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LOTUS

LOW-COST INNOVATIVE TECHNOLOGY FOR WATER QUALITY MONITORING AND WATER RESOURCES MANAGEMENT FOR URBAN AND RURAL WATER SYSTEMS IN INDIA

Deliverable D1.1

State-of-the-art water quality ecosystems

Lead: TISS, with support from INNO

Date: February 2020

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LOTUS is co-funded by the European Commission under the Horizon 2020 research and innovation programme under Grant Agreement N° 820881 and by the Indian Government, Ministry of Science and Technology.

Project Deliverable

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Abstract

This report presents our understanding of water supply ecosystems using a review of secondary literature such as census report, journal articles, and other government reports. The unprecedented growth of urban population has become a challenge to the basic need for safe, affordable, accessible supply of water. Moreover, the quality of water is another issue in itself, which threatens the health and wellbeing of India's urban population. The LOTUS project aims to work on three technology-based interventions and the implementation on these interventions for three use cases: (1) in Guwahati, providing sensor based technological solution to a section of city water supply system, addressing existing water quality issue of the city, (2) In Bengaluru, providing sensor based technological intervention on selected tankers to address water quality issue to the city water supply, and (3) in Jalgaon, proving sensor based water quality solution to provide high quality irrigation water. This report presents the description of water supply ecosystem of the three use cases and highlights issues challenges and concerns for the use cases. The finding of the report will be helpful in full scale implementation of the proposed technological interventions.

Keywords

Ecosystem actors, needs and benefits, governance analysis, local preconditions, barriers and opportunities

Disclaimer

LOTUS has been financed with support from the European Commission and the Indian Government, Ministry of Science and Technology.

The LOTUS Project

LOTUS is a project funded by DG Environment under the European Union Horizon 2020 Research and Innovation Programme and by the Indian Government. It brings together EU and Indian prominent organisations with the aim to co-create, co-design and co-develop innovative robust affordable low-cost sensing solutions for enhancing India's water and sanitation challenges in both rural and urban area.

The LOTUS solution is based on an innovative sensor and includes tailor-made decision support to exploit the capabilities of the sensor as well as a specific approach to co-creation. LOTUS aims to be co-designed and co-produced in India, and have a wide, diverse and lasting impact for the water sector in India due to intense collaborations with commercial and academic partners in India.

Based on the low-cost sensor platform, solutions for the early detection of water quality problems, decision support for countermeasures and optimal management of drinking and irrigation water systems, tailored on the functionalities of the new sensor, will be developed and integrated with the existing monitoring and control systems.

This sensor will be deployed in five different use cases: in a water-network, on groundwater, in irrigation, in an algae-based wastewater treatment plant and in water tankers. The packaging of the sensor, as well as the online and offline software tools will be tailored for each of the use cases. These last will enable to test the sensors and improve them iteratively.

The project is based on co-creation, co-design and co-production between the different partners. Therefore, an important stakeholder engagement process will be implemented during the project lifetime and involve relevant stakeholders, including local authorities, water users and social communities, and will consider possible gender differences in the use and need of water. Broad outreach activities will take place both in India and in Europe, therefore contributing to LOTUS impact maximisation.

The further development and exploitation (beyond the project) of the novel sensor platform will be done in cooperation with the Indian partners. This will create a level playing field for European and Indian industries and SMEs working in the water quality area.

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1 Executive summary

LOTUS is a project funded by DG Environment under the European Union Horizon 2020 Research and Innovation Programme and by the Indian Government. It brings together EU and Indian prominent organisations with the aim to **co-create, co-design and co-develop innovative robust affordable low-cost sensing solutions for enhancing India's water and sanitation challenges in both rural and urban area.** The LOTUS solution is based on an innovative sensor and includes tailor-made decision support to exploit the capabilities of the sensor as well as a specific approach to co-creation. LOTUS aims to be co-designed and co-produced in India, and have a wide, diverse and lasting impact for the water sector in India due to intense collaborations with commercial and academic partners in India.

The LOTUS technology includes solutions for the early detection of water quality problems, decision support for countermeasures and optimal management of drinking and irrigation water systems, tailored on the functionalities of the new sensor. It will be developed and integrated with the existing monitoring and control systems. **Important stakeholder engagement activities will be implemented during the project lifetime and involve relevant actors, including local authorities, water users and social communities, and will consider possible gender differences in the use and need of water.**

This sensor will be deployed in five different use cases: in a water-network, on groundwater, in irrigation, in an algae-based wastewater treatment plant and in water tankers. The packaging of the sensor, as well as the online and offline software tools will be tailored for each of the use cases. These last will enable to test the sensors and improve them iteratively. The further development and exploitation (beyond the project) of the novel sensor platform will be done in cooperation with the Indian partners. This will create a level playing field for European and Indian industries and SMEs working in the water quality area.

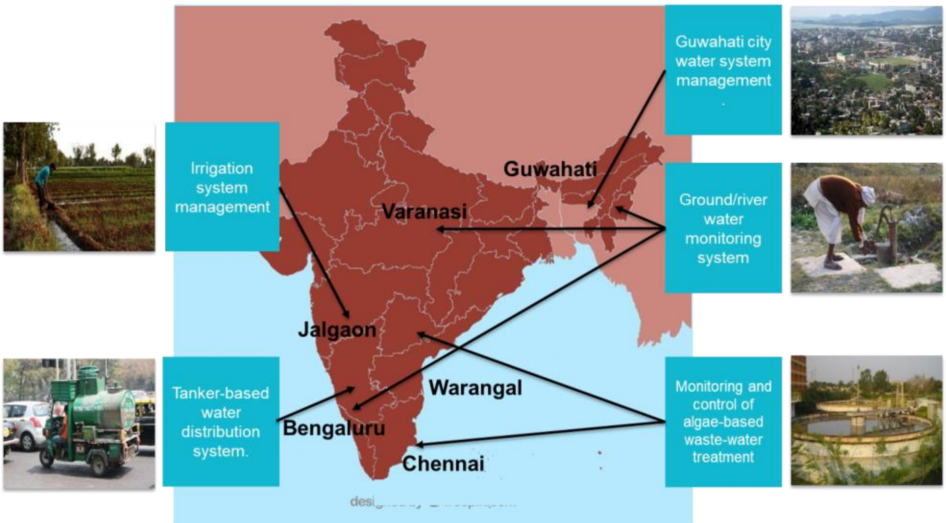

Figure 1 LOTUS Use cases

The present review was undertaken based on the **secondary literature** such as census report, journal articles, different government reports, agriculture census data.

Water is essential for human life, agriculture, and nature, however in India 163 million of people do not have access to clean water India, concentrating 19.33% of the world population (Sengupta and Pandey 2018). As a result, **India is supported by numerous initiatives and policies at the global, regional and local levels.** The EU is particularly active in supporting water management in India. This report provides an overview of the policies in place to understand the framework in which LOTUS takes place.

India's urban population was approximately 28% (292 million) as per 2001 Census of India, which has now risen to 34% (460 million) by the year 2018 (World Bank, 2019) and this growth is assumed to continue in the upcoming years. **The unprecedented growth of urban population has become a challenge to the basic need for safe, affordable, accessible supply of water.**

The pressure on water quantity and quality is further going to increase as the urban population is expected to rise to 600 million by 2031(12th Plan, Govt. of India). The report of ICLEI-South Asia (2015) observed that **big cities are dependent on municipal services while smaller towns rely on groundwater extraction. This results in inequitable water services and major gaps in supply and demand and hence emergence of unregulated water bodies or alternatives** such as, private vendors.

Various reasons like poor infrastructure and maintenance causing leakages, water theft etc., increase the non-revenue water and hinder the supply of water. In addition, there are barriers in supply of drinking water, lack of metering, lack of municipal capacity, lack of maintenance, non- volumetric water tariff resulting in less cost recovery etc.

Intermittent water supply to Indian cities is one of the key issues in drinking water supply as it worsens the existing conditions of water supply infrastructure and reduce the willing to pay. Most water utilities of urban areas run at a loss, and this loss is covered with the subsidies provided by the government. This result in a **low-level equilibrium: low tariff, poor services, and limitations on access, especially of poor households**. The Lotus project aims to develop low cost water quality sensors to improve India's water and sanitation challenges

In regards to irrigation, **different policies are being implemented by both central and state governments to enhance the irrigation capacity across India.** There are two main problems with irrigation. Firstly, irrigation is threatening groundwater resources in areas where demands exceed the supply of surface water. Secondly, fertilizers infiltrate the ground and contribute to polluting the water table. When ground water is polluted, it cannot be used for irrigation, as it contaminates the crops. The LOTUS project aims to improve agricultural farming practices by supporting drip irrigation with the LOTUS water quality monitoring technology.

LOTUS aims to undertake technology-based interventions across six different regions of India based on a participatory bottom-up approach that attempts to address water quality issues in these regions. The co-creation and stakeholder engagement process will take place in four different use cases located in three regions. This report focusses on the four use cases that are concerned by the co-creation process.

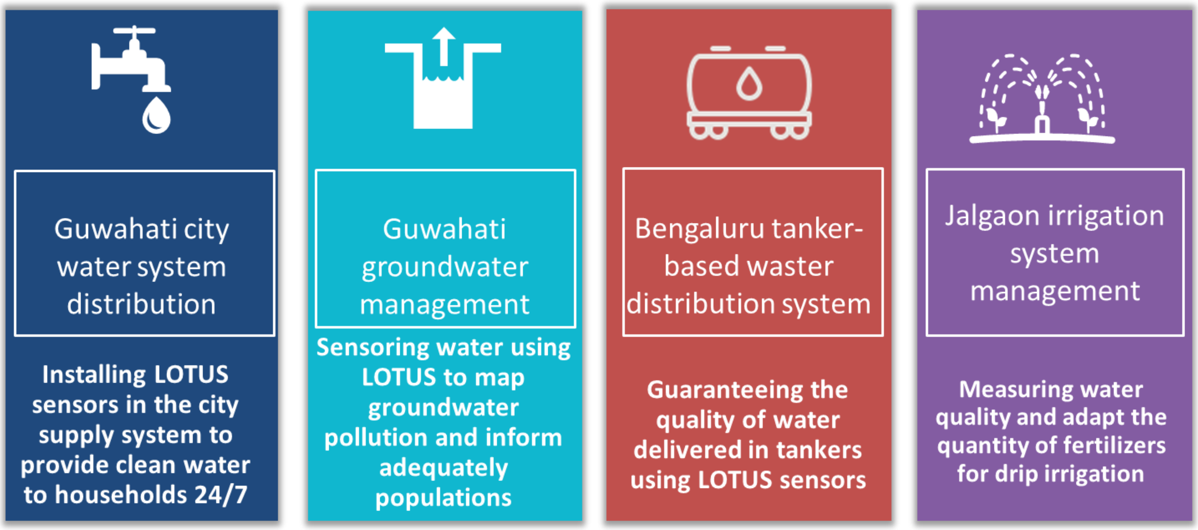

Figure 2 The four use cases studies in the present report

In each of the four use case described in the report, the water quality needs of stakeholder is described. The report also underlines the features and challenges of each ecosystem, before moving onto the main benefits, needs and opportunities for the development of the LOTUS sensor.

The first two case studies are based in **Guwahati**. The first one is using the LOTUS sensor to maintain the **quality of the pipe water supply in a section of the city**. At the same time, it will avoid the infiltration of sediment and other contaminants carried by rains. Knowledge of the quality of water, will enable the right water treatment to be applied to make it drinkable. This information will be communicated to the public to help build trust in the quality of the water supply. Though it is a centralised system, it is important to maintain the coordination among different players in this system which can ensure the quality supply to the area.

The second use case in **Guwahati** aims to measure the **quality of groundwater**. The LOTUS sensor will be used in borewells to measure the levels of pollution including arsenic and fluoride which is present in the region's groundwater. Historical data collection will enable to map groundwater pollution and its movement when it rains. This will increase the knowledge of the groundwater system and help create a reliable information system. This information is vital as many communities in the city use the groundwater for drinking and cooking.

In **Bengaluru**, LOTUS aims to benefit the middle- and upper-class population of the Bengaluru city, who rely heavily on **water tankers** to fill their apartments and companies. During the water scarce period of summer, all communities are willing to pay for good quality drinking water. The LOTUS technology aims to help the tanker company to provide their customers with high quality water. The LOTUS technology will be used by the JustPaani water tankers (private organisation engaged in water delivery

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in the city). There is also an opportunity to extend the technology to the other players in the market including the Bangalore Water Supply and Sewerage Board (BWSSB), who provides water to the more deprived parts of the city.

The last use case is in **Jalgaon** region, with the primary beneficiaries being farmers. The LOTUS technology will provide farmers with access to real-time water quality information; this will enable them to use fertilizers more effectively as they will have greater knowledge of the water quality. This will help them use less fertilisers on their crops which will have economic and environmental benefits. The population targeted is middle-high incomes farmers who use fertilizers.

2 Methodology

The present study was undertaken based on the secondary literature such as census report, journal articles, different government reports, and agriculture census data. The **census 2011 report** is an administrative unit level data conducted for 35 states/union territory, 640 districts, 5924 sub districts, 7933 towns and 640,930 villages. It covers different aspects including population, growth rate, density of population, proportion of population, sex ratio, child population, workers and category of economic activities of the workers.

To understand the quality of drinking and irrigation water, the **Bureau of Indian Standards 10500** was followed as benchmark for different quality parameters. Then we reviewed different scientific articles for different quality parameters includes physical, chemical and biological properties of water. The private sector plays a major role in the water distribution system because of the inadequate supply of water supply in view of which different newspaper article, journal article reviewed to understand the role of private players in the water distribution system.

Complementary information was collected directly from the LOTUS use case owners and their final users. This data collection occurred during the Fall of 2019, during the preparation of LOTUS first co-creation workshops. The co-creation workshops themselves, which took place in India in November-December 2019, enabled the LOTUS team to gather the final information from final users themselves to complement this deliverable.

3 Introduction

LOTUS aims to co-create, co-design and co-develop innovative robust affordable low-cost sensing solutions for enhancing India's water and sanitation challenges in both rural and urban areas. Important stakeholder engagement activities will be implemented during the project lifetime and involve relevant actors, including local authorities, water users and social communities, and will consider possible gender differences in the use and need of water. Stakeholder engagement is a process by which a project involves all people who may be affected by its action or may influence its implementation, they may support or, on the contrary, oppose the decisions taken by the project. In fact, stakeholders will be engaged to co-create and co-design the sensor. Their engagement also enables to pave the way to deployment, by adapting the implementation of the project to the local preconditions, enabling the partners to anticipate risks and difficulties, whilst channelling the main opportunities. Ultimately stakeholder engagement will ensure that the project meets the stakeholder's needs.

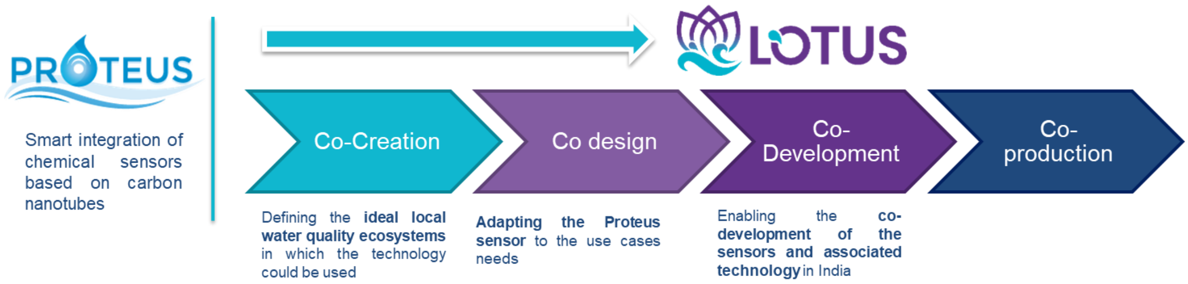

Figure 3 Stakeholder engagement process in LOTUS

The technology, an innovative sensor which includes tailor-made decision support to exploit its capabilities, will be deployed in five different use cases spread across six Indian states: in a water-network, on groundwater, in irrigation, in an algae-based waste water treatment plant and in water tankers. Each use case presents different technical, political, cultural, economic and social features which need to be considered to enable the rightful implementation of the project. The project team shall make sure that the technical requirements match the environment, local regulations, users' constraints and expectations of final users.

As a result, stakeholder engagement is key to enable the deployment of the sensor, notably at the local level. To enable stakeholder engagement, preliminary steps must be taken, including mapping of the ecosystem actors, including local preconditions potential benefits arising from LOTUS, related barriers, and main opportunities for the project. This report aims precisely at highlighting this information.

The objectives of the report are threefold:

- To draw the political and policy landscape of the project by providing an overview of the relevant priorities and EU-Indian cooperation status;
- To map and specify the relevant ecosystem actors, notably at the level of the use case, to pave the way the projects successful implementation and deployment;
- To summarise the local preconditions, the political, cultural, and technical challenges and potential barriers, as well as the main opportunities in each use case, as well as generally, for the successful implementation of water quality solutions in India.

This report starts from an analysis of EU-India cooperation, to contextualise the project. Then, it narrows down to a context analysis of India water context both in cities and in irrigation. Then, three regions in which four use cases will take place are analysed in depth to provide background information for the stakeholder engagement process. Finally, it will wrap up its findings in general conclusions about the context in which LOTUS will be implemented.

This document is conceived as a guideline for the deployment of the LOTUS project in India. It is at the inception of the stakeholder engagement process as it enables to pre-identify the stakeholders that will take part of the co-creation and business models workshop. It will also constitute a baseline for the socio-economic study assessing the satisfaction and technology adoption from user perspective for water quality and quantity as well as the best practices drawn from the project.

More importantly, this state-of-the-art water quality ecosystems description and analysis intertwines with all work packages, as it provides information about the context of the use cases and key stakeholders which will be involved in each of the technical work packages of LOTUS.

4 Overview of relevant priorities and EU-Indian water cooperation status

Water is an important topic worldwide. Its management (quantity and quality) is a major issue. Global initiatives have risen from the 1970s on, to address this challenge. India, concentrating 17% of the world population for only 4% of water is particularly at threat. As a result, India is supported by numerous initiatives and policies at the global, regional and local levels. The EU is particularly active in supporting water management in India. This part provides an overview of the policies in place to understand the framework in which LOTUS takes place.

4.1 Global initiatives addressing the water challenges

The water subject has been on the international community's agenda for a few decades now. As global awareness of the topic's importance has risen, international initiatives are developed to address the challenges related to this valuable natural yet finite resource. The international community has recognised the human right to have access to clean water in 1977 during the Mar del Plata UN Water Conference declaring that *"all peoples, whatever their stage of development and social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs"* in its Action Plan[1].

Since then, several crucial international documents and meetings addressed the environmental challenges for the 21st century took place, with great relevance on water. Among them were approved: the Agenda 21 at the Earth Summit in 1992; the Johannesburg Declaration on Sustainable Development at the World Summit on Sustainable Development in 2002; the 8 Millennium Development Goals in 2015; the 2030 Agenda for Sustainable Development with its 17 goals in 2015; and the Paris Agreement on Climate Change also in 2015[2]. These treaties were a commitment of the international community to achieve mutual goals, and took measures on reducing pollution, providing people with access to clean water and ensuring the maintenance of water resources for future generations.

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[1] United Nations Decade Programme on Advocacy and Communication (UNW-DPAC). *The Human Right to Water and Sanitation: Milestones*.

[2] UN Water. *Water, Sanitation and Hygiene: Facts and Figures*. Available in http://www.unwater.org/. Consulted in 05/28/2019.

In addition, the UN-Water was established in 2003 and developed several initiatives: the International Decade for Action "WATER FOR LIFE" between 2005 and 2015 to arise consciousness and responsibility on the water issue; the 2014-2020 Strategy in support of the 2030 Agenda; and the Integrated Water Monitoring, launched in 2015 aiming at reporting on progress on water and sanitation.

Furthermore, the Sustainable Development Goals aim at leaving no one behind in the quest of addressing many global challenges by 2030. The 6th of them has as objective to provide clean water and basic sanitation as necessary conditions for human dignity and countries' development. Among the goals' targets and concerning more specifically water quality, the international community aims at[3]:

- Achieving universal and equitable access to safe and affordable drinking water for all (6.1);
- Improving water quality by reducing pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated water and substantially increasing recycling and safe reuse globally (6.3);
- Implementing integrated water resources management at all levels, including through transboundary cooperation as appropriate (6.5);

Moreover, the international community implemented the Water Action Decade between 2018 and 2028 after averting a global water crisis with the freshwater resources continually decreasing and the population demand considerably growing. Its goal is to mobilise action that will help transform how water is managed, with special attention to[4]:

- The sustainable development and integrated management of water resources for the achievement of social, economic and environmental objectives;
- The implementation and promotion of related programmes and projects; and
- The furtherance of cooperation and partnerships at all levels to achieve internationally agreed water-related goals and targets, including those in the 2030 Agenda for Sustainable Development.

Besides initiatives resulting from the international community diplomacy, other institutions address water challenges. It is the case of the World Bank Projects and Operations**,** which finance many initiatives and, among them, some related to water issues in India[5].

[3] United Nations Sustainable Development Goals. *Goal 6: Clean Water and Sanitation*. Available in https://www.un.org. Consulted in 05/28/2019.

[4] United Nations Sustainable development goals, *Water Action Decade*. Available in https://www.un.org/. Consulted in 06/03/2019.

[5] There are over 60 projects funded by the World Bank. The complete list is available in http://projects.worldbank.org. Consulted in 06/03/2019.

4.2EU-India cooperation in the field of water

4.2.1 History of EU India Cooperation

1994	•EU-India Cooperation Agreement
2001	•EU-India Science & Technology Cooperation Agreement
2004	•EU-India Strategic Partnership
2005	•EU-India Joint Action Plan (JAP)
2006	•Joint Working Group on Environment
2012	•Indian National Water Policy inspired by the European Water Policy
2012	•Joint Declaration on S&T
2016	•Water Convention
2016	•Agenda for Action 2020
2016	•India-EU Water Partnership (IEWP)
2016	•Memorandum of Understanding EU-India & Hungary-India
2017	•Memorandum of Understanding Netherlands-India

Figure 4 India Agreements and Initiatives' Background

EU and India have long-standing cooperation relationships: from economic and scientific cooperation, both parties have deepened their cooperation in the field of water (cf. **Error! Reference source not found.**). Relations between India and the EU began with the legislative framework for cooperation set by the Cooperation Agreement in 1994. Both sides committed to consider environmental protection as an integral part of international cooperation. Moreover, they underlined the importance of environmental issues and their will to establish cooperation in protecting and improving the environment with emphasis on water[6].

Ever since, both parties have been working together towards the development of mutual initiatives and policies regarding, among others, water. As India's first trade partner[7], the EU is a key player in achieving the country's modernisation and development goals. The EU has notably participated importantly to funding development programmes in India, for example through the EuropeAid fund.

The EU and India made, in 2001, an Agreement for Scientific and Technological Cooperation with the purpose of encouraging and facilitating cooperative research and development activities in fields of

[6] *Cooperation Agreement between the European Community and the Republic of India on partnership and development*. 08/27/1994. Article 17.
[7] European Commission. *India, trade picture*. Available in http://ec.europa.eu/. Consulted on 05/27/2019.

common interest. As the guidelines set in this agreement, in 2004 the EU-India Partnership established more in-depth cooperation initiatives between both sides regarding technology and knowledge exchange. Also, the collaboration led to India's participation in the EU's Sixth Framework Research Programme (FP6), a research initiative funded by the European Commission for application-oriented projects in many fields, including water. One year later, the EU-India Joint Action Plan (JAP) was conceived to define common objectives and develop a wider range of supporting activities in many fields, including environmental protection.

4.2.2 The rise of cooperation in the field of water

In 2006, the creation of a Joint Working Group on Environment and an EU-India Environment Forum gave sequence to the cooperation about biodiversity conservation, forest protection and waste and water management[8]. EU's water policies have also been a source of inspiration for the Indian government. The European Water Policy was adopted to support the EU Member States in understanding the impacts and pressures to water by developing appropriate governance structures. The government of India, based on the European experiences, established its own National Water Policy in 2012. The policy sets the framework for the country's national policies deployment to integrate water resource development and management across the states as well as to map risks such as pollutant emissions, water over-use, climate change effects, among others.

India-EU cooperation on water increased as of 2016, when commitment by both sides enhanced with the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention). It was the opportunity for all United Nations Member States to accede the Convention regarding the sustainable use of transboundary water resources by facilitating cooperation and implementation of integrated water resources management, particularly through a basin approach[9].

Encouraged by the Water Convention, in 2016 during the EU-India Summit, the Agenda for Action 2020 was adopted by the EU and India with some aspects regarding water. Among other, the Agenda aimed at enabling more coherent and effective cooperation on India's 'Clean Ganga' flagship programme to rejuvenate the river and to achieve the objectives of India's National Water Mission adopted by the Indian Government in 2011[10].

Moreover, the Agenda approached the establishment and implementation of the India-EU Water Partnership (IEWP), signed in the same year**.** The agreement aimed to strengthen technological, scientific, and management capabilities in the field of water management. Priorities of the partnership included the sustainable development of river basins, water governance, data management (water

[8] European Commission. *International Issues: Bilateral and regional cooperation: India*. 08/06/2016.
[9] Economic Commission for Europe, United Nations, Economic and Social Council. *Meeting of the Parties to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes*. 10/10/2018.
[10] European Commission. Roadmap *Elements for an EU Strategy on India*. Ref. Ares (2018)682938. 02/05/2018.

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accounting), groundwater use, and water use in irrigation, including solar pumping. Furthermore, it enabled the exchange of views on regulatory approaches, including procurement, governance, best practices, business solutions, and research and innovation[11].

With this goal in mind, the IEWP brings together many actors both from India and the EU and opens opportunities for exchange of views on regulatory approaches, best practices, business solutions and research and innovation opportunities in the water field[12]. The cooperation tackles some priorities such as River Basin Management, assessment of environmental flows, the development of a water quality dashboard for targeted decision making, groundwater management, irrigation efficiency and reuse of treated wastewater as well as the introduction of innovative technologies[13].

Furthermore, through this partnership, both sides design action-oriented annual work programmes, organise Indo-European Water Forum events, bring together experts in Joint Working Groups to monitor the partnership activities, and support the implementation projects in the water field. [14]. It notably supports the implementation of the Ganga Rejuvenation programme a government initiative implemented by the National Mission for Clean Ganga (NMCG). This last coordinates a wide network of stakeholders across states *"To ensure effective abatement of pollution and rejuvenation of the river Ganga by adopting a river basin approach to promote inter-sectoral co-ordination for comprehensive planning and management and to maintain minimum ecological flows in the river Ganga with the aim of ensuring water quality and environmentally sustainable development."*[15]

Furthermore, bilateral agreements with European countries have been of great value for India, especially regarding the implementation of policies inspired by these relationships. For instance, India has signed a Memorandum of Understanding (MoU) in the water sector with Hungary and with the European Union in 2016 and with the Netherlands in 2017. Among the MoU goals were the cooperation in the areas of river basin management planning, integrated water resources management, water and wastewater management, water-related education, research, development and management of groundwater, as well as pollution abatement for rivers including River Ganga[16]. In the MoU signed with the EU, both sides agreed on creating a platform where the contributions of the European Union and its Member States could be coordinated to promote synergies between various bilateral initiatives[17].

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[11] *Memorandum of Understanding between the Republic of India and the European Union on water cooperation,* 10/07/2016.

[12] European Commission. *International Issues: Bilateral and regional cooperation. India*. 06/08/2016.

[13] European External Action Service. *4th India-EU Water Forum steps up cooperation between the two on water resources management in India*. 02/13/2019.

[14] European Union. *The EU and India: Partnering to Address Water Challenges*. 2016.

[15] Rejuvenation of Ganga, http://vikaspedia.in/energy/environment/know-your-environment/water/rejuvenation-of-ganga, consulted on 05/06/2019

[16] Ministry of Water Resources, River Development and Ganga Rejuvenation. *Status of Memorandum of Understanding (MoU) signed with foreign countries in water sector.*

[17] European Union. *The EU and India: Partnering to Address Water Challenges*. 2016.

Throughout the years the agreements made between the EU and India turned into cooperation activities. Great emphasis was given to research and development. India is an active member of the Group of Senior Officials on global Research Infrastructures and the Joint Research Centre (JRC) of the European Commission. It also receives supports through regional and multilateral initiatives, such as the Atlas of Regional Water Cooperation and Conflicts, and the Integrated Drought Management Programme (IDMP)[18]. All these are dedicated to ensuring water management, national water policies implementations and providing quality water as a right to every citizen while focusing on S&T initiatives.

Beside national level initiatives, the EU developed a State Partnership Programme (SPP) with the Indian state of Rajasthan which resulted in a water policy on the Integrated Water Resources Management (IRWM) adopted by the state. Together they also developed a Panchayat-based action plan for 3200 villages in 82 blocks of 11 districts. In 2013, following the EU's cooperation in the state, a water regulatory act was approved in Rajasthan.[19] Furthermore, in 2017, the 14th EU-India Summit took place in Delhi, when both sides reconfirmed their commitment to strengthen the existing partnership and agreed to launch a joint flagship funding initiative for water-related projects. They also committed to work towards reciprocal opening of the EU Framework Programme for Research and Innovation 'Horizon 2020' and Indian programmes[20]. Last but not least, it is important to acknowledge that many cooperation projects take place at a non-institutional level, with universities, NGOs and the private sector. These projects are too numerous to be described but are part of the EU-India water cooperation landscape.

4.2.3 Joint EU-India research and innovation projects in the field of water

India has actively participated in EU funding programmes FP6, FP7 and H2020. There were three projects funded under FP6, seven under FP7 and eight under H2020. In addition, the seven projects funded under SC5-2018-12 joint call, including LOTUS are presented in a separate section.

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[18] European Commission. *Roadmap for EU-India S&T cooperation.* October 2018.
[19] Report on the EU-Rajasthan State Partnership: http://waterresources.rajasthan.gov.in. Consulted in 05/28/2019.
[20] European Commission. *Roadmap for EU-India S&T cooperation*, October 2018.

4.2.3.1 FP6 Programmes

The following table presents the projects on water and involving India funded under FP6.

Programme	Date	Indian Region	EU Country coordinator	Name	Content	Technology
FP6-2004-GLOBAL-3	01/2006 - 12/2010	Delhi	Netherland	TECHNEAU[21]	TECHNEAU sought to develop and demonstrate adaptive supply system options, as well as new and improved supply and monitoring technologies and management practices.	• Bio-sand prefilter • Gravity driven technology
FP6-2004-GLOBAL-4	04/2007 - 12/2010		Italy	ANTINOMOS[22]	This project was a research project. It contributed to the implementing of a global and local knowledge networks for solving real life water supply and sanitation (WSS) problems.	
FP6-INCO	01/2005 - 06/2009	Maharashtra	Austria	DIM-SUM[23]	The DIM-SUM project produced recommendations to improve decision-making methodologies in water management.	

Table 4.7: Details of project on Water and India's Involvement under FP6

[21] For more information access TECHNEAU.
[22] For more information access ANTINOMOS
[23] For more information access DIM-SUM.

4.2.3.2 FP7 Programmes

The following table presents the projects on water and involving India funded under FP7.

Table 4.8: Details of project on Water and India's Involvement under FP7						
Programme	Date	Indian Region	EU Country	Name	Content	Technology
FP7-ENVIRONMENT	09/2012 - 02/2016	WEST BENGAL	Ireland	ECO-INDIA[24]	The overall aim of ECO-India is to design and develop innovative cost-effective solutions for community- based water- and wastewater-treatment systems. The project aimed to provide tools for both water management and monitoring as well as its treatment and distribution	• Online monitoring system at surface water site • Activated filter media systems at both surface water site and groundwater site • Electrochemical disinfection system at surface water site
FP7-ENVIRONMENT	07/2012 - 12/2015	Maharashtra	Germany	NAWATECH-EU PART[25]	NaWaTech Europe and NaWaTech India reunited to carry out a project on Innovative water management to improve water supply and combat shortages in Indian cities. The holistic approach consisted of optimising water flow in a multi-barrier manner	• Water management systems composed notably of urban water flows

[24] For more information access ECO-INDIA.
[25] For more information access NAWATECH-EU PART

					instead of individually to enhance water security and minimise water pollution for downstream users.	
FP7-ENVIRONMENT	10/2011 - 09/2014	Tamil Nadu, Delhi, Uttarakhand, Telangana, Maharashtra,	Switzerland	SAPH PANI	The collaboration project aimed to enhance water resources and water supply particularly in water stressed urban and peri-urban areas	• Bank filtration, • Managed aquifer recharge, • Constructed wetlands
FP7-ENVIRONMENT	09/2012 -05/2017	Madhya Pradesh, West Bengal, Uttarakhand, Tamil Nadu, Maharasthra		SARASWATI[26]	The first project SARASWATI contributed to improve the decentralised wastewater treatment in India. The project evaluated water issues in India and provided counselling for technologies application and improvement based on the EU countries experiences	• Trickling filters, High rate Algae Pond and UASB • Grey Water recycling system (GROW) • Ballasted flocculation technology for stormwater • Mobile aerobic sludge digester with a potential of reusing (cooking, heating) • Composting system treatment of sludge

[26] For more information access SARASWATI.

FP7-ENVIRONMENT	09/2012 - 02/2016	Madhya Pradesh, West BENGAL, UTTAR PRADESH	Spain	SWINGS[27]	This project was carried out by a consortium and its goals was to develop the energy recovery from wastewater & the water safe reusing possibilities by implementing integrated and optimized solutions to improve the water reuse and sanitation in developing regions in India using low cost, easy to adopt, sustainable and zero discharge methodology based on biological and natural systems.	Wastewater treatment plant including: • anaerobic system • horizontal and vertical constructed wetlands • solar disinfection systems
FP7-ENVIRONMENT	09/2012 - 08/2016	Karnataka	Spain	WATER4INDIA[28]	It is a research project which goal was to carry out researches on centralised/decentralised options for water treatment at community level and to develop a Decision Support System (DSS) to assess policy makers into taking the appropriate decisions regarding the issues on drinking water. It had both a quality and a quantity approach providing information on current and expected water requirements	• Ultrafiltration with optimised energy demand • Filtration based on microfibers • Desalinization technologies such as reverse osmosis • UV disinfection • Membrane distillation • Adsorption using conventional and novel low-cost, locally available materials

[27] For more information access SWINGS.
[28] For more information access WATER4INDIA.

FP7-KBBE	08/2012 - 07/2016		Sweden	WATER4CROPS[29]	This project's goal was to enhance and support the Green Economy in Europe and India. The research consortium aimed to advance individual key technologies and methodologies both in the EU and in India	

4.2.3.3 H2020 Programme

The following table presents the projects on water and involving India funded under H2020.

Table 4.9: India's Involvement of Different Projects under H2020

Programme	Date	Indian Region	EU Country coordinator	Name	Content	Technology
H2020-EU.3.5.4	06/2016 - 05/2019	Uttarakhand	Switzerland	AQUANES[30]	The project used catalyse innovations in water and wastewater treatment processes and management through improved combinations of natural and engineered components	• Oxydative pre-treatment (with electro pulse solar photocatalysis) • Post-Treatment with membranes • Biofiltration and biologically activated carbon filtration • Disinfection process (electro chlorination, UV) Sorptive and biological P-removal (algae rector)

[29] For more information access WATER4CROPS.
[30] For more information access AQUANES.

4.2.4 Current paradigm (sister projects)[31]

Under the H2020 collaboration initiative between the EU and India, both sides agreed on co-funding projects on waste management, drinking water cleaning, monitoring and distribution. The flagship initiative SC5-12-2018 was launched in the order of about EUR 30 million and received 55 submissions, among which seven were selected to be co-financed by the EU and the Indian Government, under the DST and the DBT initiatives [32] (Department of Science and Technology and Department of Biotechnology).

The projects had several objectives such as: dealing with consequent water quantities; creating technological solution that could be turned into business; targeting an important range of population; ensuring that technical solutions could be produced at a low cost; and customising the projects to match the Indian context.

Described below are the seven selected projects with their respective names; organisations; objectives; region of action; and technology applied[33]:

Table 4.10: Details of Some Projects under H2020

Project	Coordination	Objective	Indian Region	Technology
LOTUS[34]	Ecole Polytechnique (FR)	The project will develop a solution for real-time water quality and quantity monitoring enabled by innovative sensor aiming to enhance water safety	Maharashtra Karnataka Assam Telangana	• Innovative sensor (Proteus sensor) composed of carbon nanotubes with wireless transmission and cloud-based computing system

[31] The objective of this part is to approach the projects selected at the SC5-12-2018 call under the FP7 initiative. Nevertheless, other similar projects were or are being developed in India with the goal of tackling water quality issues in the country. It is the case of the following examples: Tata Chemicals' 'Swach'; PepsiCo Initiatives: Performance with Purpose; Coca-Cola Co. Initiative for aquifer recharge at Hindustan Beverages, among many others. For more information, see *Best Practices of Ground Water Harvesting in Different Parts of India* (Corporate Initiatives). Available in http://mowr.gov.in. Consulted in 05/27/2019.

[32] European Commission. *Roadmap for EU-India S&T cooperation*, October 2018.

[33] Delegation of the European Union to India and Bhutan. *EU - India to jointly fund seven research and innovation projects to the tune of EUR 40 million to tackle urgent water challenges.* 02/14/2019. Accessible in https://eeas.europa.eu/. Consulted in 05/27/2019.

[34] For more information access LOTUS.

INDIA H_2O[35]	The University of Birmingham (UK)	The project designs bio-mimetic and phyto-technologies designed for low-cost purification and water treatment. It aims to develop, design and demonstrate high-recovery, low-cost water treatment systems for saline groundwater and industrial wastewaters using low-energy water purification technologies and advanced membrane technologies	Gujarat	• Low-energy water purification technologies • Advanced membrane technologies
PANI WATER[36]	Royal College of Surgeons in Ireland (Ireland)	The project consists in photo-irradiation and adsorption based novel innovations for water treatment. It aims to develop, deploy and validate in the field six prototypes for the removal of contaminants, including CECs from wastewater and drinking water	Nagpur Udaipur Khagaria Bundelkhand Delhi	• Multifunction oxydation reactor • Solar photolytic plant • Photo-electrochemical system • Filtration Adsorption and UV-C let system, designed with solar power enabled operation • Electro coagulation Oxidation and Disinfection to remove arsenic from the water
PAVITR[37]	Verein Zur Forderung des Technologie-	The project's main goal is to develop sustainable and advanced technologies for water and wastewater		• Waste and Drinking water treatment machine

[35] For more information access INDIA H2O.
[36] For more information access PANI WATER.
[37] For more information access PAVITR.

	transfers an der Hochschule Bremerhaven EV (Germany)	treatment, monitoring and safe water reuse in India. In order to validate the project, the objective is to deploy or develop cost-effective and sustainable solutions to tackle water challenges and ensure the provision of safe water reuse, rejuvenate water quality of rivers, and restore ecosystems in India		• Sensors for emerging and traditional contaminants
PAVITRA GANGA[38]	Vlaamse Instelling Voor Technologisch Onderzoek – VITO (Belgium)	The goal of the project is to work with wastewater treatment and water re-use and resource recovery for urban and peri-urban areas in India. It aims to unlock the environmental and economic potential of municipal wastewater treatment and water reuse solutions for urban and peri-urban areas in India	Delhi Kanpur	• Polishing technologies • Photoactivated sludge system • Constructed wetland with different adsorptive layers
SARASWATI 2.0[39]		The project aims at supporting consolidation, replication and up-scaling of sustainable wastewater treatment and reuse technologies for India projects. The goal is to identify the best available technologies for decentralized wastewater treatment and resource recovery for India.		

[38] For more information access PAVITRA GANGA.

[39] Delegation of the European Union to India and Bhutan. *EU - India to jointly fund seven research and innovation projects to the tune of EUR 40 million to tackle urgent water challenges*. 02/14/2019. Accessible in https://eeas.europa.eu/. Consulted in 05/27/2019.

LOTUS is co-funded by the European Commission under the Horizon 2020 research and innovation programme under Grant Agreement N° 820881 and by the Indian Government, Ministry of Science and Technology.

SPRING[40]		The project's goal is to develop strategic planning for water resources and implementation of novel biotechnical treatment solutions and good practices. Also, it aims on developing an integrated water resource management for clean and safe water supply		• Geospatial analysis for identification of point and non-point sources of pollution of water bodies • Integrated remote sensing • Physicochemical and biochemical analysis of water sample for assessing the heterogeneity of pollutants

4.3India water policies and governance

4.3.1 India's policy for water quality

In the scenario of these complex challenges, India made its first attempts to develop a work plan to ensure water quality. Among them, in 2011 the National Water Mission under National Action Plan on Climate Change (NAPCC) was approved to ensure integrated water resource management helping to conserve water, minimize wastage and ensure equitable distribution both across and within states. Some of the Mission's goals were to[41]:

- Publish a comprehensive water database and assessment of the impact of climate change on water resources in the public domain;
- Promote citizen and state action for water conservation, augmentation and preservation;
- Involve and encourage corporate sector and industries to take up support and promote water conservation, augmentation, and preservation within the industry and as part of corporate social responsibility;
- Focus attention on over-exploited areas;

[40] Delegation of the European Union to India and Bhutan. *EU - India to jointly fund seven research and innovation projects to the tune of EUR 40 million to tackle urgent water challenges*. 02/14/2019. Accessible in https://eeas.europa.eu/. Consulted in 05/27/2019.
[41] National Water Mission under National Action Plan on Climate Change. *Comprehensive Mission Document*. Volume I. New Delhi, April 2011.

- Increase water use efficiency by 20%; and
- Develop a basin level integrated water resources management.

The Indian Government has also reviewed the National Water Policy in 2012[42] in order to deliver a common integrated approach for the planning and management of water resources while protecting the high socioeconomic, spiritual, cultural and religious value of its waterbodies[43]. Furthermore, the Central Government presented in 2016 the Final Draft of National Water Framework Bill[44] which emphasizes the water allocation aiming its conservation and efficiency. However, the bill's nature is merely recommendatory for the States, which are not bound to any national policy due to the fact that, in India, water is a State subject[45].

India had also made efforts inspired by international initiatives regarding the promulgation of the Water (Prevention and Control of Pollution) Act in 1974 and the Environment Protection Act, in 1986. The acts provide general guidelines on the protection of the environment and water, but, more importantly, they prescribe various functions for the Central Pollution Control Board (CPCB) at the national level and State Pollution Control Boards at the state level. Following the act's guidelines, the Department of Science and Technology implemented the Water Technology Initiative Programme (WTI) in 2007 alongside with the "Winning, Augmentation and Renovation" Technology Mission: WAR for Water. The initiatives' main goal is to promote R&D activities aimed at providing safe drinking water at an affordable cost and an adequate quantity using S&T interventions. The solutions supported by the programmes must be technology-related, especially regarding the use of nano-material and filtration technologies[46]. Furthermore, in 2015 the government of India implemented a Zero Liquid Discharge (ZLD)[47] system for polluting industries, especially those from the following sectors: Sugar, Distilleries, Pulp and Paper, Tanneries, Dyeing, Textiles, and Dairy. The policy implies severe

[42] The National Water Policy was firstly approved in 1987 but has been revised twice ever since: firstly in 2002 and then in 2012, when some important changes were made to the original text to meet the contemporary needs.

[43] India-EU Water Partnership work plan 2016. European Union Delegation to India.

[44] No information was found regarding the approval of this bill. The information on the Ministry of Water Resources, River Development and Ganga rejuvenation is, up until May 2019, concerning the draft, but not the final document approved, that could not be found.

[45] BHATT, Neelkanth J., BHATT, Kapil J. *An Analysis of Water Governance in India: Problems and Remedies.* International Journal of Advance Engineering and Research Development, 2017.

[46] Union Ministry of Science and Technology, Government of India. *Technology Mission: "Winning, Augmentation and Renovation" Technology Mission: WAR for Water.* 28/04/2009.

[47] "Zero Liquid discharge refers to installation of facilities and system which will enable industrial effluent for absolute recycling of permeate and converting solute (dissolved organic and in-organic compounds/salts) into residue in the solid form by adopting method of concentration and thermal evaporation. ZLD will be recognized and certified based on two broad parameters that is, water consumption versus wastewater re-used or recycled (permeate) and corresponding solids recovered (percent total dissolved /suspended solids in effluents)". Central Pollution Control Board, Ministry of Environment, Forests and Climate Change of India. Guidelines on Techno – Economic Feasibility of Implementation of Zero Liquid Discharge (Zld) For Water Polluting Industries. 2015.

consequences for the non-compliant industries, including their closures[48]. Moreover, the CPCB, as a branch of the Ministry of Environment, Forest and Climate Change (MoEFCC) implemented the National Water Quality Monitoring Programme (NWMP) in association with the State Pollution Control Boards and Pollution Control Committees (SPCBs & PCCs), its main goals being to[49]:

- Develop rational planning of pollution control strategies and their prioritisation;
- Assess the nature and extent of pollution control needed in different water bodies or their part;
- Evaluate the effectiveness of pollution control measures already in existence;
- Evaluate water quality trend over a period of time;
- Assess the assimilative capacity of a water body thereby reducing cost on pollution control;
- Understand the environmental fate of different pollutants.
- Assess the adequacy of water for different uses.

The programme works based on a quality monitoring network that presently comprises 3000 stations in 29 states and 6 Union Territories. 2101 locations are monitored on a monthly basis whereas 893 locations on a half yearly basis and 6 locations on a yearly basis[50]. The latest report from the control board, dated from September 2017[51] shows that the level of water pollution has considerably increased between 1995 and 2011 mainly due to the discharge of domestic wastewater in untreated form by urban centres and industries. Some correlated projects to the acts and to the NWMP are the India E-Track Industries and the Environmental Water Quality Data Entry System (EWQDES), both being portals created for water monitoring and quality control and designed to comply with the directives of both documents.
Moreover, the DST has developed the Natural Resources Data Management System and, as a sub-programme, the Revival of Village Ponds with the goal of improving water access and management in coordination with village farmers.

Finally, the Ministry of Water Resources, River Development and Ganga Rejuvenation created a special branch to address the National Mission for Clean Ganga (NMCG). Given the state jurisdiction on the water subject, the mission's main goal is to establish a river basin approach to promote inter-sectoral coordination for comprehensive planning and management of the river Ganga as well as to ensure its water quality by maintaining minimum ecological flows in the river[52].

In India, water governance takes place in three different levels: central, state, and municipal. It is also represented by different governmental structures from state to state acording to the degree of water

[48] Central Pollution Control Board, Ministry of Environment, Forests and Climate Change of India. Guidelines on Techno – Economic Feasibility of Implementation of Zero Liquid Discharge (Zld) For Water Polluting Industries. 2015. Article 11, iv.
[49] Central Pollution Control Board. *Mandate for Quality Monitoring*. Updated on 11/09/2017.
[50] Ministry of Environment, Forest and Climate Change. *MoEFCC, Environment, Pollution*. Modified in 24/04/2019. Available in http://moef.gov.in/.
[51] Central Pollution Control Board. *National Water Quality Monitoring Network* Updated on 11/09/2017.
[52] National Mission for Clean Ganga. *Aim and Objective of NMCG*. Available in https://nmcg.nic.in.

challenges. Furthermore, water legislation in India is not national and can vary between states. Three main Ministries have great importance on water initiatives and their branches or initiatives can also act in the same three levels.

Described below in the diagram are some of the governmental institutions working with water activities in national or state level, although in the municipal level many other branches are currently engaged with the subject.

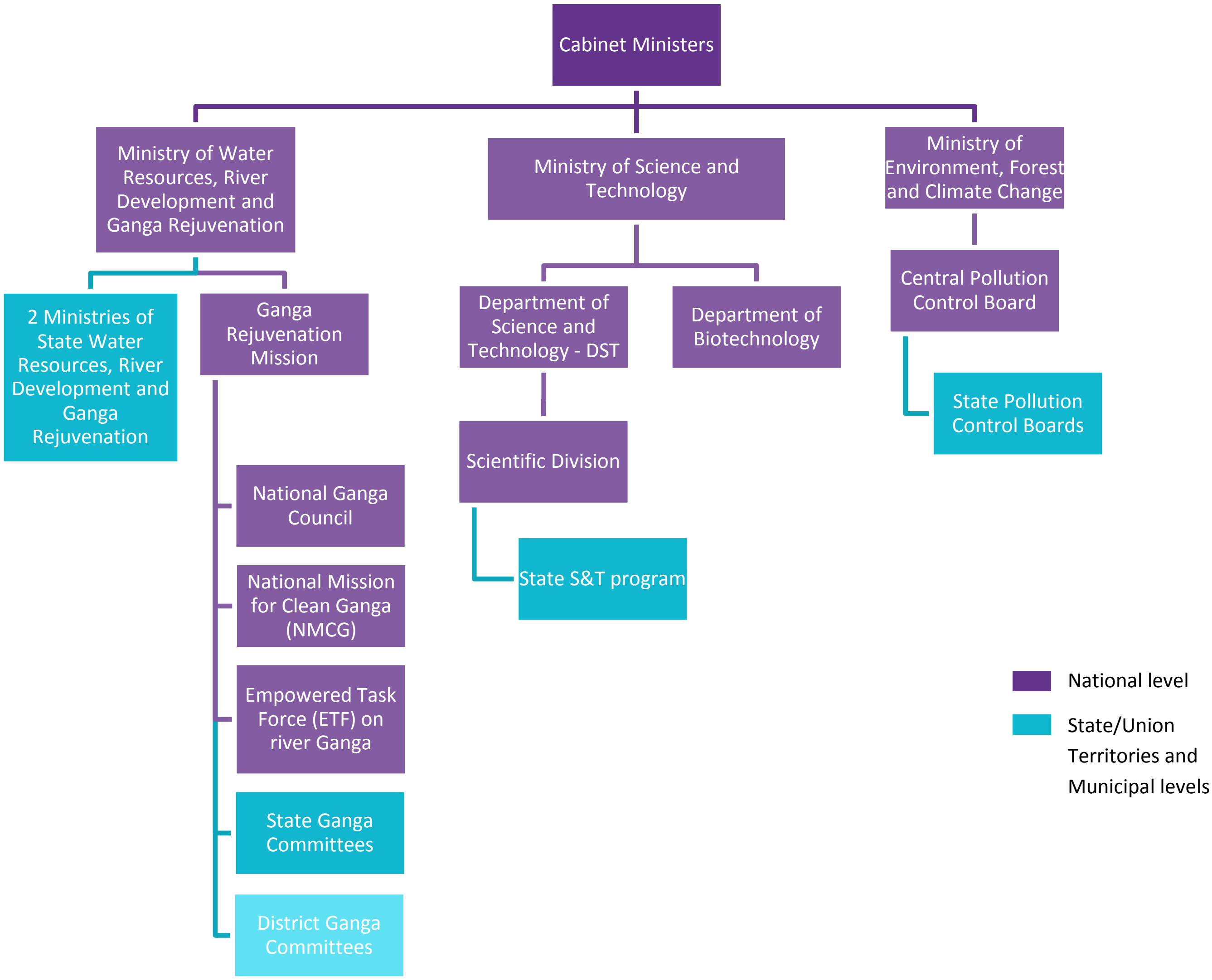


Figure 5 Government of India's main branches working with water challenges

4.3.2 India's Policy and programme for irrigation System

Irrigation policy plays a crucial role in monitoring water quality in India: irrigation requires a lot of water; polluted water is not suitable for irrigation, and irrigation, when loaded with fertilizers is a major source of pollution for the ground aquifers.

In post-independence, the Government of India has been undertaking different policies and programmes to expand the irrigation system in India. In the first Five Year Plan (FYP) (1951-1956), second FYP (1956-61) and third FYP (1961-66), the government of India implemented major irrigation program (Planning Comission 1960). A number of multipurpose and major projects were taken up such as Bhakra Nangal, Nagarjunasagar, Kosi, Chambal, Hirakud, Kakrapar and Tungabhadra. During the fourth five year plan the focus was shifted to micro-irrigation, integrated use of surface and groundwater, adoption of efficient management techniques and modernisation of existing schemes. During the fifth FYP (1974-79), some new initiatives were launched such as Command Area Development Programme (CADP) (Planning Comission 1973). It was central sponsored schemes with the objective of reducing the gap between the irrigation potential created and the optimum utilisation of available land and water. In the 12th FYP (2012-17), the major focus was on developing different watershed programmes and enhance the minor irrigation programme with the objective to enhance the livelihood and sustainability of watershed programme.

Moreover, there are different policies being implemented by both central and state governments to enhance the irrigation capacity across India. The Government of India has been promoting micro irrigation since 1992 and in 2006, the GoI launched a centrally sponsored schemes for micro-irrigation. In 2010, the central government took one more step and launched the National Mission on Micro irrigation with the objective of better water productivity in the agriculture sector which was implemented during 2013-14 by the Ministry of Agriculture & Farmers Welfare. The objective of the 12th FYP was on sustainable development. So on this basis, the National Mission for Sustainable Agriculture (NMSA) was operational in 2014 and micro-irrigation activities were implemented under the On-Farm Water Management component of the schemes (COMMISSION 2011). The other objective of the NMSA was enhancing water use efficiency by promoting technological interventions and adopting efficient on-farm water management technologies and processes.

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) scheme was launched in 2015 under the multiple ministries like Ministry of Water Resources, River Development and Ganga Rejuvenation (now Ministry of Jal Shakti) and the Ministry of Agriculture & Farmers Welfare. The theme of this program was “Har Khet Ko Paani” (water for every farm) as well as “Per Drop, More Crop.” The major focus was to provide an end-to-end solution to the irrigation supply chain. Recently in December 2019, the prime Minister of India launched Atal Jal Yojana intending to improve the groundwater level. It will improve the groundwater level in 78 districts and more than 8,00 villages in the state of Maharashtra, Haryana, Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh and Karnataka (Anon 2019).

LOTUS is co-funded by the European Commission under the Horizon 2020 research and innovation programme under Grant Agreement N° 820881 and by the Indian Government, Ministry of Science and Technology.

4.3.3 Regional cooperation

As water is a shared resource and streams flow through boundaries, India is also collaborating with its neighbouring countries to address the challenge of both quantity and quality. Being a scarce resource, water has been the main reason for some inter-regional treaties, cooperation agreements, and conflicts in the region, especially regarding the management of transboundary rivers and lakes. In 1960, India and Pakistan signed the Indus Water Treaty [53] concerning the most complete and satisfactory utilisation of the waters of the Indus system of rivers[54]. The document served as a peace ensuring towards water conflicts between the two countries and served as an example for other bilateral treaties on the matter around the globe.

Furthermore, regional cooperation in South Asia is also encouraged by external agents, which is the case of the Governments of UK, Australia, and Norway, whose support was crucial to develop the South Asia Water Initiative (SAWI) in cooperation with the World Bank. The initiative aims to help develop the Himalayan river systems management activities in order to deliver sustainable, fair and inclusive development and climate resilience. In this scenario, the EU has been active in cooperating with India in the field of water.

[53] World Bank. *Fact Sheet: The Indus Waters Treaty 1960 and the Role of the World Bank*. 06/11/2018. Available in http://www.worldbank.org/. Consulted in 05/26/2019.

[54] Other bilateral cooperation agreements were signed between India and its neighbour countries, such as the India-Nepal Cooperation in 1996, the Indo-Bangladesh Cooperation in 1972, the India-China Cooperation in 2002, and the India-Bhutan Cooperation in 1980. Biswas, in his article *Cooperation or conflict in transboundary water management: case study of South Asia* (BISWAS, Asit K., 2011) emphasises that “the collaboration between India and Bhutan is an excellent example of how transboundary rivers can be managed within an overall collaborative development framework which uses water developments as an engine for economic growth and poverty alleviation in a highly impoverished region.” The collaboration resulted in the construction of a highly effective hydropower potential and a governmental partnership that increased both countries’ population lives quality.

5 India water context in urban and rural areas

Global initiatives have proven to be crucial to raising attention upon the matter of water management. Nevertheless, India's policies and governance initiatives are of main importance to put into practice those recommendations.

5.1 An overview of urban water supply situation in India

India's urban population was approximately 28% (292 million) as per 2001 Census of India, which has risen to 34% (460 million) by the year 2018 (World Bank, 2019) and this growth is assumed to continue growing in the upcoming years at least with an average trend depicted in table 4.1. Table 4.1 describes the rapid growth of urban population in India. The unprecedented growth of urban population has become a challenge to the basic need for safe, affordable, accessible supply of water. Moreover, the quality of water is another issue in itself, which threatens the health and wellbeing of India's urban population. The pressure of rapid urbanisation is further going to increase as the population is expected to rise to 600 million by 2031(12th Plan, Govt. of India). Further, Table 1 Urban Population as percentage of total population, census 1971-2001 describes the condition of top and bottom three states of India and the share of urban population.

Table 1 Urban Population as percentage of total population, census 1971-2001

Urban Population as percentage of total population, census 1971-2001		
Census Year	**No. of urban areas/Towns**	**Urban Population as percentage of total Population**
1971	2,567	19.9
1981	3,347	23.3
1991	3,769	25.7
2001	4,378	27.8
2011	6,166	31.2
Source: Census of India (various issues; 1971-2011)		

LOTUS is co-funded by the European Commission under the Horizon 2020 research and innovation programme under Grant Agreement N° 820881 and by the Indian Government, Ministry of Science and Technology.

Urban water supply in India is also challenged by various anthropogenic activities such as pollution of urban water bodies, due to release of untreated industrial and municipal water deterioration of catchment areas, degradation of water supply infrastructure like pipelines, poor water services, low recovery of water prices etc. In addition, variability of climate is also posing further challenges mainly leading to water availability issues. Moreover, over-exploitation of groundwater levels, (which is one of the main sources of water supply) is also resulting into water supply and quality challenges.

Table 2 Share of Urban populations in Indian States

Share of Urban populations in Indian States					
Urban Population in States					
Top Three (based on population)	**Absolute Population (in million)**	**Share (in %)**	**Bottom Three (based on population)**	**Absolute Population (in million)**	**Share (in %)**
Maharashtra	50.8	13.5	Sikkim	0.15	Negligible
Uttar Pradesh	44.4	11.8	Arunachal Pradesh	0.31	0.1
Tamil Nadu	34.9	9.3	Mizoram	0.56	0.1
Source: Census of India (2011)					

The medium and low-income households are more vulnerable to existing challenges of water supply in Indian urban areas. These households invest a significant part of their time to access water. In case of absence of direct supply, they buy water from private vendor at higher rates that poses additional constraints on their financial resources. Therefore, the pressure on urban population is increasing and hence, it becomes crucial to study the status and situation of urban water supply. Various authors (Power et al., 2018; Pattnayak, 2018) have brought about the impacts of urbanisation and industrialisation on environment. Although industrialisation with urbanisation has various opportunities imbibed with it, for instance the cost of service in concentrated zones of population is much cheaper and simplistic in nature as oppose to service providing in a rural area where population is less and more scattered. However, urbanisation with industrialisation can be a serious risk for development and economic growth (Aartsen et al., 2018). The demand of water rose from 550bm^3 in 1990 to 750bm^3 in 2010, due to rapid urbanisation, economic growth and lifestyle changes (ICLEI-South Asia, 2015).

The report of ICLEI-South Asia (2015) presented the water supply and demand situation in India. The report recorded an increase in access to water supply from 69% in 1990 to 92% in 2011; programmes like National water policy, 2012 are responsible for it. The water policy first adopted in the year 1987, updated in years 2002 and 2012. The water policy envisages to establish a standardised national information system with a network of data banks and data bases. Also, it set the priority of water allocation for drinking, Irrigation, hydropower and industry sectors. At local level, the two most significant policy decisions are the 73rd and the 74th amendment of the Indian constitution. According to 73rd and 74th constitutional amendments, urban local governments are given the responsibility to provide safe drinking water to all the households and hence decentralised the approach for the equitable distribution of resources. The review of documents and literature indicated that big cities are dependent on municipal services while smaller towns rely on groundwater extraction. This results in inequitable water services and major gaps in supply and demand and hence emergence of unregulated water bodies or alternatives such as, private vendors. Various reasons like poor infrastructure and maintenance causing leakages, water theft etc., increase the non-revenue water and hinder the supply of water. The literature also described the barriers in supply of drinking water viz., lack of metering, lack of municipal capacity, lack of maintenance, non- volumetric water tariff resulting in less cost recovery etc. for the ten selected cities they examined.

Intermittent water supply to Indian cities is one of the key issues in drinking water supply. According to the report of ADB (2007) most cities supply water for in the range of 0.75-15hours. Rouse (2013), criticises the role of intermittent water supply as they intensify the issues of water supply because it worsens the existing conditions of water supply infrastructure and reduce the willingness to pay. Rouse (2013) emphasises the importance of a system refurbishment as it will promote capital inflow for funding the system expansion, which is a challenge because government do not receive the cost of supplied water. He concludes that sustainable cost recovery can only be achieved with water charges. Yet, there must be policies to safeguard the needs of low-income groups by reorienting general subsidies towards the low- income groups (Rouse, 2013). The issue of water pricing is well examined in the study by Mathur and Thakur (2003), as per the study water in most Indian cities and towns is under-priced, with ruining long-run consequences for households who have limited and poor quality water services and for water supplying entities that are unable to invest and expand water coverage. Due to this under-pricing the municipality and state government are not able to even collect the revenue to maintaining the existing water supply network (Mathur and Thakur, 2003). Therefore, most water utilities of urban areas run at a loss, and this loss has been covered with the subsidies provided by the government. This results in a low-level equilibrium: low tariff, poor services, and limitations on access, especially of poor households.

Kumar (2010) analysed the role of unaccounted for water (UFW) in aggravating the condition of water supply management. Unaccounted for water is basically the water that is not reaching the consumer due to leakage, which is 40-60% in developing nations. Two major causes of UFW in developing countries are source limitation and lack of efficient water distribution channels (Kumar, 2010). Water leakage is the main reason for UFW in urban cities. Table 3represents the water leakage in urban cities of India. For instance, Bangalore city municipal agency supplies 900 million litres of water, of which 360 million litres is unaccountable i.e. around 40% (Raj, 2013). Inaccessibility of improved water supply results in various health risks and social unrest. In this paper, 20 urban cities are analysed based on the data is represented in ADB (2007).

Table 3 Percentage of Water Leakage in Indian Cities

Percentage of Water Leakage in Indian Cities			
Cities	**Water Leakage (in %)**	**Cities**	**Water Leakage (in %)**
Agra	45	Udaipur	40
Allahabad	20	Bhopal	35
Amritsar	30	Indore	35
Delhi	52	Nagpur	30
Lucknow	30	Bangalore	40
Patna	38	Hyderabad	40
Ranchi	40	Pune	30
Guwahati	20	Bhubaneshwar	40
Jaipur	44	Chennai	30
Udaipur	40	Kolkata	35
Mumbai	30	Surat	30
Source: Ministry of Urban Development respective city development plan			

Most of the issues are demand and supply management. These issues in management of water supply are dealt in detail in section 4.3.

5.2 Mapping of Relevant Stakeholders in Urban Water Supply in India

In water resource management, integrating stakeholders can produce efficient and sustainable solutions to water- related issues. Most importantly, with their involvement, the whole process of implementation would be much easier, as they will be having prior knowledge and can influence other people around. Especially in the case of urban water development, it becomes important to consider the needs, experience and interest of stakeholders. For profitable and sustainable management, the foremost requirement is to engage stakeholders. In countries like India, where such geographic and cultural diversity exists with a large population is crucial to involve the voices of stakeholder.

Turton et al. (1998) quotes in the context of India, "*It is now widely accepted that if the productivity of natural resources is to be enhanced in a sustainable fashion, then those engaged in and affected by management of the resource—the communities—must participate in plans for its rehabilitation and management. Their participation will generate a stake in the process and enhance the prospects of both institutional and ecological sustainability.*"

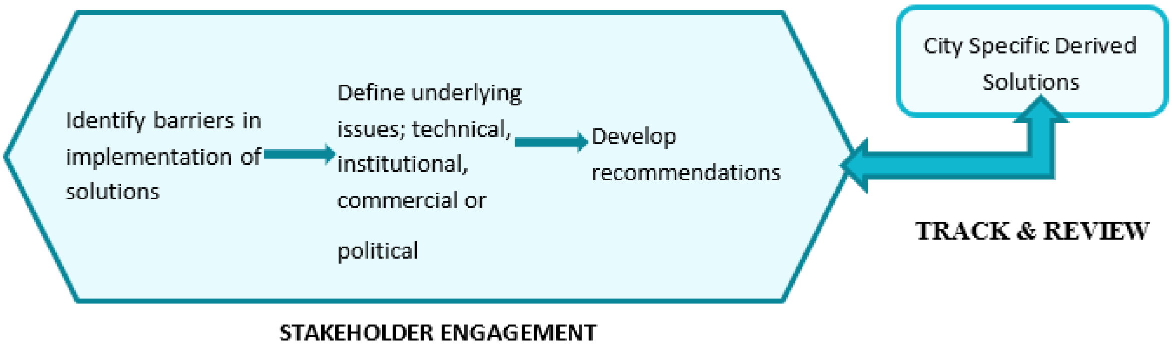


Figure 6 Stakeholder engagement approach (Source Shah 2016)

Figure 6 explains the role of stakeholders. During the stakeholder engagement process, they are responsible for identifying the barriers in implementation of solutions, defining underlying issues which can be institutional, technical, commercial or political. And finally develop recommendations. The role of stakeholder also involves the regular tracking and review of their recommendations as well as the city-specific derived solutions (Shah, 2016).

The major stakeholders for water resource governance are depicted in the following chart below:

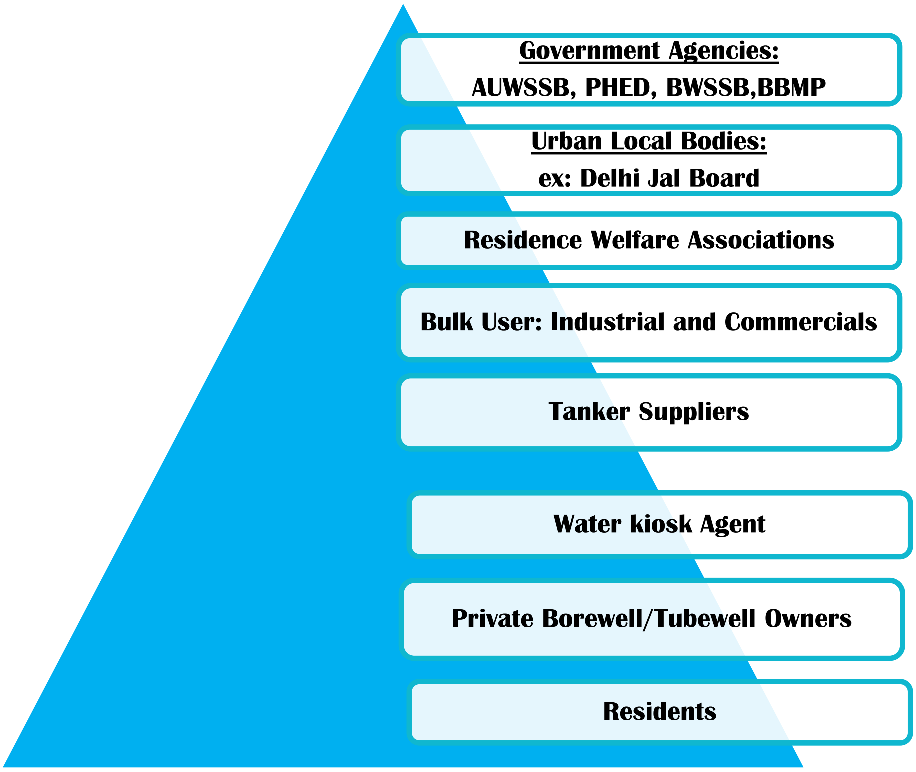


Figure 7 Major Stakeholders in Water Resource Governance in India Source: Author's Illustration

Note: AUWSSB- Assam Urban Water Supply & Sewerage Board

PHED- Public Health Engineering Department

BWSSB- Bengaluru Water Supply and Sewerage Board

BBMP- Bruhat Bengaluru Mahanagar Palike

Government Agencies: The NWP 2012 and Mihir Shah committee report emphasised on the need to engage stakeholders during planning and implementation. Yes water development agencies have a tunnel vision and do not encourage the involvement of NGOs or other stakeholders. The Government itself is one of the biggest stakeholders with the responsibility to use the resource sustainably and allocate it equally. For achieving this goal, various ministries and their projects are working simultaneously. For implementing any policy, stakeholders working in different sectors need to be involved. Apart from government organisations, the efforts of NGOs and other academic institutions are also required. However, it is observed consultations with other stakeholders is currently avoided.

Urban Local Bodies: Drinking Water supply is mainly supplied by municipalities in urban area. In some cases, there are specific water supply boards take the responsibility of drinking water supply – Delhi Jal Board, Bangalore Water Supply and Sewerage Board etc.

Residents welfare association: Interest of people residing in a same community are represented by RWAs. They take in-person participation in decision making process and address the day- to day problems of residents. They organise events for awareness, manage facilities and safeguard the rights of residents. Civil society plays the most crucial role as they act as a bridge between government agency and citizen. There are various organisations working towards the conservation and better management of water resources. For instance, TERI has been working on safe drinking water implementation model for a decentralised community. Instead of intermittent water supply the Administrative Staff College of India (ASCI) has been promoting continuous water supply and better sanitation system for the people with better distribution network and low water tariff, as water supply and sanitation (WATSAN). Various other organisation like WWF and IUCN are working for biodiversity and rejuvenation of water bodies. Also, international support from World Bank, UN, Asian Development Bank, World Water Council etc., has been continuously working towards water resource management and conservation and raising awareness for an efficient use of resource. Not only that, they also provide financial support to small NGOs for the projects under water conservation, rainwater harvesting.

Bulk user:

Industries: Indian corporation as well as multinational corporations are working towards conservation of water resources. ITC, a large private company, has taken an approach to regenerate large-scale river basin projects for the purpose of integrated water management in the states of Maharashtra, Tamil Nadu, Telangana and Madhya Pradesh. This project would achieve an annual water balance with natural flow in these selected sub-basins. This project is spread across a large landscape covering 15000 water harvesting unites in 43 districts of 16 states benefitting more than 300,000 people. a step that not only strengthens the water security but also provides livelihood to people residing in these districts.

Commercial: these involves hospitals, restaurants, schools etc. various cities have assessed the needs of commercial user for instance, Delhi development authority has assessed approximately 75lpcd for industrial and commercial use.

Tanker Suppliers: These are the lifelines of peri-urban and slum regions in urban areas. They extract water from groundwater and supply it to these areas with no accountability of water quality, and higher charges.

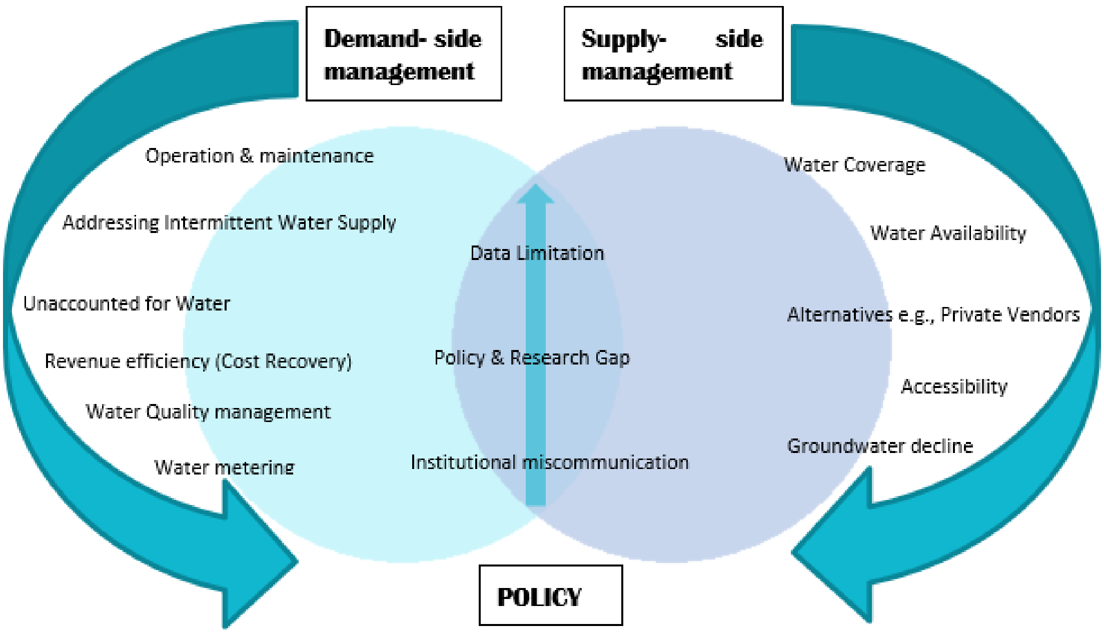
Water kiosk agency: Water kiosk are basically water ATMs, they are the quick source of paid treated drinking water. Several cities have built these ATMs for the availability of drinking water. For instance, Delhi Jal Boards has adopted design-build-operate transfer (DFBOT) model in 2012. This model was selected by a colony and provided water ATMs. 10% of the residents adopted ATMS as their primary water source, and 27% used it for secondary source, after 3 months of usage.

Private borewell/tube well owners: Acute water shortage in Chennai and Delhi has made private borewell/tube well holder an important stakeholder. These metro cities made purchasing contracts with residents and farmers living in peri-urban region for extraction of their groundwater resources.

Residents: Residents of urban India are the prime stakeholder of water resources. they hold the key interest for the needs of drinking water supply and water for domestic usage. Urban households access the water through a variety of modalities such as private connection inside premises, joint connection inside of close to the premises, public taps at a certain distance from the house. drinking water supply is supplied to the end users by the public private water supply which include mainly private tanker supply and bottle water.

5.3 Key issues in urban water management in major Indian cities

The burden of rapid urbanisation and expansion of urban spaces falls on the deteriorating water resources. Also, the issues such as shrinking of water supply, expanding demand, deficit in revenue efficiency, low tariffs on water with high subsidy, rising UFW and poor maintenance of degrading infrastructure are raised from this condition.



Source: Author's illustration

Figure 8 Schematic Diagram of the key challenges faced by Urban Cities

The following section discusses the key issues in management of urban water resources in Indian cities. Figure 8 provide a diagrammatic version of the key challenges faced that are divided based on demand-side, policy based and supply-side issue.

5.3.1 Demand Side Management

5.3.1.1 Operation and maintenance

Operation and maintenance of existing water supply network can prevent losses up to 40%. The challenge of infrastructure is the biggest issue branching out to other issues such as water pricing, unaccounted for water, accessibility and availability, revenue efficiency and other challenges that India is facing. This is to be stressed upon that the units of water resource management are not scattered, they are closely intertwined with one another. For instance, poor infrastructure makes it very difficult for spreading the network of water connection that limits the accessibility to various areas, that is compensated by depending on alternative source like private vendors. These private vendors use groundwater sources and sell the water at higher rates raising the coping cost as well as becoming the biggest reason for declining levels of ground water. But again it is a topic of debate whether to give preference to infrastructure or water supply as our existing water resources are rapidly drying up. Additionally, because of low pricing on water, the revenue efficiency is low resulting in lack of motivation in building refurbishing the infrastructure and also providing better services to the consumers (Rouse, 2013). The diagram below explains one such vicious cycle that water resource management is trapped in.

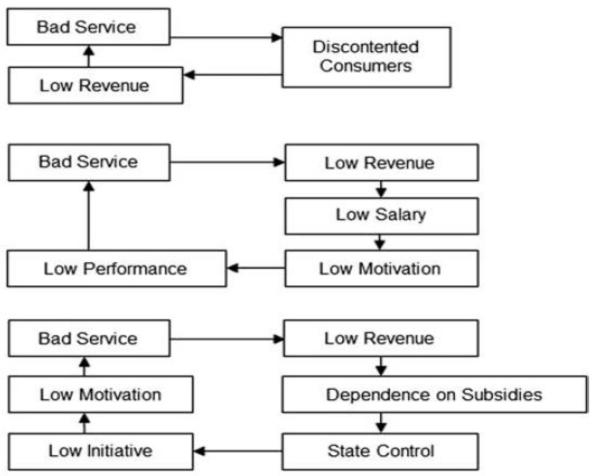


Figure 9 Concerns with resource management cycle

Source: Kontula (2004).

System refurbishment will promote capital inflow for funding the system expansion. And only with refurbished system the goal of supplying additional water could be achieved (Rouse, 2013). Various authors have given suggestion to improve infrastructure.

5.3.1.2 Intermittent water supply

Nearly all water supply channels use intermittent water supply. It is very difficult for the government to provide continuous water supply with increasing burden on resources. Vairavamoorthy et al. (2007) called it *"necessity rather than a design"*, their study pointed out various issues with intermittent supply. For instance, low pressure system is created within the water supply network as the water networks are undersized and greater the flow pattern in pipes; inequity in water distribution of water, as consumer with geographical advantages would get water at higher pressure and hence would avail higher quantities of water creating the inequitable scenario; water contamination occurs due to disrupted water flow pattern with infrastructure having leakages. This situation can be serious in cities as the sewage pipes are open and closer to water supply network. Coping cost, to manage the gap between demand and supply consumer invest in various alternatives like tanker water, groundwater storage, pumping facilities etc., (Vairavamoorthy et al., 2007). It is important to note that intermittent water supply is one of the most efficient way in region with very high-water scarcity and extremely helpful in conserving water.

5.3.1.3 Unaccounted for water

Central Public Health and Environmental Engineering Organisation (CPHEEO) accepts the UFW up to 15%. However, it is very difficult to measure the actual losses in water supply. UFW losses are of mainly two types; one that occurs due to leakages in pipelines or administrative losses and the other is due to water theft and illegal or unrecorded water connections.

Losses due to unaccounted for water and non-revenue water has a major impact on developmental economics. This issue at the very core threatens the sustainability of water resource system. Indian water utilities have the potential for increasing water delivery levels and reducing UFW by 20%, most of the utilities are operating either at constant or decreasing return to scale implying that water should be priced at the marginal cost of supply. The regression revealed that the length of distributional network and percentage of water connection metered are the major determinants of the performance of water utilities. (Kumar, S. 2010). This study gives the results of the various analysis where Ahmedabad, Bhopal, Jabalpur, Varanasi use optimal scale of production. The water utilities of Jamshedpur, Mathura and Mumbai are technically efficient but not using an optimal scale of production. Mathura and Mumbai are over utilising their production plant. The constant return scale for water utilities of Bangalore is at 0.37, Indore 0.39 and Chennai 0.46; Bangalore being the least efficient.

Raj (2013) highlighted the way forward to improve the deteriorating system of water resources, the Phnom Penh city of Vietnam stand as an example in improving their UFW, which was 75% in 1993 and reduced to 9% in 2006 with continuous water supply. This level is better than many European cities. Despite having better technical skills and better management Indian cities are in abysmal condition when it comes to controlling the UFW and non-revenue water (Raj, 2013).

5.3.1.4 Declining revenue efficiency

The lagging infrastructure with burdened water utilities is the result of rapid urbanisation. The problem with provision of water supply in cities is due to failure of urban water bodies to generate funds. Hence, they depend on government support for their financial needs which are not sufficient for managing governance in water resource. Water in most Indian cities and towns is under-priced, with ruining long-run consequences for households who have limited and poor-quality water services and for water supplying entities that are unable to invest and expand water coverage. The cost of delivering water supply in Indian cities is Rs 9-30 per kl, while the average tariff is a meagre Rs 2-8 per kl.

Due to this under-pricing the municipality and state government are not able to even collect the revenue to maintaining the existing water supply network. The standard benchmark for revenue collection efficiency is 100% for better production outcome. Cities like Bangalore, Bhopal, Chennai, Kolkata and Mumbai achieved beyond 100% standards as per the reports of ADB (2007). It is observed that Indian cities lack a uniform system for water tariff. As households in cities like Surat, Guwahati, Vishakhapatnam uses flat rates to charge the supply, while Bangalore uses increased block tariff (IBT) and Ahmedabad uses tariff system based on size of residential property. These kinds of system provide no incentive towards water conservation practices.

Table 4 Cost involved in water supply system for various cities

Cost involved in water supply system for various cities				
City	**Revenue Efficiency (in %)**	**Average Tariff (in Rs/m^3)**	**New Connection fee (in Rs)**	**Capital Expenditure/ Connection (in Rs)**
Ahmedabad	67	1.39	100	427
Bangalore	112	20.55	1740	787
Bhopal	178	0.60	1500	39
Chennai	152	10.87	1930	10080
Kolkata	100	1.13	1000	2247
Mumbai	189	4.60	660	3790
Nagpur	80	6.60	1675	719

Vishakhapatnam	86	8.55	2000	3891
Source: ADB (2007)				

5.3.1.5 Degrading water quality

Water quality is the most crucial issue with management of water resources. A study done by CSE in 2003, found that even sealed and branded bottled water has high levels of pesticides and hence unsafe to drink (McKenzie and Ray, 2009). Also, the water quality of groundwater is degrading, the levels of fluoride and toxic heavy metals exceeds 48mg/l (the acceptable limit is 1mg/l according to WHO guidelines) in the regions of Andhra Pradesh, Gujarat, Rajasthan where around 70-100% district are affected by it.

5.3.1.6 Water metering

Water metering is crucial for maintenance of cost recovery. As water metering provides positive incentive for both the supply and demand side. McKenzie and Ray (2009) suggested in their paper, introduced the technique of Increased block tariff (IBT), this would enable the municipal corporation to set operational and maintenance charges. As this technique, keeps the low-level usage at lower tariff rate and beyond a certain usage the tariff rises. This allows inclusion of poor household in revenue collection; the system manages to subsidize poorer household by wealthy people. However, this technique requires investment for new meters and maintenance of existing working meters (McKenzie and Ray, 2009)

5.3.2 Supply Side Management

There are also barriers on the supply side management like lack of metering, lack of municipal capacity, lack of maintenance, non- volumetric water tariff resulting in less cost recovery. Ten cities have been benchmarked to achieve a green growth path like water supply connection coverage, adequate and continuous water supply, reduction in non-revenue water losses, reduction in groundwater reliance. (ICLEI-South Asia, 2015)

5.3.2.1 Water coverage

This study has shown that the water consumption in major Indian cities is far less than the standards laid by the Bureau of Indian Standards. The main cause behind this is the increasing population which has raised the need of water supply. However, even though the water consumption standards are lower than the prescribed, majority of households has shown satisfaction towards the amount of water supplied to them. This is due to their adaptability towards the provided water supply which has contracted their usage of water in daily life. The study shown that the mode of use of water varies across the socioeconomic classes within the cities, the difference is around 20 litres between the higher and lower socioeconomic classes.

5.3.2.2 Water availability

Water availability in urban cities ranges from 2-4 hrs to 24 hrs. However, India still has not reached to 24hrs water supply system while Bangkok and Beijing have reached success to supplying 24 hours water and earning positive revenues from it. India faces issues like low and irregular pressure, quality challenges and financial losses making it difficult for both the supply as well as the demand side to cope. Observation reveals the consumer behaviour with 24hrs water supply uses less water while others consume more water, as they tend to collect water and discard it when freshwater is supplied (McKenzie and Ray, 2009). The study also revealed that only around 18% of the total household in a city gets 24 hours of municipal water supply. Because of this inequitable supply pattern people tend to look for other water sources like private vendors also resulting in emergence of black water market. Not only the less hours of water supply but also the inappropriate timings raise issues and burdens the urban women (Singh and Prakash, 2016). Table 5 represents the city-wise frequency of water supply. Cities like Rajkot and Indore provides less than an hour of water supply, while Amritsar provides 11 hours of water supply. Major towns like Bangalore and Ahmedabad manages to supply less than 5hours of water supply daily.

As per the census 2011, 70% of the households have access to piped water still there is outbreak of various water borne disease like cholera, typhoid etc. this is due to intermittent water supply which provides opportunity to contamination to breach in water supply channel resulting in chronic contamination in supplied water. Therefore, coping is the only way out. They use 5 basic methods of coping: Collecting, Pumping, Treating, Storing and Purchasing (Pattanayak, 2005).

Table 5 City-wise water availability of supplied water in hours

City-wise water availability of supplied water in hours								
City	**Ahmedabad**	**Bangalore**	**Bhopal**	**Chennai**	**Indore**	**Rajkot**	**Varanasi**	**Amritsar**
Water Availability (in Hrs./day)	2.0*	4.5**	0.5-1.5+	5.0*	0.75*	0.3*	6.29#	11*
*** ADB (2007) # Singh (2017) ** BWSSB (n.d.) +(Mahadevia, Bhatia, and Sebastian 2019)**								

5.3.2.3 Accessibility

Census 2011 reports approximately, 71% of urban household having access to drinking water within premises and only 8% collects water from more than 100m from the houses. Even though almost all urban household has access to drinking water but the crux is maintaining consistency and sustainability with an equitable supply of water (NIUA, 2015). As per the recent reports, through various policy interventions like AMRUT 48.82 lakh household has tab water connections with a target to reach 139 lakh household. Among the states represented in the table, Punjab is ahead of other states i.e. around 62% in terms of tap/piped water connection within premises. As an UT, Delhi is ahead of Punjab with around 68% tap/piped water coverage but also has the highest dependency of 13.56% on tanker truck/cart with small tank. While states like Assam, Madhya Pradesh, Rajasthan and Punjab are the top states extracting groundwater aquifers by boreholes/tube wells.

5.3.2.4 Ground water level decline

The ground water level is declining at the rate of 10 cm per year. Over 70 per cent of surface water and groundwater resources are contaminated. All this is leading towards a water scarce situation in many parts of the country. Inability to meet the needs of growing population led to emergence of private vendors that are satisfying the needs by extracting groundwater aquifers at mass scale. The decline in groundwater level and emergence of private vendors is a very intricate and interdependent relationship. Unfortunately, in India, groundwater is a common pool resource leading to over exploitation of aquifers. There is an absence of any government regulation restricting the extraction of ground water resources by the tanker water market. However, in Chennai due to rapid and large-scale extraction of ground water government-imposed restrictions India has been investing in technical advancements for the improving food security by increasing yield of food grain, pulses and other vegetables through development of dams, storage units, canals. Government has been investing understanding the huge stress because of the rapidly growing population and increasing burden on groundwater to fulfil the needs (TERI, 2014).

5.3.2.5 Dependence on alternatives: Private vendors

Metropolitans and nation capital like Delhi rely 13.46% on tankers or private vendors. Private vendors basically either resell the water collected from the water supplied by municipality at higher rates or rely on groundwater extraction. However, it is very important to note here that they play a crucial role in filling the demand supply gap left by the urban local agencies and reaches to the remotest regions of the country. For instance, in Chennai, the water boards spend 10% annually on hiring and monitoring these tankers (McKenzie and Ray, 2009). When the condition of cities examined, big cities depend on municipal services while smaller towns depend on groundwater. Due to less of water supply then the demand there increase in unregulated water bodies like tankers.

As per the consumption pattern, high income household, around 51% rely on tanker water system, while middle class shares 43%- and lower-income household has a small portion of 6%. In six cities examined by Londhe et al. (2004) it is found that private vendors have large scale water economy of Rs 203 crores with about 3000 tankers of various capacity. From Table 6, representing the comparative rates of eater supplied and still this kind of reliance on them reflects the worsening condition of urban water bodies enable to manage the water resources. Cities like Chennai and Bangalore requires a staggering 1000 and 700 tankers respectively to fulfil the need of growing population (Venkatachalam, 2015).

Table 6 A summary of tanker economy in six urban cities

A summary of tanker economy in six urban cities.						
City	**Indore**	**Nagpur**	**Jaipur**	**Ahmedabad**	**Bangalore**	**Chennai**
No. of tankers	300	240	350	550	700	1000
Capacity (in litres)	14000	5000	4500	4500-6000	6000	12000
Volume of water sold (in MLD)	20	14	22	18	37	55
Price (Rs/kl)	30-40	60-90	20-30	30-50	30-40	50-60
Price paid to local water supply body (Rs/Kl)	6	3-4	1.2	NA	IBT	NA
Source: Londhe et al. (2004)						

5.3.3 Policy based Management

Policy is crucial in achieving a balance between water demand and supply and further to reach a water management system to ensure protection, conservation and regulation of water resources. However, in the case of India water policy are meagre guidelines and hold no legalisation/ executive backing to ensure they are being followed. Water is a limited resource and to make the distribution equitable and sustainable there are various policies such as National water policy, national water mission etc., and this section discusses the major lacunas from the policy side of management.

5.3.3.1 Institutional coordination

There is a lack of institutional coordination in India. For instance, irrigation projects are planned and implemented without consulting the water supply projects. Similarly, surface water distribution, networking and planning is done without consulting groundwater department. Water shed projects are done without using the insights of the studies from catchment hydrology. This all proves that efforts are made but they are scattered and limited. There are no agencies allocated for the development at basin level.

5.3.3.2 Research gaps & data limitation

Data limitation is a major issue in examining the actual status of water supply. This does not provide the opportunity for further research and analysis of existing limited data would either give incorrect result or result with loopholes in them. For any policy to work, it requires a strong support from research and data side, as data act as a catalyst between them. Big cities like Surat, Guwahati, Ahmedabad have no data on non-revenue water, while small towns like Kakinada and Devangere lacks the basic data of water supply. Either the available local level data is scattered or it is not available at all. This provides negative incentive for researcher to work on such data. Data is limited on storage, groundwater, water flow even rainfall levels. And the available data is limited to water coverage, robustness and efficiency. It is to be noted here that data on domestic and industrial is only available at aggregated level. And the use of out-dated equipment raises suspicions on the accuracy of existing data, hence unreliable. The need for reliable baseline data enables the regulatory and monitoring of water supply services more efficient.

There are many cities in which up to 50% of the potential customers are not noted down in the main database due to inefficient administration. Also, the operational policy of the cities does not charge individually in a multi-storey building. Also, it difficult for the local provider to serve to each household due to limited connection network. The absence of data is the fundamental weakness in the water resource management of India.

5.4An overview of Irrigation System in India

The history of irrigation system can be traced back to prehistoric times when agriculture was practiced by mankind. Some of the ancient texts like Veda referred to wells, ponds, and canal used for irrigation during that time, and responsibility for maintenance and efficient operation was on the community members (Mandavia 1999).

The irrigation system development gained momentum in the post-independence era. The net irrigated area in 1950-51 was 20.85 million hectors (mha), with 1.71 mha irrigated during more than one crop season, whereas the gross irrigated area was 22.6 million ha (ibid). In the first five-year plan, Irrigation had the highest priority, which resulted to build some multipurpose and projects such as Bhakra Nangal in Punjab, Damodar Valley in Bihar and Hirakund in Orissa (Planning Comission 1951). The net irrigation area has been increased to 68.38 mha and 96.45 mha gross irrigation area in 2015 (Directorate of Economics & Statistics, 2015).

India is an agricultural country where more than seventy percent of people are dependent on agriculture directly or indirectly. The agricultural activity is mostly dependent on the southwest monsoon from June to September. The average precipitation in India is about 1,120 mm i.e., slightly more than the global mean of 900 mm. The strong dependence of Indian agriculture and the economy of the country on the monsoon is well established (Singh 2015). However, variation exists in the received amount of rainfall across the country but the precipitation is received during the southwest monsoon is very important as the country's agricultural production is dependent on its quantum and distribution.

As discussed, the south monsoon distribution is highly skewed, but the country can also rely on many rivers whose catchment area is about 252.8 mha (ibid, p.240). The country's water demand is dominated by irrigation needs. The irrigation infrastructure includes canals from rivers, groundwater extraction through borewell or tubewell or open well, tanks and, other rainwater harvesting products for agriculture activities. 160 million ha land is cultivated irrigation system in India till 2013 with 39 million ha irrigated by groundwater, 22 million ha by irrigated canals, and about two-thirds of cultivation in India is still depending on monsoon (Ali and Dkhar 2019).

The irrigation demand is dependent upon the areas irrigated with surface water and groundwater, different crop water requirements, and irrigation application efficiency. The irrigation efficiency ranges from a low of 31 percent where most of the area is surface irrigated to a high of 62% where most of the area is irrigated from the groundwater (Singh 2015, p.242). The groundwater is becoming increasingly popular because of the relative flexibility and ease of access. Many observers argue that a cubic meter of groundwater creates several times more income than a cubic meter of water from the large surface irrigation system. The groundwater irrigation schemes contribute more than 72% of the total ultimate potential through minor irrigation[55]. Uttar Pradesh, Bihar are two states in northern India along with Madhya Pradesh, Andhra Pradesh and Maharashtra which accounts for 58% of the total ultimate potential of major and medium irrigation in the country.

The environmental factor such as solid condition and weather are some important factor for crop growth and development. For instance, during Kharif season (July to October) when temperature is equable, the quantum and distribution of rainfall is an important to factor for crop development. Similarly, during the Rabi season (October to March) temperature regime during the reproductive phase becomes critical. At the same time, the quality of water also plays an important role in crop growth and development. The groundwater in the arid and semi-arid regions of Haryana, Punjab, Rajasthan and Gujarat are saline and brackish. In the process of crop growth and development, the salinity of the water has to be monitor to keep within the limit. If the salinity of water goes beyond the limit, then the plant has to work harder to observe the water from the soil. Also, the saline water reduces the yield. Toxicity problems occur if certain constituents (ions such as chloride, sodium and boron) in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and crop sensitivity. The sensitive crops are often more vulnerable to even low ion concentration. It is usually first evidenced by marginal leaf burn and interveinal chlorosis. If the accumulation is great enough,

[55] The irrigation schemes are classified as major, medium and minor depending on their culturable command area (CCA) which are more than 10,000 ha, between 2,000 to 10,000 ha and less than 2,000 ha respectively.

LOTUS is co-funded by the European Commission under the Horizon 2020 research and innovation programme under Grant Agreement N° 820881 and by the Indian Government, Ministry of Science and Technology.

reduced yields result. The more tolerant annual crops are not sensitive at low concentrations but almost all crops will be damaged or killed if concentrations are sufficiently high (Department of Primary Industry n.d.).

There are several other problems that occurs due to water irrigation quality. These include high nitrogen concentrations in the irrigation water which supplies nitrogen to the crop and may cause excessive vegetative growth, lodging, and delayed crop maturity. Water containing gypsum, or water high in iron, and various abnormalities often associated with an unusual pH of the water. Suspended organic, as well as inorganic sediments, cause problems in irrigation systems through clogging of gates, sprinkler heads and drippers. They can cause damage to pumps if screens are not used to exclude them. More commonly, sediments tend to fill canals and ditches and cause costly dredging and maintenance problems. Sediment also tends to reduce further the water infiltration rate of an already slowly permeable soil (FAO n.d.).

5.5 Analysis: main barriers and opportunities for LOTUS project at the national level

India's socioeconomic context is of great importance to understand the water relevance for the country's progress achievement in many fields from food security, sustainable rural development and rapid urbanisation to the adaptation to climate change, water pollution and equitable allocation of the natural resource. Every challenge or opportunity must be analysed having considered the cultural, social, economic and political fabric of India.

5.5.1 Barriers[56]

India has one of the world's biggest population (17%) but only 4% of the world's water resources[57]. The rapid population growth, urbanisation and changing lifestyle increase the demand and creates great challenges to water security. Besides, low consciousness about the overall scarcity and economic value of water, as well as inadequate maintenance of existing irrigation infrastructure, result in its wastage and inefficient use. In addition, the country faces a monsoonal climate that changes the amount of water available during the year and according to the regions. Moreover, climate change and incidences of water-related disasters, such as floods and droughts pose a serious problem for many places in India.

[56] Many of the challenges were identified through the National Water Policy report made by the Government of India – Ministry of Water Resources in 2012. Report available in http://mowr.gov.in/ . Consulted in 06/03/2019.
[57] Government of India, Ministry of Water Resources, River Development and Ganga Rejuvenation, National Water Mission and the European Commission. *Indo-European Water Forum. Summary of Event's Presentations.* 23-24 November 2015. p. 18. Available in https://www.eip-water.eu. Consulted in 06/03/2019.

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However, India's challenges regarding water are not exclusively quantitative: the country faces barriers when it comes to water quality, the main issue approached by LOTUS. Since harnessing the rain is difficult, groundwater is the greatest source to irrigate agriculture (70%) and drinking water supplies (80% in rural areas and 50% in urban areas)[58]. Nonetheless, the contamination and depletion of groundwater is a major cause for concern in India and its finite storage is one of the great challenges that authorities in the country face: specialists warn that, by 2020, 21 cities in India might run out of groundwater[59] due to a culture that perceives groundwater as an individual property without regards on sustainability and leading to an overexploitation of this source.

Although many states have been making progress in improving the quality of water, states ranking the lowest (Uttar Pradesh, Haryana, Bihar, and Jharkhand) are also India's most populous regions and centres of agricultural production[60]. Besides groundwater mismanagement, growing pollution of river basis due to extending industrialisation poses a serious challenge in India, causing environmental and health hazards. In many parts of the country, large stretches of rivers are both heavily polluted and devoid of the required flows to support aquatic ecological and, cultural requirements[61].

In short, almost 70% of the generated wastewater flows into the freshwater resources untreated[62]. Due to the pollution of the main sources for drinking water and other domestic needs, and added to the fact that the country does not have a solid infrastructure to transport water across regions, many Indians, both in rural and in urban areas, do not have access to clean and safe water for personal use. In addition, the lack of sanitation facilities leads to open defecation problem and contributes to the impossibility of water consumption[63].

Furthermore, when it comes to issues related to water governance, those have not been addressed adequately in India. According to the Ministry of Water Resources, the mismanagement of water resources has led to a critical situation in many parts of the country. In addition, there is a shortage of trained personnel for scientific planning, utilising modern techniques and using analytical capabilities incorporating information technology. The situation becomes even more difficult in India due to inter-regional, inter-state[64] and intra-state disputes for water. Water is ruled at the state level with a

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[58] Government of India, Ministry of Water Resources, River Development and Ganga Rejuvenation, National Water Mission and the European Commission. *Indo-European Water Forum. Summary of Event's Presentations.* 23-24 November 2015. p. 18. Available in https://www.eip-water.eu. Consulted in 06/03/2019.

[59] NITI Aayog. *Composite Water: Management Index, a tool for water management*. June 2018. Available in https://niti.gov.in. Consulted in 06/03/2019.

[60] NITI Aayog. *Composite Water: Management Index, a tool for water management*. June 2018. Available in https://niti.gov.in. Consulted in 06/03/2019

[61] Government of India – Ministry of Water Resources. *National Water Policy.* 2012. Available in http://mowr.gov.in/ . Consulted in 06/03/2019

[62] India-EU Partnership. *Opportunities for EU Businesses in the Indian Water Sector*. 2018.

[63] India-EU Partnership. *Opportunities for EU Businesses in the Indian Water Sector*. 2018.

[64] Under the Inter-State Water Disputes Act of 1956, the central government has established several Tribunals to deal the interstate water conflicts. BHATT, Neelkanth J., BHATT, Kapil J. *An Analysis of Water Governance in India: Problems and Remedies.* International Journal of Advance Engineering and Research Development, 2017.

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legislative dispersion. Even if at the national level great initiatives are being created, the actual implementations of frameworks, funding, action plans and schemes are done in the state and municipal level, which creates a dispersion of such policies and generates an absence of holistic approaches on the water matter[65].

Moreover, for European partners, the access to information in India can also present a challenge, given that the information on relevant departments, boards and authorities as wells as projects owners might not be easily accessible. There are various government functionaries dealing with water in different states. Therefore, it can be hard to identify the right stakeholder to approach in a given moment of the project. The country also has a slow legal enforcement in general and sometimes lacks transparency. In terms of doing business, there is low return of investment in the initial five to ten years for companies installed in India due to the high level of adaptability, administrative challenges and cultural barriers[66].

Regarding LOTUS and its goal, a great challenge concerns the increasing number of competitors in the market. As presented above, there are many actors in India offering water quality measurement and management solutions. Since the challenges are various, the interest in the subject is constantly growing. Three main sectors that are linked to water are also ought to be highlighted[67]. Firstly, the agriculture and irrigation actors are the main users of water resources and contribute greatly to its misuse, especially when it comes to thirsty crops like sugarcane, cotton, and rice[68]. Secondly, the electricity sector is of great importance in India, where 13% of the total energy production comes from hydro sources, this being one of the greatest players on the water subject in the country[69]. Thirdly, the beverage sector[70] in India also presents some challenges for LOTUS because increasing health concerns and unavailability of clean drinking water have led to the growth of the bottled water market in India[71].

5.5.2 Opportunities

India also present opportunities for the project's development and success. Firstly, it is important to highlight the political will on the subject: water has been on the international community's agenda for decades now and, in India, the awareness on the subject has increased in the last few years, so that

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[65] Government of India – Ministry of Water Resources. *National Water Policy.* 2012. Available in http://mowr.gov.in/ . Consulted in 06/03/2019

[66] India-EU Partnership. *Opportunities for EU Businesses in the Indian Water Sector*. 2018.

[67] The most polluting sectors – Sugar, Distilleries, Pulp and Paper, Tanneries, Dyeing, Textiles, and Dairy – have already been presented, but, at this point, the agriculture, electricity and beverage sectors are being addressed as the ones that may present a more direct concern on water-related projects.

[68] WWF. *Sustainable Agriculture*. 2016. Available in https://www.wwfindia.org/

[69] Some of the greatest actors in the hydroelectric production are NTPC, Tata Power, NHPC, CJVN Limited, Reliance Power and CESC Limited. India Brand Equity Foundation. *Power*. March 2019.

[70] Some of the most important actors in the beverage sector are Bisleri, Coca-Cola India, PepsiCo India, Dharibal Group, Narang Beverages, Aquaguard, Himalayan and Kingfisher. Euromonitor International. *Bottled Water in India*. April 2019. Available in https://www.ibef.org. Consulted in 06/03/2018.

[71] Research on Global Market. *Bottled Water Market in India 2017*. Available in https://www.researchonglobalmarkets.com/. Consulted in 06/03/2019.

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the implementation of water-related projects is very well welcomed by the public and private sectors in India, as well as by its population and direct beneficiaries. Since the topic has called much attention upon, there are possibilities for partnerships. Just as many actors in the market may present a competition risk, it can also mean that LOTUS might find many initiatives with sharing goals and synergies looking forward to developing bonds and partnerships that can accelerate and facilitate its execution.

Moreover, the initiatives put in place both by the Government of India and the European Union in partnership with India optimised the development of water-related projects such as LOTUS. For instance, the IEWP organises annual programmes of knowledge sharing sessions and workshops on project models, financing, transfer of technology, state investment opportunities for developing projects. It also offers guidance on project structuring for selected municipalities in India, identification, and creation of relevant project opportunities and viable financing models in consultation with development banks, funds and similar stakeholders. In addition, the IEWP provides updates and feedbacks sessions and the research and innovation partnership provides regular meetings for closer engagement and transfer between partners and projects[72].

In addition, India offers a favourable context to innovate. India is one of the top-ranking countries in the field of basic research, according to the Department of Science and Technology[73]. Also, according to the DST, Indian Science has been a great tool of growth and development for the country and its placement in a developing and changing world. Besides, due to various reforms and government initiatives from 2014 onwards, the Indian market has become more conducive for foreign business. When it comes to water, it is important to add also the population wants and needs projects such as LOTUS. Indeed, India has a considerable rural population in need of water management tools for agriculture, an increasingly urban population demanding clean water for domestic use, as well as polluting companies that need to comply to the Zero Liquid Discharge policy and reduce water waste and pollution. Moreover, municipalities need help to treat the increasing load of municipal sewage flowing into water bodies without treatment. The Indian population needs initiatives that can offer water quality measurement and management as well as treatment and distribution, all of each are approached by LOTUS. Furthermore, India has a great market opportunity given that clean and safe water is scarce, and the country faces a water crisis that only tends to aggravate within the next few years. This is the reason why alternative solutions are being tested and are welcomed by Indians, given the examples of micro-irrigation and evapotranspiration as alternatives to water pollution and scarcity[74].

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[72] India-EU Partnership. *Opportunities for EU Businesses in the Indian Water Sector*. 2018.

[73] Department of Science and Technology. *About us*. Available in http://www.dst.gov.in/. Consulted in 06/03/2019.

[74] The first one was a solution executed in India after recurring droughts in 2012, 2015 and 2015 especially in arid and semi-arid regions where groundwater is the primary source of water. The policy did not achieve success due to its ill-conception, non-holistic approach, and disintegration from the basin/watershed perspective given that small farmers often do not have access to the technology necessary to apply micro-irrigation solutions. For LOTUS, this can be viewed as an opportunity since its low-cost and more accessible technology can offer what

Barriers	Opportunities
•Problems with water governance •Regional and local disputes •Policies dispersion •Information's access difficulty •Slow legal enforcement •Low Return of Investment •Numerous competitors	•Water Scarcity •Water wastage and inefficient use •Monsoonal climate and climate change •Contamination and depletion of groundwater •River basis pollution •Absence of solid infrastructure for water transport •Lack of sanitation facilities •Political will •Various possibilities for partnerships •Governmental initiatives •EU-India cooperation initiatives •Market openess to foreign business •Great market opportunity •Great demand from various actors (urban and rural population, municipalities etc.) •Openess to new initiatives in the water field

Figure 10 Barriers and opportunities for LOTUS in India

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the micro-irrigation could not. This is relevant to this audience that is willing to change perspectives on how to have access to quality water when facing environmental challenges.
Alternatives such as the cultivation of low Evapotranspiration (ET) crops in place of water intensive crops across arid and semi-arid regions of India, virtual water trades, and water markets cause real water savings with little cost. Global Water Forum. *Micro-irrigation in India: An assessment of bottlenecks and realities.* 2017. Available in http://www.globalwaterforum.org

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6 Ecosystem of water provision in the four use cases under LOTUS

6.1 Description of the two use cases for Guwahati (Sensor based water quality monitoring)

LOTUS has two use cases in Guwahati. One is about the improvement of the city water supply system and distribution, used by about 30% of the urban dwellers. The other case is about the water taken from borewells, used by about 70% of the population, who are not connected to the water distribution system.

6.1.1 Guwahati water supply system and distribution

Guwahati is the largest city in the state of Assam, located in the North-East of India. The city has developed along the Brahmaputra river banks. The city is expanding along three corridors which radiates from the urban core, located on the riverbanks. Guwahati is one of the fastest growing cities in India with an estimated 2.8 million residents by 2025. The city takes water mainly from the Brahmaputra river. Groundwater contributes almost nil to the main city water supply. The raw water from the river is treated and supplied through the pipelines. There are around 12 water treatment plants located in the Guwahati Municipal Corporation (GMC) area. The total installed capacity of these WTPs is 96 MLD. The total supply of water, in addition to the treated water, is 103 MLD of which 90 MLD is provided by the GMC. According to the census of India (Census, 2011), the population of Guwahati is around 0.96 million, the total demand of pipe water is about 160 MLD (considering CPHEEO guideline of 150 LPCD for the city). This shows there is a sharp demand-supply gap for drinking water supply in the city. Table 7 represents the current status of Guwahati water supply.

Table 7 Status of Water Supply in Guwahati

Status of Water Supply in Guwahati	
Population (Census 2011)	1,246,082
Production Capacity in MLD	110.85
Actual production in MLD	73.4**
Unaccounted for Water (in %)	40
Per Capita Availability (in LPCD)	35

Average Supply Per Day (in hours)	2-3
Source: Assam Urban Infrastructure Investment Program(www.auiip.nic.in) (this involves pipeline leakages and other damage and issues leading to water loss)**	

Guwahati also faces a problem of irregularity in water supply, with sharp seasonal variation. Further, the quality of water is also a concern in the city, particularly during the monsoon season. In general, the water has high turbidity levels, especially during the monsoon season as the water carries a large amount of silt therefore the settlement process takes longer than usual (GMC, 2006). During the floods, polluted water enters into the water distribution pipes through the cracks and holes in the old pipes which reduce the water quality further. The intermittent water supply also does not help with the water quality.

Water supply in the region is managed by the public health and engineering department (PHED). In the municipality areas of the city it is also managed by the GMC, and in the surrounding areas the Assam Urban Water Supply and Sewerage Board jointly supplies water. It needs to be noted, not every resident of the city has access to piped water and the use case focuses on households which have access to the water distribution network. The Guwahati Water Distribution Network is managed by the Guwahati Metropolitan Drinking Water & Sewerage Board (Guwahati Jal Board), established in 2011 to *"promote uninterrupted, hygienic, piped drinking water and encourage a hygienic environment in the Guwahati Metropolitan Area (GMA)"*.

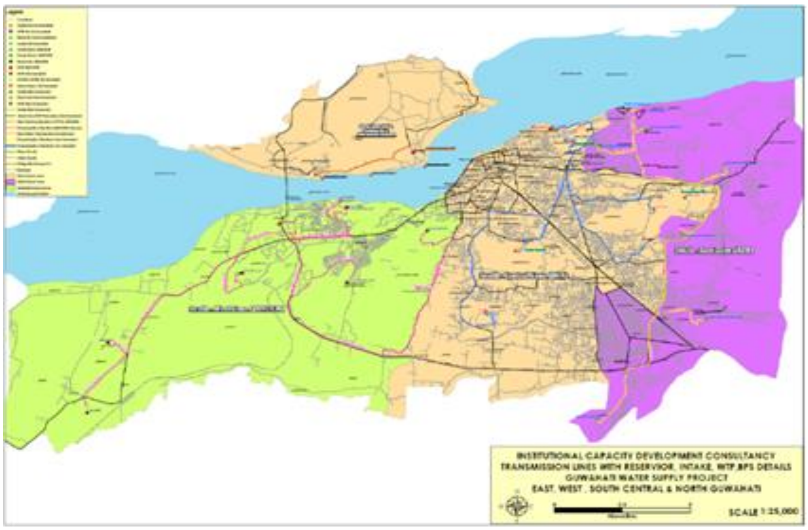

Figure 5.1: Water Distribution Network in Guwahati

The water distribution network is divided in four zones:

- South Central-zone, which covers Guwahati urban core and the southern corridor
- The South-West zone
- The South-East zone
- and the North zone (on the other side of the Brahmaputra river)

The project will first address water quality in the Southern Central zone. It will then be extended to all other three zones.

6.1.2 Guwahati groundwater management

Only 30% of the population of Guwahati have access to piped-water supply (Das and Goswami, 2013) and the existing facilities has outreached design life and running below the capacity of Water Treatment Plants (JNNURM, 2006). However, the area is abundant with groundwater at a shallow depth of 2-4 m, therefore encouraging the use of dug wells, hand pumps or bore wells (Das and Goswami, 2013). Several researchers, however, have expressed concerns towards groundwater quality with regards to iron, fluoride, nitrate and arsenic contaminations in various regions of Assam (Chakrabarty and Sarma, 2011; Chetia et al., 2011).

As per WHO guidelines, arsenic in drinking water should be below 10 mg/L (WHO, 2008) and as per the Indian standards the desirable limit is 10 mg/L and permissible limit is 50 mg/L (BIS 10500, 2012). It is well documented that high levels of arsenic exposure cause chronic health effects which include cancer, skin pigmentation, skin lesions, respiratory, neurological and haematological effects in human (Ahmad and Bhattacharya, 2019; Sogbanmu et al., 2019). As per WHO guidelines and BIS permissible limits, fluoride in drinking water should be below 1.5 mg/L (WHO, 2008). The major health problems caused by excessive fluoride are dental fluorosis, skeletal fluorosis, and deformation of bones in children as well as adults (Marya et al., 2014).

In response to the poor water quality the Ministry of Urban Development, Government of India has initiated various projects to improve the situation but many of these water supply schemes fail in terms of public acceptance. This is primarily due to lack of public awareness, transparency on water tariff policy, and angst of water privatisation. A recent study by Das et al. (2019) has found that the public perception on groundwater quality was far away from reality, only 3-4% of people being aware of contamination and the rationale for public opposition were more of public misconception. Public awareness on groundwater quality and its adverse health effects were found to be the most influencing factors affecting public willingness to procure (maximum amount an individual is willing to sacrifice to pay for a good) improved from 58 to 74% after creating awareness.

Monitoring water quality will enable people to know if the water quality is high enough to drink. When there is heavy rain, people think that the groundwater is recharged and that the quality is increased. But in reality, it causes water to move underground and can cause Arsenic leaching. A system is required to monitor and tell people if the water is safe to drink. Currently, the ground water quality data is collected manually, for a few parameters such as temperature, level and total dissolved solids (TSD). Samples are collected by the Central Water Commission. It is monitoring water quality at 531 key locations covering all the major river basins of India, including Guwahati. Data is stored by the Public Health Department and is accessible for all.

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Since the dependence on groundwater is far more than the surface water, various studies (Singh et al.,2017; Islam et al., 2014; Khadse et al.,2010) have analysed the quality of groundwater in the city of Guwahati. Singh et al (2017) analysed the issue of contamination of drinking water that is drawn from the groundwater sources. The water analysed for the presence of heavy minerals and other common parameters like pH, Turbidity, alkalinity, and conductivity. The consumption of heavy minerals larger than the prescribed limit may cause life-threatening toxic effects, therefore, it is very important to analyse the limits of various minerals such as iron, fluoride, magnesium, calcium, chloride, arsenic. From the eight locations where the research is conducted, it was found that almost all the eight locations have high levels of iron, reaching to the level of 8.59mg/l while the permissible limit is 0.3mg/l. two of the location have high fluoride levels. The rest of the parameters were within the permissible limit.

However, the increased level of iron and fluoride makes the water unsafe for the purpose of drinking. Excess consumption of iron may cause various health issues ranging from minor pain in stomach to ulceration, liver cirrhosis and brain damage in some cases. Khadse et. al. (2010) studied the quality of drinking water from the treatment stage until it reaches the consumer. The study observed a contamination of drinking water during the process of supply and at the point of use. Due to the lack of maintenance of the reservoir, the contamination by various pathogens was higher. The study emphasizes the need to use disinfectants before using the water for domestic purposes. Another study assessed the groundwater quality in the region of greater Guwahati by dividing it into five different zones. The study found the chloride levels in 2 of the zones were on the border to cross the permissible limit. Moreover, turbidity levels in the eastern zones make it mandatory to filter the water before drinking (Islam et. al., 2014). These studies reflect the condition of groundwater in the city of Guwahati is unsafe for drinking.

Table 8 Key parameters for water quality for the city of Guwahati

Key parameters for water quality for the city of Guwahati						
Parameters	BIS Standards	Drinking water quality	Ground water quality			
			North-zone	East-zone	West-zone	South-zone
Chloride	250 mg/L.	NA	✓	×	✓	×
pH	6.5 to 8.5	NA	×	×	×	×
Hardness	300 mg/L	NA	×	×	✓	×
Calcium	75 mg/L	NA	×	×	✓	×
Turbidity	10 Nephelometric turbidity units (NTU)	NA	×	✓	×	×
Iron	1.0 mg/L	NA	×	✓	×	✓
Alkalinity	200 mg/L	NA	×	×	×	×

Fluoride	1.0 mg/L	✓	NA	NA	NA	NA
Arsenic	0.01 mg/L	✓	NA	NA	NA	NA
Nitrate	45 mg/L	✓	NA	NA	NA	NA
NA: Data not available, ✓: exceeding permisible limit, ×: within limit						
Source: Chakrabarty & Sarma (2011), Islam et al.(2014)						

6.1.3 Relevant stakeholders for Guwahati Water Supply

There are public-sector, multilateral entities and local bodies playing an important role in the management and equitable distribution of water resources. In addition, these major stakeholders are linked with numerous NGOs, private sector for the supply of drinking water. Figure 11 attempts to depict the stakeholder mapping of the water supply in Guwahati.

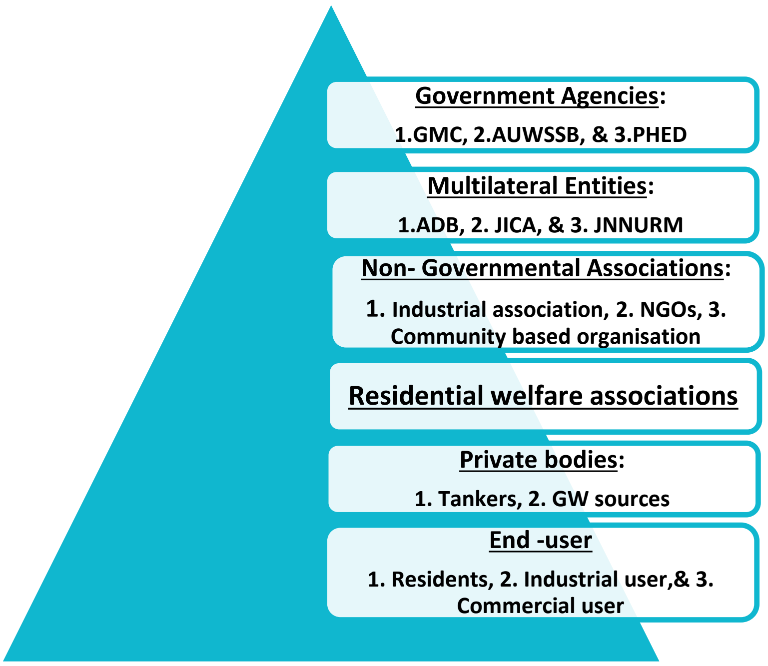

Figure 11 Stakeholder Map for Guwahati Water Supply (Source: Authors illustration)

6.1.3.1 Local water utilities

Non-Profit organizations: Non-Governmental organizations (NGOs) also play a major role in the conservation of water and rainwater harvesting in the water scarce periods. Capacity building and adaptation practices are built within the people with the help of NGOs that is important in the face of deteriorating water quality.

Private water supply: private water tankers and private bore wells, tube wells are the main sources of water to fulfil the domestic needs of the people in Guwahati. Private tankers supply water drawn from either groundwater source or municipal feeders supplying it to the outskirts of the city and to the places where the water supply network is not available.

6.1.3.2 Final users

The people that will be benefiting from this improved water distribution system are middle/upper class people who are well educated. They live in the South West zone, the most developed part of the city, connected to the city centre. They speak English and the second official language of the region, Assamese.

They are aware of the water quality issues and have the finances to find other ways to have water in the home, for example by purchasing bottled water. Even with new technology, they may be sceptical over drinking water from the taps due to the possibility of contamination and the risks of water borne diseases.

On the other hand, the population targeted by the groundwater management use case is characterised by low incomes and lower levels of education, even though some middle class people may also take their water from borewells. This is important to keep in mind because people may not know what e.g. fluoride is. Contrary to the users of the Guwahati Distribution Network users who are middle income and educated households, it is likely that they have a low access to drinkable water, for several reasons: lack of access, lack of money and lack of knowledge. Most of the houses have hand pumps followed by tube wells and dug wells.

The people that will be benefiting from this use case are in the lower and middle socio-economic bracket, with a mix of education levels. They will speak a mix of English and the second official language of the region, Assamese. Hinduism is the main religion in Guwahati city with 85 % and Islam is second with approximately 12 % following it.

6.1.3.3 Governmental bodies

The supply within the city of Guwahati is managed across three departments:

(i) Guwahati Municipal Corporation (GMC),
(ii) Assam Urban Water Supply and Sewerage Board (AUWSSB), and
(iii) (Public Health Engineering Department (PHED).

In addition, there are townships in the city area mainly run by railways, refineries and defence authorities. These townships have their own WTPs as well as distribution systems. The water production from the water treatment plant is represented in

Table 9.

Table 9 A Detailed Representation of WTP and the Executing Authority

A Detailed Representation of WTP and the Executing Authority				
Location of Water Source	**Water Treatment Plant**	**Authority**	**Installed Capacity (in MLD)**	**Present Capacity (in MLD)**
Panbazar	Panbazar	GMC	45	22.50
Satpukhuri	Satpukhuri	GMC	22.50	15.75
Kamakhya	Kamakhya	GMC	4.50	3
Satpukhuri	Zoo road	GMDW & SB	12.60	7.50
Panbazar	Panbazar	PHED	11.25	12.15
Pandu	Gauhati University	PHED	4.50	4
Pandu	National Games Village	PHED	3	3
Amingaon	Guwahati North	PHED	4.50	4.50
Pandu	Sadilapur	GMDA, funded by JNNURM	107	Under construction
Kharghuli	Kharghuli	GMDA, funded by JICA	191	Under construction
IOCL Gate, Sector-I, Guwahati Refinery	Chanshali	AUIIP, funded by ADB	98	Under construction

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Mazgaon	Mazgaon	GMDA, funded by JICA	37	Under construction
(Source: Guwahati Municipal Corporation)				

Apart from GMC and AWSSB, Guwahati Metropolitan Development Authority and Guwahati Metropolitan Drinking Water & Sewerage Board (GMDW&SB) are the major government agencies focused on the goal to ensure 24x 7 water supply in the city of Guwahati by the year 2025. In addition, it monitors the quality of water to be supplied during the operation stages. It involves temperature, pH, coliforms, BOD, dissolved solids, Turbidity, Color, Nitrate Nitrogen, Fluoride, iron. In addition, this government agency aims towards the conservation of water and capacity building for achieving it.

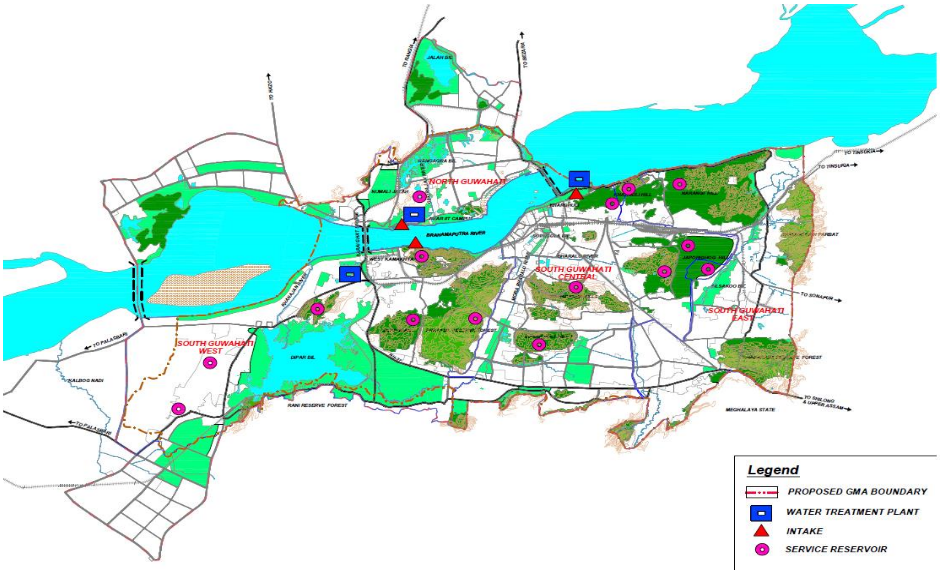

Figure 12 Water supply distribution in Guwahati (Source: GMDA)

Groundwater for drinking in managed and operated by Assam Public Health Engineering Department at present, groundwater draft is mainly for domestic and irrigation purposes and a negligible amount is for the industry. The water supply schemes for drinking purpose is drawn from dug wells, hand pump and deep tube wells, which are executed by the Assam Public Health Engineering Department. For the purpose of irrigation, the groundwater draft is 586 MCM used from shallow tube wells and handled by the agriculture department with the support of farmers. (CGWD, 2013)

Multilateral Entities: For the improvement of the city water supply condition, the city of Guwahati is divided into 3 parts with 3 different agencies assigned for each part to manage and operate the water supply. These are JICA (Japan International Cooperative Agency), ADB (Asian Development Bank) and JNNURM (Jawaharlal Nehru National Urban Renewal Mission. Figure 13 depicts the city of Guwahati with the assigned agencies for water supply development. The primary objective of this project is to spread a network of pipelines within the city for increasing the accessibility and availability of the water supply to the consumer. Once the water distribution operation is developed the 3 parts would come under a single authority. This project is expected to meet the need for water supply in the city with a 24x7 pre-paid water supply model as a goal (Bhattacharya and Borah, 2014).

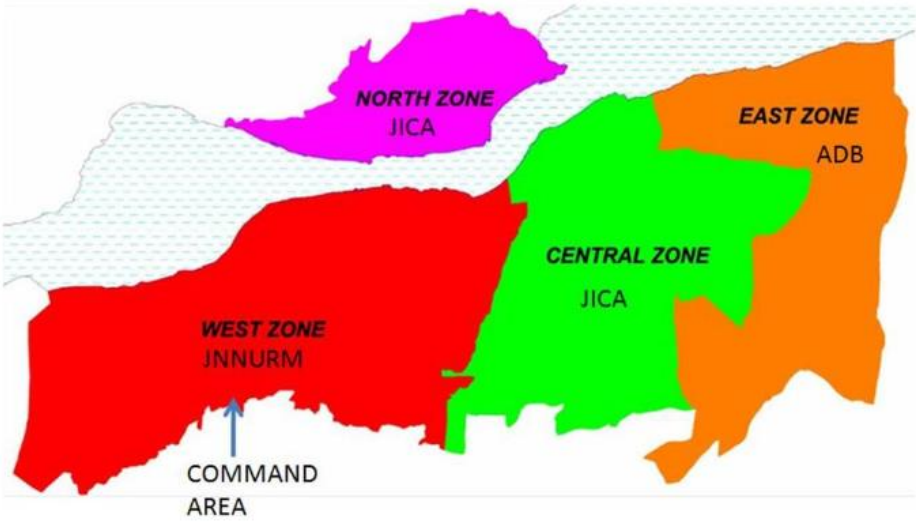

Figure 13 Zone-wise water supply projects under Guwahati Municipal Authority

(Source: Guwahati Municipal Corporation, https://gdd.assam.gov.in/portlets/water-supply-projects)

6.1.4 Issues and concerns related to water supply in Guwahati

At present, water supply in Guwahati caters to less than 30% of the population, for about 1-2 hours per day. Most of the plants and pipelines have outlived their designed life period. As a consequence, they are more prone to leakages and introduction of exterior contaminants, notably when flooding. The intermittent distribution is aggravating the water quality as low levels of water enable mud to enter the pipes. Entering a 24/7 distribution system should enable to avoid such source of contaminants. The main issues with regards to water supply in Guwahati are:

(i) Limited water distribution network,
(ii) Dependence on other sources of water such as private tankers hand pumps, bore well,
(iii) Concerns with quality of supplied water,
(iv) Intermittent water supply,
(v) High UFW and NRW,
(vi) Low revenue efficiency.

Moreover, the WTPs are working at a meagre 66% efficiency level as they lack proper maintenance and needs refurbishment. Within the WTP various components have issues with proper functioning due to which there is a concern in the quality of supplied water by GMC.

The non-revenue water covers a huge 40% of the supplied water due to leakages within the distribution network. This NRW results in reducing the per capita availability to 35 lpcd. Of which the frequency of supplied water is 2 to 3 hours per day to the regions of the distribution network. Currently, 40% of the population is catered by piped water supply through GMC the rest depends on groundwater and tanker system. Bhattacharya and Borah (2014) highlighted that almost 69% of city households are covered by the water supply scheme of the municipality. Nevertheless, during wet winters and summers the supply becomes intermittent that worsens the condition in the outskirts of the city where water supply is limited to once or twice in a month.

In addition, Guwahati also faces a problem of irregularity in water supply, with sharp seasonal variation. Further, the quality of water is also a concern in the city, particularly during the monsoon season. In general, the water has high turbidity levels, especially during the monsoon season that carries a large amount of silt in it- thus takes the settlement process longer than usual (GMC, 2006). In the case of groundwater, there is high iron content due to the presence of iron in the deep underground rocks in which the water percolates and increase the content of these minerals within the water in the aquifers. There are cases in which the content of iron is more in piped water supply than found in groundwater. This is mainly due to the use of iron as coagulating agents in the WTP or in cases where cast iron, steel or galvanized iron are used within the distribution pipelines.

Guwahati collects water tax along with property tax which is fixed at 10% of the annual rateable value if the GMC is providing the water tap and 7.5% in case if only a water supply network is provided. The water charge is generally collected with property tax. GMC takes a fixed rate per month for the supply of water in the areas where water meters are involved based on the type of use:

1. Residents using water up to 15 kl are charged Rs 8, from 15-25 kl the charged are Rs. 12 and for use above 25 kl the rate is Rs. 15.
2. Commercial use involves usage up to 15 kl are charged Rs 12, from 15-25 kl the charged are Rs. 15 and for use above 25 kl, the rate is Rs. 20.

In the case of regions where water meters are not installed GMC uses flat rated tariffs to supply piped water for domestic usage; households with up to 4 members charging Rs. 140 per month, with households more than 4 members each member is charged an extra Rs. 35 in addition to the fixed Rs. 140 (Guwahati Municipal Corporation). GMC allowed private water tankers for the supply of water to regions where the piped network is not accessible. Through the GMC feeding point, these tankers are filled up. The rates of water collecting from the GMC for private water tankers are represented in Table 10.

Table 10 GMC regulated rates for private tankers

GMC regulated rates for private tankers			
Capacity of tankers (in liters)	**up to 5 km (in Rs.)**	**5 to 10 km (in Rs.)**	**up to 15 km + next per km**
600	160	220	Rs.300 + Rs.20/next per km
2000	400	530	Rs.600 + Rs.40/next per km
3000	550	670	Rs.780 + Rs.50/next per km
6000	800	920	Rs.1050 + Rs.70/next per km
10000	1050	1210	Rs.1370 + Rs.90/next per km
Source: Guwahati Municipal Corporation (www.gmc.assam.gov.in)			

6.1.5 Main benefits, needs, opportunities and barriers for LOTUS

6.1.5.1 Guwahati water supply system

Guwahati JalBoard aims to run water 24/7 in the pipes of the Central South Area. This is a huge improvement towards the current situation. Running water constantly in the pipes will highly contribute to increase its quality, avoid the infiltration of sediment and other contaminants carried by rains.

In parallel to the modernisation of its infrastructure, Guwahati Jalboard will install the LOTUS solution in the water distribution system. Together with the IT platform, this will enable the water provider to obtain real-time information about the quality of water. It is important to manage the expectations of participants and to underline here that LOTUS is not responsible for the modernisation of the infrastructure, hence cannot provide details about this part of the programme. LOTUS is very much the water quality monitoring system. It is a research and development project, which is currently under development and may need to be iterated before becoming a final product.

Knowing about the quality of water, will enable to apply the right water treatment to the water to make it drinkable. If the water is currently infected, the information is available and reliable. As a result, the adequate awareness campaign can be run toward consumers.

6.1.5.2 Guwahati groundwater management

Unlike the water distribution system, sensors will not be placed in the phreatic table or in the wells. They will be used by technicians to measure water quality. The information collected will enable to map the movement of water in the table and anticipate and inform about pollutions. As a result, people will know what the quality of the water is and can change their source of water when the water is too polluted. Gathering data will also enable water policies to be improved, in the sense of lowering the pollution that infiltrates the water table.

6.2 Description of use case for Bengaluru water supply (Modelling and optimization of tanker-based water distribution system)

6.2.1 Bengaluru water supply system and distribution

Bengaluru is the capital of Karnataka state, the third-largest city, and the fifth-largest metropolitan area in India (BWSSB, n.d.). Due to commercial development in the city, there has been an exponential growth in the population. In addition, the increased population has spread beyond the city limits. According to the estimates of the Bengaluru Water Supply and Sewerage Board (BWSSB) for 2011, the estimated demand is about 1400 MLD, of which the city is able to supply about 950 MLD. The demand is projected to increase in the future and expected to reach 4100 MLD by the year 2050, whereas the supply is expected to remain approximately around 2070 MLD. The city water supply has a leakage loss of about 40 % of total intake (Kumar, 2018).

Figure 14 Administrative Jurisdiction in Bengaluru Source: BDA (2018)

The founders of Bengaluru in the 1600s, created an irrigation system that would supply the city with water through rainwater harvesting. This system survived through to the 1970s but in recent years many of the lakes have been drained to create space for development, and the ones which remain are heavily polluted. Today, surface water continues to be the main source of water in the city, and in addition, the city draws a large volume of water from groundwater resources. Surface water is pulled up from the Cauvery river under the Cauvery Water Supply Scheme (CWSS). The water drawn up by CWSS is supplied to the core area of BBMP, covering 575 sq. Km. For another 110 villages of BBMP amounting to 225 sq. Km water is supplied from borewell sources (BWSSB, n.d.). However, the actual borewells are engaged in supplying water to 110 villages of the BBMP area is not available [75]. The present supply from the Cauvery source is 1350 MLD, which covers approximately a population of 8.5 million, and the water supply served over an area of 570 sq. Km. The duration of the water supply by BWSSB is 2-5 hr. However, the timing and day vary from place to place. Table 11 gives a detailed scenario of the status of the water supply system in Bengaluru.

Table 11 Status of Water Supply System in Bengaluru

Status of Water Supply System in Bengaluru	
Present Supply from Cauvery Source (in MLD)	1350[76]
Present Population Served (in Million)	8.5
Area of Water Supply Served (in sq. km)	570

[75] The no. of borewell or tube wells was recorded after the Karnataka Groundwater Act, 2011 passed in state assembly. 1.75 lakhs borewell and open wells were existing till 2013. For more details see Subramanyan (2013).
[76] This amount only includes the water supply through CWSS. It does not include other source like ground water, lake etc.

Total Length of Water Pipe Line (in km)	10287.8
Public Tap providing Free Water (in no's)	7477
Water Tanker Lorries (in no's)	62[77]
Average per capita Consumption (in L/day)	65
Average Cost of Water (in Rs/kl)	28
Duration of Water Supply per Day (in hr)	2-5 hr[78]
Unaccounted for Water (in Percentage)	37.59
Source: BWSSB (n.d.), Kumar (2018)	

The BWSSB extracts water from surface sources such as lakes and rivers in the city, and additionally, it also hauls out water from a number of borewells within the city. Of the total supply of BWSSB, groundwater contributes about 70 MLD of the 900 MLD. In addition, there are a number of the households and agencies that use private groundwater resources, which is used for the individual requirements as well as water for meeting the supply requirements carried out through tanker services particularly in the periphery region of the city where there is limited coverage of water supply. As the capacity and reach of BWSSB is limited in the city with regards to water supply, there has been an exponential increase of households drawing water from private borewell resources.

The charges from private water tankers vary from location to location. For example, in Kalyan Nagar, a tanker of 5000 liters capacity comes for INR 550. Similarly, a 5000 liters capacity tanker comes for INR 800 for Benson town. The cost of water tanker lorries provide by BWSSB is INR 540 for 6000 liters (George, 2019). As of 2016, approximately 908,000 service connections are registered in BWSB, whereas 865,000 connections are metered connections (JICA, 2017).

Table 12 Details of Private Water Tanker Supply in Bengaluru

Details of Private Water Tanker Supply in Bengaluru			
Sl. No	**Area Name**	**Tanker Capacity (in Litters)**	**Price (in INR)**
1	HSR layout	5,000	1,200-1,500
2	Horamavu- Agara	5,000	700

[77] 62 water tanker lorries are provided by the BWSSB. It does not include private water tanker lorries.
[78] The timing of drinking water supply by BWSSB is 2 to 4 hours per day. However, the timing and days varies from location to location. For instance, the water supply timing of M.L.A house is 3:00 PM to 8:00 PM. For more details follow the mentioned link. Water Supply timing of BWSSB-https://www.bwssb.gov.in/watter_supply.php

3	Kalyan Nagar	5,000-7.000	550-650
4	Yashwanthpur	6,500	800
5	Benshon Town	5,000	800
Source: George (2019)			

Note: Table 12 gives the details of private tanker water supply for some areas in Bengaluru retrieved from literature. However, we did not get the details of the private water tanker supply for all regions of Bengaluru.

6.2.2 Water quality in Bengaluru

Water quality continues to be a major problem posing a serious health risk. A large population of urban and peri-urban areas of Bengaluru depends both on groundwater and surface water, which is fetched from the Cauvery river to meet their drinking water demands. However, this water quality continues to be questionable and has been found to be exposed to severe pollution and deterioration of groundwater quality. For instance, Shankar and Sanjeev (2008) did study the groundwater quality of the K. R. Puram industrial area, situated approximately 20 km away from the Bengaluru city, to know the quality of groundwater. The study found that the level of pH in groundwater is 6.48 to 8.35, which is within the BIS 10500 standard, whereas iron, nitrate, total dissolved solids, hardness, and fluorides in the groundwater exceeding the permissible limit. A similar kind of study was done by Sheeba et al., (2017) to understand the drinking water quality in the peri-urban area. It found that 93% of the household drinking water samples were unfit for consumption purposes as per the WHO standard. Total dissolved solids, calcium, magnesium, alkalinity, and hardness in drinking water were beyond the desirable limit, and the nitrate levels were consistently high and beyond WHO permissible levels. Another study was done by the Gulgundi and Shetty (2018) to understand the situation of groundwater of North Western and southwestern corner of Bengaluru city. It took 67 groundwater samples in November (post-monsoon) and March (pre-monsoon). It found that the pH in groundwater of the study area varies from 6.07 to 8.13 in pre-monsoon and 5.8 to 7.7 in post-monsoon, which shows a little season fluctuation in pH values within the permissible limit. Similarly, the total dissolved solids values in all the samples were between 129.01mg/l to 1166.05 mg/l. From the literature, it shows that the drinking water quality in Bengaluru city and periphery area of Bengaluru is in deteriorate condition, which needs some treatment to make it usable condition.

Table 13 Some Key Parameters for Drinking Water Supply and its Quality in Bengaluru

Some Key Parameters for Drinking Water Supply and its Quality in Bengaluru

Parameters	Desirable Limit	Permissible Limit	Exceeding Desirable Limit	Exceeding Permissible Limit	Reference
pH	6.5 to 8.5	No Relaxation*	Yes	NA#	Shankar and Sanjeev (2008), Sheeba et al., (2017), (Gulgundi and Shetty 2018)
Iron	0.3 mg/l	No Relaxation*	Yes	NA#	Shankar and Sanjeev (2008), Sheeba et al., (2017)
Nitrate	45 mg/l	No Relaxation*	Yes	NA#	Shankar and Sanjeev (2008), Sheeba et al., (2017), (Gulgundi and Shetty 2018)
Total Dissolved Solids (TDS)	500 mg/l	2000 mg/l	Yes	No	Shankar and Sanjeev (2008), Sheeba et al., (2017)
Hardness	200 mg/l	600 mg/l	Yes	Yes	Shankar and Sanjeev (2008), Sheeba et al., (2017)
Fluoride	1.0 mg/l	1.5 mg/l		Yes	Shankar and Sanjeev (2008)
Calcium	75 mg/l	200 mg/l	Yes	Yes	Shankar and Sanjeev (2008), Kumar et al., (2018), (Gulgundi and Shetty 2018)
Magnesium	30 mg/l	100 mg/l	Yes	Yes	Shankar and Sanjeev (2008), (Gulgundi and Shetty 2018)

Source: Author's illustration

Note- * No Relaxation indicates that the permissible limit for the parameter is not defined by the BIS 10500, a water quality standard in India.

NA indicates that the water quality sample do not exceed the permissible limit for the parameters.

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6.2.3 Relevant stakeholders for Bengaluru water supply

The major stakeholder with regards to the extraction and supply of water in Bengaluru involves many actors that include government organizations, non-governmental agencies, multiple end-users (domestic, commercial, and industrial) and private agencies.

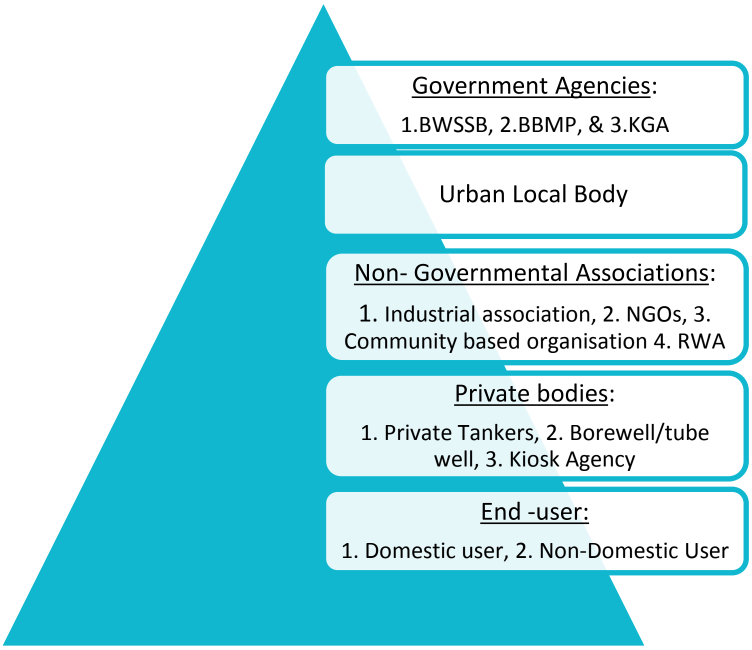

Figure 15 Stakeholder Mapping of Bengaluru Water Supply Source: (Authors Illustration)

Figure 15 attempts to depict the stakeholder mapping of the water supply in Bengaluru. See section 6.2.3.4 and section 6.2.3.5 for more further details on role and responsibilities of various government agencies in water supply system and distribution in Bengaluru.

6.2.3.1 Local water utilities

BWSSB charges water usage based on water use. The users are divided into two types, such as domestic users and non-domestic users. Table 14 gives the details tariff charged by BWSSB.

Table 14 Tariff for Water Connections

Tariff for Water Connections		
Category	**Tariff (in Rs per kl)**	**Consumption (in kl)**
	7	0-8

Domestic	11	8.001-25
	26	25.001-50
	45	Above 50
Non-Domestic/ Commercial	50	0-10
	57	10.001-25
	65	25.001-50
	76	50.001-75
	87	Above 75
Source: BWSSB (n.d.)		

As discussed earlier, groundwater is linked with the private business of water tankers. In present times, more than 10 % of the residents of the city live in slum areas, which is continuously increasing over the years. Poor households in the city rely on municipal sources, but a sizeable number of them have to additionally depend on the tanker supply to meet their requirements. In the peripheral areas, the ways of accessing water differ according to land tenure and settlement types. It also means that there is a considerable level of heterogeneity with regards to access to water supply in the peripheral regions of the city. The residents in the outer areas have varying levels of willingness to pay for different options of access to water supply, and these include paying for private tankers, sinking borewells, accessing water from outside residential premises etc. Water quality emerges as one of the key concerns in the city. In this context, Table 15 elucidates the relevant stakeholders and different modes of access to water supply in the city and its price details.

Table 15 Different Stakeholders and mode of access to drinking water in Bengaluru

Different Stakeholders and mode of access to drinking water in Bengaluru			
Mode of Access	**Who Accesses**	**Provider**	**Price/Cost**
Handpumps (very few functioning)	Poor groups living in urban and revenue layouts	Public (ULB)	Free
Borewell (Ranging from 500-800 ft in depth) stored in mini water tanks with attached public taps	Poor groups living in urban and revenue layouts	Public (ULB)	Rs 44 per month (Very few pays)
Piped Borewell water	Lower middle-income groups in revenue layouts	Public (ULB)	Rs 44 per month (Very few pays)

Tankers (Sourced from private borewells belonging to large landowners)	Middle-class households	Private	Rs 50-70/kL (Rs 200-300 per 3-4 kL tanker load) and up to Rs 1,200/month
Individual borewells (ranging from 800-1,200 ft in depth)	Wealthier middle-class households. Sufficient land and documents are needed to get a power connection to pump water up	Private	Water is free but costs a one-time amount of Rs 2 lakh to sink a borewell + recurring electricity costs
Bottled drinking water	Purchased by wealthier middle-class households to supplement tanker and bore water	Private	~Rs 6,000/kL (Rs 30 per 5 L bottle), and up to Rs 300/month
Piped Cauvery water (2-4 hours per day every other day)	Only 10% of the periphery and in BDA-approved areas only. Areas include Kengeri Satellite Township Yehalanka, technology parks like the Information Technology Park Ltd, a few large apartment complexes, etc	Public (BWSSB)	Connection charge of Rs 1,600-2,000 + prorata charges Domestic tariffs are variable. In some CMCs, BWSSB charges Rs 25/kL. In others, the domestic block tariffs are: 0-8 kL; Rs 6/kL 8-25 kL; Rs 9/kL 25-50 kL; Rs 30/kL Above 50 kL; Rs 36/kL Industrial tariffs vary from Rs 60-70/kL
Source: Ranganathn et al. (2009)			

6.2.3.2 Technology providers

Currently, there are few water testing laboratories operated by both government and private where consumer can get tested the water quality. Apart from this, Mobile van is available with all kits to test water quality collected from random spots. This service is facilitated by the BWSSB. The mobile van laboratory has the instrument to test physical, chemical and biological analysis. As we discussed, the periphery area of the city is mostly dependent on the tanker supply, there are no such facilities or system available to give the instance quality of tanker water.

6.2.3.3 End users

The end users are an important stakeholder who consumes the supplied water. In Bengaluru, the end-users are divided into two types such as domestic user and non-domestic user. The water tariff (for more details see Table 5.8) is charged based on the user category. The domestic users include premises used solely for residence purposes, Education institutions and hostels, premises belong to a statutory body established by central or state government, premises used for religious purpose, Government residential quarters, and premises used for charitable purposes. Similarly the non-domestic users includes premises used by the railways, government both state and central as official building, premises used for shops, properties used for other than residential and belonging to or occupied by the central and state government, premises used for trade or industrial purpose, photo studio, hotel, clubs, paying guest accommodation etc.

6.2.3.4 Governmental bodies

Currently, Bengaluru Water Supply and Sewage Board (BWSSB) is the premier governmental agency responsible for water supply and sewerage disposal in Bengaluru city. It is an autonomous body formed by the State legislature under the Bengaluru Water supply and Sewerage Board Act on 10-09-1964. It supplies the drinking water to the BBMP area of 800 sq.km – Bengaluru Core area of 245 sq km, 8 Urban Local Bodies of 330 sq km (7 City Municipal Corporation and 1 Town Municipal Corporation and 110 Villages of 225 sq km. The specific responsibility of BWSSB is adequate water supply to meet demand; creation of sewerage network & safe disposal of sewage; Preparation, implementation of plans & schemes for augmenting water supply & safe disposal of sewage; Levy and collection of water charges on no loss no profit basis for sustainability of the system (BWSSB, n.d.).

Apart from BWSSB, BBMP is the other major agency responsible for environmental services. Stormwater drainage and solid waste management fall under the purview of BBMP. Both BWSSB and BBMP have the representation of the Urban Department of Govt. of Karnataka, as well as Chairpersons of each agency on the other. However, the operational level challenge of coordination between the agencies is daunting.

Groundwater resources in the city by right vest with the owner of the land above. The newly constituted Karnataka Groundwater Authority (KGA) has been given the responsibility of monitoring and regulating groundwater use all across the state. The Karnataka State Pollution Control Board (KSPCB) is also in charge of monitoring pollution of surface and groundwater resources. The BWSSB extracts groundwater (in a limited manner) for municipal water supply and is the notified agency (by the KGA) for registering and granting permits for new borewells in the city.

Urban Local Body (ULB): The role of ULBs is to take over the water supply and sewerage schemes from Karnataka Urban Water Supply and Drainage Board (KUWSDB) and operate and maintain it in respective areas. Apart from this, it also responsible for levies water connection fees, installation of meters, and collects water charges.

6.2.3.5 Other Stakeholders

Non-Profit organizations: Non-Governmental organizations (NGOs) also play an essential role in the governance structure of the water supply system. The Bengaluru city, in the recent past, has witnessed NGOs and community-based organizations tanking an active and vibrant role in drinking water governance in Bengaluru (Khandekar, 2008). The Residents Welfare Association (RWA) plays an important role in the water governance process. For instance, the Rainbow Drive residence welfare association runs its water supply system to fulfil the demand of their apartment.

Private water Supply: The private tanker lorries and own private borewell/tube well plays a vital role in the drinking water supply system. The private tankers are supplied water to villages in the periphery of the city where BWSSB tanker facilities are not available. The users to be charged a high amount for tanker supply, and the price varies from place to place too. In Bengaluru, very few private kiosk agencies have set up to provide purified water to consumers. However, we did not get details about the water kiosk agency to understand more about it.

6.2.4 Main benefits, needs, opportunities and barriers for LOTUS

In Bengaluru, LOTUS sensors will be used to monitor the quality distributed by water tankers. The water quality will be monitored before filling the tanker. A small chlorination station will be installed in the tankers to ensure that the water is clean until delivery. LOTUS would benefit the middle- and upper-class population of the Bengaluru city. Especially the beneficiaries are belonging to the periphery habitation of the city. During the water scarce period of summer, even the lower middle-class people will be willing to pay for good quality drinking water. The main benefit would be not to rely on the tanker company to provide them with good quality water rather customer will possess a scientific proof to base their reliability on. Indeed, at this stage even educated people count on smell and colour to assess the water quality.

The LOTUS technology will be fixed in JustPaani company water tanker who is a private company in the market. There are also slums in the city who get tanker water by BWSSM. So, there is an opportunity to extend the technology to the other players including the BWSSB so that the quality water can be supplied through tanker supply.

The barriers include the inability to provide information on heavy metals and quantity of water. During the water rich periods of winter and monsoon, customers have various other options and might not want to spend a huge amount on JustPaani tanker water. As other cost-effective solutions like water purifier with RO systems can filter heavy metals and other contaminants.

6.3 Use case for Jalgaon (Modelling, simulation and design of irrigation system)

6.3.1 Jalgaon irrigation system

The State of Maharashtra is the second most cultivated state of India with 19.8 mha of land cultivated, accounting for 12% of India's crop area, according to the FAO. Jalgaon receives an average rainfall of 670 mm per year which is close to state average rainfall with a variation between different regions (Patil et al. 2013). The maximum amount of rainfall is received during the months of July and August. According to the Agricultural Census (2014), Jalgaon district has 0.80 mha net cultivated area out of 0.87 mha gross cropped area. The half of the net cultivated area is cultivated in both the season. The irrigation activity is mostly dependent on ground water extracted through open well and bore well. At the same time, very limited area is irrigated by surface water.

The irrigation system through has developed from Tapi river, which is maintained by the Tapi Irrigation Development Corporation, Jalgaon. Even though the canal irrigation system is available in this district, due to the technical and manual constraint farmers prefer to use groundwater through traditional well or tube well (Phirke and Mahorkar 2010). As per the Agriculture Census (2014), the major irrigation activity that comes 97.6% of the total cropped area is covered by groundwater through open well and bore well whereas the canal irrigation only constitutes 2.3 % of the total land. The increase in the number of the wells (include dug well, shallow well, medium well and deep well) to extract the water for irrigation causes the depletion across the district. Nationally, groundwater levels in India have declined by 61% between 2007 and 2017, with 89% of the extracted water being used for irrigation, according to the CGWB Fifth Minor Irrigation Census. There are strong links between cash cropping, the failure of borewells and overwhelming debts in the semi-arid regions of the State of Maharashtra. Farmers are encouraged to use groundwater as the crops have twice the crop water productivity of those that rely on surface-water alone.

The water scarcity is increasing day by day which causes the farmers to adopt new technology for irrigation which are more efficient. Currently the Jain irrigation provides different new technology such as Drip irrigation, sprinkler irrigation and some advance technology for the use pesticide to farmers. Recent studies have also suggested that traditional approaches of community-based rainwater harvesting may have the capacity to reduce demands on groundwater and help prevent droughts in the future (Agarwal, 2000).

6.3.2 Water quality in Jalgaon

As discussed, the groundwater is mostly used for irrigation as the canal irrigation system in Jalgaon district often fails. The groundwater quality is very important for irrigation purposes. Tiwari (2015) reliased a study of the 51-groundwater sample to understand the quality of groundwater Across Jalgaon district. The study finds that electrical conductivity, TDS, Alkalinity, Chlorine and Hardness are above the permissible limit in most of the samples. The groundwater is very hard due to the high salt concentration. Another study done by Ghope et al. (2019) examined the groundwater across the Jalgaon district to understand the correlation between groundwater quality and the use of inorganic fertilizers and pesticide. The study revealed that the values observed for Electrical Conductivity (EC), Sodium (Na) Bicarbonate (HCO3), Chloride (Cl), Magnesium (Mg), Calcium (Ca) and Sodium Absorption Ratio (SAR) were found well below prescribed limits for irrigation water. However, the computed values of the Irrigation Water Quality Index (IWQI) exhibits that, 70 per cent of the study area is moderately restricted and ¼ part of the study region is highly restricted for soil and growing plants based on IWQI. The study concluded that the overuse of inorganic fertilizer; pesticides, high depth water, polluted drain water and improper irrigation practices posed a serious threat to groundwater quality in agricultural areas of Jalgaon district. Another study was done by Bride (2014) to understand the geochemistry of the groundwater in the Jalgaon region. Groundwater samples of the study area showed a high concentration of TDS (>1000 ppm), Cl (>1000 ppm), NO_3 (>45 ppm), K (> 10 ppm), Ca (>200 ppm), HCO3 (> 600 ppm) and B (<1 ppm). Irrigation water quality has been inadequately affected by salinity hazards and residual soluble carbonate (RSC). However, the quality of groundwater varies from season to season. Parmar (2012) studied the groundwater of Jalgaon district for two consecutive years to understand the quality and its variation between the season. The major parameters of the study are temperature, electrical conductivity, total alkalinity, total hardness, calcium, magnesium, chloride, free CO2 total dissolved solids, dissolved oxygen. Except for pH whose range was between 7.45 to 9.19 other parameters were normal. The high pH value indicates that the water is alkalinity. Furthermore, it shows that the variations increase drastically with the change in season. In the case of groundwater, it was found that conductivity, alkalinity and hardness were high and much over the permissible limits.

Table 16 Summary of Water Quality Parameters

Summary of Water Quality Parameters		
Parameters	**FAO Standard**	**Irrigation Water Quality**
Electrical conductivity	1000 µS/cm	exceeding limit
TDS	500 ppm	exceeding limit

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Alkalinity	200 mg/L	exceeding limit
Hardness	712 mg/L	exceeding limit
Calcium	400 mg/L	within limit
Magnesium	60 mg/l	exceeding limit
Natrium	920 mg/L	within limit
Chloride	1065 mg/L	within limit
pH	6.5 to 8.5	exceeding limit
Source: (Tiwari 2015), (Ghope et al., 2019), (Parmar 2012)		

In conclusion, the quality of groundwater for irrigation is deteriorated the condition. Some parameters like electrical conductivity, TDS, Alkalinity, Hardness, Magnesium, pH is exceeding the limit prescribed by the FAO standard. So, to use the groundwater in irrigation purpose need some kind of treatment.

6.3.3 Relevant Stakeholders for Jalgaon Irrigation supply system

As discussed, the irrigation supply system is mostly dependent on groundwater through open well and bore well. So, the major stakeholder with regards to the irrigation water supply system in Jalgaon involves many actors that include government organizations, private irrigation company, material suppliers, plumbers and fitters and farmers. Figure 16 attempts to depict the stakeholder mapping of the irrigation water supply system in Jalgaon.

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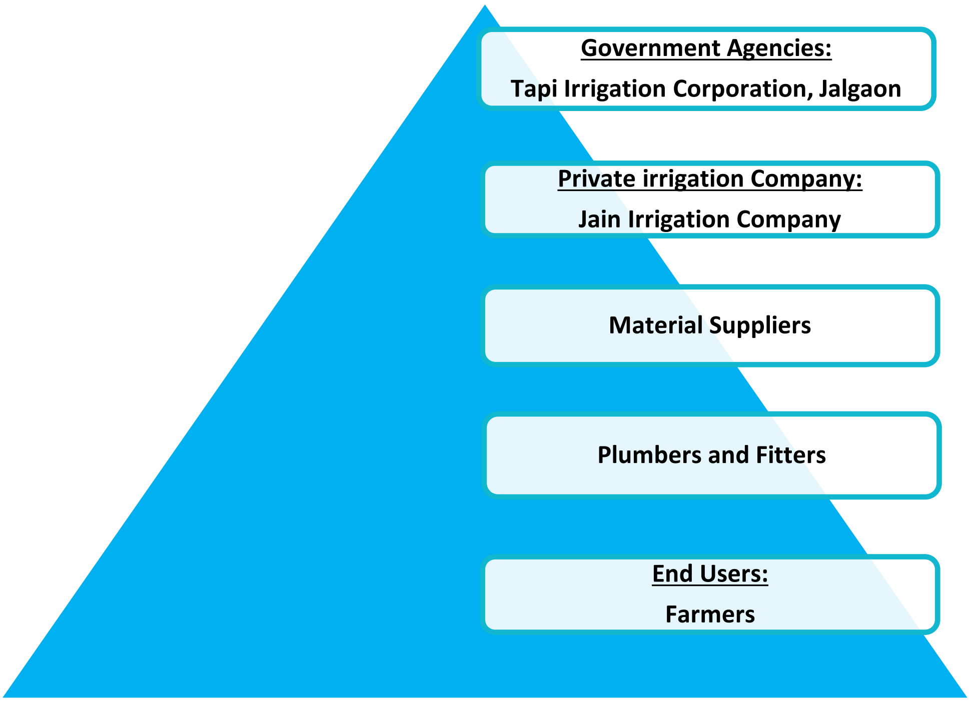

Figure 16 Stakeholder Mapping of Jalgaon irrigation Supply System Source: (Authors Illustration)

6.3.3.1 End users

The majority of end users belongs to rural areas and constitute 68.25% of the total population. The total workers of the district comprise 44% of the total population. However, 70.9% of the total worker employee in the agriculture sector in the form of cultivators and agriculture laborers[79]. Interestingly, among marginal workers female outnumber the male.

Table 17 Details of Workforce in Jalgaon

Details of Workforce in Jalgaon			
Category	**Person**	**Male**	**Female**
Total Population	4,229,917	2,197,365	2,032,552
Total Workers	1,863,571	1,186,472	677,099

[79] According to the Census 2011, the working profile is divided into two parts such as main worker and marginal worker. Again, it is divided into 5 types such as cultivators, agriculture labourers, household industry workers, other workers and non-workers. Here the 70.9% includes cultivators and agriculture labourers of main workers and marginal workers.

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Main Workers	1,643,955	1,082,936	561,019
Marginal Workers	219,616	103,536	116,080
Non-Workers	2,366,346	1,010,893	1,355,453
Cultivators and Agricultural Labours	1,321,533	749,617	571,916
Household Industry Workers	38,930	23,041	15,898
Other Workers	503,108	413,823	89,285
Source: (Census 2011)			

Jalgaon economy is primarily dependent on agriculture, dairy, agro-industries like dal mills, oil mills, spinning and ginning mills and oil mills. There are 438,634 landholders in the district, of which, 71.85% of the farmers in the district are marginal and small farmers and the remaining 28.16% farmers have landholding above 2.0 ha. Area wise, 54.62% of land operated by 27.725 of the farmers who are medium farmers. However small and marginal farmers which consist of 71.85% have only 42.03% operated land. Even though the large farmers are in minimal percent still they hold 3.35% of the land with an average are of landholding is 15.94 ha whereas the district average landholding size is 1.44 ha (Anon 2015).

Table 18 Landholding Pattern in Jalgaon District

Landholding Pattern in Jalgaon District					
Farmer Category	**Land Size (in Ha.)**	**No of Holders (in no.)**	**Land operated (in ha.)**	**% of landholders**	**% of area operated**
Marginal	0.0 to 1.0	148,857	90,947	33.94	11.70
Small	1.0 to 2.0	166,281	235,685	37.91	30.33
Medium	2.0 to 10.0	121,569	424,494	27.72	54.62
Large	Above 10.0	1,927	26,052	0.44	3.35
	Total	438,634	777,178	100.00	100.00
Source: (Anon, 2015)					

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6.3.3.2 Governmental bodies

The Tapi Irrigation Development Corporation, Jalgaon was developed in 1997 through a legislative act The Maharashtra Tapi Irrigation Development Corporation Act, 1997. It is a major irrigation system in the district. The irrigation system has developed from the Tapi river which is a major river in this district.

6.3.3.3 Technology Providers

Currently, Jain Irrigation helps farmers and supplies them with different technology. Jain irrigation offers farmers an automatic solution which enables them to inject the right amount of fertilizer in the irrigation water using just two parameters such as pH and electrical conductivity (EC). Monitoring electrical conductivity helps farmers to inject the adequate amount of fertilizers.

At the moment, the farmers use fertilizer induction machines. There are several variants of these machines. Farmers calibrate the machines themselves, by indicating the EC level and pH. Fertilizers proportion are given as an input and the machine can calculate the right amount of fertilizers. Along EC and pH, nitrogen, phosphorus, and potassium are useful parameters in fertigation.

Farmers are also using drip irrigation. The drip irrigation was started used as a copping strategy of unavailability of water. It has also some disadvantage such as risk of clogging in the irrigation systems which cost additional cost on the farmers.

6.3.4 Main benefits, needs, opportunities and barriers for LOTUS

From the literature it is observed that, the groundwater has been contaminated by different chemicals across the district. At the same time, farmers are using different technologies for irrigation purpose as well as sprinkling of fertiliser. So, from LOTUS project, farmers as a major stakeholder can potentially benefit in different ways i.e. farmer can get the real time water quality; farmer can use fertiliser most effectively by knowing the quality of water. Moreover as 71.85% of farmers are marginal and small farmers in Jalgaon who may not have such advanced technology to use in irrigation. However, there is still a challenge that pertains to how the marginal and small farmers are adopting to the new technology and its sustainable use.

7 Conclusion

This report sets the scene for the LOTUS project with an overview of the policy context, the major challenges of urban and rural water management, and an overview of the four use cases.

In each use case, the water quality ecosystem of stakeholder is presented. The report also underlines the features and challenges of each ecosystem, before moving onto the main benefits, needs and opportunities for the development of the LOTUS sensor.

With regards to **Guwahati city water system management** use case, the LOTUS sensor will monitor the water quality from water distribution network. Information about the quality of water, will enable the right water treatment to be applied to make it drinkable. This information will be made readily available to the public to help build their trust in the water quality. Regarding **groundwater management in Guwahati,** LOTUS sensor will be used in borewells to measure the quality of water, this will enable to map ground water pollution in Guwahati. This will help to understand its dynamics and to create an information system for residents.

In the **Bengaluru** use case, the LOTUS technology aims to help the tanker company to provide their customers with high quality water. The LOTUS technology will be used by the JustPaani water tankers (private organisation engaged in water delivery in the city). There is also an opportunity to extend the technology to the other players in the market to provide water to the more deprived parts of the city.

The final use case is in the **Jalgaon** region, with the primary beneficiary of LOTUS intervention being the farmers. The technology will help the farmers use fertilizer most effectively by knowing the quality of water. The majority of farmers in this region are marginal and small farmers, who may not have such advanced technology to use in irrigation. However, a challenge that still remains is how the marginal and small farmers are adopting to the new technology and its sustainable use.

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Annex (acronyms)

ADB- Asian Development Bank

ASCI- Administrative Staff College of India

AUWSSB- Assam Urban Water Supply & Sewerage Board

BBMP- Bruhat Bengaluru Mahanagar Palike

BIS- Bureau of Indian Standards
BWSSB- Bengaluru Water Supply and Sewerage Board

CPCB- Central pollution Control Board

CPHEEO- Central Public Health and Environmental Engineering Organisation

CWSS- Cauvery Water Supply Scheme

DBT- Department of Biotechnology

DST- Department of Science and Technology

EC- Electrical Conductivity

EU- European Union

EWQDES- Environmental Water Quality Data Entry System

FAO- Food and Agriculture Organisation

FYP- Five Year Plan

GMA- Guwahati Metropolitan Area

GMC- Guwahati Municipal Corporation

GMDW&SB- Guwahati Metropolitan Drinking Water & Sewerage Board

IBT- Increased Block Tariff

IDMP- Integrated Drought Management Programme

IEWP- India-EU Water Partnership

ITC- Indian Tobacco Company Limited

IUCN- International Union for Conservation of Nature

IWW- Integrated Water Resources Management

JAP- Joint Action Plan

JICA- Japan International Cooperation Agency

JNNURM- Jawaharlal Nehru National Urban Renewal Mission

JRC- Join Research Centre

KGA- Karnataka Groundwater Authority

KSPCB- Karnataka State Pollution Control Board

KUWSDB- Karnataka Urban Water Supply and Drainage Board

LOTUS- Low-cost Innovative Technology for Water Quality Monitoring and Water Resources Management for Urban and Rural Water System in India

LPCD- Litre Per Capita Per Day

MCM- Million Cubic Meter

MLD- Millions of Litres Per Day

MoEF&CC- Ministry of Environment, Forest, and Climate Change

MoU- Memorandum of Understanding

NAPCC- National Action Plan on Climate Change

NGO- Non-governmental Organisation

NMCG- National Mission for Clean Ganga

NMSA- National Mission for Sustainable Agriculture

PHED- Public Health Engineering Department

PMKSY- Pradhan Mantri Krishi Sinchayee Yojana

RSC- Residual Soluble Carbonate

RWA- Residents Welfare Association

SAWI- South Asia Water Initiative

SPP- State Partnership Programme

TDS- Total Dissolved Solids

UFW- Unaccounted for Water

UN- United Nation

UT- Union Territory

WATSAN- Water Supply and Sanitation

WHO- World Health Organisation

WTI- Water Technology Initiative

WTP- Water Treatment Plant

WWF- World Wide Fund for Nature

ZLD- Zero Liquid Discharge