	130.72	41.54	32.18	200	400

Table 8.5: *Seasonal descriptive statistics of the groundwater quality parameters for potability and irrigation usability for Sahibabad*

Further, the CPCB study on action plans for addressing industrial pollution was also reviewed for data points.

The findings of these studies were used as estimates for the groundwater quality in Sahibabad.

The following assumptions have been used for the estimation of BOD, TDS and TSS in the groundwater of the Sahibabad Plant.

- *The research on groundwater quality assessment in Ghaziabad district and Sahibabad have been used to arrive at an approximate value for the BIPL micro watershed.*
- *The mean values reported in the findings of the study by Tyagi and Sarma, 2021 have been used as estimates for TDS (Table 5).*
- *The CPCB report was used for estimation of TSS (31mg/l).*
- *The studies and reports did not report BOD in the groundwater. The BOD in the leachate was found to be 78.3mg/l in the industrial area. For the estimation BOD of Groundwater shall be taken as 0.*

Wastewater discharge, Sahibabad

The findings of the Uttar Pradesh Pollution Control Board Report have been used to propose the estimates for the TDS, TSS and BOD of Industrial and Domestic discharge (Uttar Pradesh Pollution Control Board, 2019). The values for TSS and BOD of the domestic discharge in Ghaziabad district are reported to be 343 mg/l and 120 mg/l, and for industrial water, 170 mg/l and 162 mg/l, respectively.

Another study on physico-chemical analysis of sewage water in Ghaziabad has reported TDS ranging from 3200 to 4800 ppm (Bhardwaj, 2014). These two studies have been used to estimate the micro watershed of the BIPL Sahibabad.

8.2.4 Groundwater quality, Kamshet

A study carried out by Sheikh and Chatterjee 2021, titled "The Hydrogeochemical Study of Taluka Maval from Pune District of Maharashtra", found the TDS value of groundwater between 20 and 58 mg/l, electrical conductance values ranged from 52 - 117μs/cm at 25oC, pH values ranged from 6.8 – 8.1, and the total hardness was from 20 to 77 mg/l (Chatterjee, 2021).

The results of the physicochemical analysis of another study on "Hydrogeochemical characterisation of groundwater from the semiarid region of western India for drinking and agricultural purposes with special reference to water quality index and potential health risks assessment" (Shaikh et al., 2020) are shown in Table 8.6.

Parameters	Min	Max	Average	Maximum Desirable limit (MDL)	Maximum Permissable limit (MPL)	% Sample above MDL	% Sample above MPL
pH	6.80	7.90	7.33	6.5-8.5	-	0	0
EC	418.00	2987.00	1349.14	-	-	-	-
TDS	264.67	1916.81	857.39	500	2000	81	0
TH	186	960.00	486.62	300	600	61	21
Ca^{2+}	15.31	214.02	90.18	75	200	58	2
Mg^{2+}	9.16	126.70	58.34	30	100	84	2
Na^{+}	4.92	375.73	92.80	200	-	19	-
K^{+}	0.01	2.56	0.57	12	-	0	-
HCO_3^-	125.00	490.00	272.29	200	600	81	0
SO_4^{2-}	1.38	369.12	150.85	200	400	25	0
Cl^-	35.50	367.40	154.94	250	1000	21	0
NO_3^-	0.33	108.23	32.56	45	-	26	
F^-	0.02	0.91	0.55	1	1.5	0.00	0.00

**All values in mg/L except pH and EC*

Table 8.6: *Descriptive statistics of physicochemical analysis of groundwater samples*

Devachi, in Pune, Maharashtra" revealed the value of pre-monsoon BOD as 40.8 mg/l and post-monsoon BOD as 50.44 mg/l (Nihalani et al. 2022). However, this location does not fall in the Kamshet watershed and may not represent the exact value. The same study reported pre-monsoon TSS as 596 mg/l and post-monsoon TSS as 31.8 mg/l. Another survey reported BOD between 3 -8 mg/l (Pote et al., 2023).

Further, the environmental impact assessment report in the Maval Taluka of Pune district was used to get the values for BOD and TSS (Hindustan Electricity Generation Co. Pvt. Ltd., 2017). The study reported BOD between 4 and 7 mg/l and TSS under five mg/l.

The surface water in the micro-watershed of Kamshet is the Indrayani River. A study on physicochemical parameters of the Indrayani River, Pune, Maharashtra, India analysed the river's water quality in Kamshet (Chandanshive et al., 2020). The samples were collected in the first week of every month. The results are shown in Table 8.7.

Another study on "Current Scenario of Water Quality Status of Indrayani River at Pune District, Maharashtra", analysed samples from five different sites of the river (Kolhe, 2023). The findings of the study are shown in Table 8.8.

Parameters	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
Temp °c	24.5	26	27	27.2	27.2	29.4	31	30	31	31
pH	6.9	6.7	6.7	6.8	6.7	6.5	6.3	6.5	6.5	6.4
Dissolved O_2	11.02	8.5	9.25	9.2	9.1	9.5	9.4	8.6	7.9	7.6
Free CO_2	14.5	14.2	13.8	14.4	13.9	13.5	13.12	13.9	13.8	13.9
Acidity	48.5	49.4	50.6	48.6	50.6	51.8	50.6	51.6	49.4	50.2
Alkalinity	20.6	21.9	23.7	21	20.2	22.3	23.6	22	21.6	20.8
Biological Oxygen Demand (Mg/Litre)	1.9	1.8	2.2	2.5	2.4	2.5	2.1	2.3	2.2	2.2
Biological Oxygen Demand (Mg/Litre)	20	21.1	19.1	20.2	22.5	21.5	21.2	22.3	21.8	22
Sulphate Mg/Litre	170	173	170.4	171	172	170.3	169	168	169.5	172
Nitrates Mg/Litre	31.6	30.2	31.3	30.9	31.5	32.1	30.5	30.8	30.1	31.4
Chlorides Mg/Litre	105.12	107.65	108.6	104.5	103.32	106.9	103.5	104.7	115.3	108
Phosphates Mg/Litre	121	128	125	123	128	120	121	127	122	126

Table 8.7: *Physicochemical parameters of Indrayani River collection site Kamshet*

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5
pH	7.7	8.2	8.5	8.8	7.9
DO	2.3	3.6	5.3	7.2	6.9
BOD	36	52	5.4	39	21
Total Solids	250	472	681	175	90
Alkalinity	100	120	128	92	115
Total dissolved solids	80	92	413	218	98
Hardness	120	162	156	182	126
Turbidity	9.7	15.36	8.2	21.36	10.2
E.Coli	20	24	28	18	26

Table 8.8: *Physicochemical parameters of Indrayani River*

The monthly water quality variation of the Indrayani River, as reported by the Maharashtra Pollution Control Board, is shown in Table 8.9.

Months	Parameters						
	pH	Dissolved Oxygen (mg/l)	B.O.D (mg/l)	C.O.D (mg/l)	Nitrate (mg/l)	Fecal Coliform (MPN/100ml)	WQI
Year 2022							
January	7.2	6.5	5.6	20	0.8	25	81.47
February	7.7	5.3	6.6	20	4.26	10	73.9
March	8.5	4.9	4.8	17.6	1.95	9	69.15
April	7.5	5.5	5.2	20.2	1.22	10	78.19
May	7.3	5.1	6.5	22.1	3.58	9	76.5
June	7.9	4.8	5.6	16	1.41	9	71.46
July	7.4	5.2	7	21.2	0.3(BDL)	14	73.69
August	7.3	5.2	5.8	19.4	2.35	12	77.06
September	8.3	6	4.8	16	1.99	9	76.6
October	7.2	6.5	2.8	12	1.48	11	87.85
November	7.3	4.9	7.4	24	2.33	11	73.54
December	7.3	5.3	6.3	19.9	6.74	10	77.54
Year 2023							
January	7.2	5.4	6	19.8	7.25	11	77.46
February	7.3	4.8	8.3	23.9	2.27	15	70.78
March	7.8	5.2	4.8	16	1.14	9	75.42
April	7	5.8	4.6	20	1.21	9	80.72
May	7.7	5.5	4.5	16	1.27	14	76.72
June	7	6.1	2.2	8	0.56	17	83.53
July	7.6	6.1	3.4	12	1.74	9	83.61
August	7.7	5.7	4	12	0.3(BDL)	8	80.31
September	7	5.4	4.6	20	0.3(BDL)	30	74.6

Table 8.9: *Monthly variation in the water quality of Indrayani River in Moshigaon, Pune*

Parameters	Max	Min	Avg	Stdev
pH	9.00	6.85	7.97	0.02
Dissolved Oxygen mg/l	7.32	1.30	4.66	0.17
B.O.D 27 °C (3 days) mg/l	16.00	3.00	7.57	0.47
COD	56.00	8.00	24.70	1.34
COD/BOD	5.83	1.74	3.34	0.04
Conductivity μmhos/cm	1126.00	138.00	406.55	23.25
Total Dissolved Solids	872.00	94.00	289.28	8.69
Total Fixed Solids	808.00	59.00	245.33	29.38
Total Suspended Solids	164.00	4.00	22.35	12.17
Turbidity	74.90	0.28	4.63	1.93
Hardness	746.00	40.00	147.96	28.61
Nitrate-N mg/l	8.40	0.02	1.32	0.32
Ammonia mg/l	6.92	0.04	0.81	0.24
TKN	7.68	0.00	2.16	0.16
Total Coliform (MPN) / 100ml	1800.00	350.00	1626.04	83.74
Faecal Coliform / 100ml	550.00	40.00	252.71	10.03
Chlorides	215.00	12.00	58.81	34.94
Sulphates	87.50	2.10	26.98	16.02
Calcium	194.00	10.00	69.05	38.80
Magnesium	250.00	3.90	61.40	36.88
Fluoride	20.00	0.00	1.04	1.68

Table 8.10: *Summary of river quality for four years at Indrayani River*

According to the water resources department of Maharashtra, the water quality parameters are shown in Table 8.10.

- *Based on the literature review, the following assumptions have been used to estimate the BOD, TSS and TDS in groundwater and surface water in Kamshet micro watershed.*
- *The groundwater TDS is considered as 39 mg/l (mean value) based on the study by Sheikh and Chatterjee 2021 in Maval taluka.*
- *The values of both groundwater BOD and TSS are considered as 5 mg/l based on the EIA report.*
- *The surface water BOD is considered as from the study by Chandanshive et. al. and the TSS and TDS are taken from the Water Resources department report of the Maharashtra Government.*

Wastewater discharge, Kamshet

The water quality of the discharge for Kamshet has been taken from several studies on physicochemical assessment of the wastewater being discharged into various rivers in the Pune district (Sahu et al., 2015). To estimate the water quality data for agriculture, a study of rural Maharashtra was considered to provide an approximation for the values of the parameters (Kamble et al., 2019).

8.2.5 Precipitation

The IMD gridded daily data for rainfall is used to estimate the monthly rainfall. IDLIB, a Python package, downloads and handles binary gridded data from the India Meteorological Department (IMD). The link https://imdlib.readthedocs.io/en/latest/index.html#of IMD Pune can be referred to for more information about the IMD datasets. The following code can be run in Google Colab Notebook to generate the daily data based on the latitude and longitude of the location of the BIPL Plants. For this assessment, the latitude and longitude of the Sahibabad Plant have been taken as 28.66N and 77.32E, and those of the Kamshet Plant are 18.75N and 73.52E, respectively.

```
# For installing the IMD library
pip install imdlib
# For reading IMD datasets
import imdlib as imd
start_yr = 2023
end_yr = 2023
variable = 'rain' # other options are ('tmin'/
'tmax')
imd.get_data(variable, start_yr, end_yr, fn_
format='yearwise', file_dir=path)
data = imd.open_data(variable, start_yr, end_
yr,'yearwise', file_dir)
# Getting the xarray object for further
processing:
ds = data.get_xarray()
print(ds)
```

***#Get data for a given location, convert it, and save into csv file** at = 20.03 lon = 77.23*

data.to_csv('test.csv', lat, lon, file_dir)

 # Save data in GeoTIFF format

data.to_geotiff('test.tif', file_dir)

Sahibabad

According to the Dynamic groundwater resources report of Uttar Pradesh published in 2021, the annual average rainfall for the year 2019- 2020 was 398.35 mm in monsoon months as against the normal of 641.70 mm and 115.01 mm in the non-monsoon months against 124.60 mm in Ghaziabad.

The IMD daily precipitation data was downloaded and processed for 2022, as shown in Table 8.11. The monthly precipitation values were multiplied by the micro-watershed area (0.35 sq km) to get the total rainfall in the region in cubic meters.

Month	Precipitation in mm
Jan	49.9515
Feb	16.3213
Mar	0
Apr	0
May	30.6939
Jun	20.8043
Jul	150.0813
Aug	23.1295
Sep	116.3971
Oct	79.9729
Nov	0
Dec	0
Grand Total	487.3518

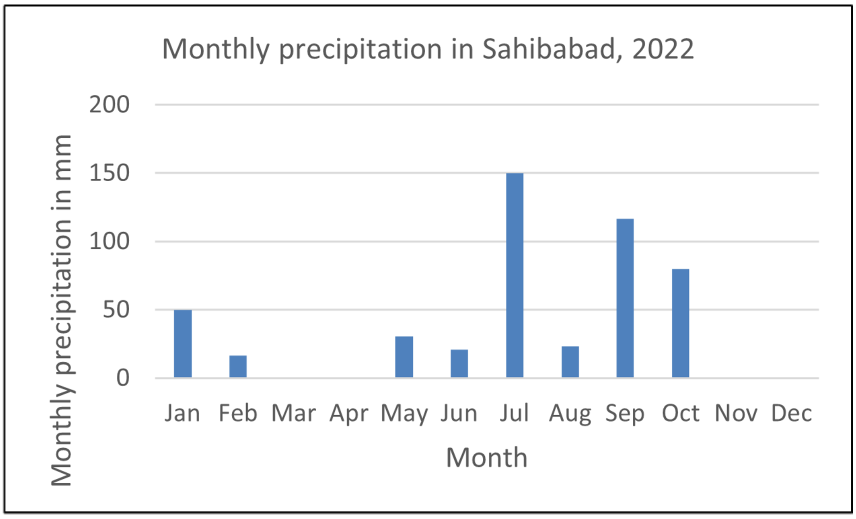


***Table 8.11:** Precipitation data 2022, Bisleri Plant, Sahibabad*

Kamshet

The total monthly rainfall for Kamshet in 2022 is shown in Table 8.12. The monthly rainfall is multiplied by the micro-watershed area, which is 10.41 sq km, to get the total rainfall in the watershed.

Month	Precipitation in mm
Jan	1.1882
Feb	0
Mar	1.3242
Apr	0
May	0
Jun	54.6107
Jul	967.8353
Aug	375.6917
Sep	344.6612
Oct	116.3324
Nov	0
Dec	0
Grand Total	1861.6437

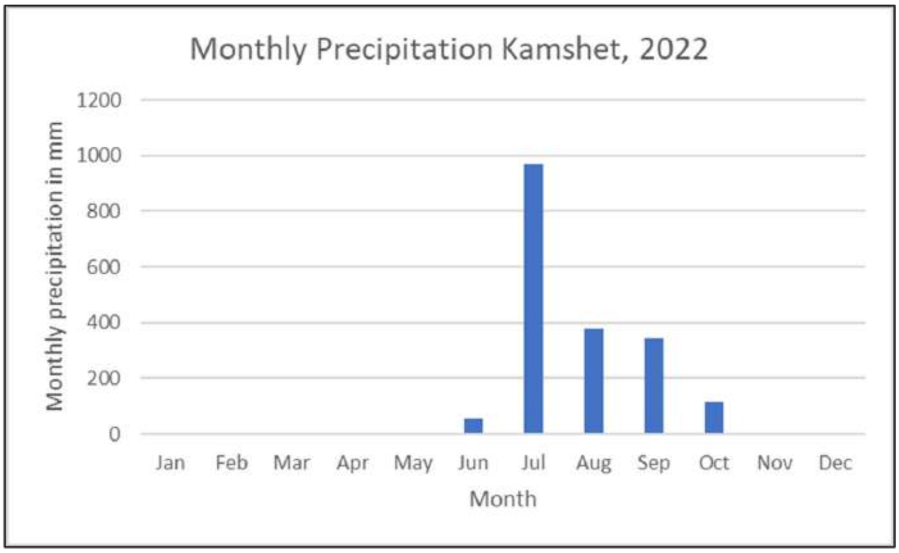


***Table 8.12:** Precipitation data 2022, Bisleri Plant, Kamshet*

For precipitation data, the monthly rainfall value and then multiplied by the micro watershed area.

8.2.6 Interbasin transfer

The micro watershed of Sahibabad does not have any surface water body; hence, the inter-basin transfer for the assessment can be considered as 0.

About Kamshet, River Indrayani passes through the micro watershed of the plant. The Indrayani River originates in Kurvande village near Lonavla, a hill station in the Sahyadri mountains of Maharashtra, India. It lies in the upper Bhima basin. The catchment area of the Indrayani River is 979.07 Sq. Km. The elevation at the outlet is 540m from the mean sea level, and the maximum in the hilly area of the Indrayani River basin is 1139m from the mean sea level. Kamshet, located in the Maval Taluka, is in the upper reaches of the Indrayani River.

For the purpose of this impacted water footprint assessment, the inter-basin water transfer is considered as 0.

8.2.7 Data used for IA-WF Estimation

Quantity and quality of monthly water at watershed Sahibabad

Source	Assumed Values (monthly)
Surface water availability (m^3)	0
Surface water BOD (mg/l O_2)	0
Surface water TDS (ppm)	0
Surface water TSS (ppm)	0
Groundwater availability (m^3)	27,689.00
Groundwater BOD (mg/l O_2)	0
Ground water TDS (ppm)	610.48
Ground water TSS (ppm)	31
Interbasin transfer availability (m^3)	0
Interbasin transfer BOD (mg/l O_2)	0
Interbasin transfer TDS (ppm)	0
Interbasin transfer TSS (ppm)	0

Table 8.13: *Quantity and quality of monthly water at Sahibabad watershed*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (m^3)	17300	5653	0	0	10630	7205	51979	8011	40313	27697	0	0

Table 8.14: *Sahibabad monthly precipitation*

Kamshet

Source	Assumed Values (monthly)
Surface water availability (m^3)	1,52,500
Surface water BOD (mg/l O_2)	2.40
Surface water TDS (ppm)	289.28
Surface water TSS (ppm)	22.35
Groundwater availability (m^3)	74,600
Groundwater BOD (mg/l O_2)	5
Ground water TDS (ppm)	39
Ground water TSS (ppm)	5
Interbasin transfer availability (m^3)	0
Interbasin transfer BOD (mg/l O_2)	0
Interbasin transfer TDS (ppm)	0
Interbasin transfer TSS (ppm)	0

Table 8.15: *Quantity and quality of monthly water at Kamshet watershed*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (m^3)	12373	0	13789	0	0	568681	10078417	3912213	3589081	121141	0	0

Table 8.16: *Monthly precipitation Kamshet*

Sector	Source	Assumed Values (monthly)
Domestic	Surface water (m^3)	0
Domestic	Ground water (m^3)	6716.6
Domestic	Rainwater harvested (m^3)	0
Domestic	Interbasin Transfer (m^3)	74,600
Agriculture	Surface water (m^3)	5
Agriculture	Ground water (m^3)	39
Agriculture	Rainwater harvested (m^3)	5
Agriculture	Interbasin Transfer (m^3)	0
Industrial	Surface water (m^3)	0
Industrial	Ground water (m^3)	22533.00
Industrial	Rainwater harvested (m^3)	0
Industrial	Interbasin Transfer (m^3)	0

Table 8.17: *Source-wise monthly water demand in Sahibabad*

Sector	Parameter	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
Industrial	Surface water (m^3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	Ground water (m^3)	13,124	11,298	12,092	12,347	12,313	10,589	10,982	10,834	11,007	10,681	10,545	11,115
Industrial	Rainwater harvested (m^3)	0	0	0	0	0	0	0	0	0	0	0	0

Table 8.18: *Source-wise monthly water demand in BIPL, Sahibabad*

Kamshet

Sector	Parameter	Monthly Assumed Values
Domestic	Surface water (m^3)	3,333
Domestic	Ground water (m^3)	1,083
Domestic	Rainwater harvested (m^3)	0
Agriculture	Interbasin Transfer (m^3)	0
Agriculture	Surface water (m^3)	29,333
Agriculture	Ground water (m^3)	12,100
Agriculture	Rainwater harvested (m^3)	0
Industrial	Interbasin Transfer (m^3)	0
Industrial	Surface water (m^3)	2,718.22
Industrial	Ground water (m^3)	192.11
Industrial	Rainwater harvested (m^3)	0
Domestic	Interbasin Transfer (m^3)	0

Table 8.19: *Source-wise monthly water demand in Kamshet*

Sector	Parameter	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
Industrial	Surface water (m^3)	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	Ground water (m^3)	11,722	9,380	7,109	7,670	8,563	8,562	9,345	8,007	4,765	6,196	6,196	8,819
Industrial	Rainwater harvested (m^3)	0	0	0	0	0	0	0	0	0	278	275	0
Industrial	Interbasin Transfer (m^3)	0	0	0	0	0	0	0	0	0	0	0	0

Table 8.20: *Source-wise monthly water demand in BIPL, Kamshet*

Water Pollution data - Sahibabad

Sector	Parameter	Monthly Assumed Values
Domestic	Monthly Discharge (m^3)	6,716.60
Domestic	Biochemical Oxygen Demand (COD), mg/l O_2	120
Domestic	Total Suspended Solids (ppm)	343
Domestic	Total Dissolved Solids (ppm)	3,280
Agriculture	Monthly Discharge (m^3)	0
Agriculture	Biochemical Oxygen Demand (COD), mg/l O_2	0

Agriculture	Total Suspended Solids (ppm)	0
Agriculture	Total Dissolved Solids (ppm)	0
Industrial	Monthly Discharge (m^3)	22,533.00
Industrial	Biochemical Oxygen Demand (COD), mg/l O_2	172
Industrial	Total Suspended Solids (ppm)	160
Industrial	Total Dissolved Solids (ppm)	328

Table 8.21: *Sector-wise water pollution data, Sahibabad*

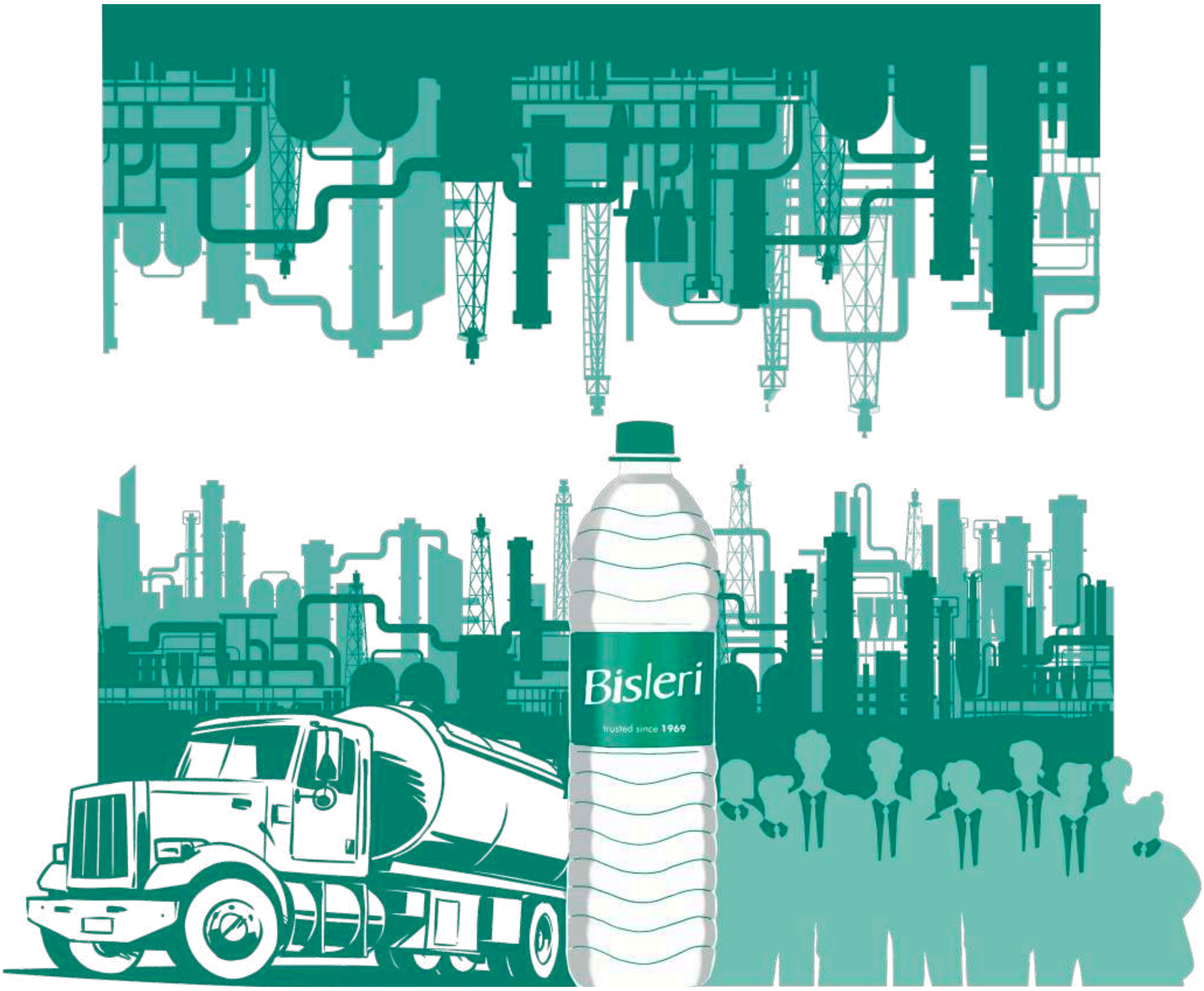
Kamshet

Sector	Parameter	Monthly Assumed Values
Domestic	Monthly Discharge (m^3)	1,083
Domestic	Biochemical Oxygen Demand (COD), mg/l O_2	28
Domestic	Total Suspended Solids (ppm)	164
Domestic	Total Dissolved Solids (ppm)	872
Agriculture	Monthly Discharge (m^3)	12,100
Agriculture	Biochemical Oxygen Demand (COD), mg/l O_2	38
Agriculture	Total Suspended Solids (ppm)	150
Agriculture	Total Dissolved Solids (ppm)	1,100
Industrial	Monthly Discharge (m^3)	192.11
Industrial	Biochemical Oxygen Demand (COD), mg/l O_2	30
Industrial	Total Suspended Solids (ppm)	225
Industrial	Total Dissolved Solids (ppm)	540

Table 8.22: *Sector-wise water pollution data, Kamshet*

CHAPTER 09

Water footprint of BIPL production units and key findings



The water footprint (WF) of a production unit comprises an **operational WF** (within the factory boundary) and a **supply chain WF** (outside the factory boundary and possibly outside the watershed- partly or wholly). Operational WF further comprises **product- and manufacturing-process-related** and **overhead water consumption** (administrative building, shared facilities like canteen, garden, etc.). Supply chain WF includes embodied water in **product ingredients** and **packaging** materials. The supply chain also has an overhead WF from energy usage, embodied water in building construction, etc. This research considers only energy to estimate the **supply chain overhead WF**. The WF itself consists of **green** (rainwater), **blue** (surface and groundwater stock) and **grey** (pollution).

Chapter 2 and Section 4.1 of this report explains various typologies of WF, and Chapter 4 describes the methodology for estimating WF footprint. Analysis has been done on an Excel-based toolkit.

Unlike carbon footprints, WF impacts local watersheds; hence, water footprints must account for background hydrology. Thus, this research illustrates the **impact-adjusted water footprint** (IA-WF) estimation by choosing two sites of similar products and manufacturing processes of BIPL. One site is Kamshet, and the other is Sahibabad, belonging to water-sufficient and deficit regions, respectively. An annual estimate of the WF for each site has been done for November 2022-October 2023.

9.1 Water footprint of BIPL, Kamshet

Estimates of WF are explained in Table 9.1 and Annexure 1. The estimated annual WF of Kamshet is 7,27,410.7 m^3, and the IA-WF is 7,01,270 m^3. As described in the previous chapter, Kamshet is in a water-sufficient region, and the impact of the production unit does not impact the sustainability of background hydrology; thus, the value is zero. Moreover, the BIPL harvests 26,141 m^3 annually and augments the groundwater stock of the region. Thus, IA-WF is lesser than its absolute WF.

Further, a significant part of WF (about 70%) is due to pollution (grey). Blue WF is 29%, and green WF is marginal (just 1%). Traditionally, the bottled water industry does not fall under the high pollution industry. The plausible explanations for higher grey WF for Kamshet BIPL are as follows.

1. Of the total grey WF, 98.7% is due to the supply chain of ingredients and packaging materials (a kind of invisible pollution in the context of the production unit location). The production unit has little control over this other than material substitution with materials with lesser WF. It is also observed from data inventory that the grey WF of packaging materials is much higher than the grey WF of product ingredients.

2. The ambient water quality of the watershed is 'good' and within permissible limits of ambient concentration. The wastewater discharged by industry has pollution over 15 times the value found in input water. Therefore, even though wastewater discharged by industry is less, the denominator is much less than the numerator value (refer to equation 4.4). Thus, the impact of pollution gets amplified in a water-abundance region with good ambient water quality compared to a production unit located in a water-polluted region.

Type/Sub Category	Annual water footprint (m^3)			
	Blue	**Green**	**Gray**	**Total**
Operational				
a) Production	71,274.7	554.5	7,714	79,543.2
b) Overhead	3955.2	0	0	3,955.2
Total	**75,229.9**	**554.5**	**7,714**	**83,498.4**
Supply-Chain				
a) Ingredients & Packaging	83,337.1	4,363.9	5,01,177.8	5,88,878.8
Type/Sub Category	**Annual water footprint (m^3)**			
	Blue	**Green**	**Gray**	**Total**
b) Overhead (Energy)	55,033.5	0	0	55,033.5
Total	**1,38,370.6**	**4,363.9**	**5,01,177.8**	**6,43,912.3**
Grand Total	**2,13,600.5**	**4,918.4**	**5,08,891.8**	**7,27,410.7**

Watershed		
Scarcity		0
Pollution		0
Total water offset		(26,141)
IA-WF		**701,270** (rounded)

***Table 9.1**: Annual water footprint of BIPL, Kamshet (m^3)*

Figure 9.1 shows disaggregated WF data for Kamshet. It is evident from Figure 9.1 that the highest water footprint, i.e. approximately 81%, is related to ingredients and packaging, which is outside the factory premises, followed by 10% water use during the direct production process and 7.6 % linked to energy use (again outside the factory). The operational overhead water consumption for the factory, which is the water used in toilets, gardening, pantry, and cleaning, is minuscule.

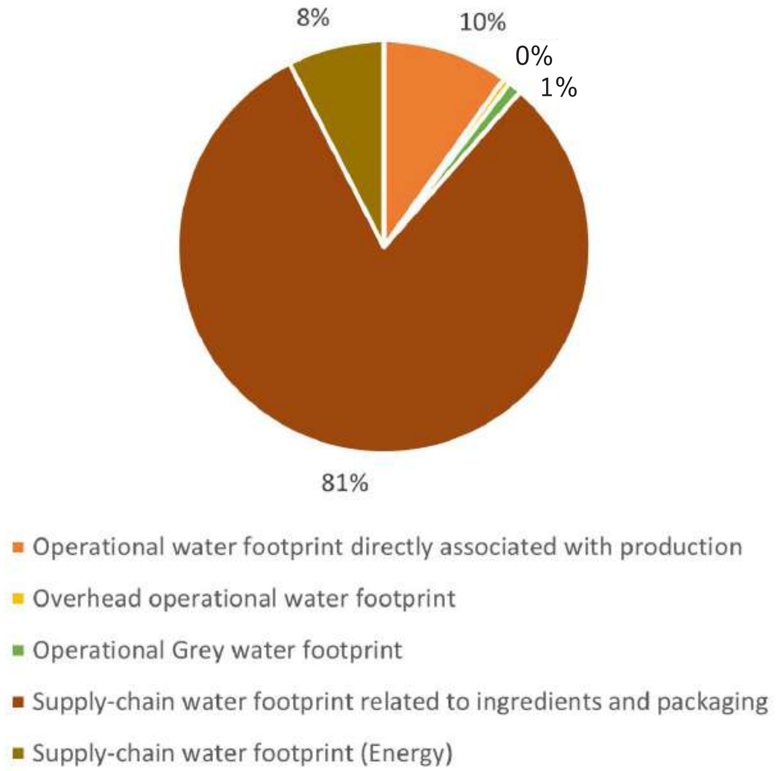
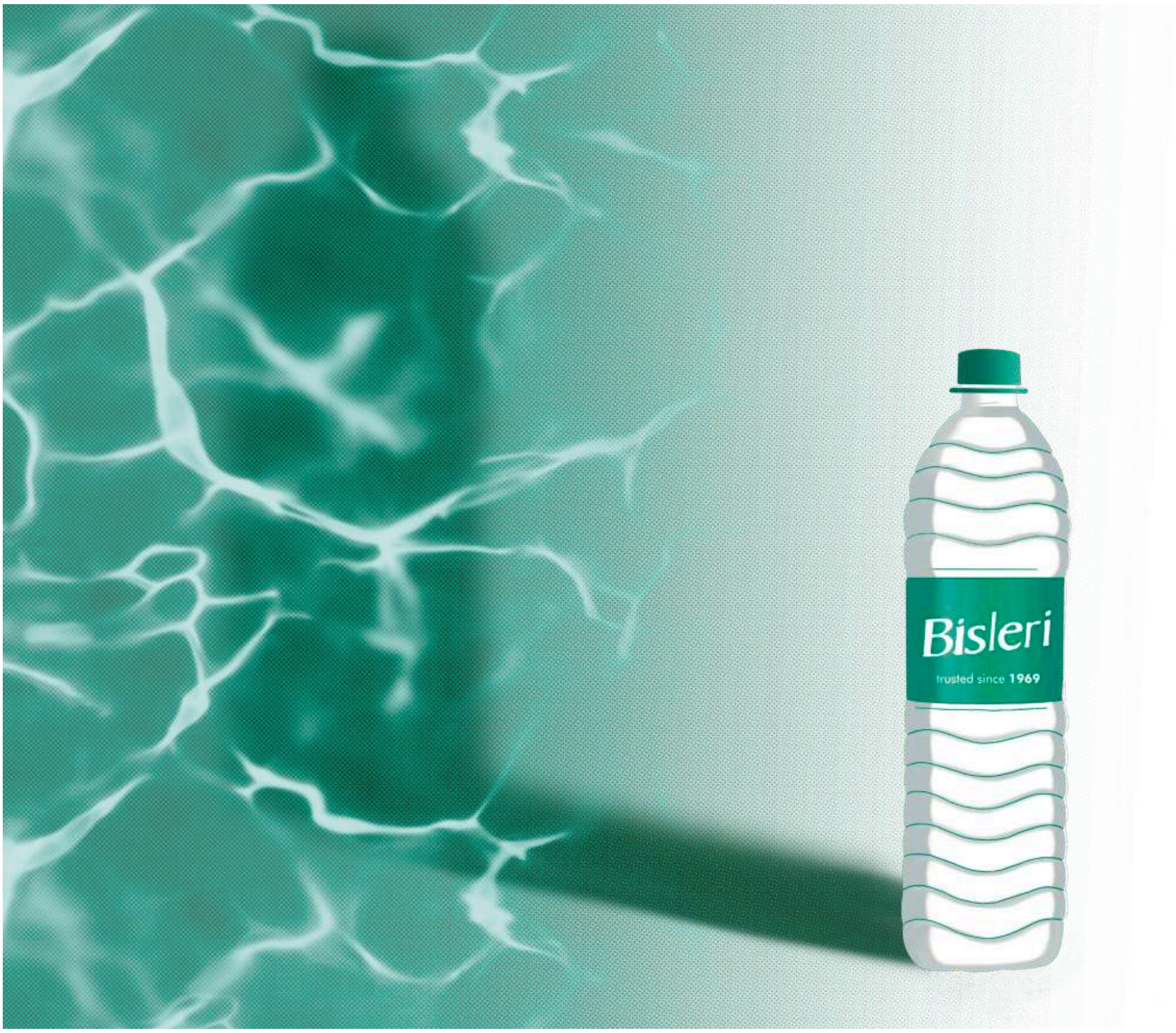


***Figure 9.1:** Disaggregated Water footprint for Kamshet*

Product Footprint

Table 6.1 (Chapter 6) shows that Kamshet annually produces 60,888 m^3 of bottled drinking water and 10,741 m^3 of club soda. Thus, the annual production of water-based products is 71,629 m^3. An accurate estimate of the water footprint for bottled water and club soda would require component-wise segregation of activities and material flow. In the absence of this information, it can be stated that the **IA-WF of products from Kamshet is 10.1 m^3 (9.8 m3 for IA-WF) water consumption per kiloliter of product.** The WF of BIPL products is far less than that of other beverage industries found in literature.



9.2 Water footprint of BIPL, Sahibabad

Estimates of WF are explained in Table 9.2 and Annexure 1. The estimated annual WF of Sahibabad is 17,09,922.5 m^3, and the IA-WF is 16,45,783.4 m^3. As described in the previous chapter, Sahibabad is in a water-stress region, resulting in a water scarcity impact of 43,774.8 m^3. Despite this, IA-WF is lowered due to efforts by BIPL to harvest 1,07,914 m^3 water annually to augment the groundwater stock of the region.

Like Kamshet, a significant part of WF (about 72%) in Sahibabad is due to pollution (grey). Blue WF is 22%, and green WF is 6%. Ingredients and packaging materials contribute significantly to grey WF; however, unlike Kamshet, the higher grey WF is due to glass bottles (which constitute 5% of the product packaging material). The dissolved solid concentration in wastewater is also high.

Figure 9.2 shows disaggregated WF data for Sahibabad. It is evident from Figure 9.2 that the highest water footprint, i.e. approximately 86%, is related to ingredients and packaging, which is outside the factory premises, followed by 6.8% water use during the direct production process and 6.26 % linked to energy use (again outside the factory). The operational overhead water consumption for the factory, which is the water used in toilets, gardening, pantry, and cleaning, is minuscule.

Type/Sub Category	Annual water footprint (m^3)			
	Blue	Green	Gray	Total
Operational				
a) Production	1,17,088.6	0	3,951	1,21,039
b) Overhead	3955.2	0	0	7212
Total	**1,24,300.6**	**0**	**3,951**	**1,28,251.6**
Supply-Chain				
a) Ingredients & Packaging	1,38,618.5	1,06,846.2	12,30,393.9	14,75,858.6
b) Overhead (Energy)	1,05,812.6	0	0	1,05,812.6
Total	**2,44,431.1**	**1,06,846.2**	**12,30,393.9**	**15,81,671.2**
Grand Total	**3,68,731**	**1,06,846.2**	**12,34,345**	**17,09,923**
Watershed				
Scarcity				43,774.8
Pollution				0
Total water offset				(1,07,914)
IA-WF				**16,45,784** (rounded)

***Table 9.2**: Annual water footprint of BIPL, Sahibabad (m^3)*

Product Footprint

Table 6.1 shows that Sahibabad annually produces 1,02,882 m^3 of bottled drinking water and 13,841 m^3 of club soda. Thus, the annual production of water-based products is 1,16,723 m^3. An accurate estimate of the water footprint for bottled water and club soda would require component-wise segregation of activities and material flow. In the absence of this information, it can be stated that the **WF of Sahibabad products is 14.6 m^3 (IA-WF) water consumption per kiloliter of product.** The product's water footprint is nearly 60% higher than in Kamshet. Two plausible reasons are: - use of glass bottles has significantly increased the supply chain grey WF and thus total WF of the production unit; second is due to its location in the water-stressed region compared to Kamshet. The WF of BIPL products in Sahibabad is far less than in other beverage industries found in the literature.

9.3 Opportunities to reduce WF

The Excel-based toolkit prepared in this research and shared with BIPL is **a decision-making tool** to enable management to assess the impact of any reformative actions on WF. We illustrate two strategies here: the effect of energy substitution on WF and packaging material substitution.

Creating clean energy dependence

Energy substitution

At present, energy in the form of electricity and petroleum products is used in the production units of BPIL. In Sahibabad, solar energy has only a 1.5% share. It is feasible to substitute electricity and fuel with solar energy. The World Bank-supported Kusum project has enabled many farmers to switch to

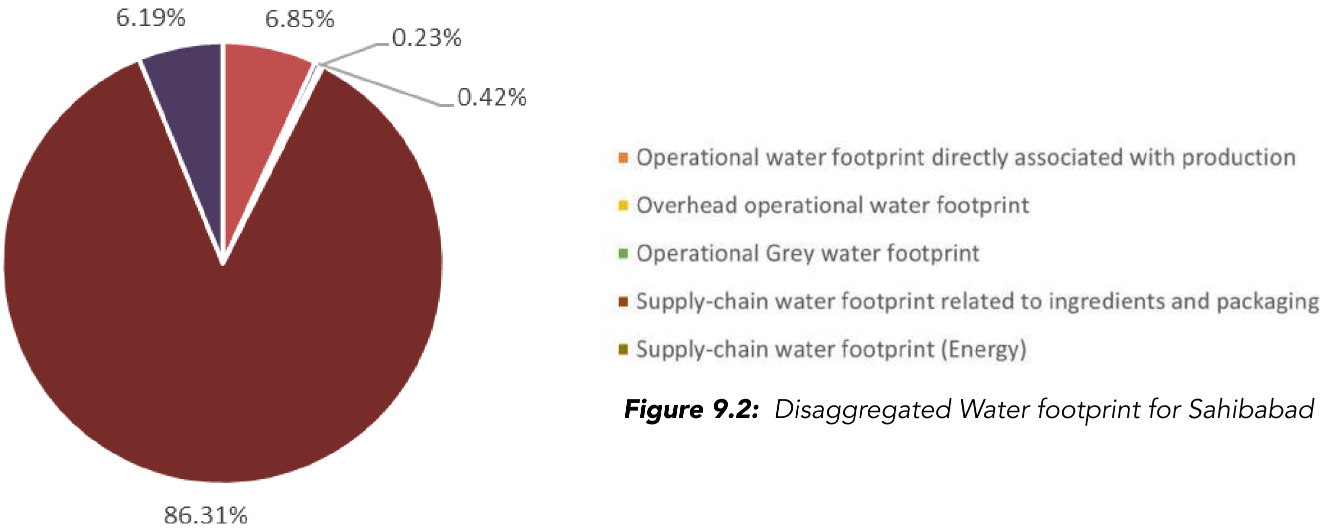


Figure 9.2: *Disaggregated Water footprint for Sahibabad*

solar-based groundwater irrigation. The share of electric vehicles in India is also increasing. Tables 9.3 & 9.4 and Figures 9.3 & 9.4 illustrate the energy transition plan and a corresponding reduction in WF where the share of solar energy is increased by 20% in successive five years.

		Year 1	Year 2	Year 3	Year 4	Year 5
Percentage change from fossil to solar/wind-based power	Present	20%	40%	60%	80%	100%
Annual petroleum-based fuel consumed (kilo litre/year)	61.7	49.36	37.02	24.68	12.34	0
Annual coal consumed (ton/year)	0	0	0	0	0	0
Annual electricity consumption (other than wind and solar) (MWh)	5,003.0	4,002.4	3,001.8	2,001.2	1,000.6	0
Annual solar/wind electricity consumption (MWh)	0	1,000.6	2,001.2	3,001.8	4,002.4	5,003.0
Switching to electric vehicles charged through solar/wind power (kWh)		111.06	222.12	333.18	444.24	555.3
Total Annual Solar/Wind power (MWh)		1,000.7	2,001.4	3,002.2	4,002.9	5,003.6

Table 9.3: *Energy transition plan for BIPL, Kamshet*

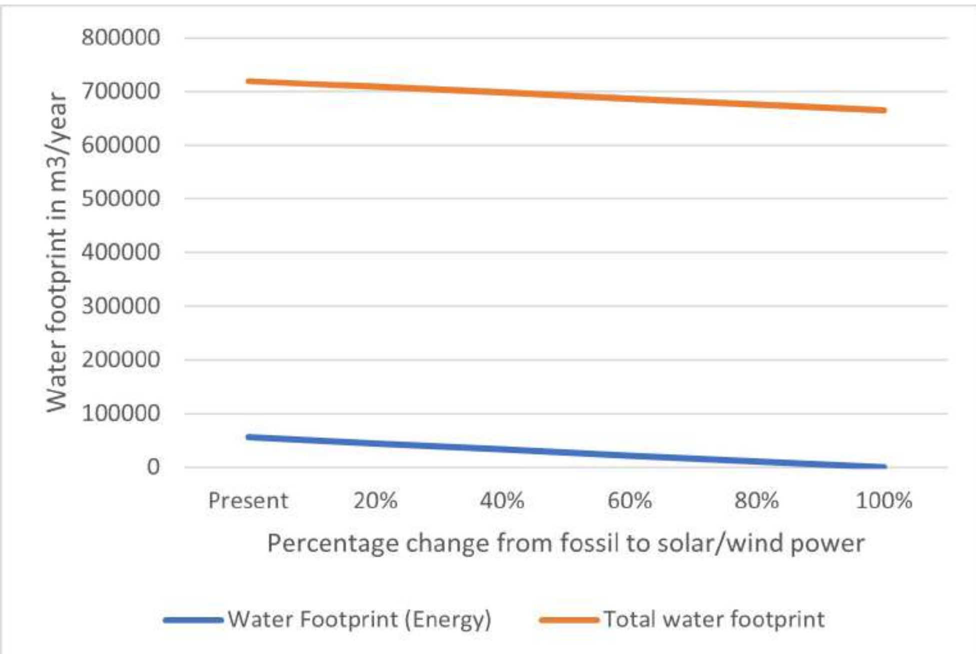


Figure 9.3: *Change in water footprint by switching to Solar/Wind power in Kamshet*

Based on the energy transition plan shown for Kamshet, the water footprint associated with energy can be brought to zero in 5 years by switching entirely to solar/wind-based power and electric vehicles, reducing the water footprint by 6.5% overall in 5 years. Similarly, in Sahibabad, the WF is reduced by 6.2%.

		Year 1	Year 2	Year 3	Year 4	Year 5
Percentage change from fossil to solar/wind-based power	Present	20%	40%	60%	80%	100%
Annual petroleum-based fuel consumed (kilo litre/year)	63.8	51.04	38.28	25.52	12.76	0
Annual coal consumed (ton/year)	0	0	0	0	0	0
Annual electricity consumption (other than wind and solar) (MWh)	6,613.2	5,290.6	3,967.9	2,645.3	1,322.6	0
Annual solar/wind electricity consumption (MWh)	107.5	1,430.1	2,752.8	4,075.5	5,398.1	6,720.8
Switching to electric vehicles charged through solar/wind power (kWh)		114.84	229.68	344.52	459.36	574.2
Total Annual Solar/Wind power (MWh)	107.5	1,430.3	2,753.1	4,075.8	5,398.6	6,721.4

Table 9.4: *Energy transition plan for BIPL, Sahibabad*

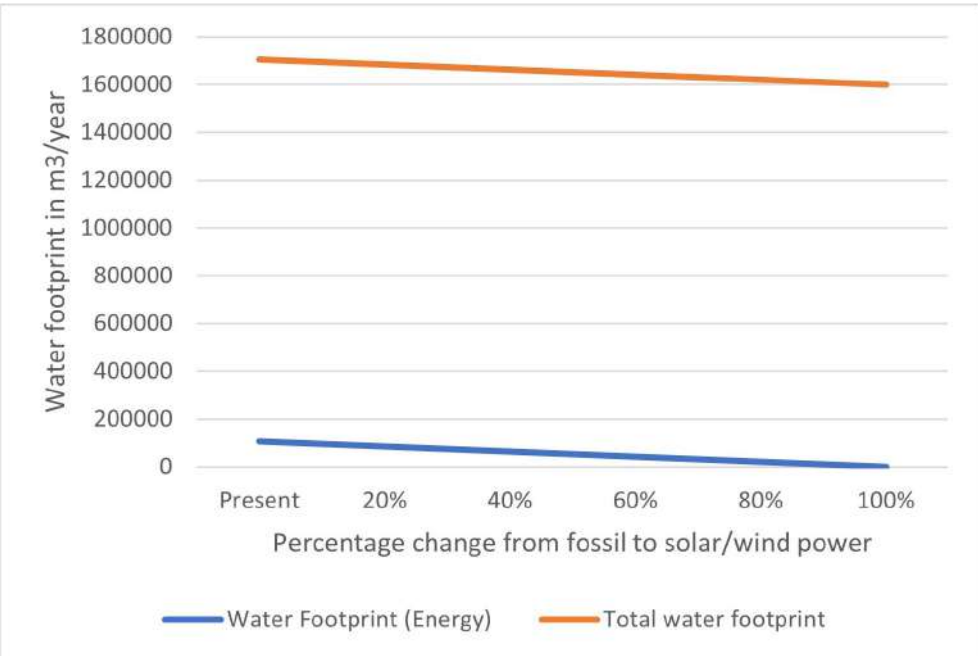


Figure 9.4: *Change in water footprint by switching to Solar/Wind power in Sahibabad*

Material substitution

Glass has a greywater footprint, nearly six times that of plastic; switching to glass may not be viable until there is a high bottle return rate. Since the Sahibabad plant combines glass and PET, they may consider gradually switching to PET and setting up a mechanism for bottle return and recycling. By doing this, they can reduce the water footprint by up to 17.8%, as seen in Table 9.5 and Figure 9.5.

Other strategies for the reduction of WF can include:

- **Lightweighting:** Design bottles with thinner walls while maintaining durability. This can significantly reduce the amount of plastic used per bottle.
- **Shift to recycled materials:** Increase recycled content in plastic bottles, reducing reliance on virgin plastic production and its associated water footprint.
- **Explore alternative materials:** Investigate alternative packaging materials like biodegradable or plant-based plastics with lower water footprints.
- **Promote bottle return and recycling:** Implement effective bottle return programs and collaborate with recycling facilities to ensure high post-consumer recycling rates.

Packaging (Percentage change from glass to PET)	Total Water footprint (m^3)
0%	17,09,922.53
50%	15,58,013.08
100%	14,06,103.63

Table 9.5: *Change in water footprint in Sahibabad with change in packaging material*

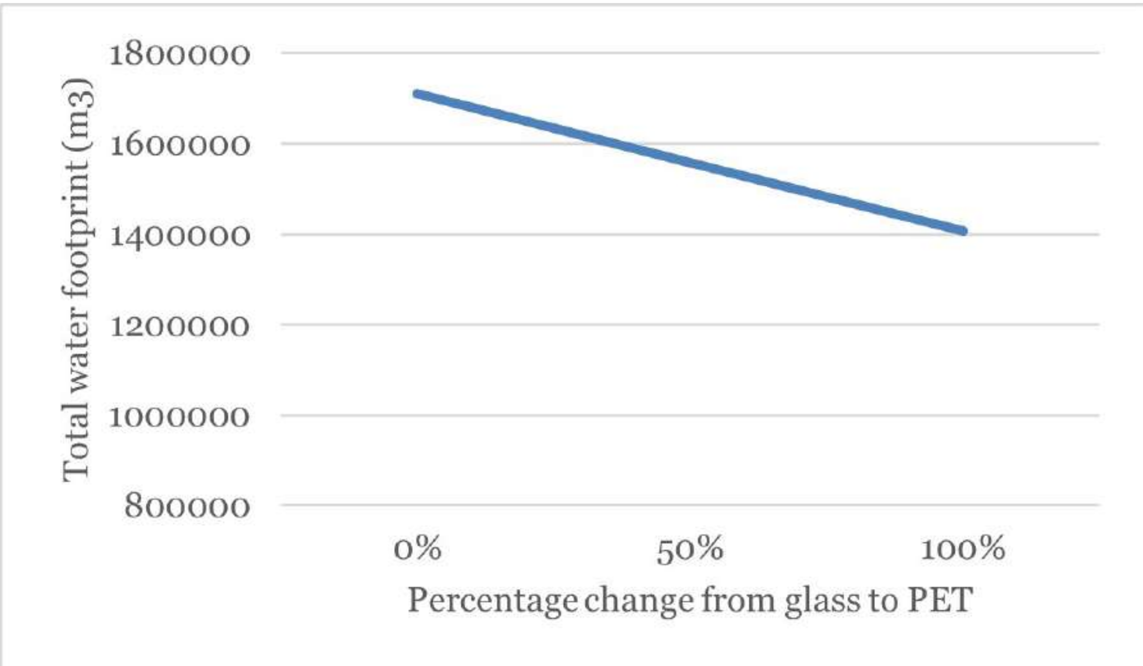
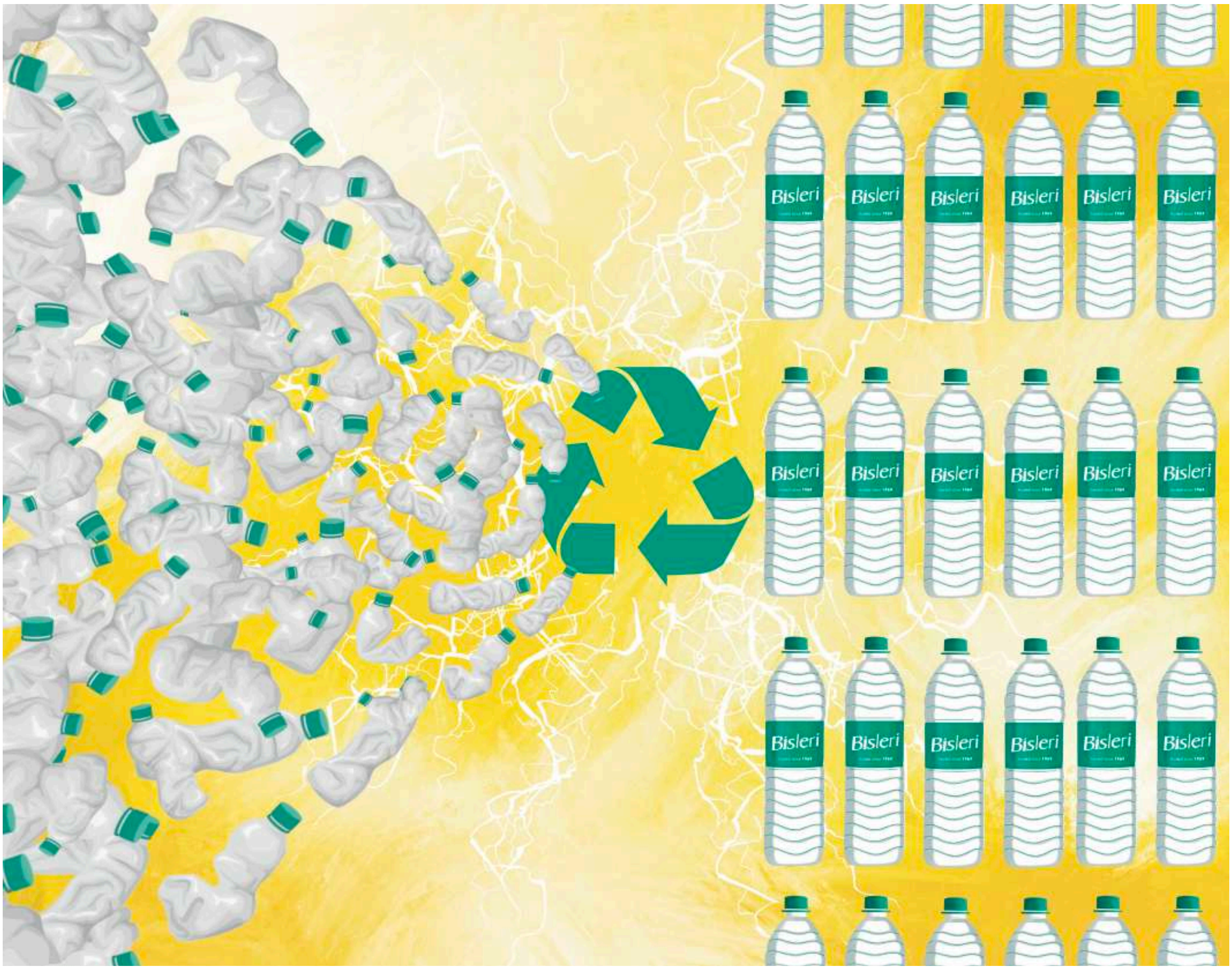


Figure 9.5: *Change in water footprint with change in packaging*



- **Invest in water-efficient technologies:** Upgrade production facilities with water-saving equipment, implement leak detection and repair systems, install low-flow valves and faucets, and use water-efficient cleaning processes.
- **Embrace closed-loop systems:** Recycle and reuse water within the production process for tasks like rinsing bottles or cooling machinery.
- **Aim to be water-positive:** Prioritize groundwater recharge areas, rainwater harvesting, and treated wastewater reuse wherever feasible.
- **Support Water Restoration/Conservation Projects:** Offset water consumption by investing in projects that replenish and restore water resources. This could involve wetland restoration, lake/pond/river rejuvenation, or aquifer recharge initiatives.
- **Collaborate with local communities:** Engage with stakeholders to ensure responsible water management practices and avoid depleting shared resources.
- **Transparency and accountability:** Conduct periodic water audits and publicly track and report water usage. Be transparent about water consumption throughout the supply chain and set realistic goals for reduction.

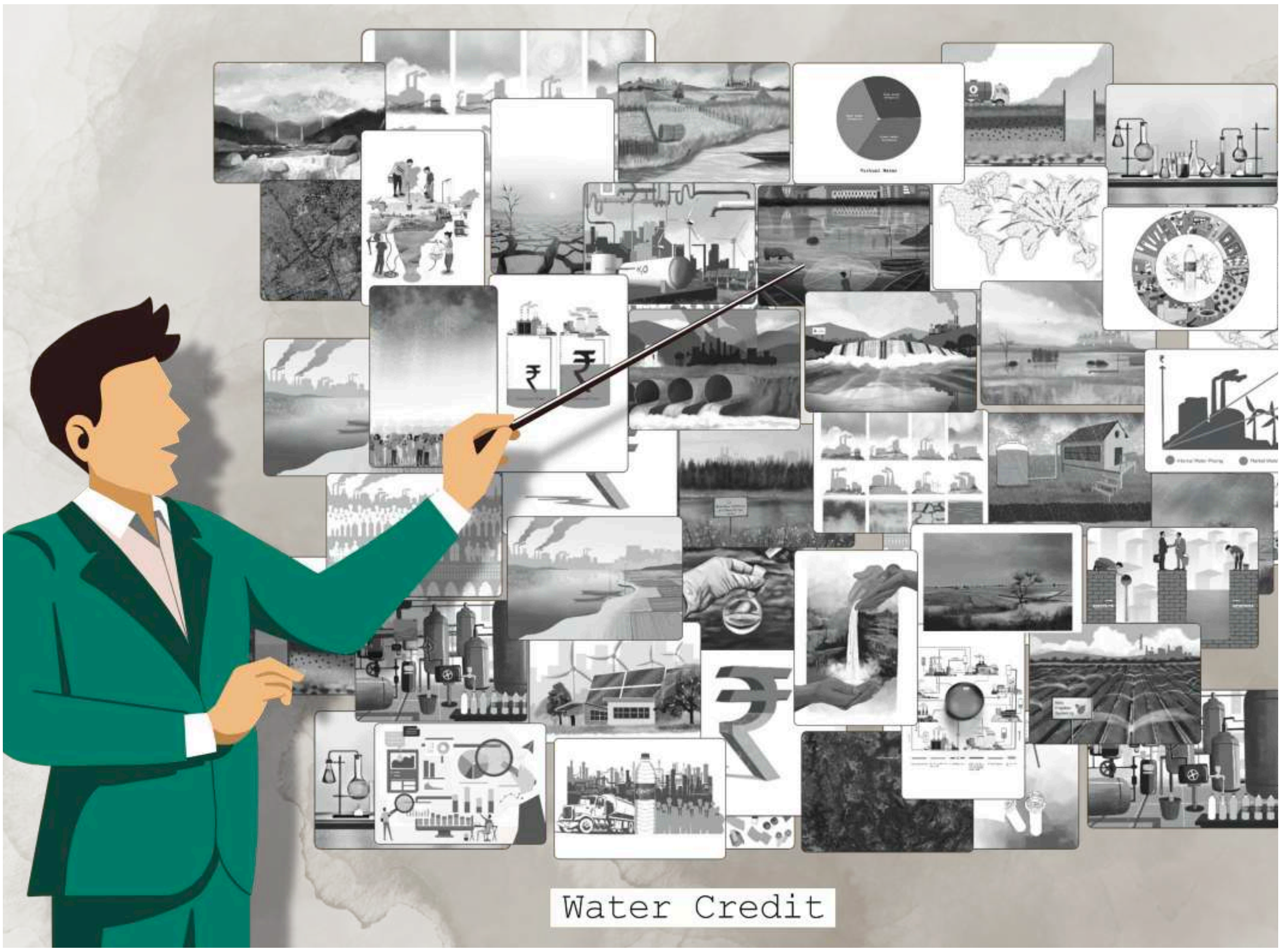
9.4 Uncertainty in data and WF estimation

The estimates are as good as the input data. The study has focussed primarily on developing methodology, toolkit, and discourse on the policy framework. The study has banked on the data provided by BIPL for production units and secondary literature for watershed-related data. No primary monitoring was involved. It is expected that BIPL will improve the estimation over a few years of continuous monitoring as required by the methodology. The following are the observations on the input data.

1. The water audit study is performed once a year. Similarly, water quality data is assessed once a year. Both are assumed to be constant for each month throughout the year. Thus, the estimates do not capture inter-annual variability, although the toolkit has provisions to account for the impact of water-scarce months.
2. Segregation of activities and material flows by-product will help improve product-based water footprint estimates.
3. Data on watersheds delineated under this study are also fraught with several assumptions to fill the information gap.
4. The data on indirect water reuse through the supply chain may not be accurate and comprehensive, leading to misestimations of the actual water footprint. As and when literature-based evidence on the WF of ingredients is established, the data inventory sheet should be regularly updated.

CHAPTER 10

Summary and Conclusions



1. A water audit is a management tool that focuses on quantifying and improving water use efficiency within a specific system, while a water footprint is a broader assessment that evaluates the environmental impact of water use associated with products and processes. Water audits are typically conducted for operational improvements, while water footprints are used to understand and mitigate the environmental consequences of water consumption and pollution. While both concepts are related to water management, a water audit focuses on quantifying all the water flows in a system to understand its usage, reduce losses, and improve conservation. On the other hand, a water footprint is focused on capturing the volume of freshwater used directly or indirectly to produce a product or service and identifying opportunities for reducing the water footprint. Water footprint is multidimensional, capturing not only the water volume used in the production process but also traces the location of water footprint, source of water uses, and stages of water use compared to a single-dimensional aspect of water audit.
2. Different approaches have been developed to estimate water footprints, ranging from simple to complex methodologies. The two major categories are top-down and bottom-up approaches. The former approach is widely used in global and national scale estimation, while the latter applies to industrial products and services.

3. Impact-adjusted water footprint is a weighted measure of the impact of a production unit (or a product) on water sustainability at the catchment/district level. It thus uses two inputs: a) the actual water footprint of a product or a production unit and b) the water scarcity of the region. It informs the effects of the production unit on the background hydrology of the watershed where it is located. Thus, estimating water footprint and impact-adjusted adjusted water footprint are integral and necessary steps for water neutrality.

4. A few key concepts used for estimation are- a) water footprint has space and time axis; (b) it is at watershed level; and (c) it includes physical as well as embodied water and supply chain of materials. The impact-adjusted water footprint accounts for a) the actual water footprint of a product or a production unit, b) the water scarcity of the region, and c) water credits earned by the production unit through measures such as water resource augmentation in the catchment or buying water credits from the market.

5. The water footprint (WF) of a production unit comprises an **operational WF** (within the factory boundary) and a **supply chain WF** (outside the factory boundary and possibly outside the watershed- partly or wholly). Operational WF further comprises **product- and manufacturing-process-related** and **overhead water consumption** (administrative building, shared facilities like canteen, garden, etc.). Supply chain WF includes embodied water in **product ingredients** and **packaging materials.** The supply chain also has an overhead WF from energy usage, embodied water in building construction, etc. This research considers only energy to estimate the **supply chain overhead WF**. The WF itself consists of **green** (rainwater), **blue** (surface and groundwater stock) and grey (pollution).

6. The total **annual water footprint** of Bisleri International Private Limited (BIPL) production unit at Kamshet is about **727.41 million litres**, whereas the yearly **impact-adjusted water footprint on its watershed** is about **701.27 million litres**, less than its absolute footprint. The reasons for the lesser footprint value on the watershed are- (a) the production unit is in a water-sufficient region, and the impact of the production unit is found to be within the carrying capacity of its background hydrology; thus, it does not add burden on water ecosystem services, (b) BIPL augments water availability within its catchment by harvesting rainwater, (c) nearly 88% of the footprint is on account of material and energy supply chain which is outside the watershed.

7. The total annual water footprint of Bisleri International Pvt Ltd (BIPL) production unit at Sahibabad is about **1,709.92 million litres**. In contrast, the yearly **impact-adjusted water footprint** on the watershed is about **1,645.78 million litres**, less than its absolute footprint. The reasons for the lesser footprint value on the watershed are- (a) BIPL augments water availability within its catchment by **harvesting over 107.9 million litres** of rainwaters annually, which overcompensates the **annual scarcity potential of about 43.77 million litres**, (b) operational greywater footprint (pollution) is low since raw water used as

input for production itself has high salt concentration and nearly to the value that industry discharges, (c) about 92% of the footprint is on account of material and energy supply chain which is outside the watershed.

8. The aggregated value of the **water footprint of products** from **the Kamshet production unit is 10.1 litres per litre of product and 14.6 litres per litre of product for the Sahibabad production unit.** This is significantly less than the water footprint values in the literature for beverage industries. It is also submitted that the beverage industry as a sector is very heterogeneous, and at present, the information on the water footprint of beverage units that produce similar products as BIPL is not available.

9. Supply-chain input in the production unit process accounts for nearly 91% of the total WF, of which energy accounts for about 7%. Only 9% of WF is due to within-fence production and overhead activities. Annexure 2 shows the water footprint of various other commodities.

10. BIPL WF is among the best in beverage industries due to extensive measures for water savings, resource augmentation, and comprehensive treatment for recycling significant amounts of water within its processes. Below, we compare BIPL's water footprint vis-a-vis another beverage industry (Source: Coca-Cola and Nature Conservancy, 2010). The comparison is based on absolute water footprint values, not watershed impact-adjusted water footprints. Further, it is noted that the other industry's example shown here has products that are different from BIPL.

11. Using solar/wind energy can reduce water footprint by about 6%, and substituting Glass with PET bottles can reduce water footprint by about 17%. These two strategies alone can bring down the **water footprint of BIPL products to about 7.5**

	BIPL, Sahibabad	**BIPL, Kamshet**	**Other beverage industry[1]**
Blue WF**	3.1	2.9	2.0
Green WF***	0.9	0.07	30
Grey WF	10.6	7.1	24
Total WF	**14.6**	**10.1**	**56**

[1]*Data Source: Coca-Cola and Nature Conservancy, 2010. Product water footprint assessments: Practical application in corporate stewardship.*

**All values are in Litres per Litre of product.*

***Blue WF of BIPL includes supply chain energy consumption, which on average is 0.85 litres per litre of product.*

****Coca-Cola's green WF is substantially higher due to agriculture-based supply-chain ingredients in production, which also impacted its grey WF.*

litres per litre of product.

12. Earning water credits through green credit trading mechanisms and water harvesting to augment water resources is another strategy to reduce water footprint. The BIPL has already created check dams to enhance the region's water security. The assessment does not include BIPL's water credits earned through such measures outside the studied watershed area of production units. **It is recommended that BIPL should initiate a study to measure water resources augmented through such measures.** As and when regulatory agencies allow the inclusion of such measures in the water footprint estimation or product labelling, these values can be used.
13. The methodology for estimating the water footprint used in this study has been developed from a comprehensive literature review to screen and adapt the most appropriate models that industries can use. **It includes the principles promulgated by the Niti Ayog in its document on Guidelines for Water Neutrality, published in July 2023.** It included spatial and temporal dimensions and accounted for within the fence, outside, and the materials supply chain. The water footprint is multidimensional, capturing not only water volume but also location, source of water and stages of water use. Experts in the domain field have reviewed the methodology in a consultative meeting organised by BIPL, Mumbai, in October 2023.
14. An Excel-based toolkit for water footprint estimation has been developed and used to help senior management and production engineers simulate their strategies to understand the impact of decisions on the product's water footprint.
15. It is recommended that BIPL implement a monitoring programme to capture input data for water footprint estimation regularly and track its water footprint.

CHAPTER 11

References

References (Chapter1-5)

1. Al-Bahouh, M., Osborne, V., Wright, T., Dixon, M., VanderZaag, A., Gordon, R., 2021. Blue Water Footprints of Ontario Dairy Farms. Water 13, 2230. https://doi.org/10.3390/w13162230

2. Allan, J.A., 1998. Virtual Water: A Strategic Resource Global Solutions to Regional Deficits. Ground Water 36, 545–546. https://doi.org/10.1111/j.1745-6584.1998.tb02825.x

3. Angara, J.S. V., Saripalle, R.S., 2022. Towards a virtual water currency for industrial products using blockchain technology. Water Policy 24, 923–941. https://doi.org/10.2166/wp.2022.285

4. Boulay, A.-M., Bare, J., Benini, L., Berger, M., Lathuillière, M.J., Manzardo, A., Margni, M., Motoshita, M., Núñez, M., Pastor, A.V., Ridoutt, B., Oki, T., Worbe, S., Pfister, S., 2018. The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). Int. J. Life Cycle Assess. 23, 368–378. https://doi.org/10.1007/s11367-017-1333-8

5. Boulay, A.-M., Bulle, C., Bayart, J.-B., Deschênes, L., Margni, M., 2011. Regional Characterization of Freshwater Use in LCA: Modeling Direct Impacts on Human Health. Environ. Sci. Technol. 45, 8948–8957. https://doi.org/10.1021/es1030883

6. Cai, H., Biesbroek, S., Wen, X., Fan, S., van 't Veer, P., Talsma, E.F., 2022. Environmental footprints of Chinese foods and beverages: Literature-based construction of a LCA database. Data Br. 42, 108244. https://doi.org/https://doi.org/10.1016/j.dib.2022.108244

7. Chenoweth, J., Hadjikakou, M., Zoumides, C., 2014. Quantifying the human impact on water resources: a critical review of the water footprint concept. Hydrol. Earth Syst. Sci. 18, 2325–2342. https://doi.org/10.5194/hess-18-2325-2014

8. Coca-Cola, Nature Conservancy, 2010. Product Water Footprint Assessments: Practical Application in Corporate Water Stewardship.

9. Debaere, P., Konar, M., 2022. Water resources and trade: A research vision. PLOS Water 1, e0000010. https://doi.org/10.1371/journal.pwat.0000010

10. Delacámara, G., Dworak, T., Gómez, C.M., Lago, M., Maziotis, A., Rouillard, J., Strosser, P., 2013. EPI-Water Deliverable 5.3:Guidance on the design and development of Economic Policy Instruments in European water policy, EPI-Water - Evaluating Economic Policy Instruments for Sustainable Water Management in Europe.

11. Derouin, S., 2018. Share the Wealth: A Cap-And-Trade System of Water Conservation and Resiliency? [WWW Document]. Stanford|Water West. URL https://waterinthewest.stanford.edu/news-events/news-insights/share-wealth-cap-and-trade-system-water-conservation-and-resiliency (accessed 8.8.23).

12. Ercin, A.E., Aldaya, M.M., Hoekstra, A.Y., 2012. The water footprint of soy milk and soy burger and equivalent animal products. Ecol. Indic. 18, 392–402. https://doi.org/10.1016/j.ecolind.2011.12.009

13. Ercin, A.E., Aldaya, M.M., Hoekstra, A.Y., 2011. Corporate Water Footprint Accounting and Impact Assessment: The Case of the Water Footprint of a Sugar-Containing Carbonated Beverage. Water Resour. Manag. 25, 721–741. https://doi.org/10.1007/s11269-010-9723-8

14. European Water Partnership, 2012. European Water Stewardship.

15. Fang, K., Heijungs, R., de Snoo, G.R., 2014. Theoretical exploration for the combination of the ecological, energy, carbon, and water footprints: Overview of a footprint family. Ecol. Indic. 36, 508–518. https://doi.org/10.1016/j.ecolind.2013.08.017

16. FAO, 2022. The future of food and agriculture – Drivers and triggers for transformation (No. 3), The Future of Food and Agriculture. Food and Agriculture Organization, Rome. https://doi.org/10.4060/cc0959en

17. Feng, K., Chapagain, A., Suh, S., Pfister, S., Hubacek, K., 2011. COMPARISON OF BOTTOM-UP AND TOP-DOWN APPROACHES TO CALCULATING THE WATER FOOTPRINTS OF NATIONS. Econ. Syst. Res. 23, 371–385. https://doi.org/10.1080/09535314.2011.638276

18. Frischknecht, R., Jungbluth, N., 2009. The Ecological Scarcity Method: Eco-Factors 2006 - A method for impact assessment in LCA. Bern.

19. Gejl, R.N., Bjerg, P.L., Henriksen, H.J., Hauschild, M.Z., Rasmussen, J., Rygaard, M., 2018. Integrating groundwater stress in life-cycle assessments – An evaluation of water abstraction. J. Environ. Manage. 222, 112–121. https://doi.org/10.1016/j.jenvman.2018.05.058

20. Gonzales, P., Ajami, N., Sun, Y., 2017. Coordinating water conservation efforts through tradable credits: A proof of concept for drought response in the San Francisco Bay area. Water Resour. Res. 53, 7662–7677. https://doi.org/10.1002/2017WR020636

21. Green Business Certification, 2020. TRUE Certification [WWW Document]. Green Bus. Certif. URL https://true.gbci.org/ (accessed 8.1.23).

22. Grunert, K.G., Hieke, S., Wills, J., 2014. Sustainability labels on food products: Consumer motivation, understanding and use. Food Policy 44, 177–189. https://doi.org/10.1016/j.foodpol.2013.12.001

23. Gu, Y., Xu, J., Wang, H., Li, F., 2014. Industrial Water Footprint Assessment: Methodologies in Need of Improvement. Environ. Sci. Technol. 48, 6531–6532. https://doi.org/10.1021/es502162w Hauschild, M.Z., 2005. Assessing Environmental Impacts in a Life-Cycle Perspective. Environ. Sci. Technol. 39, 81A-88A. https://doi.org/10.1021/es053190s

24. Hoekstra, A.Y., 2009. Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis. Ecol. Econ. 68, 1963–1974. https://doi.org/10.1016/j.ecolecon.2008.06.021

25. Hoekstra, A.Y., Chapagain, A.K., 2008. Globalization of Water: Sharing the Planet's Freshwater Resources, Globalization of Water: Sharing the Planet's Freshwater Resources. https://doi.

org/10.1002/9780470696224

26. Hoekstra, A.Y., Chapagain, A.K., 2007. Water footprints of nations: Water use by people as a function of their consumption pattern. Water Resour. Manag. 21, 35–48. https://doi.org/10.1007/s11269-006-9039-x

27. Hoekstra, A.Y., Hung, P.Q., 2002. Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade, value of water research report Series no:11. IHE Delft.

28. Hoekstra, A.Y., K. Chapagain, A., M. Aldaya, M., Mekonnen, M.M., 2011. The Water Footprint Assessment Manual - Setting the Global Standard, 1st ed. Earthscan, London.

29. Honey-Rosés, J., 2009. Reviewing the arguments for market based approaches to water distribution: a critical assessment for sustainable water management in Spain. Sustain. Dev. 17, 357–364. https://doi.org/10.1002/sd.391

30. Hoekstra, A.Y., Mekonnen, M.M., 2012. Reply to Ridoutt and Huang: From water footprint assessment to policy. Proc. Natl. Acad. Sci. 109. https://doi.org/10.1073/pnas.1205186109

31. Income Tax Department, 2011. Section 80-IA [WWW Document]. URL https://incometaxindia.gov.in/Acts/Income-tax Act, 1961/2015/Others/section80ia.htm (accessed 8.6.23).

32. India Water Stewardship Network, 2016. Alliance for Water Stewardship India [WWW Document]. URL https://a4ws.org/about/global-network/india/ (accessed 8.6.23).

33. ISO, 2014. Environmental management. ISO 14046. Water footprint — principles, requirements and guidelines. International Organization for Standardization, Geneva.

34. ISRIC, 2006. Green Water Credits (GWC) [WWW Document]. ISRIC World Soil Inf. URL https://www.isric.org/projects/green-water-credits-gwc (accessed 8.1.23).

35. IWA, 2019. Review of international water efficiency product labelling.

36. Jeswani, H.K., Azapagic, A., 2011. Water footprint: methodologies and a case study for assessing the impacts of water use. J. Clean. Prod. 19, 1288–1299. https://doi.org/10.1016/j.jclepro.2011.04.003

37. Kakad, R.G., Pachkor, R.T., 2021. Water Footprint for Different Industries-An Overview. Int. J. Eng. Res. Technol. 10, 504–507.

38. Kaminker, C., 2015. Policy Perspectives: Green Bonds - Mobilising the debt capital markets for a low-carbon transition. OECD Publ.

39. Kampman, D., 2007. The water footprint of India - A study on water use in relation to the consumption of agricultural goods in the Indian states. University of Twente.

40. Kuo, T.C., Huang, M.-L., Hsu, C.W., Lin, C.J., Hsieh, C.-C., Chu, C.-H., 2015. Application of data quality indicator of carbon footprint and water footprint. Int. J. Precis. Eng. Manuf. Technol. 2, 43–50. https://doi.org/10.1007/s40684-015-0006-y

41. Lamastra, L., Suciu, N.A., Novelli, E., Trevisan, M., 2014. A new approach to assessing the water footprint of wine: An Italian case study. Sci. Total Environ. 490, 748–756. https://doi.org/10.1016/j.scitotenv.2014.05.063

42. Lima, S., Brochado, A., Marques, R.C., 2021. Public-private partnerships in the water sector: A review. Util. Policy 69, 101182. https://doi.org/https://doi.org/10.1016/j.jup.2021.101182

43. Lovarelli, D., Ingrao, C., Fiala, M., Bacenetti, J., 2018. Beyond the Water Footprint: A new framework proposal to assess freshwater environmental impact and consumption. J. Clean. Prod. 172, 4189–4199. https://doi.org/https://doi.org/10.1016/j.jclepro.2016.12.067

44. Luck, M., Landis, M., Gassert, F., 2015. Aqueduct Water Stress Projections: Decadal projections of water supply and demand using CMIP5 GCMs. Washington, DC.

45. Manson, L., Epps, T., 2014. Water Footprint Labelling and WTO Rules. Rev. Eur. Comp. Int. Environ. Law 23, 329–341. https://doi.org/10.1111/reel.12090

46. Mario Gómez, C., Leflaive, X., 2015. Economic and financial instruments for the implementation of the water-related Sustainable Development Goals, in: 2015 UN-Water Annual International Zaragoza Conference. Water and Sustainable Development: From Vision to Action. 15-17 January 2015.

47. Mason, C.F., Plantinga, A.J., 2013. The additionality problem with offsets: Optimal contracts for carbon sequestration in forests. J. Environ. Econ. Manage. 66, 1–14. https://doi.org/https://doi.org/10.1016/j.jeem.2013.02.003

48. Mekonnen, M.M., Hoekstra, A.Y., 2011. The green, blue and grey water footprint of crops and derived crop products. Hydrol. Earth Syst. Sci. 15, 1577–1600. https://doi.org/10.5194/hess-15-1577-2011

49. Mikosch, N., Berger, M., Finkbeiner, M., 2021. Addressing water quality in water footprinting: current status, methods and limitations. Int. J. Life Cycle Assess. 26, 157–174. https://doi.org/10.1007/s11367-020-01838-1

50. Milà i Canals, L., Chenoweth, J., Chapagain, A., Orr, S., Antón, A., Clift, R., 2009. Assessing freshwater use impacts in LCA: Part I—inventory modelling and characterisation factors for the main impact pathways. Int. J. Life Cycle Assess. 14, 28–42. https://doi.org/10.1007/s11367-008-0030-z

51. Ministry of Jal Shakti, 2021. New National Water Policy. Delhi.

52. Ministry of Water Resources, 2012. National water policy. New Delhi.

53. MOEFCC, 2023. Draft Green Credit Programme Implementation Rules 2023 (No. CG-DL-E-27062023-246825). Delhi.

54. MJS. 2020. Central Ground Water Authority (CWGA) Guidelines, 2020. Ministry of Jal Shakti, Government of India.

55. MoWR RD&GR, 2016. Draft National Water Framework Bill, 2016.

56. NITI Aayog, 2023a. Report on Water Neutrality for Indian Industry - Standardization of the definition and approach. Delhi.

57. NITI Aayog, 2023b. Water trading mechanism to promote reuse of treated wastewater. Delhi. Nydrioti, I., Grigoropoulou, H., 2022. Using the water footprint concept for water use efficiency labelling of consumer products: the Greek experience. Environ. Sci. Pollut. Res. 30, 19918–19930. https://doi.org/10.1007/s11356-022-23573-w

58. Pathak, A., 2023. Market-Based Solutions to Water Problems in India: Some Thoughts. Res. Rev. Int. J. Multidiscip. 8, 01–08. https://doi.org/10.31305/rrijm.2023.v08.n05.001

59. Pawlowska, E., Machnik-Slomka, J., Klosok-Bazan, I., Gono, M., Gono, R., 2021. Corporate Social Responsibility of Water and Sanitation Company in the Czech Republic—Case Study. Energies 14, 3981. https://doi.org/10.3390/en14133981

60. Pfister, S., Koehler, A., Hellweg, S., 2009. Assessing the Environmental Impacts of Freshwater Consumption in LCA. Environ. Sci. Technol. 43, 4098–4104. https://doi.org/10.1021/es802423e

61. Pierrat, É., Laurent, A., Dorber, M., Rygaard, M., Verones, F., Hauschild, M., 2023. Advancing water footprint assessments: Combining the impacts of water pollution and scarcity. Sci. Total Environ. 870, 161910. https://doi.org/10.1016/j.scitotenv.2023.161910

62. Ravi Shankar, S., Jayasri, A.S. V., 2015. The need for Virtual Water Credits and Trading System. Water Supply 15, 933–939. https://doi.org/10.2166/ws.2015.047

63. Reid, A.J., Carlson, A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T.J., Kidd, K.A., MacCormack, T.J., Olden, J.D., Ormerod, S.J., Smol, J.P., Taylor, W.W., Tockner, K., Vermaire, J.C., Dudgeon, D., Cooke, S.J., 2019. Emerging threats and persistent conservation challenges for freshwater biodiversity. Biol. Rev. 94, 849–873. https://doi.org/10.1111/brv.12480

64. Reliableplant, 2023. Coca-Cola, Nature Conservancy release water footprint report [WWW Document]. RP news wires. URL https://www.reliableplant.com/Read/26423/Coca-Cola-water-report (accessed 8.5.23).

65. Ridoutt, B.G., Juliano, P., Sanguansri, P., Sellahewa, J., 2010. The water footprint of food waste: case study of fresh mango in Australia. J. Clean. Prod. 18, 1714–1721. https://doi.org/10.1016/j.jclepro.2010.07.011 old_website/Regions/CR/Reports/CR_Nagpur_GWYB_2018-19.pdf>

66. Ridoutt, B.G., Juliano, P., Sanguansri, P., Sellahewa, J., 2010. The water footprint of food waste: case study of fresh mango in Australia. J. Clean. Prod. 18, 1714–1721. https://doi.org/10.1016/j.jclepro.2010.07.011

67. Ridoutt, B.G., Pfister, S., 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Glob. Environ. Chang. 20,113–120. https://doi.org/10.1016/j.gloenvcha.2009.08.003

68. Sarkar, S.K., Tigala, S., 2023. Let water credits flow. The Hindu. The Statesman, 2023. PWRDA to implement water conservation credits in Punjab. The Statesman. UNDESA, 2013. Green Water Credits, in: International Annual UN-Water Zaragoza Conference 2012/2013. United Nations Department of Economic and Social Affairs, Zaragoza.

69. Unified Water Label Association, 2017. Unified Water Label [WWW Document]. URL https://uwla.eu/ (accessed 7.31.23).

70. van Oel, P.R., Mekonnen, M.M., Hoekstra, A.Y., 2009. The external water footprint of the Netherlands: Geographically-explicit quantification and impact assessment. Ecol. Econ. 69, 82–92. https://doi.org/10.1016/j.ecolecon.2009.07.014

71. Velázquez, E., Madrid, C., Beltrán, M.J., 2011. Rethinking the Concepts of Virtual Water and Water Footprint in Relation to the Production–Consumption Binomial and the Water–Energy Nexus. Water Resour. Manag. 25, 743–761. https://doi.org/10.1007/s11269-010-9724-7

72. Water.org, 2023. WaterCredit Initiative [WWW Document]. URL https://water.org/solutions / watercredit/ (accessed 8.9.23).

73. Water Footprint Network, 2023. Water Footprint Network [WWW Document]. URL https://www.waterfootprint.org/water-footprint-2/what-is-a-water-footprint/ (accessed 8.9.23).

74. Wheeler, S., Bjornlund, H., Loch, A., 2014. Water Trading in Australia: Tracing its' Development and Impact Over the Past Three Decades. pp. 179–202. https://doi.org/10.1007/978-94-017-9081-9_10 161 I Water Credits

75. Woodward, R.T., Newburn, D.A., Mezzatesta, M., 2016. Additionality and reverse crowding out for pollution offsets in water quality trading. Ecol. Econ. 128, 224–231. https://doi.org/https://doi.org/10.1016/j.ecolecon.2016.05.001

76. World Bank, 2022. Water in Agriculture. World Bank.

77. World Bank, 2013. Crowdfunding's Potential for the Developing World. Washington DC.

78. Young, M., 2015. Fiscal instruments and water scarcity, GGKP Research Committee on Fiscal Instruments, Working Paper 04. Venice.

79. Zhang, S., Taiebat, M., Liu, Y., Qu, S., Liang, S., Xu, M., 2019. Regional water footprints and interregional virtual water transfers in China. J. Clean. Prod. 228, 1401–1412.

80. https://doi.org/10.1016/j.jclepro.2019.04.298

References (Chapter6-9)

1. Acharya, D., 2023. As NITI Aayog Looks into Water Trading, it Should Know the High Costs it May Bring. The Wire. Accessed on 18 November 2023 https://thewire.in/government/as-niti-aayog-looks-into-water-trading-it-should-know-the-high-costs-it-may-bring

2. Bhardwaj, M., 2014. Physico-Chemical and Biological Analysis of Sewage Water along Hindon River Ghaziabad City (U.P) India. https://www.ijert.org/research/physico-chemical-and-biological-analysis-of-sewage-water-along-hindon-river-ghaziabad-city-u.p-india-IJERTV3IS030081.pdf

3. Central Ground Water Board, 2022. Aquifer Mapping and Management of Ground Water Resources Ministry of Jal Shakti, Government of India. https://cgwb.gov.in/sites/default/files/2022-11/pune_f.pdf

4. Chandanshive, N.E., Khandagale, T., Burade, D., Wandre, S., Shinde, P., 2020. Studies on physicochemical parameters of Indrayani River, Pune, Maharashtra, India. https://www.isca.me/IJENS/Archive/v9/i4/5.ISCA-IRJEvS-2020-014.pdf

5. Chatterjee, R., 2021. Hydrogeochemical Study of Taluka Maval from Pune District of Maharashtra. https://www.academia.edu/59461137/Hydrogeochemical_Study_of_Taluka_Maval_from_Pune_District_of_Maharashtra

6. CME Group. Nasdaq Veles California Water Index. Accessed on 12 December 2023 < https://www.cmegroup.com/markets/equities/nasdaq/nasdaq-veles-california-water-index.html>

7. Deoli, V., Nauni, S., 2021. Groundwater Quality Analysis using WQI for Sahibabad (UP). https://www.researchgate.net/publication/352743349_Groundwater_Quality_Analysisusing_WQI_for_Sahibabad_UP

8. Ercin, A.E., Aldaya, M.M., Hoekstra, A.Y., 2011. Corporate Water Footprint Accounting and Impact Assessment: The Case of the Water Footprint of a Sugar-Containing Carbonated Beverage. https://link.springer.com/article/10.1007/s11269-010-9723-8

9. Frost & Sullivan, 2016. Challenges and Opportunities in the Indian Water Market. Accessed on 18 November 2023 <https://www.frost.com/frost-perspectives/challenges-and-opportunities-indian-water-market/>

10. GeoIQ website. Accessed on 12 December 2023 <https://geoiq.io/places/Sahibabd/ZqQ7GdH91K>

11. Government of Maharashtra. Upper Bhima Sub basin DRAFT report. https://wrd.maharashtra.gov.in/Site/Upload/PDF/booklet-Upper%20Bhima.pdf

12. Ground Water Department, U.P and CGWB, 2021. Dynamic Ground Water Resources of Uttar Pradesh. https://upgwd.gov.in/MediaGallery/ESTIMATIONREPORT_2020.pdf

13. Gu, Y., Xu,J., Keller, A.A., Yuan, D., Li, Y., Zhang, Bei., Weng, Q., Zhang, X., Deng, P., Wang, H., Li,

F., 2015. Calculation of water footprint of the iron and steel industry: a case study in Eastern China. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2014.12.094.

14. Hoekstra, A.Y., 2017. Water Footprint Assessment: Evolvement of a New Research Field. https://link.springer.com/article/10.1007/s11269-017-1618-5
15. Indian Cement Review, 2020. Water neutrality for a sustainable future. Accessed on 20 December 2023 < https://indiancementreview.com/2020/01/05/water-neutrality-for-a-sustainable-future/>
16. Indian Village Directory website. Accessed on 10th December 2023 <https://villageinfo.in/maharashtra/pune/mawal/kamshet.html>
17. Indian Village Directory website. Accessed on 13 December 2023 <https://villageinfo.in/maharashtra/pune/mawal.html>
18. Kamble, T., Hamand, C., Pensenwar, S., Patil, S., Kharat, P., 2019. Quality of Waste Water in Rural Area, Dongaon MH. INDIA. https://www.irjet.net/archives/V6/i4/IRJET-V6I4624.pdf
19. Kanade, R., Lohakare, K., Bhadbhade, N., Joy, K. J., Thomas, B.K., Martin, J., Willaarts, B., 2023. Situational Analysis of the Upper Bhima sub-basin in the context of the Water-Food-Biodiversity Nexus. https://pure.iiasa.ac.at/id/eprint/19014/1/WFB%20Nexus%20Situational%20Analysis%20Bhima%20Basin%20Kanade%20et%20al%202023.pdf
20. Khan, S., Gupta, K., Kumar, K., Routela, R., 2022. A Review of Groundwater Status and Problems due to Industrial Pollution: Case Study of Ghaziabad City. https://doi.org/10.1016/j.matpr.2022.08.474
21. Kolhe, P., 2023. Current Scenario of Water Quality Status of Indrayani River tt Pune District, Maharashtra. https://www.ijcrt.org/papers/IJCRT2310199.pdf
22. Kulkarni, H., Deolankar, S. B., Lalwani, A., Joseph, B., Pawar, S., 2002. Hydrogeological framework of the Deccan basalt groundwater systems, west-central India. https://link.springer.com/article/10.1007/s100400000079
23. Leenes, P.W.G., Hoekstra, A.Y., Bosman, R., 2017. The blue and grey water footprint of construction materials: Steel, cement and glass. https://doi.org/10.1016/j.wri.2017.11.002
24. M/s. Hindustan Electricity Generation Co. Pvt. Ltd. 2017. Environmental Impact Assessment of Proposed Integrated Industrial Area at Navlakhumbre & Badhalwadi Village In Taluka Mawal, District Pune, Maharashtra. https://environmentclearance.nic.in/DownloadPfdFile.aspx?FileName=t+j2fLXdsOTUO4rPsiqZAcBqwC3RODAMFXvP4pjQD4S+X/
25. MDBA, Government of Australia. Accessed on 11 December 2023 <https://www.mdba.gov.au/water-use/water-markets/water-trade>
26. Ministry of Jal Shakti, Government of India. 2019. Ground Water Year Book of Maharashtra and Union Territory of Dadra and Nagar Haveli. Accessed on 10 November 2023 <https://cgwb.gov.in/

Appendix

Glossary

The relevant terminologies of green credits are given in Table A.1, while Table A.2 shows the terms relevant to water credits highlighted in blue.

Term	Definition
Accredited Green Credit Verifier	'Accredited Green Credit Verifier' means an entity accredited and authorized by the Green Credit Programme Administrator to carry out verification activities in respect of the Programme.
Green Credit	'Green Credit' means a singular unit of an incentive provided for a specified activity, delivering a positive impact on the environment.
Registered Entity	'Registered Entity' means any entity, registered for generation of Green Credits.
Registry	'Registry' means an electronic database system maintained by Green Credit Programme Administrator or its accredited agency to record issuance and exchange of Green Credits.
Third-party certifiers	'Third-party certifiers' means an entity that certifies an activity for its registration.
Verification	'Verification' means an independent evaluation of the green credit activity by the accredited Green Credits Verifier for acquiring Green Credits.
Empaneled Auditors	'Empaneled Auditors' means an entity empaneled by the Central Government for auditing the entire system of the Programme.

Table A.1: *Terminologies related to Green Credits (MOEFCC, 2023)*

S.No	Name	Scope
1.	**Tree Plantation-based Green Credit**	To promote activities for increasing the green cover across the country through tree plantation and related activities.
2.	**Water-based Green Credit**	To promote water conservation, water harvesting, and water use efficiency/savings, including treatment and reuse of wastewater.

3.	**Sustainable Agriculture based Green Credit**	To promote natural and regenerative agricultural practices and land restoration to improve productivity, soil health and nutritional value of food produced.
4.	**Waste Management based Green Credit**	To promote sustainable and improved practices for waste management, including collection, segregation and treatment.
5.	**Air Pollution Reduction based Green Credit**	To promote measures for reducing air pollution and other pollution abatement activities.
6.	**Mangrove Conservation and Restoration based Green Credit**	To promote measures for conservation and restoration of mangroves.
7.	**Ecomark based Green Credit**	To encourage manufacturers to obtain Ecomark label for their goods and services.
8.	**Sustainable building and infrastructure based Green Credit**	To encourage the construction of buildings and other infrastructure using sustainable technologies and materials.

Annexure 1

Water footprint toolkit output for Kamshet (values in m^3/annum)

	Operational Water Footprint (A)		
1.	**Operational green and blue WF associated with production**		**71,829.20**
	1.1	Rainwater incorporated into the product as an ingredient	553
	1.2	Rainwater consumed during the production process	1.50
	1.3	Blue water incorporated into the product as an ingredient	71,060
	1.4	Blue water consumed during the production process	214.70
2.	**Overhead green and blue operational water footprint**		**3,955.20**
	2.1	Rainwater consumed by employees (drinking water)	0
	2.2	Rainwater consumed in toilets and kitchen	0
	2.3	Rainwater consumed due to cleaning activities in the factory	0
	2.4	Rainwater consumed in gardening	0
	2.5	Blue water consumed by employees (drinking water)	163.20
	2.6	Blue water consumed in toilets and kitchen	1,440
	2.7	Blue water consumed due to cleaning activities in the factory	120
	2.8	Blue water consumed in gardening	2,232
3.	**Operational Grey water footprint**		**7,714**
	Supply Chain Water Footprint (B)		
4.	**Supply-chain water footprint related to the products**		**5,88,878.90**
	4.1	Water footprint of product ingredients - Green WF	0
	4.2	Water footprint of packaging materials - Green WF	4,363.90
	4.3	Water footprint of product ingredients - Blue WF	50.30
	4.4	Water footprint of packaging materials - Blue WF	83,286.70
	4.5	Water footprint of product ingredients - Grey WF	956.10
	4.6	Water footprint of packaging materials - Grey WF	5,00,221.70

5.	**Overhead supply-chain water footprint**		**55,033.50**
	5.1	Energy for heating and power- Green WF	0
	5.2	Energy for heating and power- Blue WF	55,033.50
	5.3	Energy for heating and power- Grey WF	0
	Water Footprint Impacts on Watershed (C)		
6.	**Pollution impact within watershed**		**0.0**
	6.1	Surface water Pollution	0.0
	6.2	Groundwater Pollution	0.0
	6.3	Interbasin transfer water Pollution	0.0
7.	**Water scarcity impact within watershed**		**0.0**
	7.1	Surface water Scarcity	0.0
	7.2	Groundwater Scarcity	0.0
	7.3	Interbasin transfer water Scarcity	0.0
	Water Augmented		
8.	**Total water replenished or conserved**		**26,141**
	8.1	Water trading	0.0
	8.2	Water offset programs	26,141
	8.3	Water conserved through improved water quality in industrial processes	0.0
	Summary		
	I.	**Total estimated water footprint of production unit (A+B)**	**7,27,411**
		Green WF	4,918.40
		Blue WF	2,13,600.50
		Grey WF	5,08,892
	II.	**Impact-adjusted water footprint (A+B+C-D)**	**7,01,270.20**

Water footprint toolkit output for Sahibabad (values in m^3/annum)

	Operational Water Footprint (A)		
1.	**Operational green and blue WF associated with production**		**1,17,088.60**
	1.1	Rainwater incorporated into the product as an ingredient	0
	1.2	Rainwater consumed during the production process	0
	1.3	Blue water incorporated into the product as an ingredient	1,16,727
	1.4	Blue water consumed during the production process	361.60
2.	**Overhead green and blue operational water footprint**		**7,212**
	2.1	Rainwater consumed by employees (drinking water)	0
	2.2	Rainwater consumed in toilets and kitchen	0
	2.3	Rainwater consumed due to cleaning activities in the factory	0
	2.4	Rainwater consumed in gardening	0
	2.5	Blue water consumed by employees (drinking water)	336
	2.6	Blue water consumed in toilets and kitchen	1,440
	2.7	Blue water consumed due to cleaning activities in the factory	108
	2.8	Blue water consumed in gardening	5,328
3.	**Operational Grey water footprint**		**3,951**
	Supply Chain Water Footprint (B)		
4.	**Supply-chain water footprint related to the products**		**14,75,858.60**
	4.1	Water footprint of product ingredients - Green WF	0
	4.2	Water footprint of packaging materials - Green WF	1,06,846.20
	4.3	Water footprint of product ingredients - Blue WF	64.80
	4.4	Water footprint of packaging materials - Blue WF	1,38,553.70
	4.5	Water footprint of product ingredients - Grey WF	1,231.6
	4.6	Water footprint of packaging materials - Grey WF	12,29,162.30

5.	**Overhead supply-chain water footprint**		**1,05,812.60**
	5.1	Energy for heating and power- Green WF	0
	5.2	Energy for heating and power- Blue WF	1,05,812.60
	5.3	Energy for heating and power- Grey WF	0
	Water Footprint Impacts on Watershed (C)		
6.	**Pollution impact within watershed**		**0.0**
	6.1	Surface water Pollution	0.0
	6.2	Groundwater Pollution	0.0
	6.3	Interbasin transfer water Pollution	0.0
7.	**Water scarcity impact within watershed**		**43,774.80**
	7.1	Surface water Scarcity	0.0
	7.2	Groundwater Scarcity	43,774.80
	7.3	Interbasin transfer water Scarcity	0.0
	Water Augmented		
8.	**Total water replenished or conserved**		**1,07,914**
	8.1	Water trading	0.0
	8.2	Water offset programs	1,07,914
	8.3	Water conserved through improved water quality in industrial processes	0.0
	Summary		
	I.	**Total estimated water footprint of production unit (A+B)**	**17,09,922.50**
		Green WF	1,06,846.20
		Blue WF	3,68,731.80
		Grey WF	12,34,345
	II.	**Impact-adjusted water footprint (A+B+C-D)**	**16,45,783.40**

Annexure 2

Water footprint at national level

Figure I shows water footprint of various countries and relative contribution of various commodities.

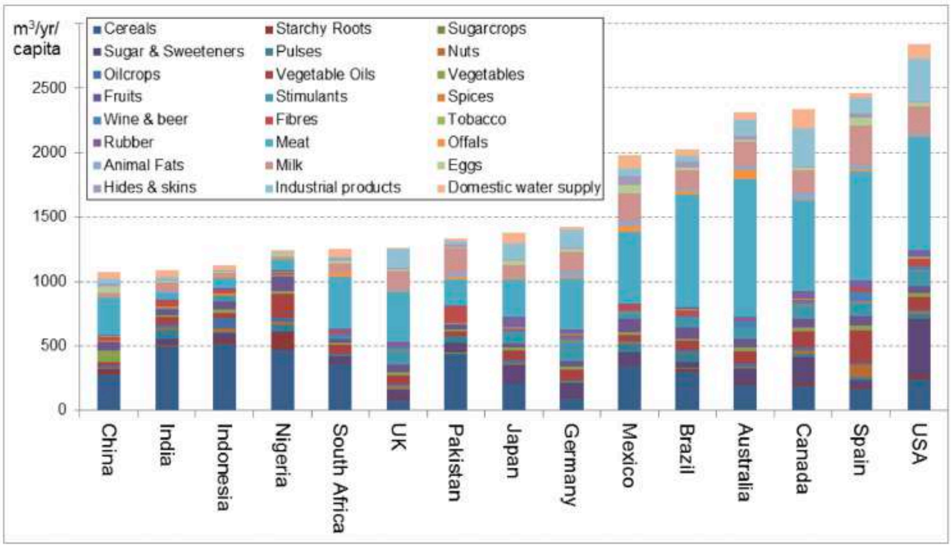


Figure I: *Water footprint at national level*

Data Source: *Hoekstra & Mekonnen (2012) The Water Footprint of Humanity, PNAS*

Water footprint of Indian consumer

Water Footprint of a consumer in India is a mix of direct and indirect (invisible) consumption. It is estimated that on an average, the direct consumption of water is insignificant as compared to the indirect. Within the indirect consumption, only 7% of water footprint is attributable to industrial products (Figure II).

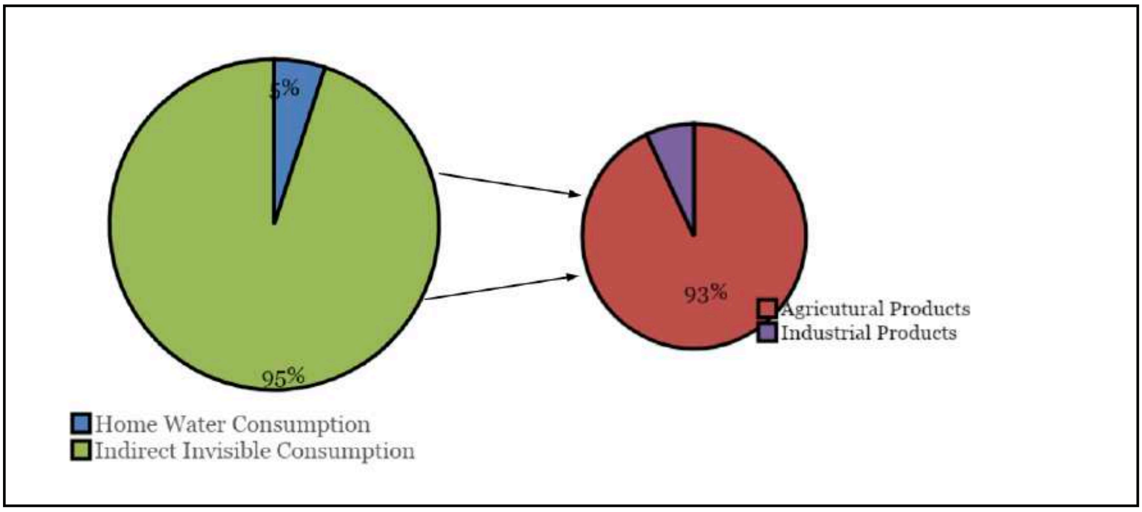


Figure II: *Direct & Indirect water footprint of an average consumer in India*

Data Source: *Hoekstra & Mekonnen (2012) The Water Footprint of Humanity, PNAS*

For more information

ICWMR, TERI SAS
10 Institutional Area, Vasant Kunj, New Delhi- 110070
akansal@terisas.ac.in | icwmr.terisas.ac.in

teri school of advanced studies

Bisleri