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ISSUE BRIEF

Fostering Resource Circularity and Efficiency in the Management of Urban Water Systems in India

Context

This issue brief on urban water-energy nexus comments on the potential of resource circularity while enhancing efficiency, equity and resilience of urban water systems, and the advantage that decentralised solutions offer to contribute to this aim. It is based on a study of water flow assessments in tier II cities in India. The objective of the study was to build an understanding of the relationship between the efficiency environmental impacts of the urban water system. Energy consumption, GHG emissions and water resource flows were studied and linkages between increasing system efficiencies and resource resilience were identified. While flow assessments were conducted for four cities, two Indian cities – Dehradun and Bhubaneswar were studied in detail and data collected from the published public sources was also validated through stakeholder engagement and some primary studies. The study is limited to the energy assessment and associated environmental impacts of material flows, and energy consumption recorded in the municipal utility system. The water extracted from unauthorised personal borewells or/and any other means of water sources in the community outside the public utility system and the wastewater generated from the consumption of the resource extracted outside the system is recognised but not included in the calculations. The study acknowledges that source and sink sustainability is critical to the urban water system resilience and addresses the optimisation of the urban municipal water system to reduce stresses on sources and sinks outside the city.

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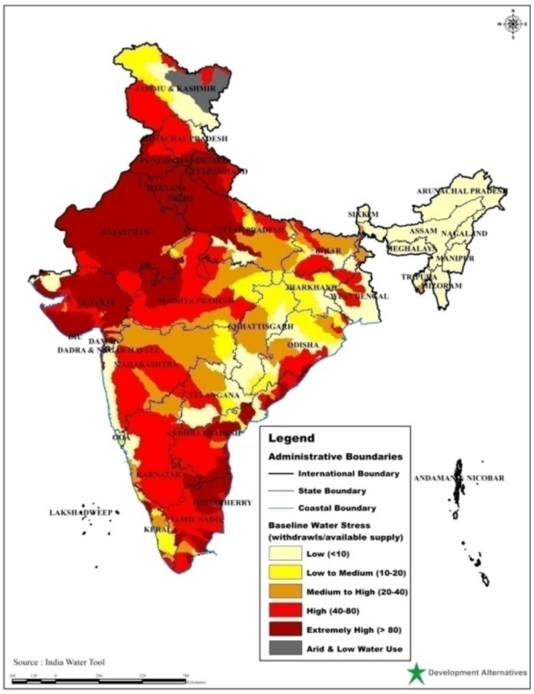
A Systems View of the Urban Water-Energy Nexus

Introduction

Cities are epicentres of economic and social development, at the same time demand centres of resources. With rapid urbanisation and increasing urban population, the demand for water is also increasing. Urban population in India is estimated to reach 590 million by 2030 (Sankhe et al., 2010). Assuming a water supply of 135 litres per capita per day (lpcd), domestic water demand is estimated to reach 79,650 million litre per day (MLD), an increase of 56.5 percent from 2011 at 50,895 MLD for a population of 377 million[1]. Although the demand for water is increasing, the per capita water availability in the country is declining, partly due to an increase in urban population but also due to gross mismanagement (Ministry of Jal Shakti, 2020)[2]. More than 54% of India is currently under high or extreme water stress (Shiao et al., 2015).



Source: WRI-India Water Tool

Baseline Water Stress in India

According to recent studies by Worldwide Fund for Nature, about 30 Indian cities will face increased water risks in the next few decades (Koshy, 2020)[3]. Increased urbanisation of Indian cities coupled with improved urban living standards have resulted in increased demand for water than ever before. With many cities depending on groundwater as their primary source of water, the country is the largest user of groundwater in the world at over 25% of the total groundwater extracted globally at 260 cubic Km per year (Kulkarni, 2018). Municipalities across the country have increasingly shifted to ground water sources to service their cities while at the same time ignoring the management of surface and rainwater systems. Unreliable and inadequate municipal water supply has led to dependence on individual bore wells at the domestic and commercial levels in urban areas. There has been an increase from 1 million to 30 million tube wells in the country between 1950 and 2010 (World Bank, 2020). Over 60% of irrigation and 85% of drinking water needs in India is met from groundwater sources (World Bank, 2012). The faster rate of freshwater source depletion along with a disintegrated water management system can have dire consequences on water availability for future needs. Many Indian cities have already seen the zeroth day resulting from overexploitation without letting the time for natural replenishment of these sources.

Another element adding to the urban water menace in India is the unaccounted for or Non-Revenue Water (NRW). Indian cities, on an average lose around 30-50% of their supplied water along distribution lines due to joints and valve leakages, overlived pipelines, unauthorised connections, thefts, etc. (Water India). Lack of circularity is yet another matter of concern in the Indian urban water system. The wastewater generated is mostly disposed into nature (drains, rivers and open lands) without any prior treatment. With only 37% of the wastewater treated in the country, apart from environmental pollution, we are also losing valuable nutrients (Ministry of Environment, Forest, and Climate Change, 2015). Treating wastewater and reusing along with water conservation helps in augmenting water supply and reducing stress on freshwater sources while reducing water pollution.

Increased energy intensity of urban water systems also demonstrates a threat to the environment due to high GHG emissions at every stage of the urban water cycle. Two types of emissions are distinguished for the water system; direct emissions (related to electrical energy usage and emissions from water extraction, distribution and wastewater treatment plants) and indirect emissions (related to untreated sewage, truck transport, biogas, etc.) (Bylka and Mroz, 2019).

[1] Assumption of data for FY 2011 derived from (M.N, 2019).

[2] As per the Ministry of Jal Shakti, the per capita availability of water was assessed at 1816 cubic meters and 1545 cubic meters for the years 2001 and 2011 respectively which is estimated to drop to 1486 cubic meters and 1367 cubic meters in the years 2021 and 2031, respectively.

[3] Access the city date here: Water Risk Filter Analysis, Worldwide Fund for Nature.

The water system requires external energy throughout its lifecycle starting from extraction, treatment, pumping, and distribution through to wastewater treatment and final disposal or back into re-use. Although the energy consumption of the water sector remains low compared to other economic and development sectors, GHG emissions from water supply and sewage treatment plants (STPs) are extremely high in tier 2 Indian cities with an average of more than 50% of the total corporation emissions[4]. Emissions from water supply and STPs in the cities of Dehradun and Bhubaneswar accounts for 51% and 70% of the total corporation emission of the cities, respectively (ICLEI, 2009). While energy assessment of the urban water system is important to assess utility efficiency, as the cost of electricity forms the major component of the operating cost of the system; the GHG footprint of the system enables an understanding of the climate mitigation potential[5]. The water-energy nexus together enables an understanding of the potential of resource efficiency and circularity from both water use optimisation as well as nutrient recovery perspective.

Fig: STP at Kargi

Having discussed the issues of Indian urban water system, a fact that is often overlooked is the interconnectedness of the water supply and wastewater management sub-systems, often treated in silos in municipalities. A report by Uttar Pradesh Pollution Control Board in 2018 revealed that in a quality test conducted for Ganga water, 19 out of 31 samples failed to pass because of continuous discharge of untreated sewage into the river. The level of faecal coliform and total coliform bacteria was more than the maximum permissible limit of 2,500 most probable number (MPN) per 100 ml of water (Hindustan Times, 2018). The water-energy nexus study conducted in Dehradun shows that 80% of the city's supplied water is dependent on groundwater sources making it a highly energy-intensive system. While Dehradun consumes 42.08 Million KWh electricity annually for water supply and STP, other tier 2 cities with much higher population like Coimbatore, Guntur, Indore uses only 2.9, 7.43, and 19.9 Million KWh electricity respectively (ICLEI, 2009). A shift from conventional freshwater sources to alternate sources like stormwater, rainwater harvesting, and reuse of treated wastewater can significantly help the city in augmenting its supply and thereby reducing energy consumption and associated GHG emission. A study in Munich, a city in Germany, shows that wastewater recycling and reuse can save 26% of water demand and decentralised biogas generation from sewage can save 20% of energy demand (Gondhalekar and Ramsauer, 2017). Another initiative by Alliance to Save Energy in the city of Pune by adopting energy efficiency in water system helped the city in achieving an increase of 10% in water delivered to the community, annual energy saving of 3.8 Million KWh, and a reduction of carbon emissions by 38,000 tonnes/year (Barry, 2007). These examples clearly show the cross-linkage between the water-wastewater-energy management, and additionally between these and nutrient recovery-pollution abatement of terrestrial and marine ecosystems emphasising the need to view the urban water system holistically.

[4] In the study conducted by ICLEI, 'Energy and carbon emissions profiles of 54 south Asian cities', community sectors include residential, commercial, industrial, transportation, and waste, etc. and corporation sectors include street lighting, water supply system, sewage system, building and facilities.

[5] Utility efficiency includes operational efficiency, system resilience, sufficiency and equity in water distribution.

Integrated Urban Water Management - A holistic approach to Water Systems Management

Integrated Urban Water Management (IUWM) is a systemic approach wherein the water sector in an urban region is managed and maintained by integrating all elements of the water cycle such as water supply, sanitation, stormwater management, and other city systems including land use, housing, industries, mobility, and energy and nutrient management sectors. Adopting IUWM helps in addressing diverse factors such as sustainable urban planning and implementation, management of competing water uses at the watershed level, recognising the needs of the city as well as upstream and downstream users, and securing resilience in the water source management. It considers the demand of all the users in a region within the administrative boundaries to overcome the disintegration in the urban water value chain (Kirchner, 2017).

Principles of IUWM

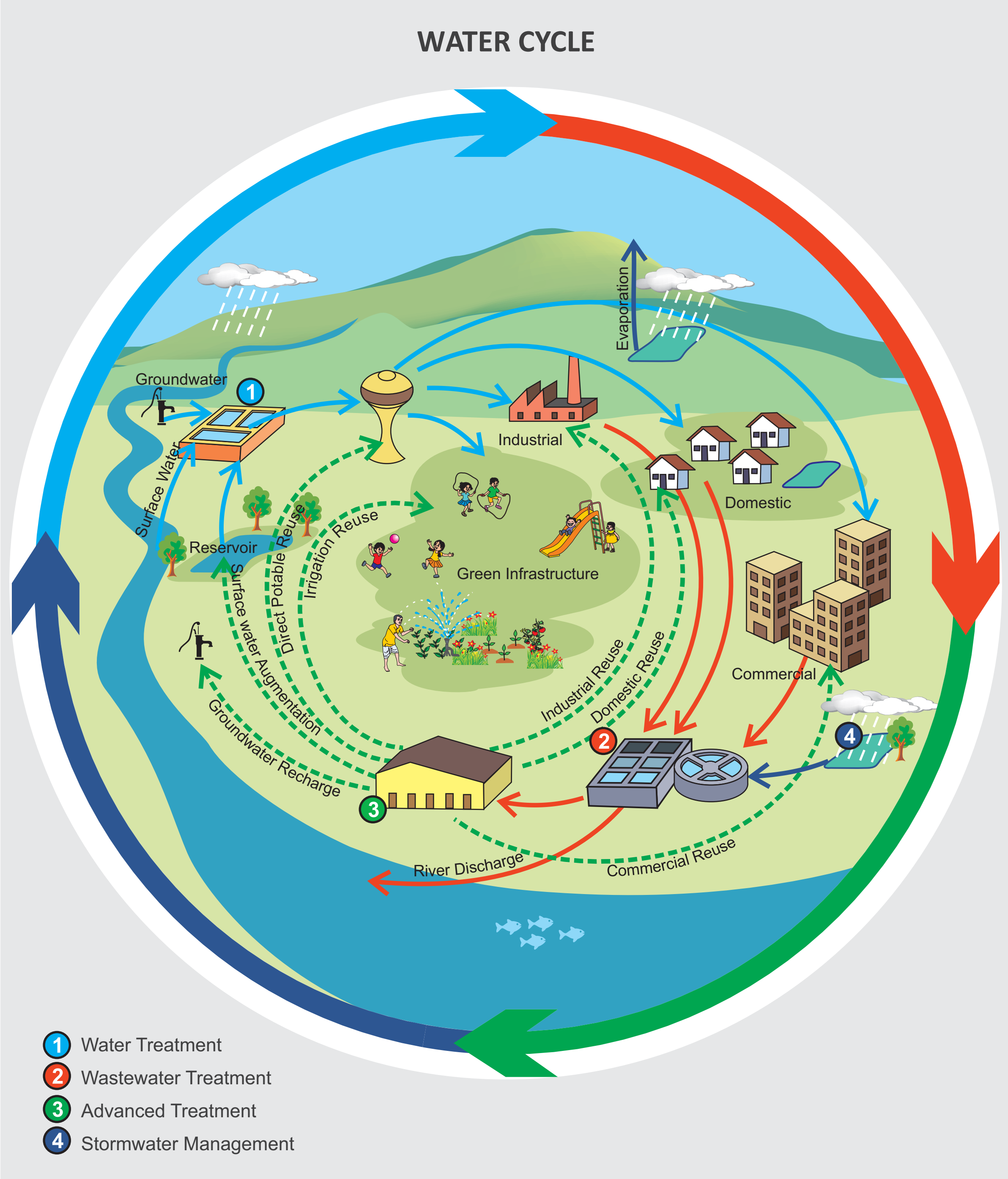
- Recognising the interconnectedness and simultaneous planning of different city systems.
- Encompassing alternate water sources like rainwater harvesting, stormwater, wastewater reuse, aquifer storage.
- Integrating water cycle including storage, distribution, treatment, recycling, and disposal as part of same resource management cycle.
- Matching water quality with water use
- Protecting, conserving and utilising water resource at their source.
- Aligning formal and informal institutions that govern water in and for the city.
- Combination of centralised and decentralised systems.
- Social inclusion and exposure of poor and marginalised community to extreme events.
- Need for capacity development and stakeholder engagement and participation in planning and decision making.

Source: (Anton and Reil, 2017)

Often in Indian cities, water sector management is fragmented with the water supply and its sub-sectors such as stormwater drainage, wastewater, and sanitation working in silos. The water cycle and the nutrient cycle though distinct are interlinked at the wastewater and sewage node in human settlements. Sewage management, while seen as the end of pipe of the water system value chain in reality is a significant node in the urban water-cycle.

India has the capacity to treat only 37% of the sewage generated (Ministry of Environment, Forest, and Climate Change, 2015). Lack of adequate wastewater treatment and continuous disposing of untreated wastewater to the environment has polluted and contaminated our freshwater resources. In India, many Urban local bodies (ULBs) and municipalities have implemented treated wastewater reuse projects in many water sensitive cities. However, the challenges such as lack of planning and feasibility studies, incentives, social acceptance, regulatory guidelines and poor institutional framework have made it difficult to sustain such projects. There would be an increase of 400% in the volume of available wastewater to retrieve and directly reuse if 80 percent of urban wastewater could be treated by 2030 (Kumar and Goyal, 2020). Standing extremely low at the water quality index, the country's 70% of water source is contaminated (ICLEI, 2018). The introduction of treated wastewater system back into the supply system and nutrient recovery from sewage can significantly help in reducing water pollution, augmenting water supply, energy-saving and reducing GHG emissions.

At the supply end, only 70% of the urban households in India have access to piped water supply (ICLEI, 2018). In India, about 0.2 million people die every year due to inadequate access to safe and clean water (ICLEI, 2018). Alongside reclaimed wastewater reuse, water conservation has a crucial function in reducing freshwater stress. Rainwater harvesting is one of the common water conservation methods. Although, rainwater is a major alternate source that can cater to the increasing demand for water, its collection and conservation is highly neglected in India(ENVIS Centre, 2016). Assuming an annual rainfall of 500 mm and run-off coefficient of 0.8, a



Integrated Urban Water Management

roof of 20 m x 10 m has a potential to harvest 80,000 litres per year[6]. This harvested water can cater to year-round requirements of non-potable water activities such as flushing and gardening of a four membered family for a daily consumption of 180 litres per day with an excess of 14,300 litres still left which can be used for other activities (Down To Earth, 2019). Apart from meeting demand of water sensitive regions and reducing freshwater stress, rainwater harvesting helps in reducing flood hazard, groundwater depletion, soil erosion, water pumping cost, and prevents water run-off reducing the need for water treatment (ENVIS Centre, 2016).

Indian cities also face high NRW at an average of 38 percent. Digitisation of water-wastewater utilities helps in retrieving real-time data and helps in understanding system capacity utilisation rate, remote operation and monitoring, and enables improved decision making and quick response to emergencies. Moreover, city system operators continue to employ conventional methods in urban water system due to a lack of knowledge in emerging technologies in the water space that could help achieve a city's aspirations as laid out in its master/development/smart city plan etc. Achieving system resilience and sustainability requires coordination,

[6] Rainwater harvesting potential = Area of catchment x Run-off co-efficient x Annual rainfall.

real-time data availability, technology, knowledge, and information exchange between the interlinked sectors. The above issues that are interlinked at different nodes in their respective lifecycle bring forth the need to view these systems with a holistic approach and hence the need for Integrated Urban Water Management in India.

Moreover, the water and wastewater infrastructure in Indian cities have not been able to pace up with the rapid urban sprawl and population increase. Unprecedented spatial expansion of urban areas have led many cities being devoid of planned water supply and sewage treatment (Keya Acharya, 2012). The water supply system for the city of Dehradun was first introduced in the year 1885 by laying pipelines from a natural spring situated 25 km away from the city which is no more in use. The existing system is more than 30 years old. Although the city has adequate water sources availability, the actual supply at the consumer end is lower than the service level benchmark. The water system experiences huge water loss during distribution causing from factors such as WTPs that have outlived its design period, old and dilapidated pipelines, and resource constraints for systemic updates of system. Also, in many points these pipelines have gone to deeper depths due to improvements made in road surface and have become inaccessible for repairs (ADB, 2016). Apart from these challenges in operation and maintenance of old infrastructure, cities like Jhansi also faces other major challenges in infrastructural expansion to meet its water and wastewater treatment demand. The city of Jhansi has rocky terrain with mostly granite which makes it less feasible for the city to build a centralised underground system (CSE, 2018). The existing centralised approach in many Indian cities has limited sewerage network access, inadequate functional STPs and budgetary restrictions (Matto et al., 2019). Such circumstances reinforce the need for adopting and integrating decentralised system into urban water utilities[7]. Decentralised systems have simpler designs and requires lesser investments for incremental expansions compared to centralised system[8]. However, successful implementation and sustenance of decentralised systems require sound policy and regulatory interventions by the Central and state governments. Despite its role in increasing sanitation coverage, water reuse and protecting the environment, the governance framework of decentralised wastewater system is still weak in India (Reymond et al., 2020).

Life Cycle Assessment (LCA) and Material Flow Analysis (MFA) for whole system data visualisation in water and wastewater systems

Life Cycle Assessment: LCA is a holistic approach that evaluates the environmental impact associated with the life stages of a product, process, or a service. It assesses the overall impact of a product from its cradle to grave by considering each step that goes into its production from extraction of raw materials through disposal at the end of life. LCA helps in quantifying a product's impact and effects on climate change, human health, ecosystem, and resources and helps in identifying environmental hotspots, improved decision making, cost assessment, system transparency, and sustainable development.

Material Flow Analysis: 'MFA is a systematic assessment of the flows and stocks of materials within a system defined in space and time', as defined by Paul H. Brunner and Helmut Rechberger in 2004. It considers an input-output methodology including both materials and economic information and data. MFA is also based on the laws of thermodynamics. In practice, MFA is a sub-set of LCA with the purpose of minimising material flows within a system to maximise human benefits. MFA finds its application in a wide range of sectors including industries, environment and engineering, resources and waste, socio-economic metabolism, human metabolism, and recently in urban metabolism.

Combining LCA and MFA to evaluate municipal utilities: MFA is a macro-level tool that evaluates the input and output of a system. It is used for identifying early environmental indicators, analysing potential interventions, and formulating appropriate solutions. Whereas LCA is a micro-level tool that evaluates the environmental impact of a product at every stage of its life. While MFA does not provide the environmental impact of a product, the identified environmental indicators by the tool could be used as an inventory for impact assessment in LCA. A combination of LCA and MFA tools in evaluating urban utilities provide a descriptive approach to understanding the current state and future planning scenarios, policy making, and environmental impact assessment of the current and future scenarios (Zhang, 2018).

[7] To generate awareness, involvement, local users' engagement on the decentralised approach, CSE has developed an online web-based tool - MOUNT.

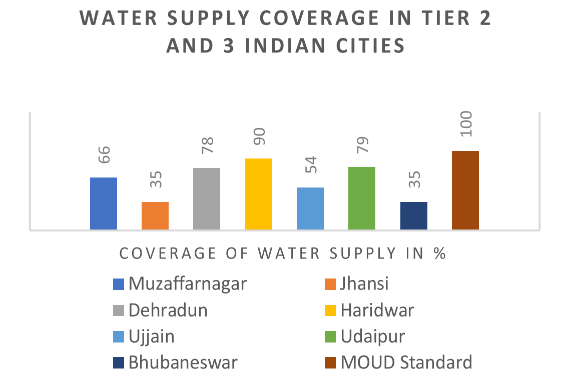
[8] Technology options for decentralised wastewater treatment - Handbook on Decentralised wastewater Treatment Module, NIUA, 2016.

Potential for improving operational efficiencies, resource sufficiency, resource resilience and resource equity in tier II and III Indian cities

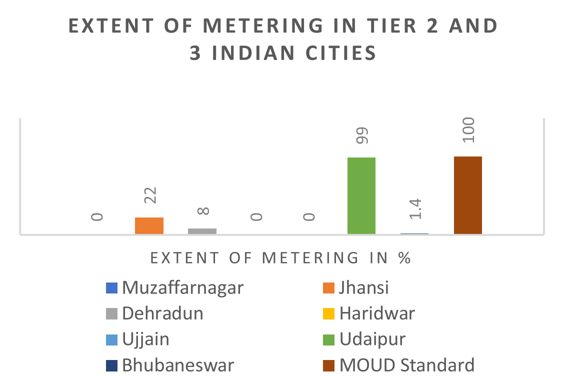
Studies conducted in four tier II Indian cities for mapping water-wastewater flows, water system energy, and distribution equity show that these cities still have a long way to go and a tremendous potential to achieve a sustainable and healthy water system through appropriately scaled technological innovations and approaches for integrated water management. As discussed in the earlier sections of this brief, Indian municipal water utilities have low supply coverage, faces high NRW, low collection efficiency in water-related services, low grievance redressal rate, lack adequate infrastructure for water and wastewater management, and low or no resource and nutrient circularity. The graphs below compare existing water system datapoints of a few tier 2 and 3 cities to respective benchmarks set by the MOUD.

Existing Scenario in water-wastewater management in tier 2 and 3 Indian cities[9]

Compares water supply coverages in tier 1 and 2 Indian cities to the standards set by MOUD i.e., 100 percent



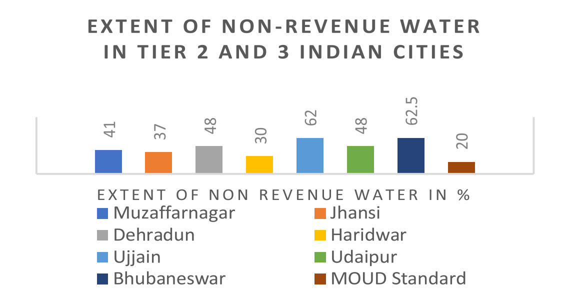
Graph 1: Water supply coverage in tier 2 and 3 Indian cities in % in comparison to MOUD standards



Graph 2: Extent of metering in tier 2 and 3 Indian cities in % in comparison to MOUD standards

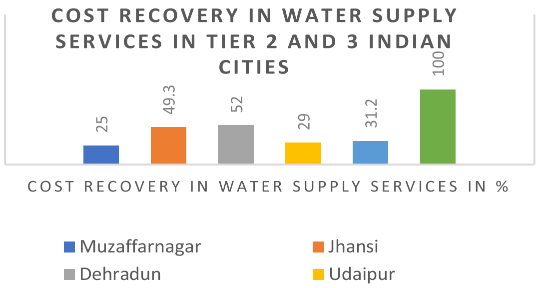
Compares the extent of metering in tier 2 and 3 Indian cities to the standards set by MOUD i.e., 100 percent

Compares the extent of non-revenue water in tier 2 and 3 Indian cities to the standards set by MOUD i.e., 20 percent



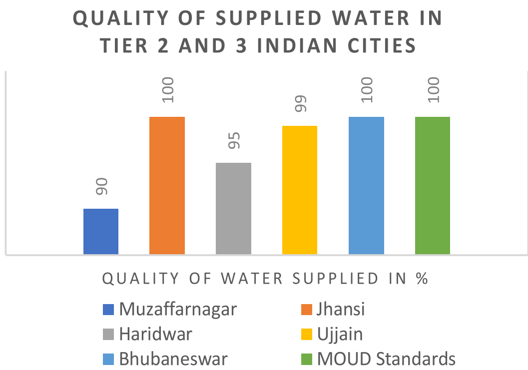
Graph 3: Extent of non-revenue water in tier 2 and 3 Indian cities in % in comparison to MOUD standards

[9] The data for 4 cities namely Dehradun, Bhubaneswar, Ujjain, and Udaipur were collected from the study, Understanding Water Flows conducted in 2018 and their respective Smart City proposals, AMRUT SLIPs and SAAPs. The data for other cities are collected from their respective Smart City proposals, AMRUT SLIPs and SAAPs.



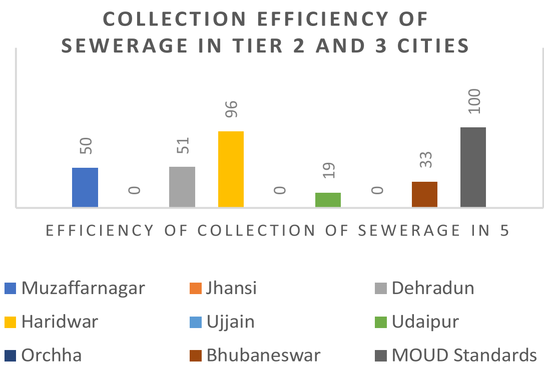
Graph 4: Extent of cost recovery in water supply in tier 2 and 3 Indian cities in % in comparison to MOUD standards

Compares extent of cost recovery in water supply in tier 2 and 3 Indian cities to the standards set by MOUD i.e., 100 percent



Graph 5: quality of supplied water in tier 2 and 3 Indian cities in % in comparison to MOUD standards

Compares the quality of supplied water in tier 2 and 3 Indian cities to the standards set by MOUD i.e., 100 percent



Graph 6: sewerage collection efficiency in tier 2 and 3 Indian cities in % in comparison to MOUD standards

Compares the sewerage collection efficiency in tier 2 and 3 Indian cities to the standards set by MOUD i.e., 100 percent

Source: (Bhubaneswar AMRUT SLIP, 2015; Dehradun smart city annexure, 2015; Governement of Uttarakhand, 2015; Govt. of India, 2017; Shruti Issar and Singh, 2018b, 2018c, 2018a; Sruti Issar and Singh, 2018; Jhansi AMRUT SLIP water, 2017; MP AMRUT SAAP, 2017; Muzaffarnagar AMRUT SLIP Sewerage, 2011; Muzaffarnagar AMRUT SLIP Water, 2015; Sewerage, 2017; Udaipur CDP, 2014)

The above data clearly depict that none of the cities studied meet the service level benchmark and lack in resource sufficiency, equity, efficiency, and operational performance. Immediate measures need to be taken to achieve healthy and sustainable water utilities.

Case study: Dehradun

The water-energy nexus study in Dehradun, the capital city of the state of Uttarakhand was aimed at assessing the energy consumption of urban water infrastructure throughout its lifecycle and assessing environmental impact by estimating associated GHG emissions in terms of CO_2 equivalent using the tool Umberto LCA[+]. The study found that groundwater extraction is the largest energy consuming stage in the entire water system accounting to 83% of the total annual energy consumption. The total annual GHG emission for the urban water system for the city was calculated to be 1.49 lakh ton CO_2 eq.

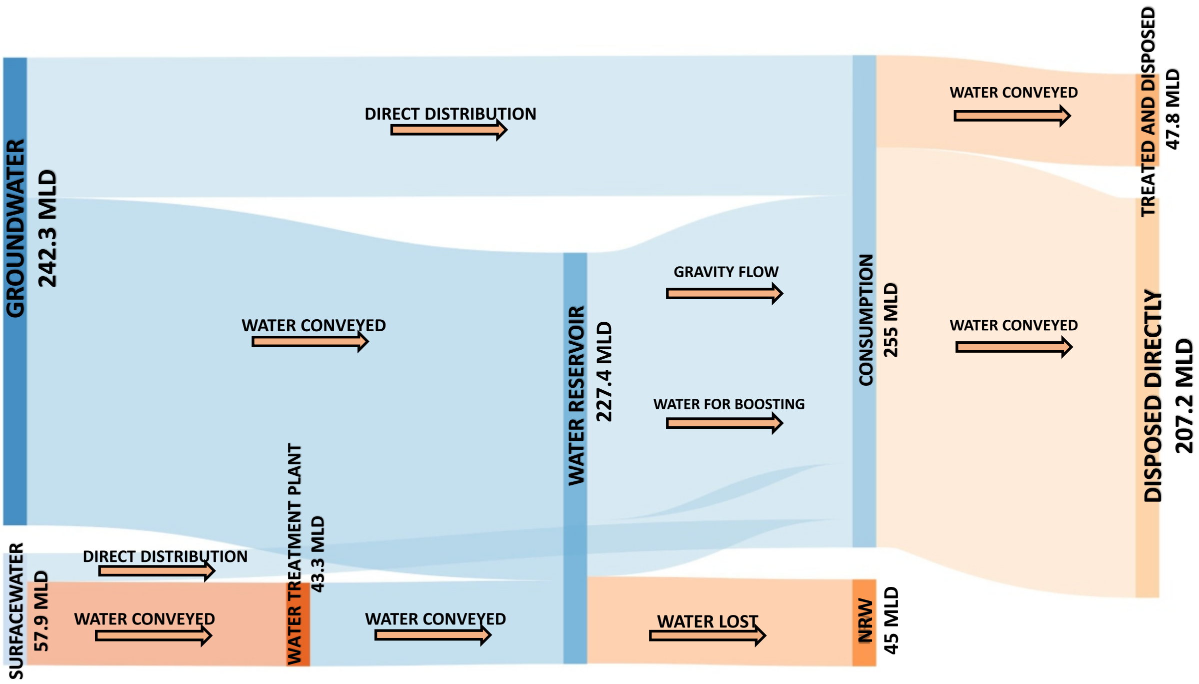


Figure 1: Water flow in the city of Dehradun

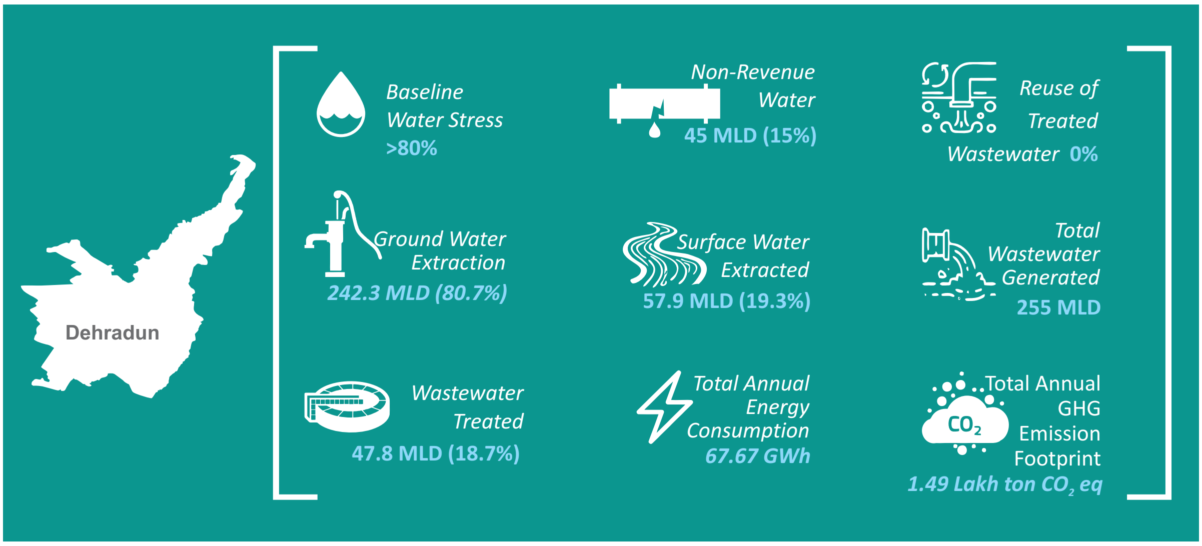


Table 1: Total Annual energy consumption of Dehradun water system

Urban Water System Stages	Total Annual Energy consumption (GWh)
Groundwater extraction	56.17
Surface extraction	0.98
Water treatment	3.68
Distribution(boosting)	2.84
Wastewater treatment	3.99
Total	**67.67**

Table 2: Issues identified and potential interventions in Dehradun urban water system

Areas where interventions required	Potential intervention
High groundwater extraction leading to increased energy consumption	- Shift from GW to alternate water sources like treated wastewater, stormwater, rainwater harvesting.
Increased reliance on freshwater sources leading to high baseline water stress	- Shift to alternate water sources like treated wastewater, stormwater, rainwater harvesting.
High Non-Revenue water	- Mandatory metering of all water connections - Online monitoring and tracking using technologies such as SCADA, IOT, Cloud, Big data, etc. - Infrastructure solutions such as replacement of old and outlived pipelines and pumping system
Lack of sewerage network and low rate of wastewater treatment and reuse	- Shift from conventional centralised system to decentralised system - Shift to nature based plug and play systems.
Increased energy consumption and associated GHG emission[10]	- Integration of analysis tools like Life Cycle Assessment and Material Flow Analysis to assess the current and future scenarios and interventions' environmental impact and energy efficiency of the system.
Lack of utility mapping and data availability	- Mapping of system layout using Geographic Information System - Automation of WTP, STP, FSTP

Data Source: (Medha et al., 2020)

As a continuation of the study, a virtual stakeholder engagement was conducted for the city of Dehradun in the month of November 2020. The stakeholder engagement was held in association with the National Institute of Urban Affairs (NIUA), Been There Doon That, and supported by the Heinrich Böll Stiftung. The objective of the engagement was to understand the technological, institutional and governance challenges faced the city and innovative technologies in the water and wastewater treatment space. The key insights from the engagement are given in the box below.

[10] According to ICLEI's study on energy and carbon emissions profile of 54 South Asian cities evaluated Dehradun's energy consumption to be 43 GWh for the year 2007-2008. The water-energy nexus study conducted in Dehradun by Development Alternatives shows an increase of energy consumption by the city's water system which stands at 67.67 GWh for the year 2018.

Lack of metering system at the consumer end and non-implementation of volumetric tariff leading to inequitable usage, losses and decreased revenue for government water agencies and municipality.

Lack of underground infrastructure mapping system leading to disrupted network system resulting from departments working in silos and damaging the existing water pipelines for new projects.

City requires infrastructural policing

As per the city officials, s it was noted that the city residents use drinking quality water for non-potable activities like car washing, cattle washing, gardening, etc.

The existing water transmission and distribution system have outlived their design period life and have become insufficient to cope with increased demands of the city.

The city lacks last-mile connectivity of water and sewage connections.

Old and dilapidated infrastructure in the city leads to high NRW.

80% of the water extracted from ground making water a highly energy intensive sector in Dehradun.

Dehradun city water officials

The city should adopt IUWM by exploring alternate water sources, volumetric billing, water matching, online and remote monitoring, integrating water cycle including storage, distribution, treatment, recycling, and disposal as part of same resource management cycle, and aligning formal and informal institutions that govern water in and for the city.

The city should integrate decentralised wastewater system to the existing system.

The city should implement third eye enforcement, strict rules and regulation laying out penalty for misuse and wastage of water resources on consumers as well as authoritative department.

The city should provide frequent citizen awareness workshops and trainings on reuse of treated wastewater rainwater harvesting, and ULB capacity development.

The city should pass regulations for conserving rainwater and stormwater.

Subject matter experts

Small scale decentralised and customisable nature-based solutions with lower capital and operational costs can enhance the capacity of urban water system.

Dynamic data provision for tracking and monitoring will help in improving the city water system significantly over time.

The city should explore mechanisms for PPP models with start-ups and new age service providers.

The city can adopt 'use and pay' method in which the city can pay a monthly user charge per wastewater treated. This business model is highly viable for cities facing financial constraints.

Agile service providers with faster ROIs and new payment models making solutions and services affordable to the city and citizens.

Technology providers

Findings and Conclusions

This brief tries to elucidate the water crisis and challenges faced by municipal water utilities in India to achieve efficiency and sustainability of safe water supply and sewage management. The analysis found that there is a lack of comprehensive understanding of the functioning of the interconnected elements in the system. Urban water systems need to adopt technological interventions and infrastructural improvements, capacity building and training programmes, stakeholder engagement, financial alternatives, and innovative business models to achieve resource sufficiency, equity, efficiency and operational performance. The table below discusses some of the overarching issues identified from the graphs presented in the previous section of this brief in Indian municipal water utilities and potential solutions to overcome these challenges.

Table 3: Issues in urban water system, solutions identified and advantages

Issues	Solutions	Advantages
Low coverage of municipal water supply /distribution	- Conservation at source - Mandatory rainwater harvesting - Identifying alternate water source like wastewater reuse, and stormwater	- Equitable distribution of resource - Low stress on freshwater sources - Reduced environmental impacts - Augmented water supply
High Non -Revenue Water	- Mandatory metering of all water connections - Replacement of old and outlived infrastructure - Online monitoring and tracking - Strict policies and rules to take penal actions against unauthorised connections	- Reduced loss of water resource - Augmented water supply - Improved municipal revenue generation - Improved and constant pressure of water supply avoiding pipeline bursts - Real-time data accessibility and enhanced emergency responsiveness - Automated response
Low recovery of cost of water related services	- Mandatory metering of all water connections - Implementing volumetric tariff system - Online monitoring and tracking - Reducing non-revenue water - Expanding consumer base - Digitising water billing system - Penalty mechanism and disconnection clause	- Improved cost recovery - Improved service efficiency - Discourages wasteful use of water - Accurate pricing of water enhances resource equity - Real-time data accessibility and enhanced emergency responsiveness - Automated reports
Low/no sewerage connection and Low Collection efficiency of Sewage Lack of resource and nutrient circularity	- Adopting decentralised solutions in parallel to existing centralised systems - Adopting nature-based solutions for reduced environmental impact and energy efficiency - Plug and play water- wastewater treatment systems - Automation of STPs and FSTPs - Adopting circularity in water by enhancing wastewater treatment and reuse - Enabling nutrient recovery from treated wastewater	- Decentralised solutions have low footprint enabling easy implementing in land scarce municipalities - Nature based solutions are energy efficient and produces less/no sludge - Plug and play systems and automation of WTPs, STPs, FSTPs enable remote operation and monitoring - Reduces manpower and operation costs - Augments water supply - Reduced water pollution and environmental impacts - Nutrient recovery enhances municipal revenue
Lack of availability of data on utility infrastructure	- Online monitoring and tracking system with technologies like SCADA, IOT, Cloud, Big Data, etc - Mapping of municipal utilities with Geographical information System (GIS) - Maximising interdepartmental co-ordination and improved data, information, knowledge and technology exchange between municipal departments	- Real-time data accessibility - Improved transparency and enhanced decision-making ability - Enhanced emergency responsiveness - Remote operation and monitoring - Manpower and operation cost reduction - Improved asset and resource management - Automated reports - Assess capacity utilisation rate - Secured data storage - Improved inter-departmental co-ordination

The above table indicates that few solutions identified can be applied across the subsectors of water system like sewerage, stormwater, sanitation, etc, and can bring improvement at various fronts. This once again emphasises the need for adopting Integrated Urban Water Management (IUWM) in Indian cities.

Recommendations for a Way Forward

Adopting an integrated approach: As discussed in the earlier sections of this brief, IUWM is the future of urban water utilities. IUWM promotes simultaneous planning of urban infrastructures by keeping in mind the demand of all the users of urban resources. With many schemes and programmes rolled out at the national, state, and city level, the country is heavily investing in adequate and efficient urban infrastructure. But often fails to realise the inter-connectedness between these city systems. It is a common sight in Indian cities to have existing urban utilities tampered with on account of new utility projects which shouts out the disintegration and lack of coordination between these utility departments. As a first step towards this, there is a need for breaking the silos between these departments. This can be achieved through introducing a digital platform that facilitates data and information sharing across the sectors. The platform can be used as a forum for the utility departments to register their grievances on any issue caused by another utility project holding them responsible for the restoration of the damage caused. Citizen engagement could also be introduced in the form of third eye enforcement to report any utility breakdown/damage identified across the city. Integrating city-systems helps in improved transparency, accountability, and collective and responsible decision-making. The integrated urban development approach is to be integrated into the system as early as in the conceptualisation stage of development projects in a city.

Improving resource and the energy efficiency of water utilities by integrating system evaluation tools like MFA-LCA and capacity development programs: So as to achieve resource and energy efficiency in urban water system, there needs to be an understanding of the resource flow, energy consumption and environmental impact at each stage. With tools like MFA and LCA, integrating these into the evaluation of urban system provides in-depth foundation to resource and energy optimisation enabling strategic planning and design of the system. Now, in developing countries like India the utility data required for system evaluation using these tools are often not available. Hence, along with integrating these tools into the system, ULBs also need to make sure that the department officers are educated and well equipped with knowledge on the data required for the evaluation, methods of data search, interpretation of the results that help in better decision making and improved interventions, enhanced operational efficiency, and resource and asset management.

The water-energy nexus study conducted in Dehradun discussed in this brief was evaluated with the tool; Umberto LCA+, which helped in understanding resource flow and identifying environmental hot spots in Dehradun water system. Adopting the tool at the city level across the sectors will significantly help in understanding and assessing urban metabolism.

Decentralisation of wastewater systems: The conventional wastewater systems follow a centralised design for sewage networks and treatment. The conventional wastewater treatment system is resource, capital, and energy intensive. Centralised system increases the capital and energy cost due to the need for long distance conveyance of wastewater generated and thus minimises the scope of recycling/reusing wastewater (Mahreen Matto, Shivali Jainer, 2012). Whereas decentralised wastewater system collects wastewater from small clusters eliminating the need for conveyance of wastewater to a central treatment unit enabling the reclaimed water reuse near the source and hence reduces the operation cost. It enables easy expansion of wastewater systems in cities with layered sewer system. A decentralised system has low footprint, low maintenance cost, and does not require skilled manpower to operate the system. Most importantly, the failure of a decentralised system affects only the respective cluster and not the entire city as in case of a centralised system.

Technologies and business models: Generally, along with groundwater extraction, wastewater treatment is considered one of the energy- intensive steps in the water lifecycle. However, in India with only 37% of the wastewater generated treated, it can be assumed that the energy requirement for country-wide wastewater treatment may be low in practice. Though there are extensive technological advancements in water and wastewater system in the country, it is observed that the urban water utilities still follow a conventional centralised system which requires a huge land area, high installation and maintenance costs, skilled labour, and high energy requirement. Innovations in WTP, STP, and FSTP include decentralised, compact, plug and play, and mobile systems. Automation of these systems enables real-time data access, remote operation, management, and monitoring[11]. The market provides WWTPs/STPs based on various technologies such as vermiculture[12], electro-coagulation, electro-oxidation[13], biomimicry[14], and tethered sensors[15], etc. The systems are characterised by low or no energy requirement as they run on solar power, gravitational flow[16], etc. The capital and operational

[11] Faclon Labs Pvt. Ltd.

[12] Absolute Water Pvt. Ltd.

[13] Inphlox Water Systems Pvt. Ltd.

[14] ECOSTP Technologies Pvt. Ltd

[15] Solinas Integrity Pvt. Ltd.

[16] Consortium for DEWATS Dissemination Society

cost for these systems is minimum compared to conventional systems and has faster ROIs. These technologies treat wastewater to the quality which the treated water can be used for non-potable consumption such as irrigation, horticulture, etc. These innovative technologies also convert the sludge into nutrient-rich digestate that can be used as manure. The new-age technology providers are also coming up with new business models for cities facing financial strain such as 'Use and Pay' in which the city can pay a monthly user charge for wastewater treated.

However, these technology providers often find it difficult to bag projects with municipalities resulting from lack of interest of utility authorities to shift to a newer technology and their lack of knowledge in the benefits these technologies could bring into their system. Hence, the need for capacity development to sensitise these officers on the emerging technologies. ULBs need to work on procuring system for piloting these technologies and mechanisms for PPP models with new-age technology providers.

Stakeholder engagement and awareness generation: With water scarcity worsening in the nation with every passing day it is estimated that 30 Indian cities will face an acute water crisis by 2050(WWF, 2020). The need of the hour is to shift from our 'use and throw' mentality to 'use, recycle, and reuse' and spread knowledge on the importance of conserving water at the micro-level. Frequent citizen awareness campaigns and drives to sensitise the community on the water-crisis awaiting and workshops that disseminate knowledge on water conservation methods, and onsite treatment and reuse of greywater needs to be provided. The citizens need to be made aware through radio, social media campaigns, and awareness drives that it is safe to reuse treated wastewater and along with responsible conservation can significantly help in augment water supply, reduce water pollution, and reduce stress on freshwater sources.

Water being a commodity resource, community interest plays a major role in bringing resource efficiency and sufficiency. The importance of community engagement is more evident in cases where they are required to pay an extra user charge for better services. This suggests a community-consultative planning before bringing in any betterment interventions into the system. Multi-stakeholder engagement and local community-consulted interventions creates a sense of ownership and empowerment amongst the citizens and helps in sustainable infrastructure management.

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