Decentralised Urban Water Management in Chhattisgarh

Research Report

National Institute of Urban Affairs

Sanitation Capacity Building Platform

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Contents

Figures

Tables

Executive Summary

The need for a circular economy to ensure water security, is being stressed by the latest guidelines of the Government of India to achieve Goal 6 of the Sustainable Development Goals with regard to ensuring sustainable and equitable access to water supply and sanitation. Decentralised Urban Water Management is more amenable to a circular water economy primarily because the huge complexities and costs involved in the transportation of water over long distances is obviated. It is a perfect alternative that needs to be pursued for achieving economic viability and ecological sustainability of urban water management. This study intends to detail various aspects of centralised and decentralised urban water management systems by analysing water management scenarios in the world, India and specifically in Chhattisgarh state. This report also gives steps to implement decentralised urban water management to establish a circular water economy.

The challenge starts for urban areas with accessing water from a distant source as local surface water sources have not been able to keep pace with demand, and also escalating land values have led to their being converted into real estate as ponds and streams have been built up. Thus, water availability is adversely affected and a corollary to this is that ground water extraction has increased, driving down the water table in the unconfined and confined aquifers. Similarly, the collection and treatment of used water and the disposal of stormwater have become problematical with sewers getting choked and sewage treatment plants not operating properly resulting in pollution of surface and ground water. Costs of centralised urban water management are high and urban local bodies find it difficult to raise them through user charges from the citizens. Thus, on the one hand the water and used water services provided are of low quality and on the other hand a large section of the poor citizens is not properly served and have to do with less and lower quality water supply and polluted surroundings. While the Swachh Bharat Mission has eliminated the problem of open defecation, the considerable number of onsite systems that have been built and thereby increasing demand for technologies and systems to collect, convey and treat the faecal sludge. Consequently, centralised urban water management in India is faced with the twin challenges of economic unviability and ecological unsustainability which it is finding difficult to deal with.

The Government of India has taken note of this problem and approved two significant programmes for establishing a circular water economy recently: Swachh Bharat Mission – Urban Second Phase (SBM-U 2.0) and Atal Mission for Rejuvenation and Urban Transformation Second Phase (AMRUT 2.0). These come on the heels of the Jal Shakti Abhiyan earlier which also stressed implementing a circular water economy. SBM-U 2.0 focuses on ensuring sustainability of Open Defecation Free outcomes by properly processing the faecal waste from pit latrines and septic tanks built in all cities as part of the SBM. Properly managing the used water in cities so that it does not pollute water bodies and the underground aquifers is the other priority of this new programme. AMRUT 2.0 provides the impetus to developing infrastructure for providing functional tap connections to all households, undertaking water source conservation and augmentation through rejuvenation of water bodies and wells and recycling and reusing treated waste water and rainwater harvesting and recharging. A circular water economy is envisaged for the sustainability and viability of the urban water sector to ensure water security.

This study details out the prevailing situation in the urban water sector in the state of Chhattisgarh and also that in a few other cities across India, including the city of Indore which has been declared "water plus" in the treatment and reuse of used water, based on primary and secondary research involving literature review, interviews, water testing and site inspections. This review confirms based on data analysis that both in the cities and towns in Chhattisgarh and in other cities across the country, centralised urban water management is facing problems in providing good water services in an ecologically sustainable, financially viable and socio-economically equitable manner. An analysis of the finances of centralised water supply and sanitation shows that the costs of proper service delivery are unaffordable to over 90 percent of the urban population.

A brief review of international practice in centralised urban water management in the developed countries revealed that even there, where the urban local bodies can raise the higher finances required for this from user charges, climate change is adversely affecting water availability and also causing more storms and hence, there too decentralised water management is being adopted to reduce the costs of water services. Water Sensitive Urban Design involving rainwater harvesting and recharge, and used water treatment and reuse has become mandatory globally so as to secure water availability and prevent flooding from storms and pollution of surface and ground water.

A detailed description of the provisions made by the Government for implementing a circular water economy is provided in this study followed by the schematic design of a decentralised water management system at the household and community levels in accordance with these Government policies .The various components of this system and their contribution to making the water economy circular are also described. The water balance is estimated for the study towns of Chhattisgarh and this shows that the water availability is much more than the demand and so a substantial part of the precipitation can be recharged into the aquifer ensuring long term ecological sustainability.

The costs of the decentralised and centralised systems have been compared and the former have been found to be much less, and it is to be borne mostly by individual households and layouts, leaving the urban local bodies with having to cater only to the poor households. This will have a salutary effect on the finances of the urban local bodies which are currently highly stressed due to the inability to recover costs through service charges.

Finally, the policy changes required for implementing a circular water economy through decentralised water management are detailed. These mainly involve the strict implementation of the laws and rules with regard to building, construction, and urban planning which provide for decentralised water management but these are being flouted at will at present. A major recommendation is that the Government must create an ecosystem of water sector professionals from designers and academicians to technicians who will holistically support the implementation of decentralised water management systems in a sustainable manner. Currently, in the absence of such an ecosystem decentralised urban water management is being practiced only at the margins. The funds being provided by the Union and State Governments to urban local bodies have to be tied to the implementation of decentralised water management so as to make this possible. Last but not the least, a huge awareness campaign needs to be undertaken to explain to people the challenges facing centralised urban water management and the benefits of decentralised urban water management. Jal Sakti Abhiyan promotes water conservation and water resource management by focusing on accelerated implementation of five target interventions, viz. water conservation & rainwater harvesting, renovation of traditional and other water bodies/tanks, reuse and recharge of bore wells, watershed development and intensive afforestation. With this campaign, stakeholders have started taking steps for water conservation.

Decentralised Urban Water Management

Centralised urban water management faces many challenges globally because the linear economy of “take, make, consume and waste” that undergirds it, has not only become economically unviable but also lacks ecological resilience and sustainability (World Bank, 2021). Consequently, there is a need for a circular and resilient economy of water in which “waste” is treated, recycled and reused reducing the “take”, “make” and “consume” factors that bedevil the linear economy and so the term “wastewater” has been replaced by the new term “used water” (MoHUA, 2021a), which will be used hereafter in this report. Thus, the Atal Mission for Rejuvenation and Urban Transformation Second Phase of the Government of India has stressed the promotion of a circular water economy to make cities water secure (MoHUA, 2021b).

A Circular Water Economy (CWE) is one that reduces water consumption and reuses and recycles treated used water generating manure and energy in a socio-economically inclusive manner mitigating greenhouse gas emissions and enhancing resilience to climate change (Brears, 2020).

Typically, it is easier to design and implement a CWE in urban areas in a decentralised ‘manner’ than in a centralised manner, because the complexities and costs of conveying water and used water over long distances in a centralised system are eliminated in a decentralised system. Therefore, it is necessary to give more weightage to decentralised urban water management in India than the case at present. However, well planned decentralised urban water management is a rarity in India. Taking a cue from the colonial approach of planning, urban water management has followed a centralised model since independence both in existing towns and cities from the colonial times, and in new greenfield ones like Chandigarh, Bhubaneswar and Navi Mumbai to name just a few. Decentralised Urban Water Management (DUWM), in a CWE, can be defined as follows for the purposes of this study –

Decentralised systems are generally understood as being localised wastewater systems or as systems supplying water resources, that are sourced close to the point of use. It refers to on-site, clustered or development scale decentralised wastewater systems and provides water and wastewater services It can involve an amalgam of systems at the onsite (or allotment) scale and those at the cluster or development scale.

1. Introduction

Centralised Urban Water Management (CUWM) in the Indian context has been pursued primarily because there is significant expertise in design, implementation and Operation and Maintenance (O&M) of such systems that have developed over the past century and a half in urban development in India and across the world. However, CUWM is not compliant with CWE principles in many respects as it is still largely part of the linear economy as detailed below.

1.1 Linear Economy Characteristics of Centralised Water Supply

- The increase in population over the years has resulted in local surface water sources becoming both insufficient and severely polluted (NIUA, 2019a). Distant sources have to be tapped and these require huge capital and O&M expenditures. These sources too become inadequate over time and so newer sources are required to be found at greater capital and O&M expenditures (Banerjee, 2019). Thus, both the "take" factor, the sourcing of water and the "make" factor, the treating of water and delivering it to the consumer, have in the linear development model have increased impacting economic viability and ecological resilience negatively.
- Piped water supply leads to greater wastage. Piped water supply obviates the required labour the consumer household in bringing water from a distance, and instead delivers water to them through pumps and pipes and hence, people tend to use more water in bathing and washing oblivious of the tremendous actual costs of this water supply since it is highly subsidised. So, the "consume" factor in the linear development model increases.
- Since the centralised supply is not adequate in most cases, there is also individual ground water extraction through borewells, which results in water mining and over extraction from the confined aquifers. This also leads to the tapping of deeper aquifers which may lead to geogenic contaminants in water such as fluoride and arsenic (Shah and Kulkarni, 2015). Once again this leads to an increase in the "take" factor in the linear development model.

This non-compliance with CWE results in economic unviability and poor service delivery of centralised water supply in India as follows:

- The high cost of water supply is not recovered in the form of user charges and so its quality and frequency are unreliable and intermittent, and much less in most towns than the 135 litres per capita per day (lpcd) norm for cities, which is necessary in urban areas with sewerage in order to have enough flow in the sewers to carry the sludge by gravity to the Sewage Treatment Plants (STP) and prevent the corrosion of the sewers (NIUA, 2005).
- The high cost of water and its scarcity results in a high proportion of non-revenue water due to theft in collusion with the suppliers (World Bank, 2012) and this further aggravates the finances of the Urban Local Bodies (ULBs).
- Distribution networks are not maintained properly due to this lack of funds faced by ULBs and so, they are plagued with leakages and contamination from sewage (CPHEEO, 2005).
- The O&M of the whole water supply system from the sourcing of raw water from distant sources to its treatment and distribution is very complex and requires a high degree of technical skill which is not available due to lack of finances with most ULBs (CPHEEO, 2005).

1.2 Linear Economy Characteristics of Centralised Used Water Disposal

The centralised used water disposal systems have some inherent design flaws, which make proper treatment and reuse of used water for meeting some of the water demand in compliance with the CWE difficult.

- Sewerage systems ideally require 135 lpcd water supply to maintain adequate flow and in no circumstances can this be less than 100 lpcd. However, this is rarely the case and so there is deposition of solid matter leading to choking of sewers and higher costs of O&M (NIUA, 2005).

- Even where there is adequate water supply, there are not enough house connections and in most cases, these connections are to the overflow from septic tanks and the kitchen and bathroom used water. The septic tanks dampen the flow of the used water from the toilets and reduce its velocity. This results not only in inadequate flow but also there is not enough faecal matter as most of it is deposited in the septic tanks.
- The mixing of greywater from the kitchen and bathroom, which constitutes 80 percent of the used water generated and is less costly to treat, with the blackwater from the toilets, which is more expensive to treat, unnecessarily increases the amount of used water to be treated as blackwater. However, this is inevitable in centralised used water systems as it is not possible to have separate transportation and treatment for the two types of used water (CPHEEO, 2013). Thus, in most cases used water is not treated to prescribed standards for non-potable water reuse. A survey of 54 cities with million plus population revealed that only 17.8 % of the treated water is being reused primarily because of the high costs involved in pumping the treated water back to the city from the STPs (CPHEEO & MoHUA, 2021).

This results in economic unviability and poor quality of used water conveyance as follows:

- There are inadequate resources with the ULBs for the Operation and Maintenance (O&M) of the sewerage system. The user charges that are levied from the users do not cover the cost of O&M of the sewerage systems let alone the huge capital costs (World Bank, 2012).
- The cleaning of sewers which get clogged due to inadequate flow and the flushing of plastics is largely outsourced to contractors. There is an inadequate supply of machines capable of cleaning the sewers due to lack of funds and so this work is mostly done manually in violation of the law against manual scavenging. This frequently results in deaths of the staff employed for the purpose.
- The huge investments required for building sewers necessitates the adoption of a long design period of about 30 years. However, when the sewers are newly built there are not enough houses in some of the less congested areas and so there is much less than the design flow which is anyway less because the water supply is insufficient. The velocity of flow in the sewers should be between 0.8 m/sec which is the minimum requirement for non-deposition of solids and 3 m/s which is the scouring velocity which leads to erosion of the sewer (CPHEEO, 2013). However, the velocity falls below the minimum level and this leads to deposition of sludge in the sewers and corrosion and so the huge investment is wasted without proper use.
- There is an anomaly concerning stormwater management also. Stormwater drains have to be designed for the highest recorded intensity of precipitation of twenty-five years. The design peak flow estimated from this is a high value that is rarely there for more than two or three days a year when heavy rainfall occurs. So unnecessarily big sections have to be designed for stormwater drains and constructed at great expense, which rarely flow to their capacity. Instead, they get choked with rubbish and cannot transport the runoff during heavy rains. Due to the high capital expenditures involved in most cases, the lack of funds forces the ULBs to design and construct smaller stormwater drains, that is not designed to take peak flows, and leading to water logging in most cities in India during the monsoons (CPHEEO, 2019).

The treatment of the used water and so its reuse too is adversely affected due to lack of resources with ULBs adversely affecting the possibilities of using the "waste" factor for reducing the "take" and "make" factors as revealed by studies conducted by the Central Pollution Control Board and the National Institute of Urban Affairs from time to time (CPCB, 2015 & CPCB, 2021, NIUA, 2018, NIUA, 2019a, NIUA, 2019b):

- There is a big gap between the used water generation and treatment, with installed STP capacity in the country being only 44% of the estimated sewage generation in 2021 (CPCB, 2021). The inadequately treated and untreated used water is being released into water bodies and the open causing surface and ground water contamination.
- The agencies or departments engaged in the O&M of STPs are suffering from a financial crisis and lack of skilled manpower due to the poor financial status of the ULBs (World Bank, 2012).
- The treatment and disposal of sludge from the STPs is a problem because this too is a costly proposition and is not being done properly. There is a reduction in the emptying of the STPs, resulting in a drastic reduction in treating capacity. There is little attempt to generate energy and manure from the sludge and thus recover some of the costs (CPCB, 2015 & NIUA, 2019a).
- Industrial effluents are also being mixed into the sewage coming to the STPs instead of being treated in Effluent Treatment Plants separately (CPCB, 2015 & NIUA, 2019a).
- All the STPs have a by-pass arrangement. The STPs treat only a portion of the sewage received and the rest of the sewage is discharged untreated through by-pass arrangements. During monsoons when it rains heavily, the whole flow is bypassed (CPCB, 2015 & NIUA, 2019a).

- The treated sewage of most of the STPs is not being monitored and analysed on a regular basis for the assessment of the degree of treatment as in most cases there are no dedicated and functioning laboratories in the STP campus for this purpose (CPCB, 2015 & NIUA, 2019a).
- There is little planned reuse or recycling of treated used water which is an important means of cost recovery as this involves more investment in treated used water delivery systems. The non-potable water use, which constitutes a substantial proportion of the total urban water use can be met from treated used water but this is mostly not being done (CPCB, 2015 & CPCB, 2021).
- The treated sewage is mostly discharged in the nearest used water drain. Chlorination is mostly not being done at the outlet of most of the STPs for control of Total and Faecal Coliforms and fungi, thus contributing to contamination of surface water bodies and groundwater (CPCB, 2015, NIUA, 2019a).
- Diesel generator sets are not provided in most of the STPs for backup power, that aids in operation of the biological system without any interruption during power failure, and without this treatment quality suffers in case of grid power failure (CPCB, 2015, NIUA, 2019a).

The Manual on Sewerage and Sewage Treatment published by the Central Public Health and Environmental Engineering Organisation also corroborates the above findings (CPHEEO, 2013).

A SWOT analysis of CUWM on the basis of the above discussion is presented in Table 1 below.

Table 1: SWOT Analysis of Centralised Urban Water Management

STRENGTH	**OPPORTUNITIES**
Technology and Standard Operating Procedures are well developed in India and so considerable design, installation and O&M expertise is available for implementation.	The harvesting of precipitation and the proper treatment and reuse of used water can reduce costs of supply and also ensure better cost recovery and service delivery.
WEAKNESS	**THREATS**
The inability of urban local bodies to recover the costs of operation and maintenance results in poor quality of service especially to the socioeconomically deprived population who constitute a substantial proportion in India.	Failure to comply with the requirements of a Circular Water Economy will seriously jeopardise the availability of water, pollute the environment and result in social strife in future.

1.3 Decentralised Urban Water Management

The Report of the National Mission on Sustainable Habitat (NMSH) has focused on the increasing unsustainability of centralised water supply systems due to their huge dependence on electrical energy and water from distant sources for their operation and suggested the greater use of decentralised systems. These are proposed to be based on in situ rainwater harvesting and recharge for fulfilling water supply needs including the recharge of stormwater from public spaces and roads (GoI, 2019a). The sub-committee on stormwater management of NMSH states as follows –"encroachment of natural streams passing through urban areas, it was observed, on the one hand results in the pathway / water line being blocked / constructed and on the other hand, more and more developments are enhancing the run-off causing increased peak flow and frequent inundation. To overcome this, rainwater harvesting is to be made mandatory and artificial ground water recharge should be encouraged" (GoI, 2019b). There is haphazard and excessive exploitation of ground water for water supply by contiguous households, without any scientific study of the underlying hydro-geological situation. Groundwater constitutes 50% of total urban water supply and so augmenting it through water recharging on a large scale will considerably ease the water supply problem (Narain, 2012). The guidelines for water conservation published under the Jal Shakti Abhiyan (GoI, 2019d) too, reiterate the above recommendations of the NMSH as will be detailed later.

The Manual on Sewerage and Sewage Treatment published by CPHEEO, 2013 lists the benefits of decentralized used water management (DUWM) as follows:

- Prediction of sewage volumes is far easier in decentralized sewerage micro collection areas and to that extent, the design, construction, and O&M become much easier and better.

- Flows in decentralized sewerage are relatively smaller and this implies that environmental damages from any mishaps are also minimal.
- Since the sewage network is much smaller It is easier to detect the release of industrial waste into DUWM systems.
- The main problem in centralised systems is the impracticability of separation of grey and blackwater and this is a major reason for a high cost of treatment. The treatment and reuse of used water in a segregated manner for grey and blackwater is much easier in decentralised systems leading to more efficient outcomes.
- The ecology of rivers, streams and ground water is better managed as greywater is treated and reused and smaller volumes of treated blackwater discharges and recharge take place at multiple locations.
- The generation of energy from treatment of blackwater and the composting of sludge into manure becomes easier due to lesser volumes.

The Report of the Sub-Committee on Water Supply and Sewerage of the National Mission on Sustainable Habitat has gone a step further and recommended as follows (GoI, 2019c):

- In case of multi-storeyed constructions and gated communities, internal dual piping for toilet flushing shall be made mandatory. It shall also be mandated for high-end users such as Hotels, Malls, and Industries.
- Such building communities and groups of housing implementing dual piping shall also ensure on-site treatment of used water to the water reuse standards of the nation or as per international best practices till the national standards are developed.

Two detailed studies of urban sanitation conducted by the Sanitation Capacity Building Platform (SCBP) of the National Institute of Urban Affairs (NIUA) in the states of Rajasthan and Madhya Pradesh have advocated a combination of decentralized water supply and sanitation at the household level as the optimum solution in the Indian context in both ecological and economic terms (NIUA, 2018, 2019b). These studies have also revealed that at present the decentralised water supply and used water management are not being done in a proper manner and it is aggravating the problems rather than resolving them. The National Faecal Sludge Management Policy (GoI, 2017) details these problems as follows:

- Mostly septic tanks or pits are used for collecting and treating the blackwater and these are often placed under toilets and are sealed or have limited access. Often the septic tanks are unlined and so the polluted water seeps directly into the ground without any treatment.
- Septic tanks are often oversized even if they are lined due to lack of technical competence. They are not designed as per the IS code 2470. Thus, regular cleaning is not done and the householder waits for the tank to fill up and this reduces its treatment efficiency and the outflow is highly polluted.
- Septic tanks are not accompanied by soak trenches or soak pits and effluent is released untreated into open drains posing a health hazard.
- Urban Local Bodies have inadequate services like suction tankers and trained human resources and do not provide faecal sludge treatment facilities.
- There are very few formal private tank cleaning service providers and those that are there mostly dump the collected faecal sludge into open fields or drains creating health hazards.
- The widespread perception due to the caste system, that handling of faeces pollutes the person, has resulted in illegal Manual Scavengers being prevalent despite a stringent legislation, i.e., The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013.

The above mentioned studies also concluded that there are many cost-effective and environmentally sound decentralised treatment options, some of which have been detailed in the Guidelines for Decentralised Used Water Management (GoI, 2012) and by the Consortium for Decentralised Water Treatment System (DEWATS) Dissemination Society (CDD & NIUA, 2017). The main considerations for used water treatment systems, depending on the technology used, are the area required and the capital and O&M expenses. These are much less for decentralised systems because the used water volume and conveyance distance are much less than for centralised systems. The costs of used water treatment go up exponentially with volume and distance of conveyance. The greater availability of treated used water for reuse and recharging reduces the demand for expensive potable water from distant sources. Increase in availability of groundwater and energy generated from the anaerobic digestion of sludge means lesser use of fossil fuel based electrical energy, which in turn means lesser emission of greenhouse gases. Alternative decentralised systems also have a positive climate change mitigation impact by reducing the demand for fossil fuel based electricity (GoI, 2019c).

However, DUWM suffers from a lack of expertise due to its marginality in overall planning and implementation of urban water management. Currently, there is no ecosystem for the implementation of decentralised urban water management. Therefore, individuals and NGOs are trying to implement it on their own with marginal impact (Biome Environmental Trust, 2021). People will adopt decentralised systems only if there are trained architects, engineers, plumbers, masons, and manufacturers of components in large numbers and an easily accessible maintenance and repair facility. The lack of this is preventing DUWM from being widely adopted. A SWOT analysis of DUWM on the basis of the above discussion is presented in Table 2 below.

Table 2: SWOT Analysis of Decentralised Urban Water Management

STRENGTH	OPPORTUNITIES
Simple to implement whereas the economic and ecological costs are much less than for CUWM. Totally compliant with CWE.	The precarious financial condition of ULBs which is deteriorating further will result in more and more possibilities for adoption of DUWM.
WEAKNESS	**THREATS**
The absence of an ecosystem consisting of designers, implementers and O&M providers to facilitate DUWM.	The reluctance of water management professionals and policy makers to promote DUWM on a greater scale

The Government of India has taken these above factors into consideration and given approval to two very important programmes – Swachh Bharat Mission – Urban Second Phase (SBMU 2.0) and Atal Mission for Rejuvenation and Urban Transformation Second Phase (AMRUT 2.0) (IE, 2021). SBMU 2.0 will focus on ensuring sustainability of Open Defecation Free outcomes by achieving proper processing of the faecal waste from the huge number of pit latrines and septic tanks that have been built in all cities as part of the SBM (MoHUA, 2021a). Properly managing the used water in cities with less than 1 lakh population in Census 2011 so that it does not pollute water bodies and the underground aquifers is the other priority of this new phase of SBM. AMRUT 2.0 is to provide the impetus to developing infrastructure for providing functional tap connections to all households, undertaking water source conservation and augmentation through rejuvenation of water bodies and wells and recycling and reusing treated used water and rainwater harvesting (MoHUA, 2021b). Thus, a circular water economy is envisaged by the Government for the sustainability and viability of the urban water sector so as to ensure water security.

1.4 Structure of Present Study

This study builds on the earlier research work of the NIUA for the improvement of urban water management by critically analysing its status in the state of Chhattisgarh and suggesting a way forward in compliance with CWE. The Structure of the study is as follows:

- First, the town plans and project documents and the actual prevailing situation in a few sample towns are studied. Chhattisgarh has a total of five river basins draining it – Mahanadi, Godavari, Ganga, Brahmani and Narmada. However, the latter two have very small drainage areas, so a town each, of differing size from the big to the small, has been chosen from the first three basins for this study as follows –
    - The first is the city of Raipur in the Mahanadi basin which has a million plus population.
    - The second is Jagdalpur in the Godavari basin which has a population of about 3 lakhs.
    - The third town is Surajpur in the Ganga basin with a population of about 25000.
    - Along with these, the greenfield capital complex of Naya Raipur has also been studied.
- This is followed by a study of centralised water management across India and the globe and a critical analysis of the characteristics of present urban water management practices that prevent them from complying with CWE.
- Then, detailed planning is undertaken for DUWM and the costs, both economic and environmental, of DUWM and CUWM in the study towns of Chhattisgarh are compared.
- Finally, a detailed listing is done of the policy changes required for implementation of CWE in consonance with the Government of India's latest policy directives.

2. Objectives

The overall goal of the study is to prepare a plan for decentralised urban water management in Chhattisgarh to ensure economic viability and ecological sustainability and resilience with active people's participation within a CWE. The subsidiary objectives for achieving this goal are as follows:

1. Evaluating the prevailing linear economy characteristics of centralised urban water management systems in the state of Chhattisgarh.
2. Studying a sample of towns of various sizes and locations in Chhattisgarh and in India to contextualise the various aspects of centralised urban water management.
3. Design of a decentralised urban water management system in the study towns and a comparison of its economic and ecological costs with that of a centralised urban water management system.
4. Determining the policy, legal and governance changes required to make it possible to implement a circular water economy.

3. Methodology

The study is a mix of primary and secondary research and interdisciplinary urban planning based on data garnered from this research. The study was carried out by a small team of researchers and so is limited in scope with its greater reliance on secondary data. The primary research for the study involved the following:

1. Field visits to the study towns to evaluate the operation of the existing water supply and sanitation systems including conducting tests on water sources and used water in drains.
2. Informal discussions with people living in slums, people relying on tankers for water supply, water supply tanker operators, private septic tank cleaning agencies, private centralised sanitation operators, people's representatives and various Government staff involved in water supply and sanitation to get a broad qualitative picture of the water management scenario in the study towns.

The secondary research involved a critical analysis of the following existing data and reports:

1. The Town Plans and Detailed Project Reports of projects undertaken through the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Atal Mission for Rejuvenation and Urban Transformation and the Smart City Initiatives.
2. The annual budget documents of the urban local bodies of the study towns and the state of Chhattisgarh as a whole.
3. The O&M records of the water supply and sanitation systems.
4. The district groundwater report prepared by the Central Groundwater Board and the relevant section for the study towns in the National Artificial Recharge Masterplan prepared by the same agency (CGWB, 2016).
5. Survey of literature on water management.

The socio-economic water balance for the study towns has been prepared on the basis of the data collected from the above-mentioned sources.

The final output on the basis of the above is a detailed CWE compliant water management plan listing the infrastructure, O&M systems, governance systems and community participation processes along with an estimation of the costs and affordability.

4. State Level Analysis

The state of Chhattisgarh has an area of 137,900 square kilometres of which forest area is 63,530 sq kilometres or a healthy 46.1 percent. The cultivated area is 46,770 sq. kilometres or 33.9 percent with a very low irrigation proportion of 20.1 percent (CECB, 2021). Total population of Chhattisgarh as per 2011 census is 25,545,198 of which males are 12,832,895 and females 12,712,303, which is estimated to have become 30 million currently. Male literacy in 2011 was 80.27% and female was 60.24%. The urban population proportion was 23.24% which is estimated to have gone up to about 29.6% in 2021. The work participation rate for males in 2011 was 55.59% and for females 39.69% which were significantly above the national average of 51.7% for males and 25.6% for females. Chhattisgarh had a Net State Domestic Product per capita of Rs 1,17,615 in 2021 which is significantly below the national average of Rs 1,63,080 and so it had a low rank of 25 among The Indian states (MoSPI, 2021).

4.1 Hydrogeology of Chhattisgarh

Table 3: River Basins in Chhattisgarh

River Basin	Area (sq. kms)	Proportion (%)
Brahmani	1466.0	1.1
Godavari	39444.6	28.6
Ganga	18784.3	13.6
Mahanadi	77443.9	56.2
Narmada	761.0	0.6

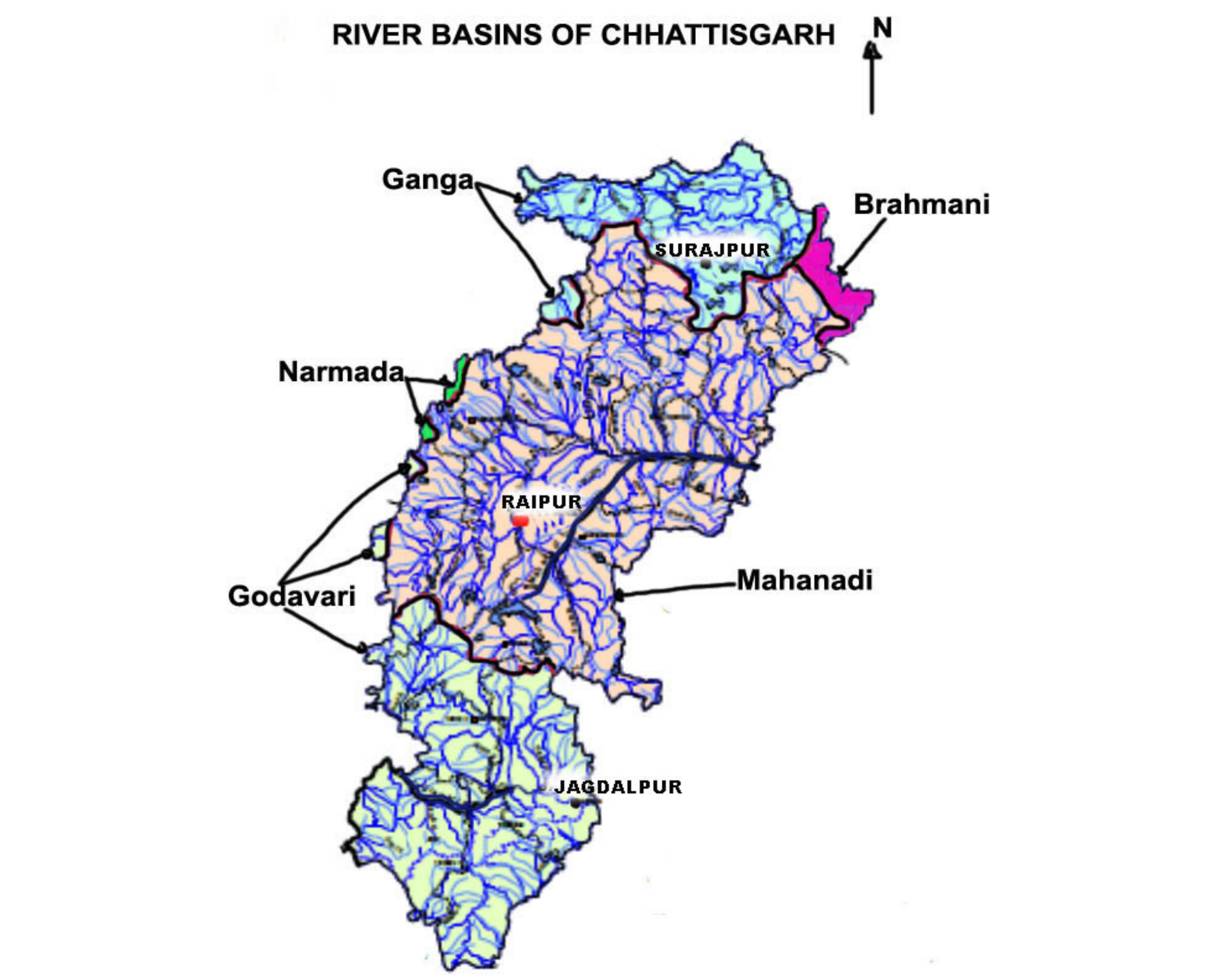
Source: CGWB 2012

The Mahanadi is the biggest basin constituting 56.2 percent of the total area of the state and also accounting for most of the water flow. The Raipur-Naya Raipur-Durg-Bhilai conurbation which is industrially the most developed area of the state lies in this basin as do the other major urban-industrial areas such as Rajnandgaon, Bilaspur and Raigarh. Most of the irrigated agricultural land is also in this basin. The Godavari Basin is the next largest basin and is situated in the southern part of the state and is densely forested. There is iron mining activity in this basin but otherwise it is less developed as most of the iron is either exported abroad or sent to the steel plants in the Raipur-Bhilai-Durg conurbation for processing. Some areas of the northern part of the state are in the Ganga basin and this area has coal mines which are now slowly becoming exhausted. This area too is heavily forested and comparatively less developed. The River Son rises in this region and all the other rivers in this basin in Chhattisgarh eventually drain into it. The Brahmani and Narmada basins have very low area in the state.

The river basin map of Chhattisgarh is shown in Fig. 1 below with the location of the study towns of Raipur, Jagdalpur and Surajpur in the Mahanadi, Godavari and Ganga basins. The annual rainfall in Chhattisgarh is between 1300 and 1500 mm and based on this it has been estimated that the annual replenishable water availability is 12.22 Billion Cubic Metres (BCM). There are 146 blocks in the state out of which 68 blocks have stage of total water resource development within 30%, 38 blocks have stage of development between 30 to 50%, 25 blocks have development within 50 and 70% and only 15 blocks have attained stages of development more than 70%. The State as a whole has a stage of water resource development of only 31.04%. Only 14 blocks have been categorized as semi-critical with regard to ground water development and they are all in the Mahanadi basin. The remaining 132 blocks have been categorized as safe from ground water development point of view (CGWB, 2012).

The post monsoon average depth to water level is in the range of 3 to 6 meters below ground level in the shallow unconfined aquifer. Thus, the volume of unsaturated zone available for artificial recharge up to 3 m below ground level is 58237.38 Million Cubic Meters (MCM) for the whole state (CGWB, 2020). The total precipitation at 75 percent dependability is 102700 MCM and so a considerable part of this can be utilised to saturate the shallow aquifer and some of it will infiltrate into the confined aquifer depending on its hydrogeological characteristics.

Fig. 1 River Basin Map of Chhattisgarh showing Study Towns (Adapted from CGWB, 2012)



The district wise confined aquifer characteristics of Chhattisgarh are given in Table 4 below. This is from the year 2012 when Chhattisgarh had only eighteen districts. The confined aquifers in most parts of the state are less productive, being of crystalline nature.

Table 4: District wise Aquifer Characteristics in Chhattisgarh

Sl No	District Name	Area (sq km)	Aquifer Condition
1	Bastar	10577.7	Major parts of the district covered with gneiss and other crystalline aquifer, low yield potential and represented by high ground water gradient. Eastern part of the district is covered with limestone aquifer which is more potential in the district.
2	Bijapur	8809.6	Major parts of the district covered with gneiss and other crystalline rocks with low yield potential and represented by high ground water gradient.
3	Bilaspur	8342.9	District is covered partly by crystalline aquifer and sedimentary aquifer. Sedimentary aquifer mainly consists of limestone and shale. Discharge potential of this aquifer is very high (upto 20 lps). Ground water gradient is very low.
4	Dantewara	8390.3	Major parts of the district covered with gneiss and other crystalline rocks having low yield potential and represented by high ground water gradient.
5	Dhamtari	4068	Major part covered with granitic aquifer, yield potential ranges from 3 to 5 lps. Sedimentary formation is having high yield potential in the district.
6	Durg	8627.2	Northern part of the district is covered with sedimentary aquifer mainly consist of shale and limestone. Due to karstification, these aquifers are highly productive.
7	Janjgir- Champa	3877.6	About 50% area of the district is covered with sedimentary formation and remaining part by crystalline aquifer. Yield potential of sedimentary formation is moderate.
8	Jashpur	5826.7	Entire district is covered with gneiss and basaltic aquifer. Yield potential of this formation is very low.
9	Kanker	6773.4	Entire district is covered with granitic aquifer. Due to fracturing potential zones are developed in localized patches.
10	Kawardha	4228.3	A small portion of the district is covered with limestone and shale aquifer. Due to cavernous nature these formations are highly productive. Remaining part is covered with schist and phyllite, which behaves as aquiclude.
11	Korba	6621.8	Major part of the area is covered with semi- consolidated sandstone and shale aquifer of Gondwana formation. Due to argillaceous nature, these formation are low productive.
12	Koriya	6643.8	Major part of the district is covered with semi- consolidated shale and sandstone aquifer of the Gondwana formation. Due to argillaceous nature, these formations are less productive.
13	Mahasamund	4758.1	Major part of the district is covered with granitic aquifer which is less productive. Eastern part of the district is covered with limestone, shale and sandstone aquifer of Chhattisgarh group which acts as potential aquifer in the district.
14	Narayanpur	4640.8	Major parts of the district covered with gneiss and other crystalline rocks of low yield potential and represented by high ground water gradient.
15	Raigarh	7088.9	Major part of the district is covered with semi-consolidated shale and sandstone aquifer of Gondwana formation. Due to argillaceous nature, these formations are less productive. Southern part of the district is covered with shale aquifer of Chhattisgarh formation.
16	Raipur	12461.9	Major part of the district is covered with granitic aquifer which is less productive. Northern part of the district is covered with limestone, shale and sandstone aquifer of the Chhattisgarh group which forms potential aquifer in the district.
17	Rajnandgaon	8080.9	Major part of the District is covered with granitic aquifer which is less productive. Northern part of the district is covered with limestone and shale aquifer of the Chhattisgarh group which forms potential aquifer in the district
18	Surguja	15777.9	Major part of the district is covered with semi consolidated shale and sandstone aquifer of Gondwana formation. Due to argillaceous nature, these formation are low productive.
Total		135595.8	

Source: CGWB (2012)

4.2 Urban Water Situation and Planning in Chhattisgarh

The combination of high rainfall and water retention in the shallow aquifers has traditionally facilitated the digging of shallow tanks in Chhattisgarh for water security. So, all habitations, villages and towns had many tanks and ponds which provided adequate water supply. When the modern piped water supply was introduced in cities and towns, too, water was available in plenty in the many perennial rivers flowing near these towns. Therefore, despite the water supply quantity having increased considerably, the sources have been adequate.

Chhattisgarh has witnessed accelerated urbanisation since the state was formed in 2000 and land values have increased exponentially in towns and cities throughout the state and especially in the Raipur-Bhilai-Durg conurbation. As a result, the tanks that were privately held in urban areas have been increasingly sold to be filled up and constructed into buildings, resulting in a drastic reduction in the number of tanks (Chakravarty, 2015). The problem is compounded by the fact that there are no sewerage systems in any urban areas in Chhattisgarh except for the Steel Authority of India township in Bhilai and the new greenfield capital city of Naya Raipur. So, in most cases the open drains carrying the used water from nearby areas flow into the few tanks that still remain in the public domain, polluting them badly and resulting in their eutrophication.

Nine of the biggest cities in Chhattisgarh, which are all municipal corporations, have been chosen for urban development under the Atal Mission for Rejuvenation and Urban Transformation on the basis of their population as given in Table 5 below. The population of these nine cities, which all have municipal corporations, cumulatively constitute 54 percent of the total urban population of Chhattisgarh. Five other municipal corporations and 43 Municipalities, constitute 21 percent of the urban population and 112 Nagar Panchayats constitute the balance 25 percent (UADD, 2021).

Table 5: Cities selected for Urban Development under AMRUT

S. No	City	Population 2011 (in lakhs)
1	Raipur Municipal Corporation	10.48
2	Bhilai Municipal Corporation	6.25
3	Korba Municipal Corporation	3.63
4	Bilaspur Municipal Corporation	3.49
5	Durg Municipal Corporation	2.67
6	Raigarh Municipal Corporation	1.66
7	Rajnandgaon Municipal Corporation	1.63
8	Ambikapur Municipal Corporation	1.25
9	Jagdalpur Municipal Corporation	1.25

Source: GoCG 2016

The AMRUT guidelines for water supply and sanitation projects are as follows (UADD op cit):

Water supply:

- Water supply systems including augmentation of existing water supply, water treatment plants and universal metering.
- Rehabilitation of old water supply systems, including treatment plants.
- Rejuvenation of water bodies specifically for drinking water supply and recharging of ground water.
- Special water supply arrangement for difficult areas, hill and coastal cities, including those having water quality problems (e.g. arsenic, fluoride)

Sewerage facilities and septage management:

- Decentralized, networked underground sewerage systems, including augmentation of existing sewerage systems and sewage treatment plants.
- Rehabilitation of old sewerage system and treatment plants.
- Recycling of water for beneficial purposes and reuse of wastewater.

Storm water drains to reduce flooding:

- Construction and improvement of drains and storm water drains in order to reduce and eliminate flooding.

The funding for these programmes sanctioned for Chhattisgarh for the five-year period from 2015-2020 in Rs crores as given in Table 6 below.

Table 6: Allocation for AMRUT in Chhattisgarh 2015-20 (Rs Crores)

S. No.	Name of ULB	Water Supply	Sewerage and Septage Management
1	2	3	4
1	Ambikapur	46.16	6.00
2	Bhilai	242.73	20.00
3	Bilaspur	245.53	21.79
4	Durg	47.43	15.00
5	Jagdalpur	74.00	10.00
6	Korba	207.03	18.00
7	Raigarh	96.44	10.00
8	Raipur	147.00	651.29
9	Rajnandgaon	80.83	12.00
	TOTAL	1187.15	764.08

Source: GoCG 2016

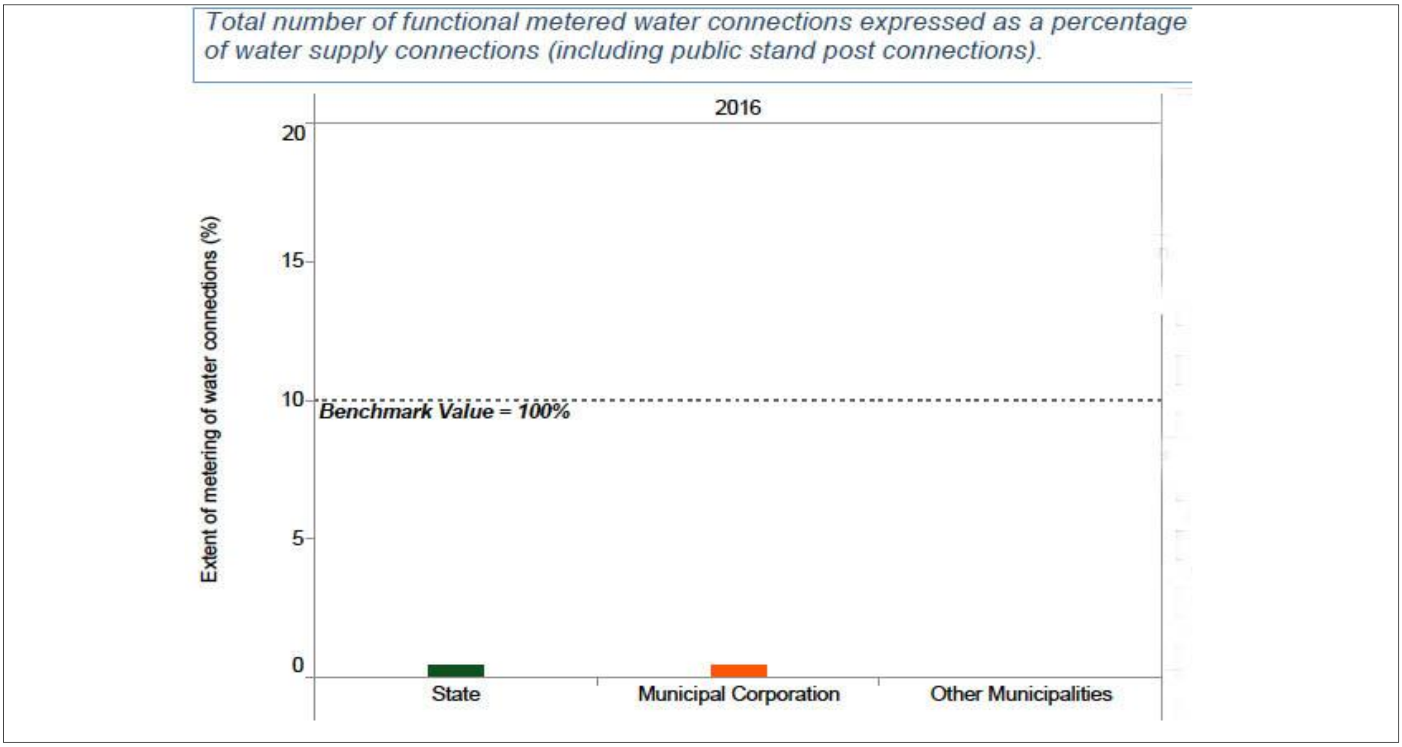
The bulk of the funding for sewerage and septage management is for the city of Raipur and other cities have been allocated much less in proportion to their population. Despite it being specifically mentioned in the AMRUT guidelines above that tanks and ponds should be rejuvenated, decentralised sewerage systems should be implemented and used water should be treated and reused, none of this is being done in Chhattisgarh.

The successful implementation of the Swachh Bharat Mission has ensured that urban areas in Chhattisgarh all became open defecation free in 2018 itself due to construction of individual and community toilets (Bhatia and Bhaskar, 2018). However, this has aggravated the problem of collection, treatment and disposal of faecal sludge which is now being generated in huge quantities. Around 1.5 lakh pit latrines have been constructed in urban areas in Chhattisgarh under the Swachh Bharat Mission and assuming that each latrine when filled will have, on an average, dry faecal sludge of 1 cubic metre, the total faecal sludge load in the near future will be a huge 1.5 lakh cubic metres.

4.3 Urban Water Supply in Chhattisgarh

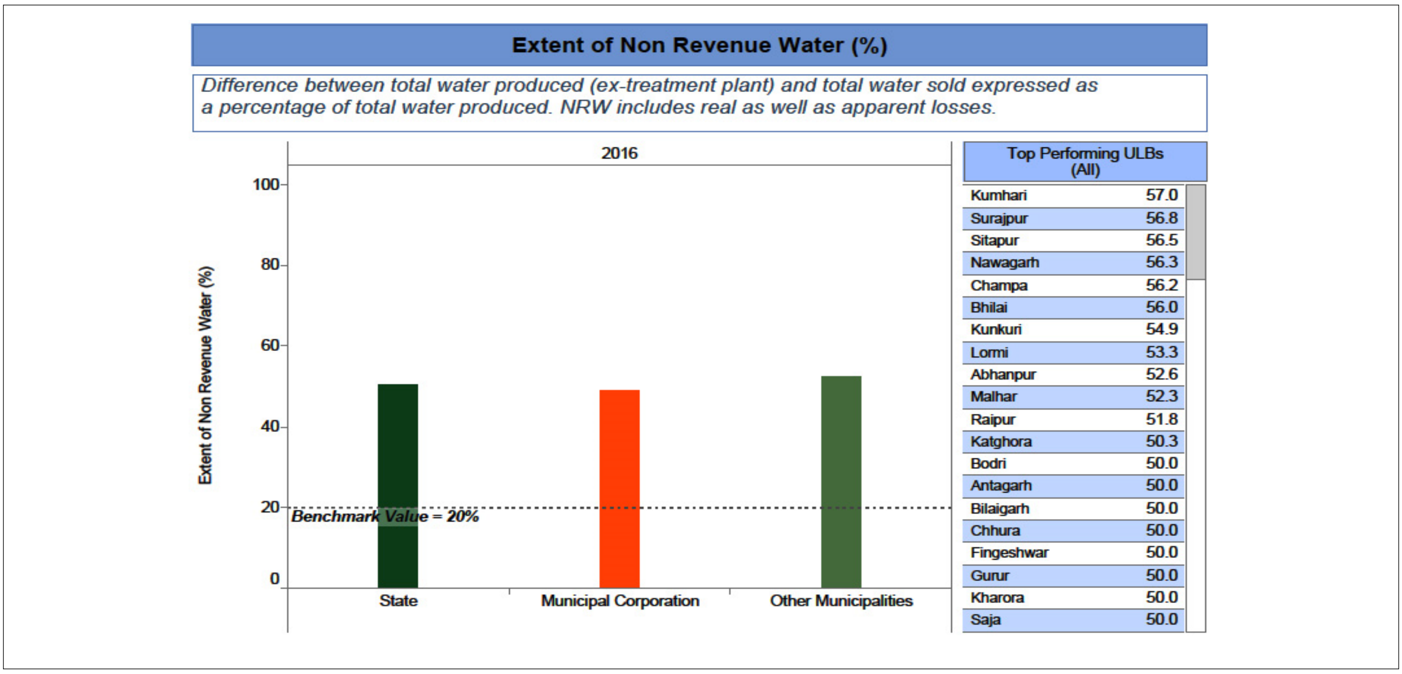
The Government of Chhattisgarh carried out a survey in collaboration with CEPT University for determining the service level benchmarks of urban water supply and sanitation in 2016 as mandated by the Ministry of Housing and Urban Affairs. The data presented here is from that report. Piped water systems supplied by treated water from rivers and streams are the norm in all urban areas of Chhattisgarh. However, there is very little metering of water supply as shown in Fig. 2 below.

Fig.2: Extent of Metering of Water Supply Connections (%) (CEPT, 2016)



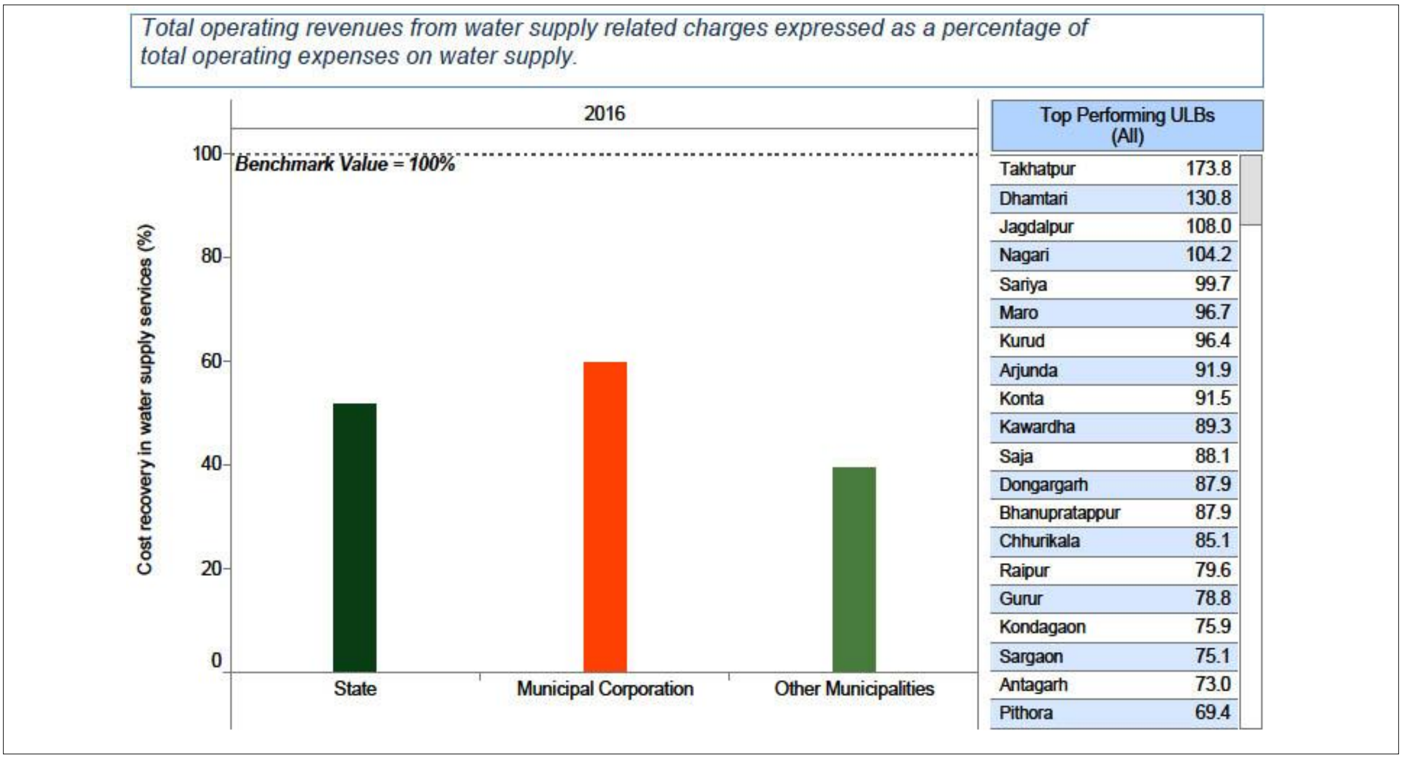
The quantity of non-revenue water is also very high as shown in Fig.3 below.

Fig.3: Extent of Non-Revenue Water (%) (CEPT, 2016)



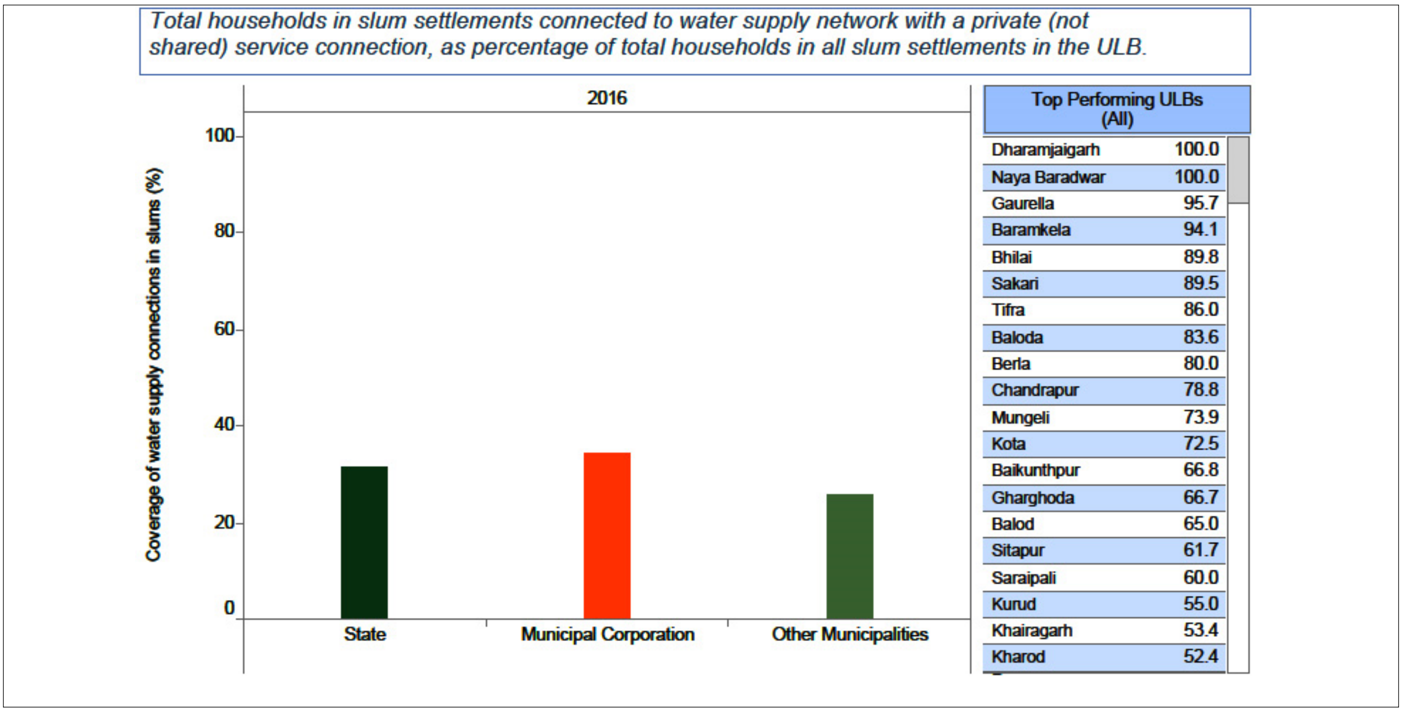
Moreover, the user charges for water are low and so in most cases despite water sources being close by and so the costs being low, the recovery of costs is poor as shown in Fig. 4 below.

Fig.4: Extent of Cost Recovery in Water Supply (%) (CEPT, 2016)



The Urban Local Bodies are unable to bear the subsidy required to provide service and so the State Government has to provide grants for operation and maintenance in addition to the grants from the Central and State Governments for the capital expenditures in putting centralised water supply systems in place. This also results in inadequate water supply as the average for the state is 78 lpcd and the supply to slums, whose residents are even less able to pay for water and should be provided free water as shown in Fig. 5 below.

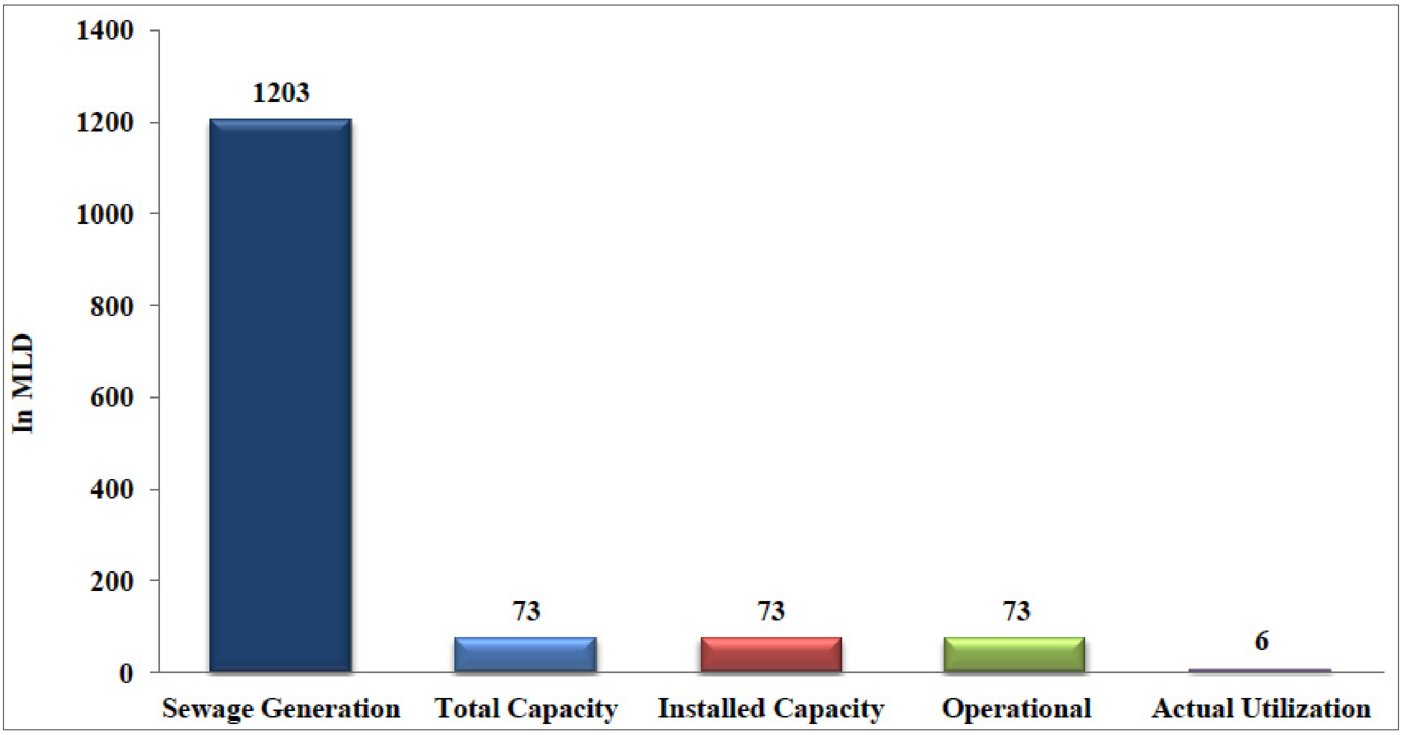
Fig.5: Coverage of Water Supply in Slums (%) (CEPT, 2016)



4.4 Urban Used water Management in Chhattisgarh

The estimated sewage generation in urban areas in Chhattisgarh is 1203 Million Litres per Day (MLD). So far, only three large Sewage Treatment Plants (STP) are operational of a total capacity of only 73 MLD and these are for treating used water diverted to them from open drains (CPCB, 2021) as shown in Fig. 6 below.

Fig.6: Sewage Generation and Treatment Status (CPCB, 2021)



Currently, all towns in Chhattisgarh, except for the Steel Authority of India township in Bhilai and the new capital city of Naya Raipur, are without sewers. Instead, covered or open drains on the sides of the roads carry the used water and stormwater to natural drains which in turn empty into rivers. The Chhattisgarh Government does not plan to implement sewerage systems and continues with the existing system of roadside drains. Under pressure from the National Green Tribunal, it has begun constructing diversion weirs on the open drains to intercept the used water before it empties into the rivers and diverts it to STPs for treatment (ToI, 2020).

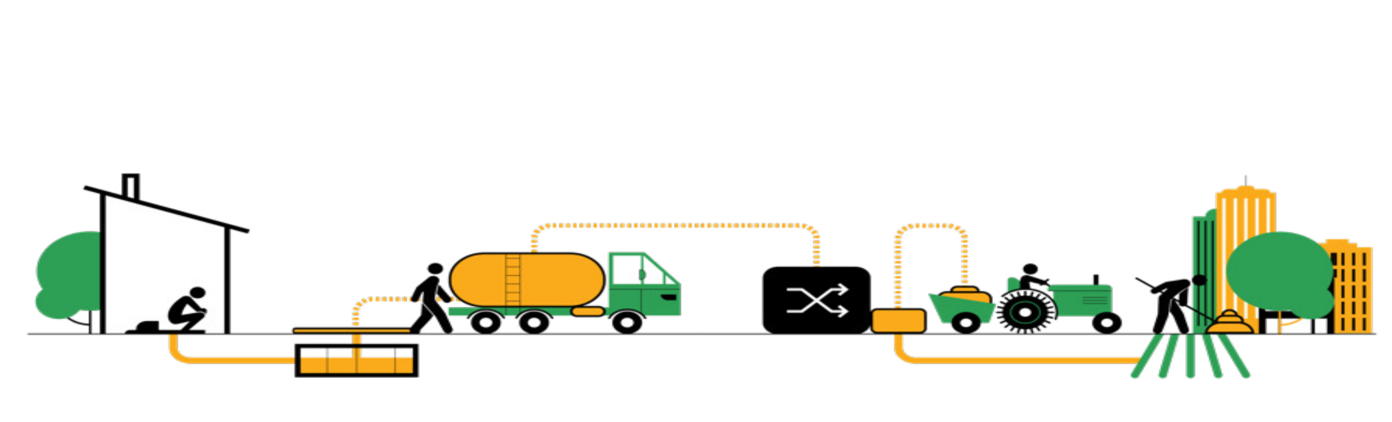
4.5 Faecal Sludge Management in Chhattisgarh

The Government of Chhattisgarh, recognising that implementation of centralised sewerage systems is economically and operationally difficult, has notified a Faecal Sludge and Septage Management Policy for management of onsite sanitation systems (GoCG, 2017) which has the following goals:

1. Ensuring timely collection and treatment of faecal sludge by shifting towards a scheduled desludging of septic tanks and their transportation to faecal sludge treatment plants for proper treatment and subsequent reuse of manure, water and energy.
2. Greater awareness among citizens to ensure the implementation of the policy and enough cost recovery for making the sludge recovery and treatment operations commercially viable without burdening the ULBs for operating expenses.
3. Setting up an institutional framework that will promote partnership of ULBs with civil society and private entities to ensure proper functioning of the faecal sludge and septage management system.

Chhattisgarh Government has also formulated a State Sanitation Policy that clearly states that sewage, septage, faecal sludge and liquid waste should be safely managed, treated and reused covering the entire sanitation chain. (GoCG, 2018).

Fig. 7: Faecal Sludge and Septage Management



The policy also crucially states that in urban areas with a population above 100,000 sewerage systems may be implemented if costs and contexts permit it, but this is not mandatory as what is to be ensured is that whether the above framework is being followed or not. Consequently, the Government of Chhattisgarh has not initiated sewerage systems in any larger towns and cities that are eligible for this. The Government has plans for cluster based faecal sludge treatment plants for non-AMRUT ULBs. Initially, district wise clusters were formed but the distances from the towns to the FSTPs were longer for economic feasibility. So smaller clusters are planned. The characterisation of sanitation systems in urban areas of Chhattisgarh is given in Fig. 8 below (NIUA & CEPT, 2018).

Fig. 8: Types of Sanitation Systems in Urban Chhattisgarh (NIUA & CEPT, 2018)

Assuming about 1 percent increase over the three years from 2018, the number of households with onsite systems of sanitation will be roughly 13,50,000 in 2021. Estimating the faecal sludge generation after digestion in onsite systems is very difficult due to the wide variability of toilets and onsite systems used (Ross et al, 2016). Nevertheless, field studies have been done in recent times that provide a fairly reliable estimate of 280 litres per capita per year of digested faecal sludge from onsite systems (Strandea et al, 2018). However, while cleaning the septic tanks the whole of the blackwater in the tank has to be evacuated and so the volume becomes at least 3 kilolitres per septic tank (as per the average size recommended by IS 2470) but in Chhattisgarh towns the sizes of the septic tanks are larger and their average volume of blackwater is 6 kilolitres (NIUA & CEPT, 2018). Assuming an ideal cleaning frequency of two years for septic tanks (CPHEEO, 2018) with half of the total households cleaned in a year and that their faecal sludge load evacuation is spread evenly throughout the year, the daily faecal sludge load for the state turns out to be roughly about 11.1 MLD (6x675000/365).

However, currently there is only one operational Faecal Sludge Treatment Plant (FSTP) in the whole of Chhattisgarh in the city of Ambikapur and that too has a capacity of just 5 KLD. There are currently about 23,000 properties in the town extrapolating from an earlier estimate (NIUA & CEPT, 2018) and so adopting the same methodology that was adopted for estimating the faecal sludge load for the whole state, we arrive at an estimate of 189 KLD (6x11,500/365) of faecal sludge load that should ideally be treated in Ambikapur. However, since the septic tanks are cleaned very infrequently, the FSTP is not running to even its limited capacity. On an average about 2 KLD is treated every day and on some days, it does not operate at all. Only the vehicles of the Ambikapur Municipal Corporation empty their sludge in the FSTP as the private cleaners find it uneconomical to transport the sludge to the FSTP which is situated at a distance of 5 kms from the city centre. The FSTP in idle state is shown in Fig. 9 below.

Fig. 9: Faecal Sludge Treatment Plant in Ambikapur

The towns and cities in the rest of the state are emptying their faecal sludge from septic tanks at an average frequency of about once, in ten years, by trucks or smaller vehicles and then it is mostly disposed of in streams and fields without treatment. Both the ULBs and private operators are thus violating environmental laws in this regard.

The town of Kavardha has a system of interception of outfall drains and diversion through a sewer along the River Sakri which conveys the intercepted sullage to an STP of 2.1 MLD capacity. However, this system is not functional. The sewer has choked with sludge and plastics and so the polluted used water is not flowing in it and is being released into the river instead. Consequently, the water in the STP is stagnant and has eutrophied resulting in its being covered with algae and the polluted water from the drains is flowing in the river as shown in Fig. 10 below.

Fig. 10: The Clogged Inlet Chamber, Idle STP with eutrophied water & polluted River in Kawardha

The water in the river was tested and the results in Table 7 show the high level of pollution in it.

Table 7: Test Results of Water Sample from River Sakri in Kawardha

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Water of stream at Kara village near Kharun River	25	570	39	1	TNTC*	TNTC	TNTC	0.8	3.9
Permissible Value for Class A Water Sources (IS:2296) except for TSS	3	500	20	>5	50	50	50	Absent	Absent

***Too Numerous to Count. Date of Test Report 4.03.2022**

This failure of the interception and diversion system in Kawardha puts a big question mark on the policy of the Government of Chhattisgarh of implementing only interception and diversion sewers and STPs for treating used water instead of laying sewers in the whole of the urban areas.

There is little being done to build awareness among citizens or set up governance and operational systems for proper faecal sludge, septage and sullage management and so the State FSSM policy is not being implemented.

4.6 Institutional and Legal Framework for Water Management in Chhattisgarh

ULBs ranging from the biggest, Municipal Corporations, followed by Municipal Councils to the smallest, Town Panchayats, are the people's representative institutions in charge urban water management. These institutions are governed by the Chhattisgarh Municipal Corporation Act 1956 and the Chhattisgarh Municipalities Act 1961 as amended from time to time. These bodies have standing committees for water management constituted from among the elected members. Only the capital city of Naya Raipur is governed directly by the State Government through the Naya Raipur Development Authority which has been constituted under the provisions of the Chhattisgarh Town and Country Planning Act 1973. Unlike in some other states, there are no ringfenced boards for urban water management in Chhattisgarh.

The Chhattisgarh Town and Country Planning Act provides for the drawing up and publication of development plans for towns and regions. These development plans have a detailed section on water management but so far, all the plans drawn up have been in the linear economy model except for that of Naya Raipur which has robust provisions for used water treatment and reuse.

Urban Development is also regulated through two other delegated legislations and they have important provisions related to making water management CWE compliant. The Chhattisgarh Land Development Rules 1984, as amended from time to time, provide for mandatory rainwater harvesting and recharging in all buildings. Similarly, the Chhattisgarh Municipal Corporation and Municipalities (Registration of Coloniser, Terms and Condition) Rules 2013 provide for rainwater harvesting, greywater treatment and reuse, and blackwater treatment and reuse separately within the colonies developed by private parties and by the Government housing board so as to obviate the need for costly transportation and treatment of used water by the urban local bodies. However, these provisions are not being enforced and even in colonies developed by the Chhattisgarh Housing Board, rainwater harvesting and recharging and used water segregation and treatment and reuse are not being implemented.

4.7 Conclusions regarding Urban Water Management in Chhattisgarh

The urban water management situation in the state is linear. Apart from the new greenfield capital city of Naya Raipur and the industrial township of Bhilai, the water supply and used water management systems are ad hoc and inadequate. Non-Revenue water is high and cost recovery is low in water supply and this affects both quality and adequacy of service, especially for the people residing in slums. The absence of sewerage and the location of STPs only at the confluence of drains with rivers means that the "waste", "take" and "make" factors in the prevailing linear economy of water cannot be reduced and neither can used water be reused adequately. Moreover, there are very few systems in place for faecal sludge and sullage treatment and even they are not wholly functional. The legal and policy provisions for water conservation and used water treatment and reuse are not being enforced. Therefore, there is great scope for revamping urban water management in Chhattisgarh to make it CWE compliant.

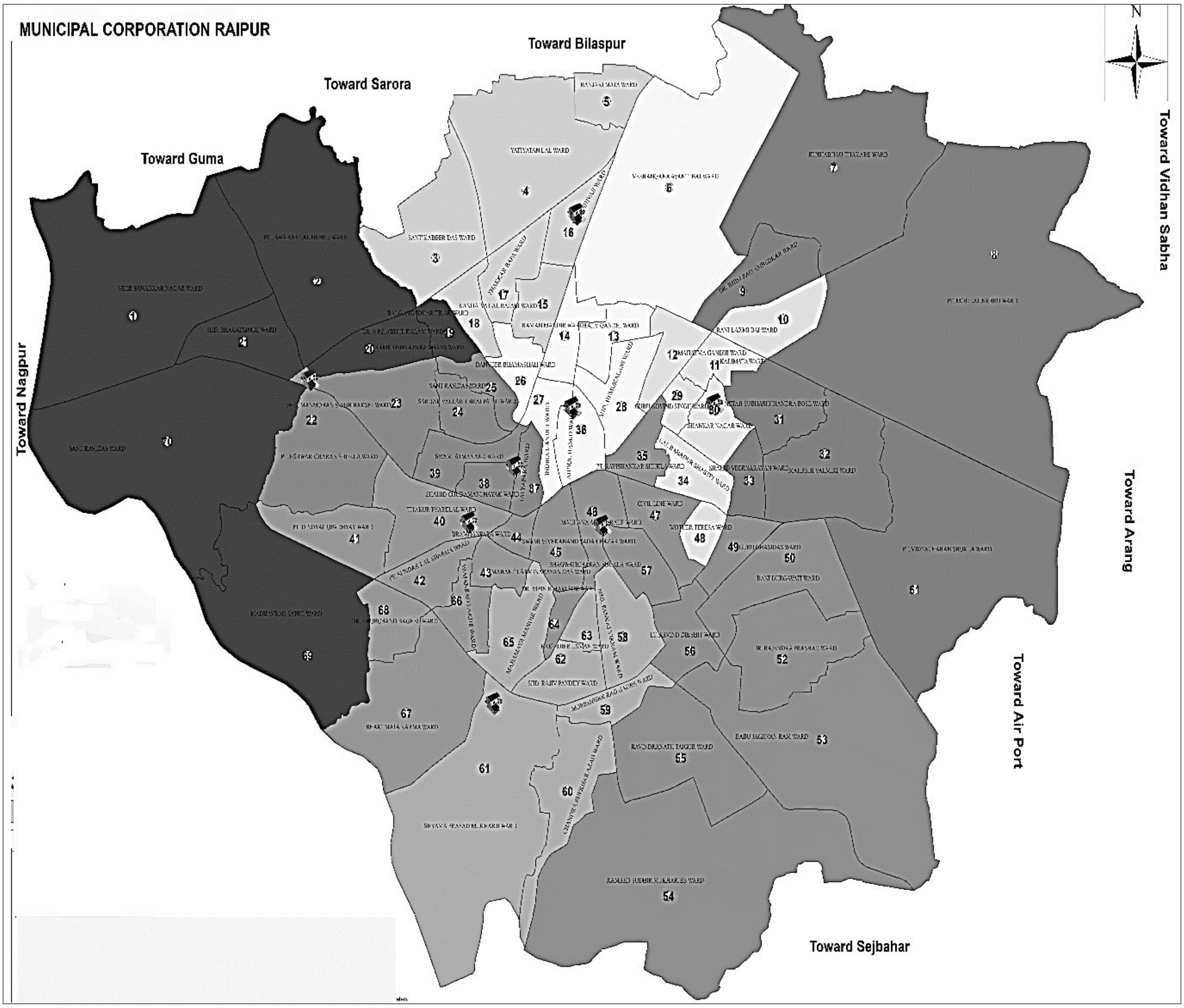
5. Town Level Analysis

A detailed analysis of a few selected towns of various sizes has been done to get an in depth understanding of the status of urban water management in Chhattisgarh. The towns selected are Raipur, Naya Raipur, Jagdalpur and Surajpur.

5.1 Raipur

Raipur is the capital city of Chhattisgarh; even though a new greenfield capital city of Naya Raipur has been built, it is still not fully functional. Raipur is located in the Mahanadi River Basin at 21.2514° N latitude and 81.6296° E longitude, spread over an area of 175 square kilometres. The city is situated on a plateau and drains into the Kharun river which flows to the west of the city in a south to north direction and is a tributary of the Sheonath River which in turn is a tributary of the Mahanadi. The average annual rainfall is 1325 mm. The top soil is alluvial and it is underlaid by granitic gneisses, shale, limestone and sandstone which are all water bearing rocks and the depth of water table is consequently quite high at 2.7 m pre monsoon and 0.6 m post monsoon. The temperatures range from 13 degrees centigrade in winter to 43 degrees centigrade in summer (CGWB, 2013a). The map of the municipal area is shown in Fig. 11 below.

Fig. 11: Map of Municipal Corporation of Raipur showing Zone and Ward Locations (RMC 2021)



There are 70 wards in 8 zones in the Raipur Municipal Corporation (RMC) and the details are given in Table A1 in the annexure. Apart from 5 wards there are notified slums in all the other wards with 11 wards having more than 30 percent of the population living in slums with the overall proportion of the slum population being 13.3 percent (RMC, 2021). However, according to the Census 2011 the slum population in Raipur city is 39.6 percent. The population of Raipur city as per the 2011 census is 1,010,087 with a low sex ratio of 948 females per 1000 males. Estimates of the current population are around 1,590,000 in 2021 (RMC, 2021). The proportion of Scheduled Castes in the population was 12.8 percent and that of Scheduled Tribes 4.3 percent. The literacy rates were 90.8 percent for males and 79.6 percent for females. The work participation rate is 55.1 percent for males and only 17.2 percent for females (Census 2011).

5.1.1 Water Supply

Water supply to Raipur by the RMC is from intake wells in the Kharun River, water from which is treated in water treatment plants with a combined installed capacity of 277 MLD (RMC, 2021). The actual supply is 215 MLD which is augmented with 15 MLD of supply from borewells at an average of three hours of daily supply. There are 1,14,345 individual domestic connections and another 8000 households residing in apartments and housing layouts served by 157 bulk connections for a total of 1,22,345 households with water connections of which only 11,000 are metered. This works out to an average water supply of 145 lpcd which is alright for a city of the size of Raipur though there is inequity in distribution with the slum areas getting much less than this as compared to the more up market areas. There are only 19,112 individual water connections in slums which is 15.6 percent and much less than the 39.6 percent proportion of people living in slums. These are only the notified slums that were captured in the Census but in reality, there are many more slums in the city regarding which there is no data with the RMC. The billed water supply is only 117.4 MLD and so the proportion of non-revenue water is a very high (49 percent). The financial analysis of the RMC water supply is given in Table 8 below.

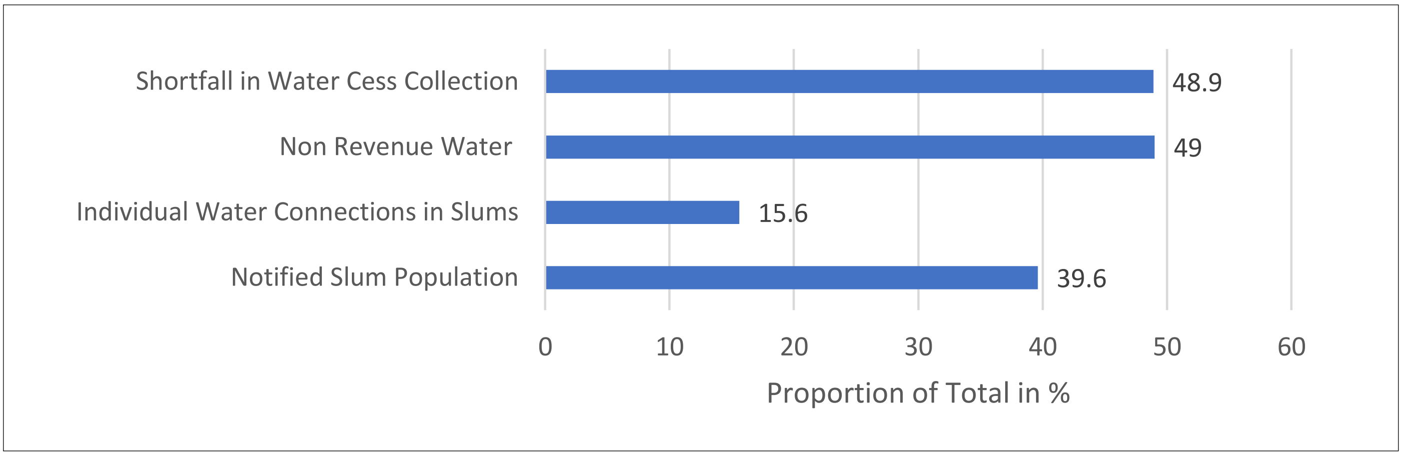
Table 8: Finances of RMC Water Supply

Accounts Categories	Actual Exp. And Income (Rs Cr)		
	2017-18	2018-19	2019-20
Exp. on Salaries	4.74	5.11	7.43
Exp. on Tanker Supply	1.2	2	2.89
Exp. on Electricity	22.13	43.36	30.0
Maintenance Exp.	7.36	13	11.2
Total Expenditure	35.43	63.47	51.52
Water Cess Income	24.86	27.67	26.32
Shortfall (%)	29.8	56.4	48.9

Source: Budgets of RMC for 2019-20 and 2020-21 and 2021-22

There is a heavy shortfall in water cess collection compared to the operating expenses. The major component of this expenditure is that on electricity. Since the non-revenue water proportion is 49 percent, better efficiency in collection of water cess will improve matters but given the increase in expenditures on electricity there will still be a huge shortfall underlining the economic unviability of centralised water supply. This despite the fact that since the Kharun river is close to the city, the cost of supply is comparatively low at Rs 6.14 per kilolitre. The water supply network of RMC has been considerably augmented with the laying of new distribution mains and other lines and construction of overhead storage tanks at a cost of Rs 434 crores under the smart city programme which is funded by the central government. If this cost is also factored in to be levied in instalments then the economic unviability of centralised water supply becomes even more stark. These iniquitous and economically unviable characteristics of water supply of RMC are summarised Fig. 12 below.

Fig.12: Characteristics of Water Supply in Raipur



Moreover, due to breakages in the distribution pipeline, used water seeps in and contaminates the water supplied (Purohit, 2018). The results of tests conducted randomly on water supplied by RMC as part of this study given in Table 9 below confirms this. The high levels of bacterial contamination and nitrogen in the test samples indicate seepage of used water into distribution lines.

Table 9: Test Results of RMC Water Supply

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
RMC Water Supplied in Railway station Area	1	200	15	5.8	TNTC*	TNTC	TNTC	0	5.4
RMC Water Supplied in Telibandha Area	1	155	13	5.4	TNTC	TNTC	TNTC	1	4.3
RMC Water Supplied in Pandhri Area	1	198	12	6.1	TNTC	TNTC	TNTC	1	4.7
Permissible Value for Class A Water Sources (IS:2296)	3	500	20	>5	50	50	50	Absent	Absent

** Too Numerous to Count. Date of Test Report 8.09.2021*

5.1.2 Used water Disposal and Treatment

Raipur does not have a sewerage system and used water is transported either in open drains or covered drains on both sides of roads. There are sewers below the roads when the used water in the drains have to be taken across roads. All households have onsite sanitation mostly through septic tanks and pit latrines. Soak pits for recharging the outflow from septic tanks are few and mostly the outflow is discharged into the open drains. Faecal sludge is emptied by both the RMC and private operators at long intervals and then disposed of into nearby streams. Initially, there were a few oxidation ponds to the north of the city but as the flow increased with the increase in population these tanks became choked with sludge and fell into disuse. Consequently, the surface water bodies are critically polluted (GoCG, 2020). The drains are in bad shape as seen from the photograph below of an open drain in the Telibandha area.

Fig. 13: Open Drain in Telibandha Area of Raipur

The small sewers that carry the used water in the drains, on the sides of the roads under and across the roads at their junctions, get choked due to this solid waste in the drains and have to be cleaned frequently as shown in the picture below.

Fig. 14: Choked Sewer Opened for Cleaning

Most of these drains Opens up into streams which then flow into the Kharun River. The RMC has planned a series of STPs at Nimora, Bhatagaon, Chandanidihi and Kara to divert water from the nalas for treatment before release into the rivers. The STP at Kara village of 35 MLD capacity is still under construction, while the others have not yet been started. However, it is not possible to divert an entire large stream into the STP, so this is not an appropriate solution. Interception and diversion to STPs can only be done with small drains which can be tapped and connected with a sewer. But, problems arise during the monsoons when heavy rains increase the flow in the drains much beyond the capacity of the tapping sewers leading to waterlogging. The structures being built for diverting the nala water to the STP at Kara are shown below. Even though the diversion structure is still under construction it is evident that it will have gates which will be opened to let most of the water go through during the monsoons when the flow will be beyond the capacity of the STP.

Fig. 15: Structure for diversion of used water from stream to STP at Kara Village

The test results for the water of the stream at Kara village before it meets the Kharun river are given in Table 10 below and show that the water is highly polluted.

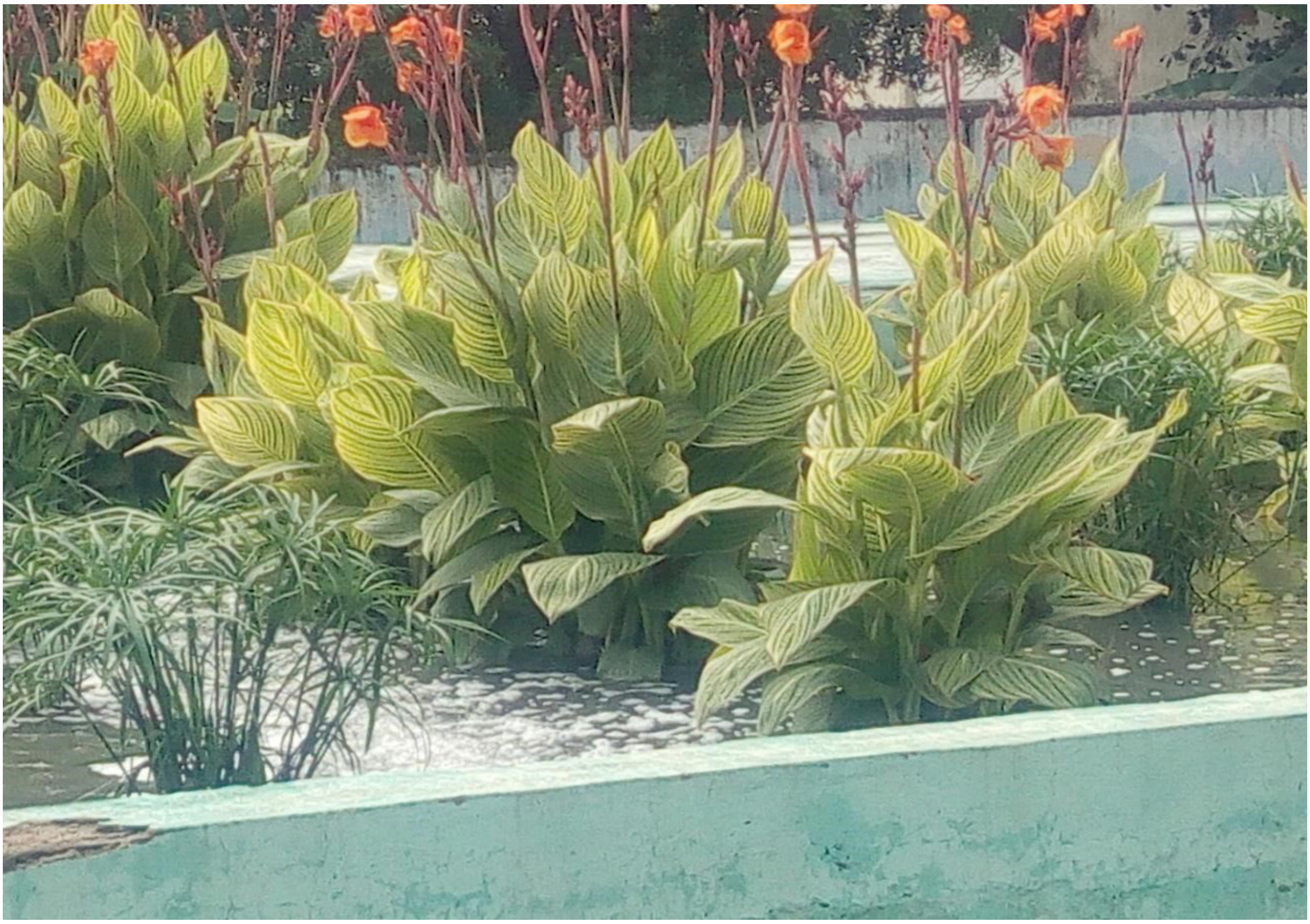
Table 10: Test Results of Water Sample from Stream at Kara Village

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Water of stream at Kara village near Kharun River	30	530	38	1	TNTC*	TNTC	TNTC	0.7	4
Permissible Value for Class A Water Sources (IS:2296) except for TSS	3	500	20	>5	50	50	50	Absent	Absent

**Too Numerous to Count. Date of Test Report 8.09.2021*

Some of these drains empty into the ponds in the city of Raipur and pollute them heavily. One such pond in Telibandha has been taken up for improvement. The Bharat Heavy Electricals Limited has tapped most of the drains flowing into the pond and has installed a Phytorid system of treatment of the used water by plants before its release into the pond as shown below.

Fig. 16: Plant based Phytorid STP at Telibandha Pond



However, the water flowing out of this STP as shown in Table 11 below is still polluted with bacteria and nitrogen even though the sample was taken at the other end of the tank from where the STP is releasing its water into it. This means that the Phytorid system is not operating properly as there is nitrogen in the sample, above limits, and also that tertiary treatment is not being done resulting in the presence of bacteria in the sample.

Table 11: Test Results of water of Telibandha Pond

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Water of Telibandha Pond	2.5	217.5	22.5	6.8	TNTC*	TNTC	TNTC	0.5	2.1
Permissible Value for Class A Water Sources (IS:2296)	3	500	20	>5	50	50	50	Absent	Absent

** Too Numerous to Count. Date of Test Report 8.09.2021*

There are no separate stormwater drains and stormwater is carried in the used water drains. This creates a problem of waterlogging during heavy rains. Even though there are rules in place for rainwater harvesting and recharging these are not implemented.

The aquifer characteristics of Raipur district which includes the cities of Raipur and Naya Raipur are given in Table 12 below.

Table 12: Aquifer Characteristics of Raipur district

Parameter	Range	Area Sq. Km	Percentage Area
Depth to Water Table (m)	3-5	495.36	66.99%
	5-7	228.53	30.90%
	7-9	15.5	2.09%
Net Recharge (mm/year)	100-200	79.13	10.70%
	200-300	554.21	74.95%
	300-500	106.05	14.34%
Aquifer (Geology)	Alluvium	3.29	0.44%
	Arenite	143.25	19.37%
	Limestone Dolomite	536.99	72.62%
	Shale	55.86	7.55%
Soil (Soil Texture/ Type)	Clay Loam	99.92	13.51%
	Loamy Black Soils	427.76	57.85%
	Sandy Clay Loam	211.71	28.63%
Topography (% slope)	0-2	335.7	45.39%
	2-6	357.35	48.32%
	6-12	41.35	5.59%
	12-18	3.95	53.00%
	18-40	1.05	14.00%
Impact of Vadose Zone (Lithology)	Alluvium	147.6	19.96%
	Shale	51.49	73.07%
	Stromatolotic Sandstone	540.27	6.96%
Conductivity (m/day)	0.397 - 1.598	302.04	40.85%
	1.598 - 3.196	276.51	37.39%
	3.196 - 6.293	160.82	21.75%

Source: Shukla et al, 2015

The water table in the district is very high as is the recharge rate and conductivity. There is alluvium underlain by limestone and sandstone which are all good water retainers and so there is great potential for using the aquifers as storage and this is what has been traditionally done in Raipur. However, this also leads to the problem of contamination of the aquifer. The groundwater from a borewell in the Telibandha area was tested and found to be contaminated with bacteria and nitrogen indicating that the used water from the open drains and improperly designed and irregularly cleaned onsite faecal systems, is seeping into the confined aquifer and contaminating it as shown in Table 13 below.

Table 13: Test Results of water from Borewell in Telibandha Area

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Water of Telibandha Pond	1	200	15	2.8	TNTC*	TNTC	TNTC	1.2	5.4
Permissible Value for Class A Water Sources (IS:2296) except for TSS	3	500	20	>5	50	50	50	Absent	Absent

** Too Numerous to Count. Date of Test Report 8.09.2021*

The unconfined aquifer is also affected by contamination from open drains as is shown by the results of testing of a water sample from an open well in the Telibandha area in Table 14 below.

Table 14: Test Results of water from open well in Telibandha Area

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Water of Telibandha Pond	2	210	8	1	TNTC*	TNTC	TNTC	4	9.4
Permissible Value for Class A Water Sources (IS:2296) except for TSS	3	500	20	>5	50	50	50	Absent	Absent

** Too Numerous to Count. Date of Test Report 8.09.2021*

There is no specific department of the RMC for used water management and the cleaning of drains and sewers are done by the general staff who are responsible for overall cleanliness including solid waste management. There are no charges separately for used water management. Therefore, it is not possible to do a detailed financial analysis of the actual costs and revenues related to used water and stormwater management of the RMC.

5.1.3 City Sanitation Plan

A detailed City Sanitation Plan was prepared for Raipur in 2011 by the Raipur Municipal Corporation with the help of external experts (RMC, 2011). The strategies for complete used water collection and treatment in this plan to be implemented at a cost of Rs 927.8 crores by 2021 were as follows:

1. Separation of grey and blackwater and complete collection of the same through a gravity sewer system of length 1032 kms and 13 sewage pumping stations.
2. Proper treatment of grey and blackwater and reuse of treated water, manure and energy generated from sludge with the construction of three STPs with a total capacity of 200 MLD.
3. Regular cleaning of on-site systems and proper treatment of faecal sludge.
4. Provision was made for reducing the stormwater runoff through water harvesting and water recharging measures in both private and public spaces. There were also provisions for constructing a 1200 km network of stormwater drains at a cost of Rs 25.2 crores by 2021.
5. Stress was laid on elaborate information, education and communication campaigns to raise the level of public awareness about water harvesting and recharge of ground water, and used water treatment and reuse.

However, these detailed plans for used water and stormwater management and raising of public awareness for creating a CWE have not been implemented in the city.

5.1.4 Financial Analysis of RMC Budgets

The major heads of the RMC budgets are given in Table 15 below.

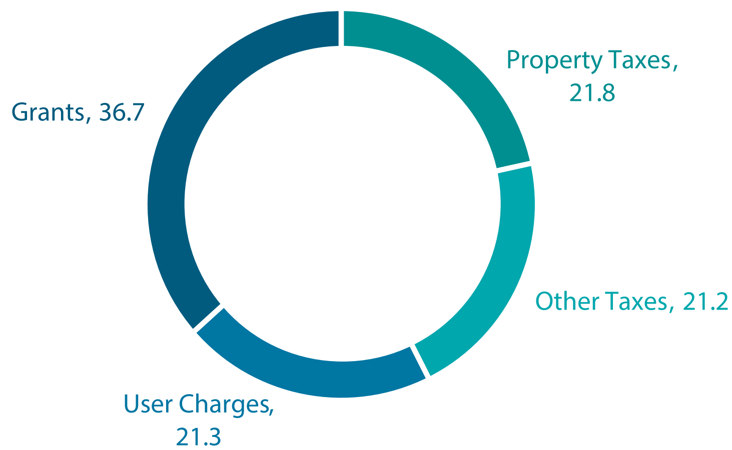
Table 15: Analysis of Budgets of RMC

Accounts Categories	Actual Exp. And Income (Rs Cr)		
	2017-18	2018-19	2019-20
Taxes	104.53	106.73	113.78
Rent and Leases	6.83	5.55	5.64
Fees and Charges	30.62	36.06	29.71
SWM Charges	0.76	0.46	0.66
Miscellaneous	36.3	37.67	17.56
Grants	86.2	75.7	97.14
Total Revenue Income	265.24	262.17	264.49
Total Revenue Exp.	195.02	250.6	274.73
Revenue Surplus	70.22	11.57	-10.24
Capital Income	274.67	264.87	416.24
Capital Expenditure	277.74	294.19	455.22
Capital Deficit	3.07	29.32	38.98
Per Capita Revenue Exp (Rs)	1436	1770	1864
Per Capita Capital Exp (Rs)	2045	2078	3088

Source: Budgets of RMC for 2019-20 and 2020-21 and 2021-22

The finances of the RMC are not very buoyant. The per capita revenue and capital expenditures are very low as compared to the national averages for the same for 2019-20, which are Rs 4300 and Rs 2700 respectively, as extrapolated from the Annual Survey of India's City-Systems Report 2017 (Janagraha, 2017). Another matter of concern with regard to revenue mobilisation is that the share of property tax in the total revenue income of RMC was only 21.8 percent in 2019-20 and it has remained stagnant at this level for quite some time. Property tax is a progressive tax as it garners more revenue from the affluent sections who are not only more capable of paying for the urban services but also consume much more of them as compared to the poor. This level was achieved after a programme was implemented for digitising the property records with the help of GIS in Raipur, which led to a 74% increase in property tax collections (MoHUA, 2021c). Property taxes should constitute at least 60% of the ULB revenue income for equity reasons (MoUD, 2011). In the event, due to the shortfall in tax collection, grants from state and central governments constitute 36.7% of the revenue income and the capital income is wholly from grants and loans from the state and central governments. These characteristics of RMC finances are summarised in Fig. 17 below.

Fig. 17: Proportion of Revenue Income by Category (%) of RMC 2019-20



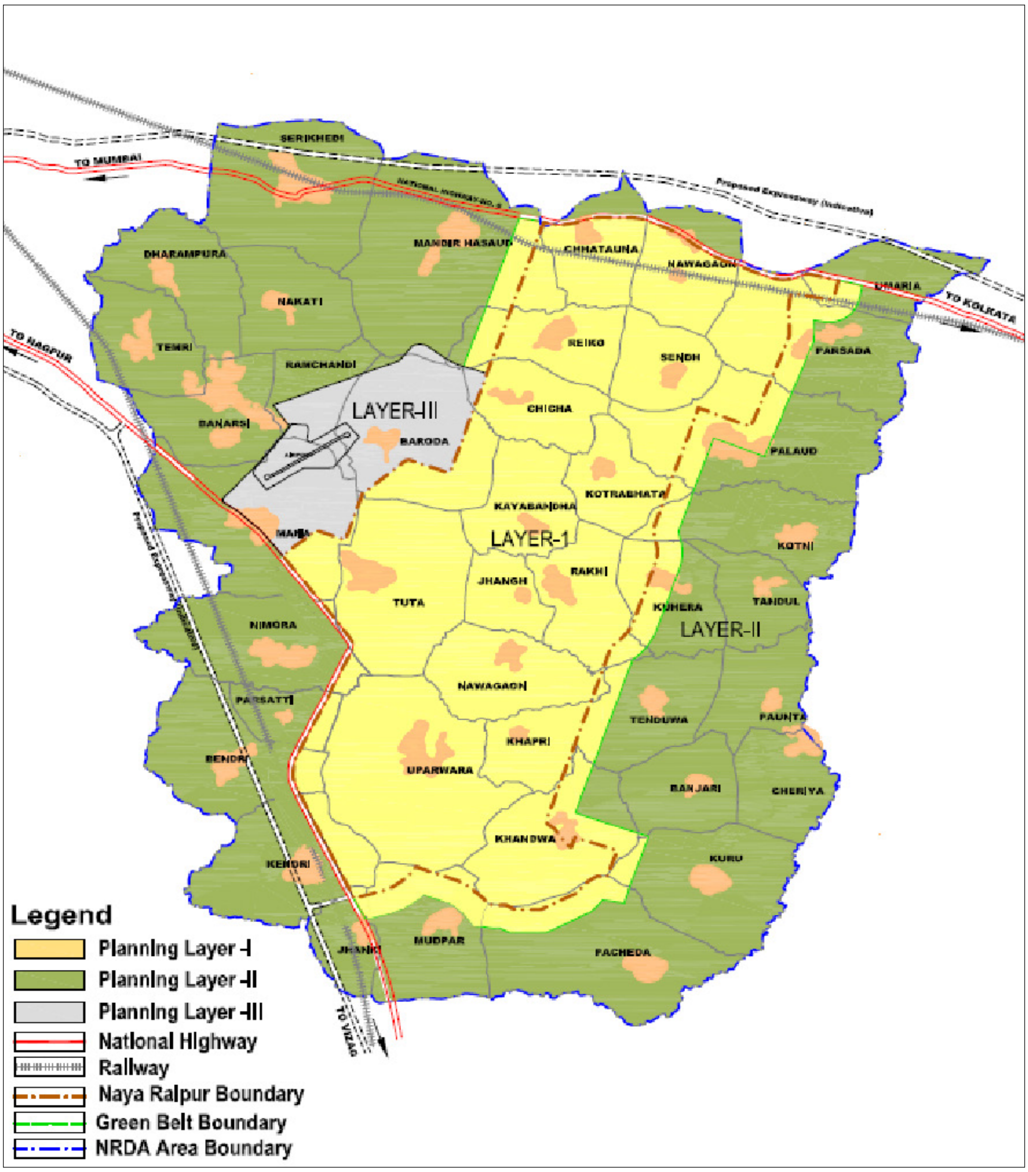
5.1.5 Lack of Civic Awareness and Management and Technical Skills

The City Sanitation Plan of 2011 had mentioned a serious lack of civic awareness regarding proper used water management on the one hand and the need for rainwater harvesting and recharge on the other. The plan had also mentioned that the RMC staff sorely lacked management skills and technical competency in the areas of water supply and used water management. Therefore, it had recommended elaborate measures for improving civic awareness and people's participation in water management and improving the institutional set up and technical and management skills of the RMC in this regard. However, discussions with citizens, elected representatives and RMC officials revealed that like in other aspects of the City Sanitation Plan discussed earlier, there has been no implementation in civic awareness and management and technical skills. Even though rules have been framed and government orders passed, they haven't been implemented.

5.2 Naya Raipur

A new greenfield capital city of Naya Raipur has been developed over an area of 95.22 square kilometres to the south east of the city of Raipur and at a distance of 17 kms from it, situated further ahead from the airport and next to it. The development plan of the city has been prepared with 2031 as the design date and keeping in mind it is estimated that the population of the city will be 5.6 Lakhs (NRDA, 2008). The map of the city with the Layer I extending over 95.22 sq. kms at the centre is given in Fig. 18 below.

Fig.18: Map of Naya Raipur (NRDA, 2008)



The city is well planned from the water supply and used water management point of view. Water supply is from the Main Irrigation Canal of the Gangrel Dam on the Mahanadi River which flows to the south of the city. In the first phase a Water Treatment Plant of capacity 90 MLD was constructed in the southern part of the city and as far as possible distribution of potable water is done by gravity through underground reservoirs and distribution lines. Underground reservoirs have been chosen as they are less expensive to build and maintain and also do not obstruct the view. Pumping is to be done only where the pressure falls below prescribed levels for proper water supply.

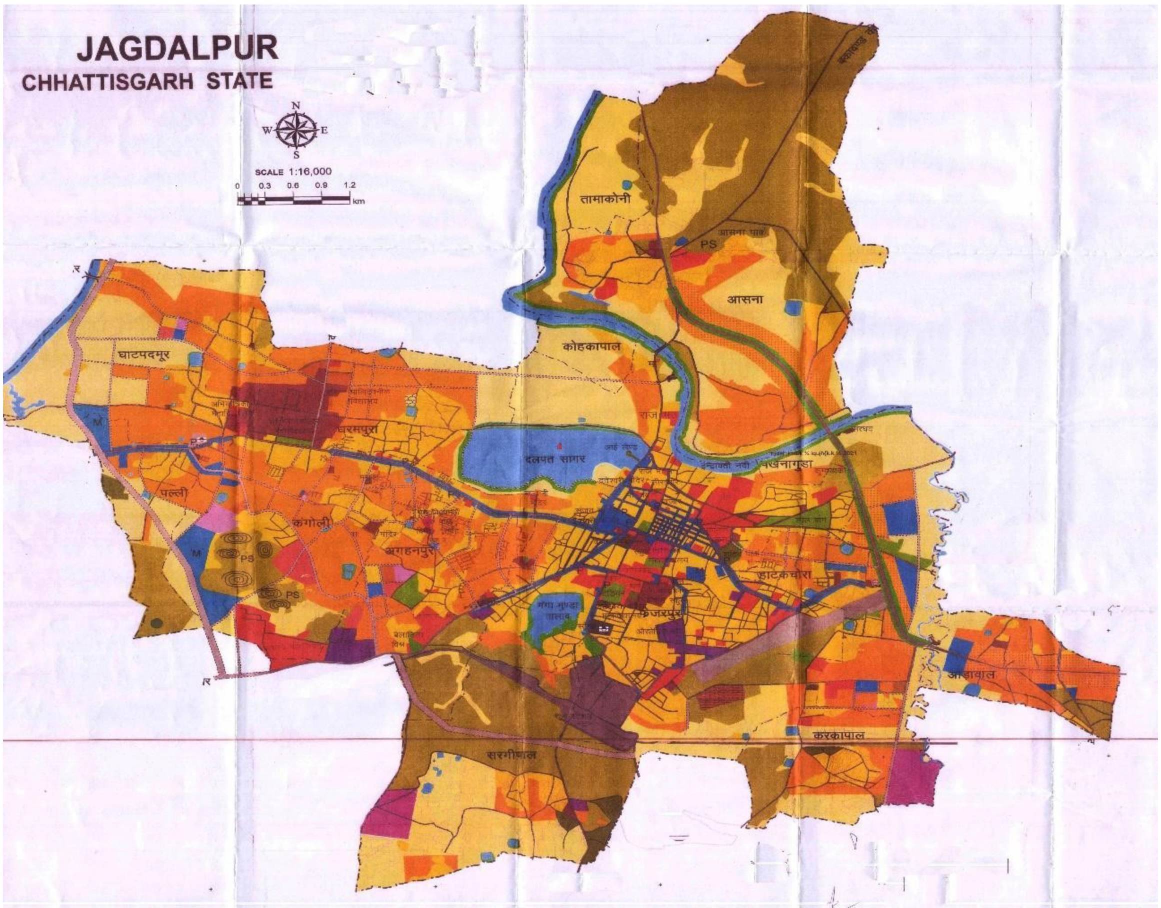
Used water is to be collected and transported in sewers to STPs which are to be cumulatively of 60 MLD capacity in the first phase. Some of the treated used water is to be used for gardening and flushing of toilets and the rest treated at the tertiary level and released back into the irrigation canal. Stormwater is to be collected and transported in open drains to the rivers and streams running nearby. To reduce the amount of stormwater and demand for potable water, rainwater harvesting and recharging in a decentralised manner is advocated.

Unfortunately, Naya Raipur has not developed as envisaged. The legislative assembly and the residences of the ministers, legislators and the bureaucrats have not been shifted to the new capital. Only the Secretariat functions from the new city and all the staff commute to it from Raipur and the resident population is less than 15,000. Consequently, due to lack of a large resident population, businesses and other amenities are not functional and it has become a ghost town. The water supply is partially functional and only two STPs are operational with installed capacity of 17 MLD. An investment of Rs 10000 crores has been made on the city, including residential and commercial areas apart from roads and office buildings, but all this infrastructure is mostly unoccupied and lying idle (Dasgupta, 2017). It would have been much better to have built the legislative assembly and secretariat on the outskirts of the city of Raipur at the place where a residential colony, Kamal Vihar, has been developed by the Chhattisgarh Housing Board, which too is lying mostly unoccupied and expended this huge amount on improving the water supply and sanitation of Raipur instead.

5.3 Jagdalpur

Jagdalpur is the headquarters of the Bastar division and is situated 287 km to the south of Raipur. The location is N 19.62 latitude and E 81.30 Longitude over an area of 20 square kilometres on the Bastar Plateau on the banks of the River Indravati, which is a tributary of the Godavari River. The map of the town is shown in Fig. 19 below.

Fig. 19: Map of Jagdalpur (Department of Town & Country Planning, GoCG)



The average annual rainfall is 1387 mm, with a winter temperature of 10 degrees centigrade rising to 46 degrees centigrade in summer. The soils are red clayey, sandy and loamy alfisols with underlying rocks of granite, gneiss, sedimentary and basalts. The unconfined and confined aquifers are well stocked with water with pre-monsoon groundwater level at 1.7 meters below ground level and the post-monsoon level at 0.43 meters below ground level with fractured gneisses and shale which have good storage and conductivity (CGWB, 2013b). Therefore, water recharging potential is also high.

Jagdalpur town is a municipal corporation with 48 wards, which, in 2011, had a population of 1,25,463. The sex ratio was 961 and the proportion of Scheduled Castes and Scheduled Tribes were 5.9 percent and 18.8 percent, respectively. The literacy rate was 90.8 percent for males and 78.8 percent for females while the work participation rate was 54.0 percent for males and substantially less at 17.1 percent for females. The proportion of slum population was 31.5 percent and the literacy and work participation rates in the slums were only marginally lower than for the whole population. The ward wise population details as given in Census 2011 are given in Table A2 in the annexure but at that time there were only 40 wards some of which have been subsequently bifurcated into newer wards.

Water Supply for the city by the Jagdalpur Municipal Corporation (JMC) is from the Indravati River and the current supply is 14 MLD for an average of two hours daily. Since this is insufficient this is augmented with 6 MLD of supply from borewells and tankers. This works out to 130 lpcd assuming a current population of 1,50,000. Under the Smart City Programme a new water treatment plant with capacity of 45 MLD is under construction. No water harvesting or recharging is being done in the town. The water supplied was tested in a colony near the bus stand and turned out to be contaminated as shown in Table 16 below.

Table 16: Test Results of Jagdalpur Water Supply Sample

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
JMC Water Supplied in Bus Stand Area	2	250	17	5.3	TNTC*	TNTC	TNTC	2	5.4
Permissible Value for Class A Water Sources (IS:2296)	3	500	20	>5	50	50	50	Absent	Absent

**Too Numerous to Count. Date of Test Report 13.09.2021*

There are combined open drains on both sides of roads for used and stormwater and these empty into 8 streams which in turn empty into a big lake, Dalpat Sagar and the Indravati River without any treatment. A 2.5 MLD capacity STP is under construction as part of the Smart City Programme to which some of the used water from the streams will be diverted. Presently the Dalpat Sagar Lake is badly polluted as is evident from the eutrophication that has taken place as shown in Fig. 20 below.

Fig. 20: Eutrophication of Dalpat Sagar Lake

The test results of the water from the Dalpat Sagar Lake as shown in Table 17 below, which shows that the water is badly polluted. On-site systems are used for blackwater and are not properly designed or managed with the disposal of untreated faecal sludge in streams and fields. There are no private septic tank cleaning agencies, so only the JMC faecal sludge cleaning vehicles operate.

Table 17: Test Results of Water Sample from Dalpat Sagar Lake

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Water Sample from Dalpat Sagar Lake	12	350	32	1.3	TNTC*	TNTC	TNTC	6	11.4
Permissible Value for Class A Water Sources (IS:2296)	3	500	20	>5	50	50	50	Absent	Absent

** Too Numerous to Count. Date of Test Report 13.09.2021*

The borewell water and open well water were also tested in Jagdalpur and the test results in Table 18 below show that they are contaminated, most probably due to seepage of used water from the open drains into the aquifer.

Table 18: Test Results of Borewell and Open Well Water Samples Jagdalpur

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Water Sample from Borewell in Bus Stand Area	2	258	5	6.2	TNTC*	TNTC	TNTC	2	4.4
Water Sample from Open well in Bus Stand Area	2	235	3	5.1	TNTC	TNTC	TNTC	3	5.3
Permissible Value for Class A Water Sources (IS:2296)	3	500	20	>5	50	50	50	Absent	Absent

** Too Numerous to Count. Date of Test Report 13.09.2021*

Thus, the water supply is deficient in the town but the used water is also not being treated at all and is being released into the surface and groundwater polluting both. Faecal sludge from onsite systems is dumped without treatment into streams and fields further polluting the environment.

The expenditures on water supply and used water management and the user charges for water supply and sanitation are not separately available in the JMC budgets and so these could not be analysed for determining the economic viability of these services being provided by the JMC. The major heads of the JMC budgets are given in Table 19 below.

Table 19: Analysis of Budgets of JMC

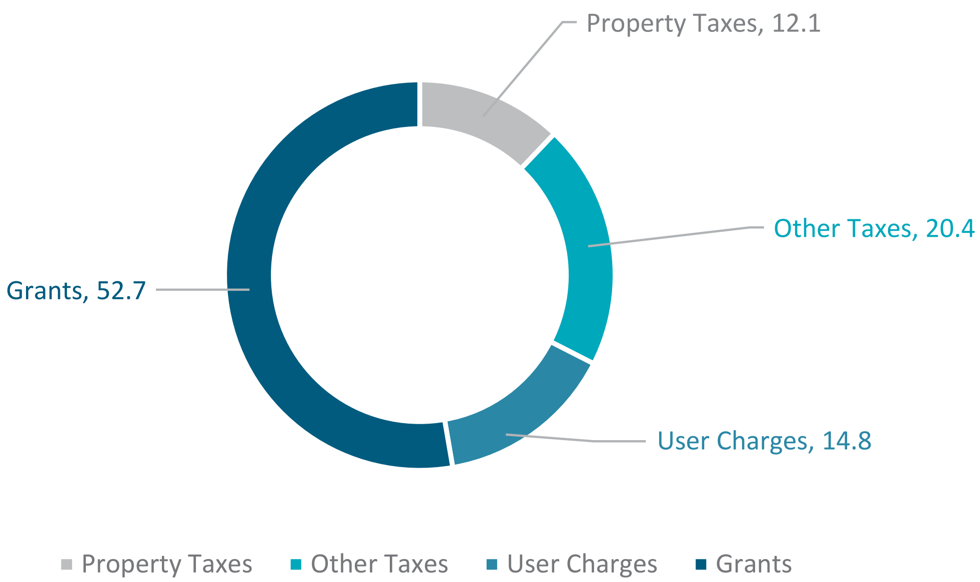
Accounts Categories	Actual Exp. And Income (Rs Cr)		
	2017-18	2018-19	2019-20
Taxes	10.35	10.44	10.45
Rent and Leases	4.87	3.68	2.04
Fees and Charges	1.45	3.08	2.8
Assigned Revenues	5.59	5.03	5.05

Accounts Categories	Actual Exp. And Income (Rs Cr)		
	2017-18	2018-19	2019-20
Miscellaneous	1.52	1.52	2.20
Grants	15.05	25.11	25.11
Total Revenue Income	38.83	48.86	47.65
Total Revenue Exp.	37.14	49.31	50.29
Revenue Surplus	1.69	-0.45	-2.64
Capital Income	53.73	23.24	68.27
Capital Expenditure	39.18	31.95	66.91
Capital Surplus	14.55	-8.71	1.36
Per Capita Revenue Exp (Rs)	2634	3424	3421
Per Capita Capital Exp (Rs)	2779	2218	4552

Source: Budgets of JMC for 2019-20, 2020-21, 2021-22

The own revenue mobilisation by JMC is very low, and as much as 52.7% of the revenue income is from grants and assigned revenues. The property tax collection is also low, about 12.1 percent of revenue income. The Capital income is dependent on grants from the state and central Governments. The per capita revenue and capital expenditure are better than for Raipur. The budgeting is not done in a way that can indicate to the JMC how much is being spent on water supply and used water management and so proper planning cannot be done for this. These characteristics of JMC finances are summarised in Fig. 21 below.

Fig. 21: Proportion of Revenue Income by Category (%) of JMC 2019-20



Discussions with citizens, elected representatives and municipal staff revealed that like in Raipur, there is a lack of awareness regarding proper water management, technical and management skills among water utility staff.

5.4 Surajpur

Surajpur town is the headquarters of the eponymous district and is situated 355 kilometres to the north of Raipur. The location is N 23.21 latitude and E 82.86 longitude over an area of 10 square kilometres in the fertile valley of the Rihand river on the banks of which it is situated. Thus, it is in the Son river basin which is a part of the Ganga basin. The map of the town is shown in Fig. 22 below.

Locally the river is known as Rehar in the Gond Adivasi majority region. The soils are clayey, sandy and loamy with underlying Gondwana rocks and sediments which are profusely water bearing. The average annual rainfall is 1130 mm with a winter temperature of 10 degrees centigrade rising to 42 degrees centigrade in summer. The unconfined and confined aquifers are both well stocked with water due to high rainfall and good aquifer conditions which are fractured Gondwana rocks with pre-monsoon groundwater level at 1.5 meters below ground level and the post-monsoon level at 0.40 meters below ground level (CGWB, 2013c).

Surajpur town is a municipality with 18 wards which had a population in 2011 of 20,189. The sex ratio was 936 and the proportion of Scheduled Castes and Scheduled Tribes were 6.5 percent and 14.3 percent, respectively. The literacy rate was 86.7 percent for males and 72.7 percent for females while the work participation rate was 51.9 percent for males and only 14.4 percent for females. The ward wise population details as given in Census 2011 are given in Table 20 below but at that time there were only 15 wards some of which have been subsequently bifurcated into newer wards.

Fig. 22: Map of Surajpur (Department of Town & Country Planning, GoCG)

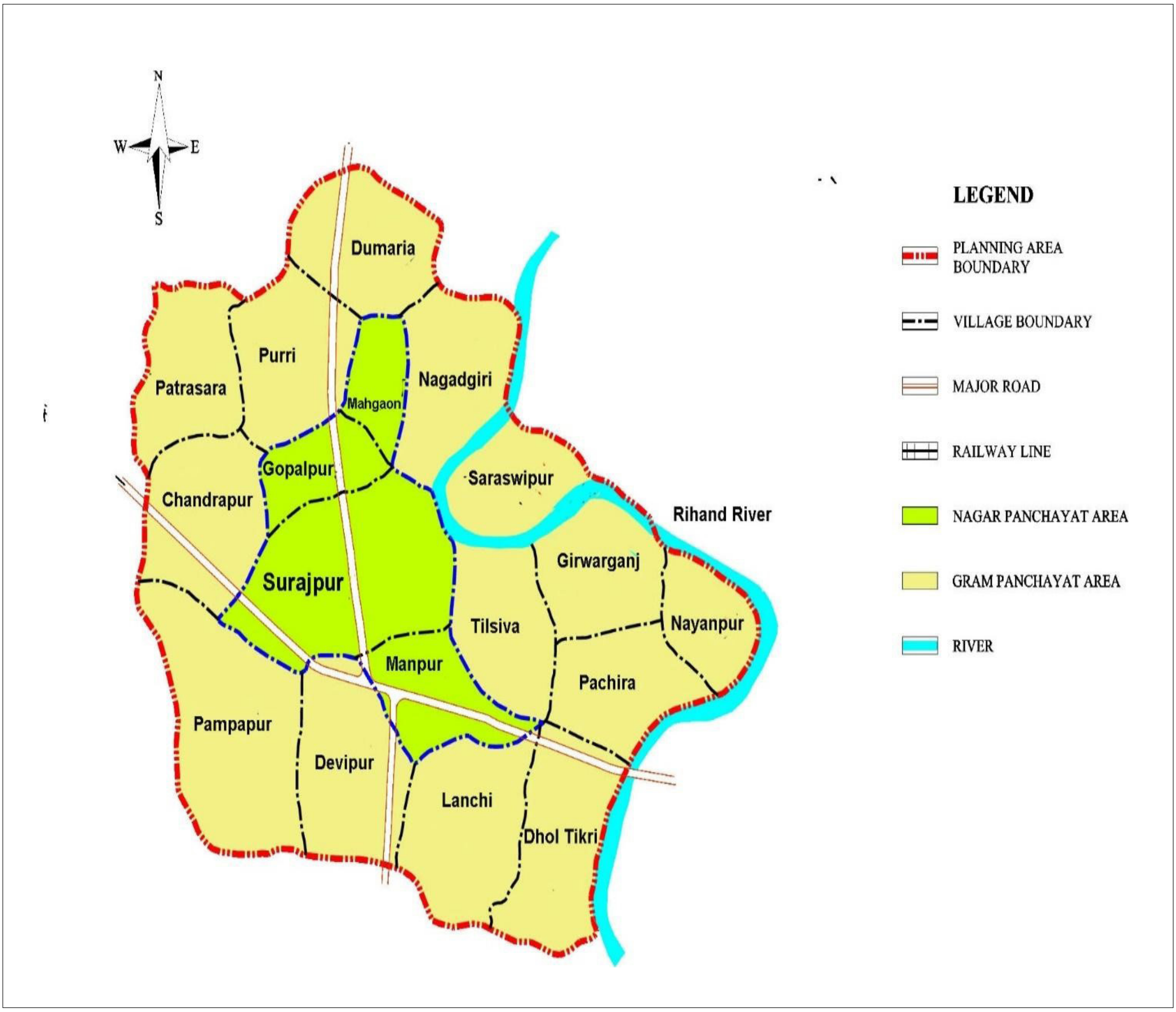


Table 20: Population of Surajpur (Census 2011)

Sl. No.	Ward No.	No. of Households	Population
1	1	429	1732
2	2	249	1206
3	3	272	1286
4	4	287	1312
5	5	237	1229
6	6	276	1350
7	7	294	1228
8	8	347	1821
9	9	336	1486
10	10	336	1470
11	11	288	1287
12	12	270	1208
13	13	228	1200
14	14	288	1298
15	15	260	1076
	Surajpur	4397	20189

The water supply to the town is from the Rihand river through an intake well, and treatment plant of capacity 3.2 MLD supplied for two hours daily. This works out to a supply of 120 lpcd which is relatively good for such a small town. There are combined open drains for stormwater and used water and these release the untreated used water into the ponds, the Rihand river and other streams.

On site systems are used for blackwater. These are not properly designed or managed which can be observed by the disposal of untreated faecal sludge in streams and fields, by vehicles of the Surajpur Municipal Council (SMC). Consequently, the ponds are severely polluted(as shown in Figure 23), as confirmed by the test report of the water sample from a pond in Table 21 below.

Table 21: Test Results of Water Sample from pond in Surajpur

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Water Sample from pond in Surajpur	16	330	36	0.3	TNTC*	TNTC	TNTC	7	13.4
Permissible Value for Class A Water Sources (IS:2296)	3	500	20	>5	50	50	50	Absent	Absent

** Too Numerous to Count. Date of Test Report 18.09.2021*

Fig. 23: Eutrophied Pond in Surajpur

The water supply, borewell water and open wall water are contaminated by bacteria and nitrogen as a result of untreated used water seeping into the ground and the water supply distribution network as shown in Table 22 below.

Table 22: Test Results of Samples of Municipal Water Supply, Borewell and Open Well in Surajpur

Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l	Total Suspended Solids mg/l	Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Prob. No./100 ml				
Municipal Water Supply	1.1	220	5	5.7	TNTC*	TNTC	TNTC	1	4.4
Borewell water	1.2	260	12	5.3	TNTC	TNTC	TNTC	1.4	5.3
Open Well Water	1.4	240	11	5.1	TNTC	TNTC	TNTC	1.6	5.7
Permissible Value for Class A Water Sources (IS:2296)	3	500	20	>5	50	50	50	Absent	Absent

** Too Numerous to Count. Date of Test Report 18.09.2021*

The finances of Surajpur Municipal Council (SMC) are given in Table 23 below.

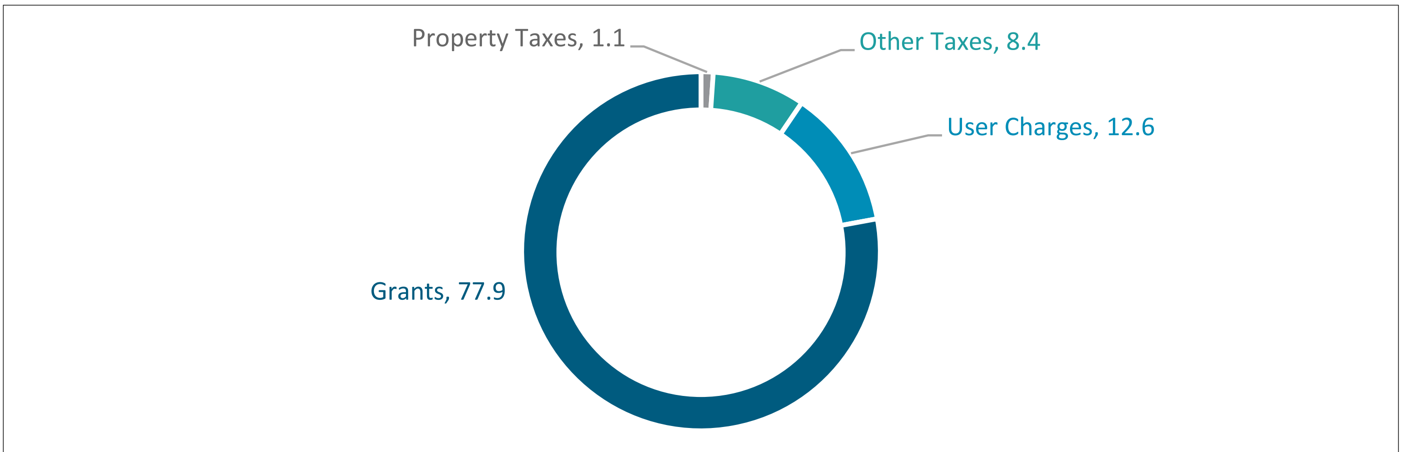
Table 23: Analysis of Budgets of Surajpur Municipal Council

Accounts Categories	Actual Exp. And Income (Rs Lakhs)		
	2017-18	2018-19	2019-20
Taxes	16.47	23.89	17.41
Rent and Leases	10.21	22.37	14.76
Fees and Charges	41.38	12.97	21.35
Assigned Revenues	45.2	31.64	45.0
Miscellaneous	35.77	44.82	46.85
Grants	162.37	166.08	510.0
Total Revenue Income	311.40	301.77	655.37
Total Revenue Expenditure	266.68	247.16	626.10
Revenue Surplus	44.72	54.61	29.27
Capital Income	367.93	419.52	1585.00
Capital Expenditure	351.13	282.92	2050.40
Capital Surplus	16.80	136.60	-465.40
Per Capita Revenue Exp (Rs)	1111	1009	2504
Per Capita Capital Exp (Rs)	1463	1155	8201.6

Source: Budgets of SMC for 2019-20, 2020-21, 2021-22

The SMC is heavily dependent on grants from the State and Union Governments which in 2019-20 constituted 100 percent of its capital income and 77.9 percent of its revenue income. This is nowhere more evident than in the finances of the water supply service. The operational expenses of water supply in 2019-20 were 49.19 Lakhs but the user charges recovered were only 3.5 lakhs resulting in a shortfall of 92.9 percent. Thus, for small towns centralised water supply is even more economically unviable than for the larger cities. The budgeting has once again been done so that it is not possible to plan properly for improvement of facilities. The finances of SMC have been summarised in Fig. 24 below. The contribution of property taxes is meagre.

Fig. 24: Proportion of Revenue Income by Category (%) of SMC 2019-20



Discussions with citizens, elected representatives and municipal staff revealed lack of awareness of good water management practices and the water utility staffs lack requisite skills. There is no water harvesting or recharging being done in the town.

5.5 Faecal Sludge Management in the Study Towns

There are no facilities for the treating faecal sludge in any of the study towns. The ULBs in Surajpur and Jagdalpur have suction vehicles for cleaning onsite systems. Still they dump the untreated sludge in water bodies and open fields and there are no private operators in these towns. The RMC disposes of the sludge from its vehicles in one of the STPs in Naya Raipur which is 20 km away. There are nine private septic tank cleaning operators in Raipur who charge Rs 3000 to Rs 4000 depending on the size of the tank for desludging. These operators dump the sludge without treatment in nalas and fields as they find it uneconomical to transport the sludge to Naya Raipur.

The Surajpur ULB has only one vehicle, for faecal sludge transportation, of 2.5 kilolitre capacity. On an average there is a demand for 2 cleanings per month or about 0.2 KLD, which is very low as for regular cleaning as per the methodology adopted earlier the faecal sludge load for treatment should be 40 KLD (6x2400/365). Moreover, even in the septic tanks in the Government buildings there are no soakpits and the outflow from the septic tanks is being released into open drains as shown in Fig. 25 below. In fact, this is the case in all the study towns and in most of the state.

Fig. 25. Outflow from Septic Tank being Released into Open Drain in Surajpur

JMC has two sludge suction vehicles of 9 kilolitre and 3 kilolitre capacity but with only one driver. The charge for the larger vehicles is Rs 3000 while the smaller vehicle costs Rs 2000. On an average there are about 2 cleanings per day with the smaller vehicle and the larger ones are rarely used. This works out to an actual faecal sludge load of 6 KLD whereas according to the methodology adopted the faecal sludge load should be at least 164 KLD (6x10000/365) for proper operation of the septic tanks.

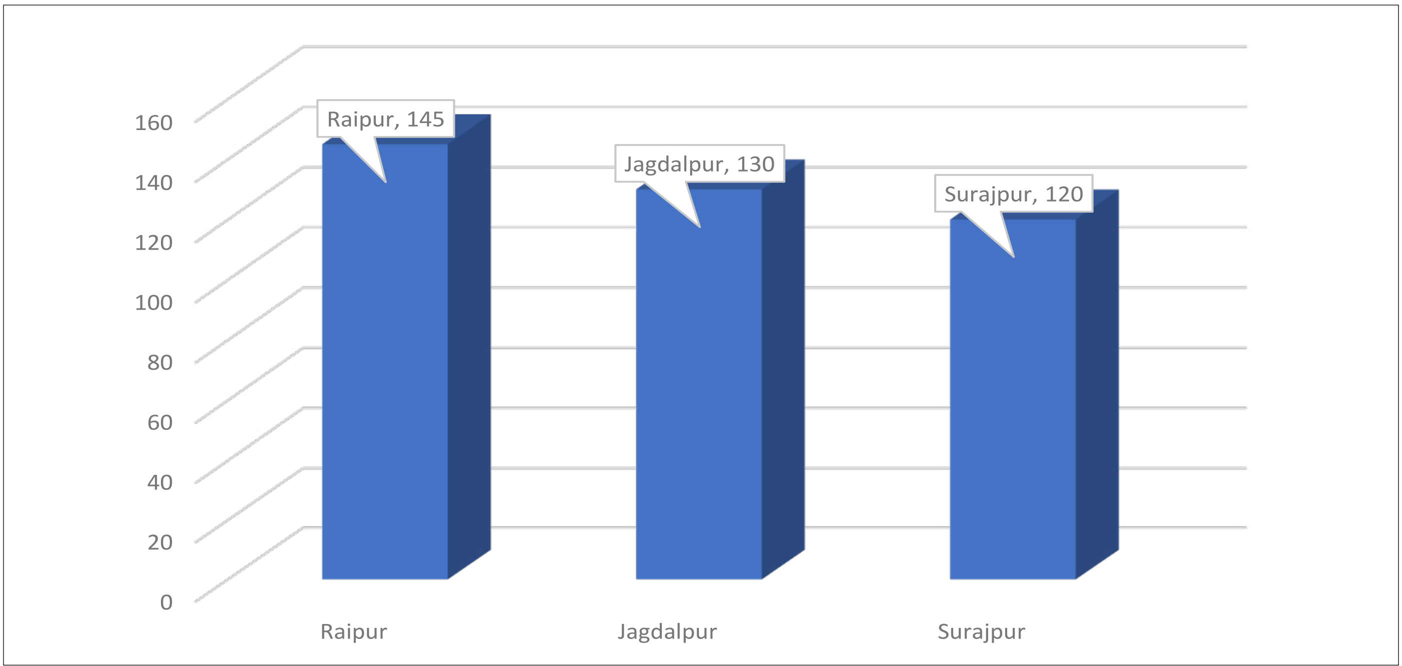
RMC has three sludge suction vehicles of 3, 4 and 7 kilolitre capacities. The charge is heavily subsidised costing Rs 1000 for the smaller vehicles and Rs 1200 for the 7 kilolitres vehicle. On average there are 5 cleanings daily, mostly by the smaller vehicles which amount to about 18 KLD of faecal sludge load, whereas according to the methodology adopted it should be at least 1 MLD (6x62,500/365). The faecal sludge situation in all the towns will deteriorate further as the pit latrines fill up in the future.

5.6 Conclusions

This detailed survey of the sample urban areas in Chhattisgarh has revealed the following characteristics of water management in the study towns:

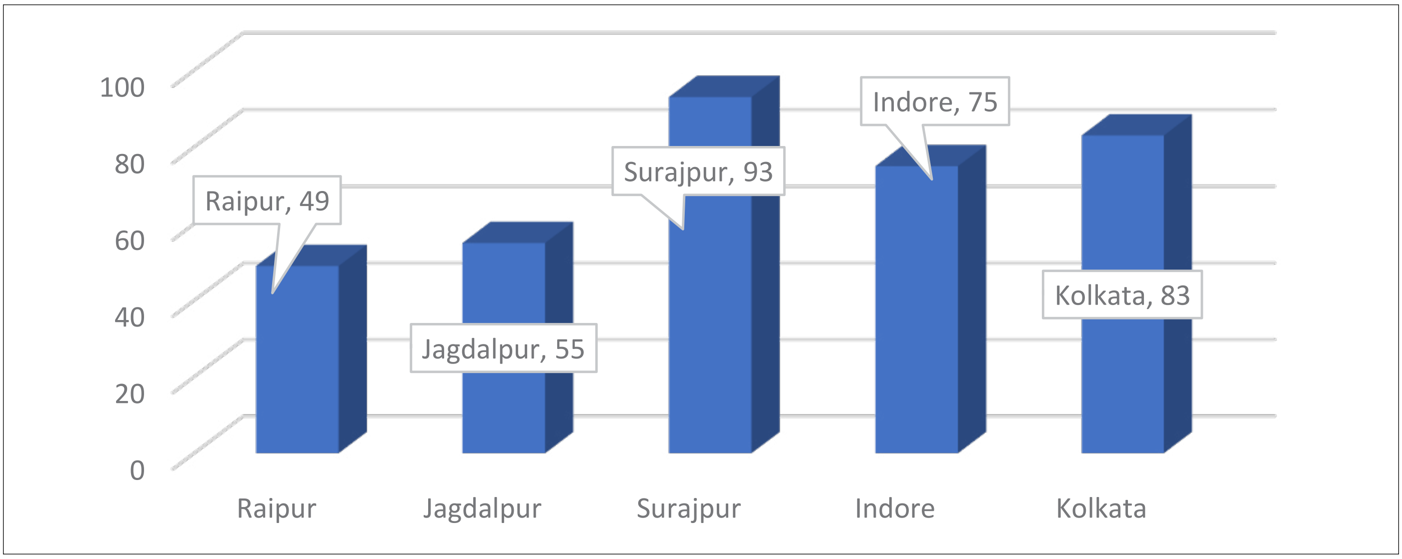
1. All the towns are well endowed with perennial water sources nearby and so the per capita supply is comparable to the 135 lpcd standard as shown in Fig. 26 below.

Fig. 26: Water Supply in Study Towns of Chhattisgarh



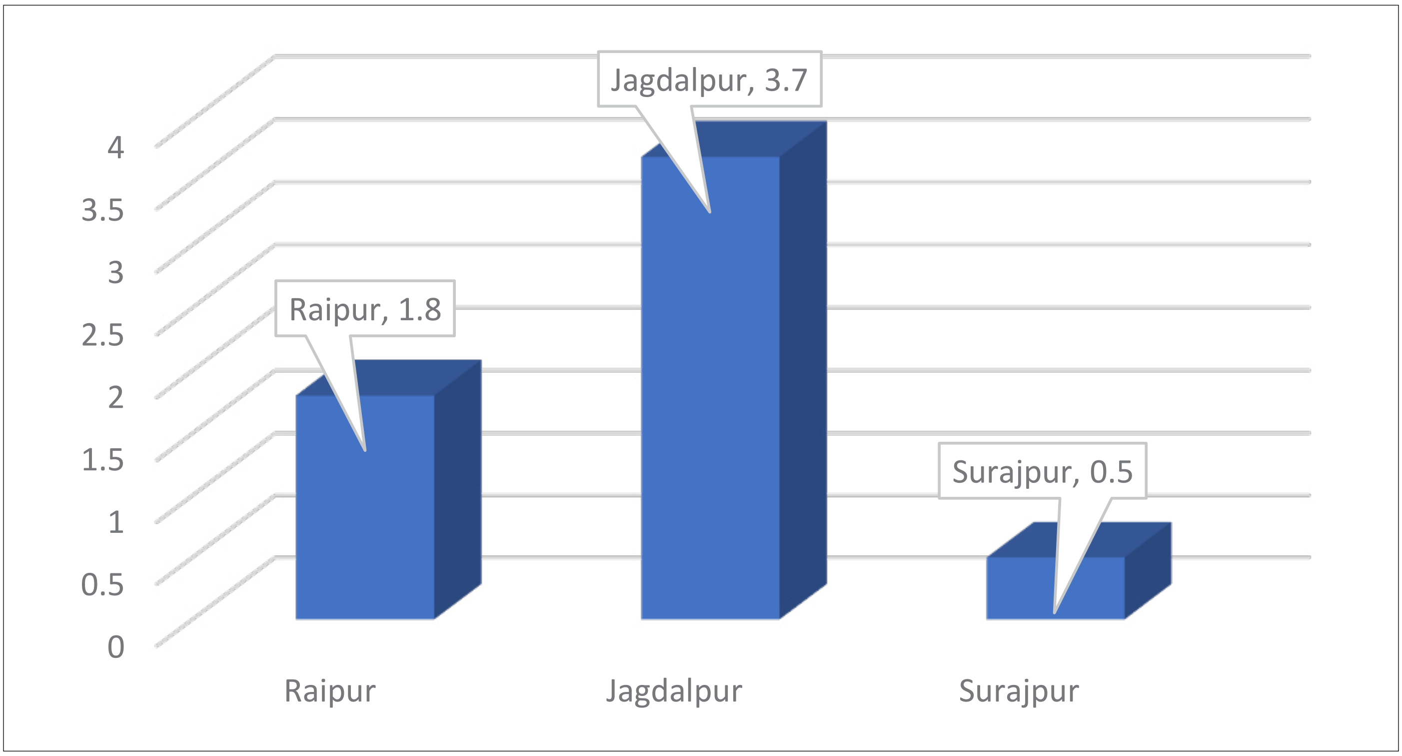
2. However, in the case of Raipur, the operating cost of the water treatment and distribution is high and this is not being met by the collection of user charges, primarily because there is a high proportion of non-revenue water, which is 49 percent of total supply. In the case of the Surajpur the under recovery of water supply charges is as high as 93 percent. The budget documents of Jagdalpur do not separately list the water supply costs but assuming them to be a modest Rs 10 per kilolitre, it can be estimated that the annual cost for the 20 MLD of water supply to be Rs 7.3 crores. Whereas the user charges collected for water supply in 2019-20 were only Rs 3.3 crores or an under recovery of 55 percent. This cost under recovery in centralised water supply is seen across urban India, as is shown in Fig. 27 below. The cost under recovery in the study towns in Chhattisgarh have been compared with that in Kolkata (KMC, 2021), as these towns has a nearby water source and also with Indore (IMC, 2021) which has a distant water source.

Fig. 27: Under Recovery of Water Supply Costs (%) Across Towns



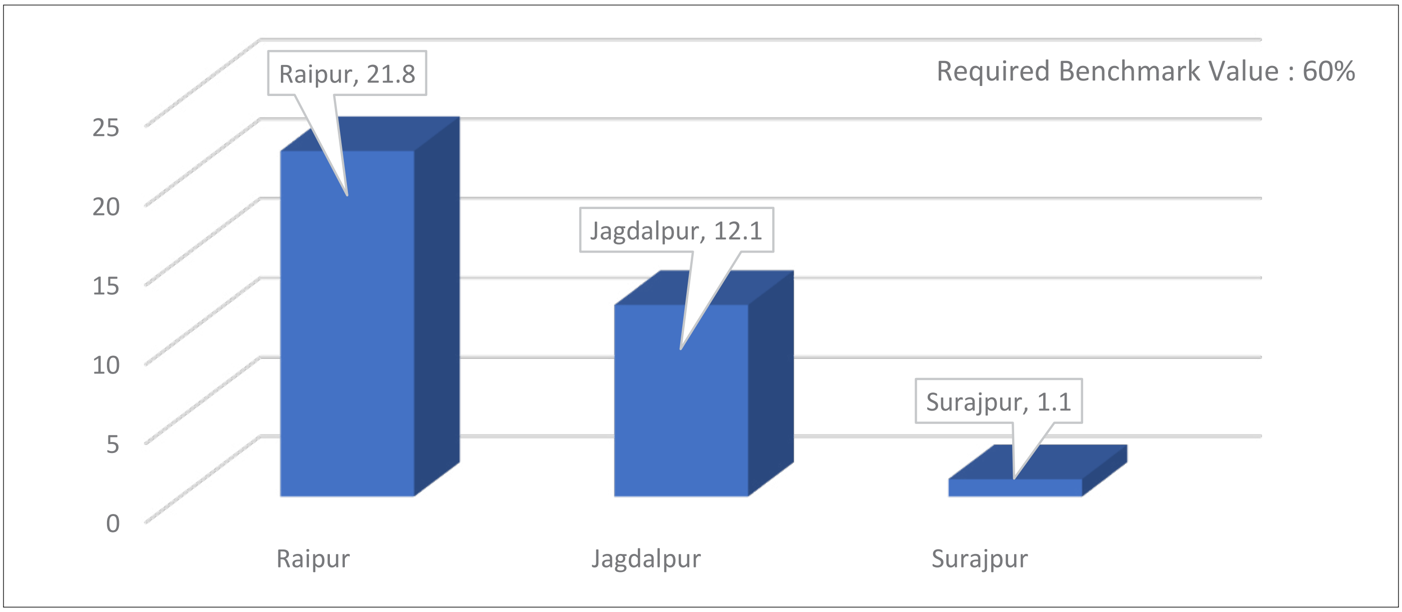
3. There are no sewerage systems and blackwater outflows from the onsite systems to open drains releasing their untreated used water into ponds, streams and rivers, resulting in widespread pollution of water bodies and the aquifers as corroborated by the water quality tests conducted during the study. Moreover, due to cracks in the water supply lines ,water gets contaminated as confirmed by the tests conducted on potable water sources during the study. So far, only some STPs being built to treat a part of the used water from the drains and streams by interception and diversion. However, it is not very efficient as the treatment system in Kavardha town is not functioning properly. Moreover, interception and diversion of drains creates the problem during monsoons of waterlogging in the catchment of the drains as it regularly happens in the city of Indore, since the flow is higher than the capacity of the tapping sewers (Banerjee, 2021). Finally, the treatment of used water from the drains only at their confluence with rivers far away from the towns precludes the reuse of treated water due to the high capital and operating costs of transporting and distributing it back to the town. Thus, this is coming in the way of implementing a CWE compliant urban water system in the State. The costs of used water conveyance and disposal are not separately listed in the budget documents and so it is not possible to analyse the extent of cost recovery through user charges for the study towns.
4. The capital costs of upgrading the water supply, used and storm water systems are met from grants of the state and central governments, as the surplus revenue for ULB's are not enough for this and neither are they being recovered from user charges. This, further hampers the mobilisation of funds for proper water management. The ULBs in the state have poor credit ratings due to their weak finances and so their ability to raise loans from the market for funding capital expenditures is limited (ToI, 2017). Consequently, the infrastructure for centralised water supply and sanitation is inadequate in all the study towns.
5. Faecal sludge from the septic tanks is cleaned after long intervals of ten years and then mostly dumped untreated in ‚nalas' and fields, since, the only FSTP in Ambikapur is not functioning properly. The efficiency of actual sludge removal from septic tanks in the study towns, measured as a proportion of the ideal cleaning frequency required for proper functioning of the septic tanks, is very poor as is shown in Fig. 28 below.

Fig. 28: Efficiency of Septic Tank Cleaning as Proportion of Ideal Cleaning Frequency (%)



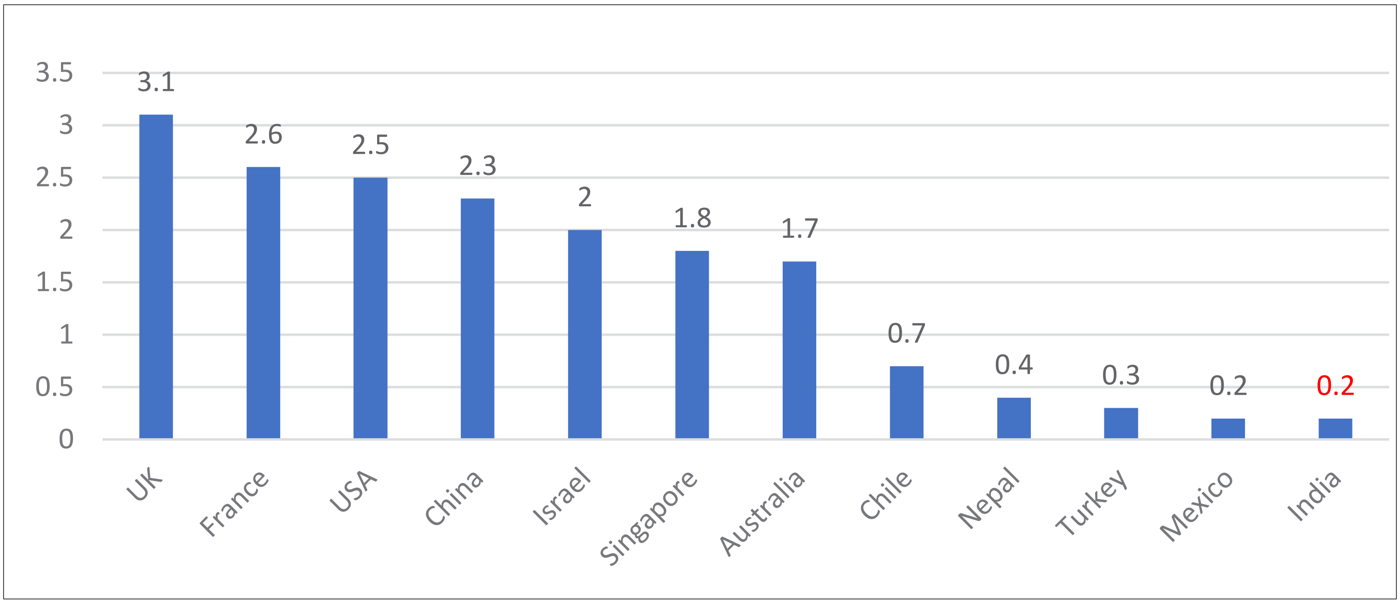
6. The finances of the ULBs are in bad shape with poor revenue mobilisation mainly due to inadequate collection from property taxes and user charges. There is heavy reliance on the state and the central government grants, even the revenue expenditures and capital expenditures are being met totally from such grants. This dependence is more in the case of the smaller towns. The inadequacy of the collection of property taxes in the three study towns as compared to the requirement of their constituting 60 percent of the total revenue income is shown in Fig. 29 below.

Fig. 29: Proportion of Property Tax in Total Revenue Income (%) in Study Towns in Chhattisgarh



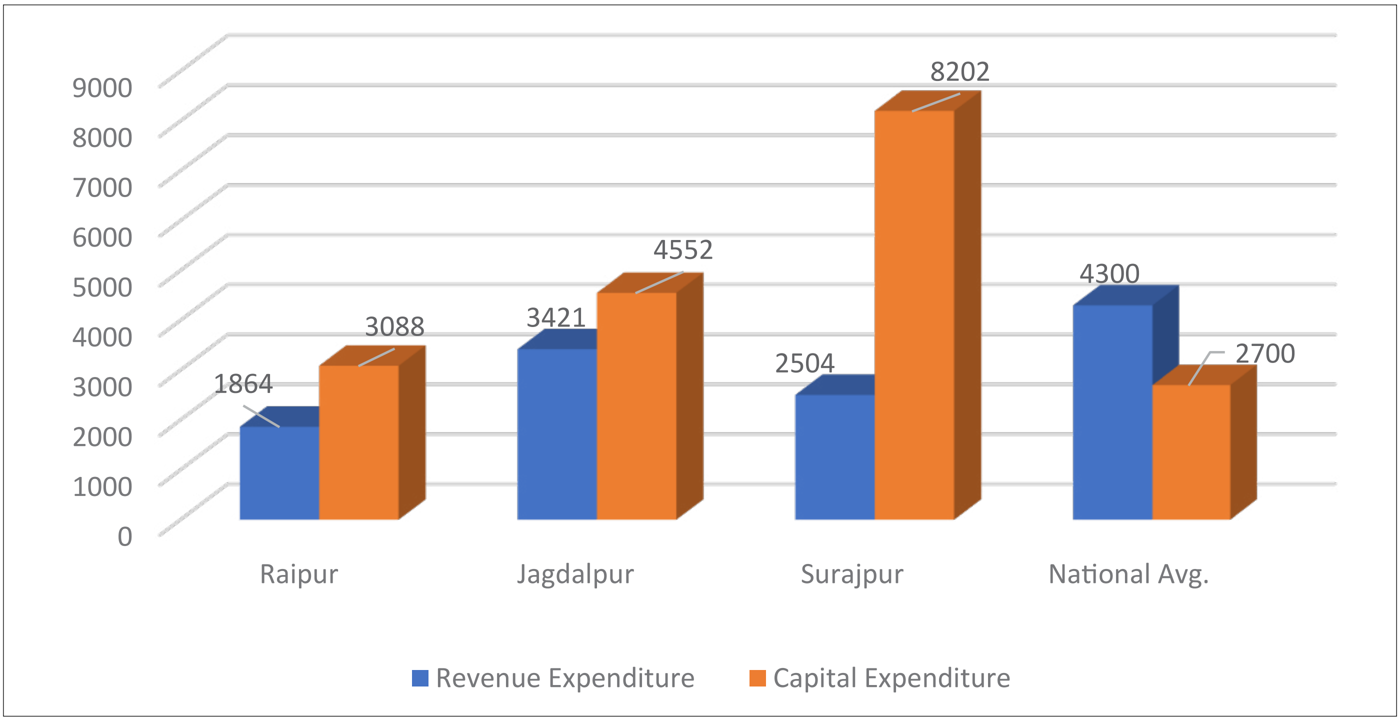
Also, if we consider the property tax levied per capita, the study towns perform badly as compared to the national average for the twenty most populous cities which is Rs 421 (ICRIER, 2019). Raipur has a per capita property tax collection of Rs 363, for Jagdalpur it is Rs 387 and for Surajpur it is just Rs 20. This inadequacy of property tax collection is a common phenomenon across India and it severely limits the capacity of ULBs to incur capital and revenue expenditure to provide quality urban services (MoUD, 2011). Compared to other countries, especially the developed ones, the share of property tax in GDP in India as a whole is very poor as it is ranked at the bottom (Awasthi & Nagarajan, 2020), as shown in Fig. 30 below.

Fig. 30: Property Tax as Proportion of GDP (%) for Selected Countries (Awasthi & Nagarajan, 2020)



7. Another crucial indicator of urban development is the per capita expenditure of ULBs. These are shown for the three study towns and compared with the national averages in Fig. 31 below.

Fig. 31: Per Capita ULB Expenditures



The revenue expenditures of the study towns are much less than the national average of twenty large metropolitan cities, while the capital expenditures are more. The latter is wholly funded by the State and Union Governments and these levels will not be sustainable in the long run. The revenue expenditures are low because of inadequate own revenue mobilisation described earlier.

8. Awareness and skills for proper water management are lacking both among the citizens and the staff of the ULBs. The laws, regulations and plans that are in place for rainwater harvesting and recharge, and, treatment and reuse of used water are not being implemented at all. This lack of skills is most acute in the smaller towns. The staff of SMC were not even aware that they were part of the Ganga River Basin.

Clearly, water management in the study towns is still being done in the linear economy mode of "take", "make", "consume" and "waste" despite detailed legal, policy and planning provisions that are in place for making it CWE compliant.

6. Challenges of Making CUWM Compliant with CWE

Centralised urban water management will have to be analysed for the Indian and global context to pinpoint it's challenges in becoming CWE compliant. Especially since the urban areas of Chhattisgarh have underdeveloped water management systems in place and so their study has not provided an overall picture of CUWM. Therefore, a few other cities in India and abroad are studied.

6.1 Wider Analysis of Functioning of Sewerage Systems

The functioning of the sewerage systems of two other cities will be analysed to understand the complexities involved in centralised sewage conveyance, treatment and reuse. The city of Kolkata is situated close to a river in an alluvial plain and has a developed sewerage system, while the city of Indore, which has been declared water plus city under the Swachh Sarvekshan programme of the Ministry of Housing and Urban Development for its exemplary used water management (Hindustan Times, 2021), not only has an extensive sewerage system but it has also implemented interception and diversion sewers which are being planned in Chhattisgarh state.

Kolkata has a unique drainage topography due to the silt levees deposited along the banks of the River Hooghly. The slope of the land is towards the east, away from the river and there is a sewerage system and a canal system that carry the wastewater and stormwater to the East Kolkata Wetlands and thereafter to other rivers that drain into the Bay of Bengal. The East Kolkata Wetlands is a United Nations Ramsar site where 1000 MLD of the used water from Kolkata is naturally treated through fisheries and then by vegetable farming without any expenditure on artificial sewage treatment plants. However, since the wetlands are situated about 15 kilometres from the city, there are a number of sewage pumping stations in between so that the sewer lines do not go too deep into the ground. The city has expanded over time hence, all of the sewage cannot be transported to the East Kolkata Wetlands therefore, the Kolkata Municipal Corporation (KMC) also has five STPs with an installed capacity of 180 MLD (CPCB, 2021).

The rivers Khan and Saraswati drain the city of Indore and a considerable part of the sewage drains into these rivers. Over the past few years, a massive programme has been undertaken to tap these open drains and outfalls, numbering in thousands, discharging untreated used water into these rivers by laying sewers along their banks, and thereafter directing the used water to seven new STPs constructed at intervals along these rivers. Currently there are about 1100 kms of sewers in the city. There was already a group of STPs run by the Indore Municipal Corporation (IMC) downstream of the city at Kabitkhedi along the river Khan to treat the used water from the sewerage system laid in the city, but they were partially treating only about 100 MLD, of the total used water of 320 MLD or so that is generated, as there were not enough sewers to carry the used water to them. Now, with the tapping of all the thousands of outfalls and treatment of the used water in the seven new STPs constructed along the rivers and icreasing the flow to the Kabitkhedi group of STPs as a consequence of new sewers being laid, 312 MLD of used water is being partially treated and some of this is being reused in washing roads and in maintaining the various gardens and parks while the rest is being released into the rivers (Free Press,2021a). The treatment and reuse of used water has made the city best in urban water management in India. This has been achieved at a huge investments done in, thousands of crores of rupees, for laying sewer lines, tapping outfalls and augmenting treatment capacity.

However, in both these cities (refer Fig 27) there have been a considerable shortfall in the recovery of the costs of water supply. This is also the case with the costs of sewage conveyance and treatment with the shortfall being 88.2 percent in Kolkata (KMC, 2021) and 48.8 percent in Indore (IMC, 2021). This huge shortfall in cost recovery affects the quality of service provided. Faced with this huge shortfall in cost recovery, the IMC have announced a hike in water taxes, making it double of what they were, and introduced a new sewerage tax which was supposed to be effective from April 2021. However, this was immediately met with opposition from the citizens, and both the ruling party and the opposition politicians, who pressurised the IMC to withdraw this proposed hike (Free Press, 2021b). This shows that the high costs for proper implementation of CUWM will be difficult to recover from user charges as will become clear from further analysis of these sewerage costs in Table 24 below.

Table 24: Comparison of Actual O&M Exp on STPs and Sewers with Standard Exp in Indore Municipal Corporation (2019-20)

Sl. No.	Type of Service	Total Quantity Treated	Standard Annual Expenditure Required		Actual IMC Expenditure on Sewerage and Sewage Treatment (Rs Crore)	Shortfall (%)
			Per MLD or Km (Rs Lakhs)*	Total (Rs Crores)		
1	STP	320 MLD	30	96.0	26.58	82.4
3	Sewerage	1100 Km	5	55.0		
	Total			151.0		

Source: Municipal Budget of IMC 2019-20 and 2020-21 and 2021-22

**Estimated from CPHEEO Manual of Sewerage and Sewage Treatment (2013) and CPHEEO & MoHUA (2021).*

The standard expenditures for sewerage and sewage treatment have been taken on the lower side based on the actual expenditures on sewer maintenance and STP operations across the country. Clearly, the IMC is under spending by a very large proportion on sewerage and sewage treatment. The total installed capacity of STPs in Indore is 402 MLD which can easily treat the 320 MLD of used water that is generated in the city. However, in reality due to shortage of funds and all the STPs are being run much lower than capacity and most of the used water is being bypassed without treatment as is evident from the picture below of foaming dark polluted water in the River Khan at Kabitkheri at the end of the town.

Fig. 32: Foaming Dark Polluted Flow in Khan River at Kabitkheri

The water in the River Khan at Kabitkheri was tested for various parameters and the results are given in Table 25 below.

Table 25: Test Results of Khan River Water at Kabitkheri

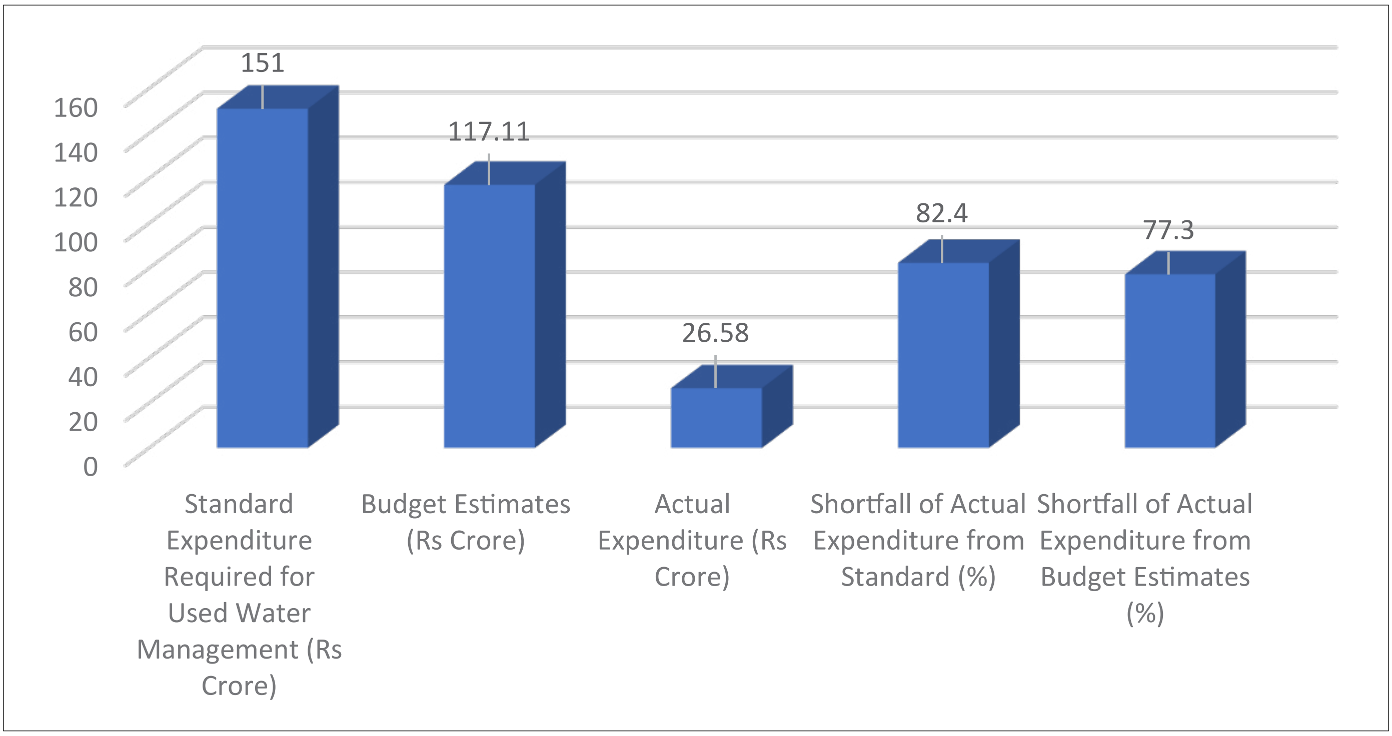
Test	Biochemical Oxygen Demand mg/l	Total Dissolved Solids mg/l Total Dissolved Solids mg/l	Total Suspended Solids mg/l Total Suspended Solids mg/l	Dissolved Oxygen mg/l Dissolved Oxygen mg/l	Total Coli-form	Faecal Coli-form	Faecal Strepto-cocci	Ammoniacal Nitrogen mg/l	Total Nitrogen mg/l
					Most Probable No./100 ml				
Observed Value	20	230	28	1	TNTC*	TNTC	TNTC	0.3	4
Permissible Value for Class A Water Sources (IS:2296)	3	500	20	>5	50	50	50	Absent	Absent

**Too numerous to count. Date of Test Report 25.11.2021*

The test results establish that the water is highly polluted and that the secondary treatment is not being done properly in the STPs, also the tertiary treatment of chlorination is not being done correctly, and that is why there is such a high level of coliform bacteria in the water.

Thus, even after making substantial capital investments in thousands of crores in the tapping of outfalls, laying sewer lines and setting up STPs, due to a sheer lack of regular mobilisation of financial resources from user charges, these investments are not yielding the desired results. The STPs are not operated properly and most of the used water is released untreated into the rivers. In fact, the budgeted estimate of the IMC for sewerage and sewage treatment for the year 2019-20 was Rs 117.11 crores, which means that there is enough awareness that the operating and maintenance costs for proper centralised collection and treatment and reuse of used water are very high. However, as is always the case, actual revenue mobilisation falls far short of estimates and so does the actual expenditure which in this case at Rs 26.58 crores which is a shortfall of 77.3 percent from the budget estimates (IMC, 2021). These details of costs and shortfalls have been summarised in Fig. 33 below.

Fig. 33: Sewerage and Treatment Expenditures and Shortfalls of IMC (2019-20).



The claims of the IMC regarding reuse of water to the tune of 100 MLD are also false. Not only is the quantity of tertiary treated water, that can be reused, is much less, but also enough lines have not been laid to carry this water back to reuse points from the STPs. This is a major problem with the reuse of treated water from the STPs as they are located downstream of the area where the water can be reused and so this requires the installation of large pumps and overhead tanks to take the water to reuse areas. This involves not only capital expenditure but also considerable operating and maintenance expenditure which is difficult to recover from user charges.

6.2 Ringfencing of Water Management Functions of ULBs

Both researchers and policy makers advocate the ringfencing of the water management functions of ULBs for better service delivery and financial viability – "The Water Supply and Sanitation (WSS) assets, staffing, costs and revenues should be ring fenced within the ULB. International good practice shows that further deepening of this ringfencing activity, particularly with regard to governance structures, is likely to lead to improved outcomes. WSS entities under company law, or under statutes, tend to deliver improved performance. This can be seen in the various Water Boards in India" (GoI, 2012a). However, a financial analysis of some of the bigger boards, such as WSS in this country belies these expectations as far as financial viability is concerned as shown in in Table 26 below.

Table 26: Water Supply and Sewerage Board Finances of Bengaluru, Chennai and Delhi (2020-21)

Sl. No.	City	Own Revenue Income* (Rs Crore)	Revenue Expenditure** (Rs Crore)	Deficit	
				(Rs Crore)	(%)
1.	Bengaluru	1600.00	2125.00	525.00	32.8
2.	Chennai	761.36	1052.38	291.02	38.2
3.	Delhi	3062.27	3664.72	602.45	19.7

**   Income from user charges only excluding government grants*

*** Expenditure on establishment and O&M only excluding interest payments and depreciation.*

Source: Budgets of Bengaluru Water Supply and Sewerage Board, Chennai Metropolitan Water Supply and Sewerage Board and Delhi Jal Board.

Even though Delhi has a lesser shortfall in revenue mobilisation than Bengaluru and Chennai, its debt servicing expenditure, which has not been included in the above analysis, is Rs 3592.31 Crores or 117.3 percent of the own income whereas these numbers for Bengaluru are Rs 775 Crores or 48.4 percent, while for Chennai they are Rs 86.62 Crores or 11.4 percent. All three cities are unable to finance their centralised water supply and sewerage systems from user charges hence, the capital expenditures have to be subidised by the respective state governments. Even after this, since the expenditures are below the amount than what is required for provision of quality and adequate WSS services, the actual service delivery is poor in most cases and especially so in the slums and poorer neighbourhoods (ICRIER, 2019, MoUD, 2011 & MGI, 2010).

6.3 Financial Requirements of Centralised Water Supply

The urban population of India can be taken to be about 420 million currently. Assuming that it will have to be supplied at 135 lpcd, the daily water supply quantity comes to 56,700 MLD. The naturally water scarce regions of the country are 70 percent of the whole (CGWB, 2013d) and here water has to be sourced and supplied to urban areas from a distance at about Rs 15 per kilolitre. The rest 30 percent are in water abundant areas and there the cost of water supply is Rs 7 per kilolitre. There is an associated problem of non-revenued water arising from physical leakages in the supply system and water theft. Revenued water is roughly 50% of the total urban water supply for India as a whole and the AMRUT 2.0 guidelines aim to bring it down to 20 percent (MoHUA, 2021b). Therefore, even at the very best a provision of 20 percent has to be made over and above the demand, to arrive at the supply to cover for this loss. Thus, the total annual O&M cost of centralised water supply for urban areas is –

$56700 \times 1000 \times (0.7\times15 + 0.3\times7) \times 365 \times 1.2 \approx$ Rs 31300 Crores

This is about 0.14 percent of the GDP and amounts to an expenditure of Rs 745 per capita per year which is more than double the current per capita expenditure on water supply of the city of Raipur which is Rs 324.

There is also the capital cost of properly providing this water as the average water supply in urban areas is only 90 lpcd. This means that there has to be a 133 percent increase in the water supply from current levels, which involves a huge capital investment, which is estimated to be annually about 0.2 percent of GDP (ICRIER, 2019). The ULBs do not have the ability to mobilise resources through taxes, user charges and loans for either this huge capex or the recurring opex, as we have seen for the various urban areas studied so far, and thus, this enhanced expenditure has to be provided by the state and union governments as grants.

Moreover, due to the inadequacy of centralised water supply, people are sinking borewells to access the unconfined aquifers, which is why they are getting drained unsustainably. Currently the withdrawal of groundwater for domestic and industrial use in urban areas is 30,300 MLD (CGWB, 2021).

6.4 Financial Requirements of Centralised Sewerage & Sewage Treatment

The Central Pollution Control Board (CPCB) has carried out a National Survey of sewage treatment in 2020-21 and the broad national level findings are summarised in Table 27 below (CPCB, 2021).

Table 27: Status of Sewage Treatment in Urban Areas in India 2020-21

Sewage Generation (MLD)	Installed Capacity (MLD)	Proposed Capacity (MLD)	Total Treatment Capacity Including planned / proposed (MLD)	Operational Treatment Capacity (MLD)	Actual quantity treated / capacity Utilised		
					(MLD)	% of Sewage Generated	% of Inst. Cap.
72368	31841	4827	36668	26869	20236	28	64

This clearly shows that only 28 percent of the total sewage being generated in urban areas is being treated. Moreover, according to this survey the quantity of sewage being treated as per relevant standards and in compliance with all norms is only 12197 MLD or 16.9 percent of the sewage generated. Thus, there is a huge shortfall. As we have seen in the case of Kolkata and Indore, even if adequate installed capacity is constructed to collect and treat this huge amount of sewage, the running costs are so high that the STPs will not be operated properly. The estimate arrived at earlier for the operating and maintenance cost of mechanical STPs is Rs 30 lakhs per MLD per year and the maintenance of the sewer lines is Rs 5 lakhs per km. Assuming a ratio of 3 km of sewage lines per MLD of sewage, the annual cost of collecting and treating the urban sewage generated in the country is –

72368 MLD x 30 Lakhs + 72368/3 x 5 Lakhs ≈ Rs 32,600 Crores.

This is about 0.15 percent of the Indian GDP. Therefore, it is unlikely that ULBs will be able to bear this cost given the reluctance of citizens to bear it through user charges and both the Central and State Governments too cannot go on indefinitely subsidizing this cost.

Moreover, taking the capital cost of setting up an STP as roughly Rs 1 crore per MLD (MoHUA & CPCB, 2021), the total cost of eliminating the backlog of 35,700 MLD of STP capacity is Rs 35,700 crores and a similar amount for the laying of sewer lines and the construction of sewage pumping stations. Such huge resources are not available with ULBs and so they are dependent on Central and State Government grants and loans from development institutions like the World Bank and Asian Development Bank to fund the construction of STPs and the laying of sewer lines. Moreover, to make used water management CWE compliant the treated water must be reused and this requires further capex and opex which are difficult to recover from end users (IITR, 2021).

This financial crunch has led to the dilution in the norms for discharge of treated effluents from STPs. The Environmental Protection Rules 1986 were amended in 1993 to relax the standards for release of STP effluents. To take just one important parameter, the BOD was made 30 mg/l for release of effluents into surface water bodies like lakes and streams. The permissible level of BOD for such surface water bodies is 3 mg/l (IS:2296, 1982). However, the Bureau of Indian Standards has since withdrawn IS:2296. Given the serious contamination of surface water bodies that is taking place, The Ministry of Environment, Forests and Climate Change (MoEFCC) had notified in 2015 under the Environment Protection Rules 1986, a more stringent standard for BOD of effluents of STPs at 10 mg/l (MoEFCC, 2015). However, this is not being followed.

6.5 Affordability Analysis of Centralised Water Management in Indore

A major problem in India resulting from the high cost of water utility services, is their unaffordability due to the high levels of inequality and low incomes of most of its citizens (Oxfam, 2022) and consequent inability of ULBs to recover these high costs from user charges. Therefore, it is necessary to test whether the high costs of CWE compliant CUWM are affordable or not. The finances of centralised water management of the IMC was analysed for this purpose. Let us assume that the total number of households paying the user charges for water supply will also be those that will need to pay sanitation charges for recovery of costs by the IMC and leave out other households on the grounds of equity. Thus, there were 2.01 Lakh water tax payers in 2015 (IMC, 2021). However, this number needs to be increased by 20 percent to cover those that are not paying for water but should be, and also by another 10 percent to account for the increase over the five years from 2015 to 2020. Thus, the total tax payer households will be 2.6 lakhs.

The total actual expenditure on water supply was Rs 273.36 crores, and that required for proper used water management was Rs 151 crores in 2020 or a total of Rs 424.36 crores as we have seen earlier. The average per household water supply cum used water management charge per month required to cover the actual expenditures required for proper service delivery can then be estimated as follows –

User Charge for Water Supply and Used Water Management per Month = Total Annual Expenditure on Water Supply and Used Water Management/No. of tax paying households/12 months

User Charge = 424.36 crores /2.6 lakhs/12 = Rs 1360 per month.

The Average urban per capita monthly Household Consumer Expenditure in the 68th round of the National Sample Survey Organisation survey for Madhya Pradesh in 2011-12 was Rs 1967 (NSSO, 2013). Assuming a household of five persons this gives the average monthly household consumer expenditure in 2011-12 to be – 1967 x 5 = Rs 9835.

Assuming an average annual consumer price inflation rate of 6% from 2011-12 to 2020 the average monthly household consumer expenditure in 2020 would be Rs 15675.

Thus, for recovery of costs the ratio of the centralised water management charge that has to be levied to the average household consumer expenditure works out to be –

100*1360/15675 = 8.7 percent

The proportion of households who had monthly consumer expenditure less than the average is 65 per cent of whom the bottom 30 per cent are exempted as being too poor to pay. Thus, as much as 35 per cent of the population would have to spend 8.7 per cent or more of their monthly consumer expenditure on water charges. The Environmental Protection Agency in the USA has mandated that water charges in excess of 2.5% of a community's mean household income for water and 2% for sewer (or 4.5% combined) are “unaffordable” (Grinshpun, 2020). In the USA the capex is also recovered from user charges and so if that were also to be added in this case, then the leviable charge per household for financial viability of CWE compliant CUWM would be around Rs 2500 per month, which would be 4.5% or less of the monthly per capita expenditure for less than 10% of the total households (NSS, 2013). Thus, the charge for full recovery of capital and O&M expenditures of CWE compliant CUWM would be unaffordable for more than 95 percent of the households in Indore. Clearly this is not feasible in a country like India.

This lays down a big question mark on the economic viability of CUWM. The capital and operation and maintenance costs of well provisioned and operated centralised water management systems are very high and the vast majority of users, ULBs and the Governments are unable to meet them.

6.6 Treatment of Faecal Sludge

Given the high operating costs of running STPs it has been proposed that instead of laying sewer lines and building STPs it would be better to transport the faecal sludge to Faecal Sludge Treatment Plants (FSTP) in smaller towns and to co-treat it with sewage in STPs (MoHUA, 2021a). Faecal sludge from septic tanks and pit latrines is currently collected and transported to nearby drains or farms and emptied there, leading to pollution of both surface and ground water in violation of the national policy on faecal sludge management (GoI, 2017). The main problem in this is the cost of transportation. As the price of Diesel has escalated, the cost of transportation has increased tremendously, which is why both the ULBs and the private operators dump the sludge into drains and farms that are close to the on-site system, because it is very costly to carry the sludge to STPs or FSTPs that are farther from most of the cities. There is also the deleterious practice of disposing of the sludge in sewer manholes. However, this clogs the sewers further as they anyway have lesser than self-cleansing flow. Since most STPs in the country are running at less than their installed capacity and the used water coming into them in most cases is diluted and does not have enough sludge, the emptying of faecal sludge into them for co-treatment is a good option.

Co-treatment of faecal sludge in STPs is being successfully done at a few locations in India and the main features of this are as follows (Gupta et al, 2018):

- The septage load that can be added to the various STPs without affecting adversely their operational efficiency has to be estimated.
- The maximum catchment area that can be taken for providing this amount of septage load has then to be estimated.
- Infrastructure must be built at the STP for emptying of septage trucks into the STP. Even though in some cities septage is also added to the sewer system this is not recommended given the lower flow that prevails already leading to blockage of sewers.
- Regulations have to be notified for private operators to empty septage in STPs and the costs worked out in consultation with them.
- A public campaign needs to be initiated to build up awareness among owners of on-site sanitation systems regarding regular cleaning of their systems and proper treatment and disposal of faecal sludge.

However, as mentioned earlier the most important consideration in co-treatment is the prohibitive cost of transportation of septage to the STPs from areas that are situated at a distance from them. The successful FSTP that has been running for five years at Devanahalli near Bengaluru is operating at only one third capacity because the private sludge cleaners prefer to illegally dump the sludge elsewhere (CDD, 2020). Similarly, the FSTP in Ambikapur is also functioning well below its capacity. Therefore, provisions have to be made for setting up transfer stations in areas that are distant from the STPs for collection of faecal sludge at a cost that is acceptable to the owner of the on-site sanitation system and the private sludge cleaners. Thereafter, large vehicles can be used to transport the sludge from the transfer stations to the STPs but the cost of this has to be borne by the ULB. This once again limits the efficacy of the method because of the resource crunch that most ULBs face.

There is also the alternative of directly supplying the septage to farms near the city if precautions are taken that these farms produce only commercial crops like mulberry, flowers and cotton and there is no immediate contact with humans till the sludge gets oxidised by bacterial action (NIUA, 2018b). In some towns the private operators do dump the faecal sludge on farms as farmers find that its fertiliser value is very good and take care of sanitising the field from human or animal contact till the sludge gets oxidised naturally (NIUA, n.d.). However, this is a very rare phenomenon because of the taboo against touching human excreta among most farmers.

6.7 International Practice in CUWM

Internationally, centralised urban water management is followed in the developed countries where the ULBs are mostly able to recover their capital and O&M costs through user charges. The USA has relied on centralised water supply from distant sources for all its major cities followed by extensive sewage systems to carry away the used water to be treated in sewage treatment plants. The details of supply and costs for four major cities in the East, West, North and South of the country are given in Table 28 below.

Table 28: Water Supply and Used water Treatment in Selected Cities in USA, 2021

Sl. No.	Area of USA	City	Water Supply (lpcd)	Cost of Water Supply Recovered as User Charges (Rs/kilolitre)*	Cost of Used water Treatment Recovered as User Charges (Rs/kilolitre)**
1.	East	New York	450	23	25
2.	West	San Francisco	240	101	89
3.	North	Chicago	280	29	32
4.	South	Phoenix	350	21	9

**The conversion has been done at the Purchasing Power Parity rate of 1 US$ = Rs 21.69*

*** The quantity of used water has been assumed to be 80% of the water supply.*

Source: City of Phoenix, 2021

The per capita water supply is much higher in the USA as compared to India and so are the costs of both water supply and used water collection and treatment. However, in recent years, climate change has resulted in drought in the west and south and higher precipitation in the north and created considerable problems (City of Phoenix, 2021). In the case of San Francisco and Phoenix, the available water supply, a substantial part of which comes from dams on the River Colorado and its tributaries, has been reduced and in the case of Chicago higher storms have meant that the combined used water cum stormwater sewage system has been adversely affected, resulting in flooding of houses with used water mixed with stormwater (Grabar, 2019). This has led to a rethink about centralised water supply and sanitation in the USA. The three major concerns currently are the resilience of supply, huge expenditures in renewing and augmenting aging water supply and sewerage systems and the increasing difficulty of financing the rising capex and opex costs through user charges and loans (AWWA, 2021). The city of Chicago had spent a huge amount of money over the last fifty years in building a tunnel below the city to channel the sewage and used water to big reservoirs outside the city from where the used water is pumped up to sewage treatment plants but with the increasing number of storms taking place this is proving to be inadequate. Consequently, there is now a stress on reducing the demand and so over the past decade the water demand has gone down as individual swimming pools and gardens in cities have been curtailed. The supply side has been augmented with rainwater harvesting and recharging which has also led to a reduction in the stormwater load on the centralised sewers (AWWA, op cit). The city of New York has implemented a special watershed management programme in its source areas that needs to be discussed in detail.

The water supply of New York city is unique in that it requires only minor water treatment. Streams in the Catskill and Delaware Mountains, about 160 kms northwest of the city, are directed into six reservoirs. The water is piped into the city and delivered to the consumers (Mehaffy et al, 2001). The region is heavily forested with a population of only 60,000 people and so the soil acts as a purifying medium and the water flowing in the streams is potable. However, in the early 1990s it was noticed that the water quality was deteriorating and that very soon huge investments would have to be made to install a filtration plant in New York to purify the water. The capital costs were estimated then at around US $ 6-8 billion and the annual operating costs at about US $ 300 million.

This set the city planners thinking about why the water quality had deteriorated despite there still being heavy forests and a sparse population as before. The US Environment Protection Agency (EPA) conducted a detailed study to investigate the reasons for the deterioration of water quality. The study found that chemical agriculture and cattle farming had increased near the streams and this was causing excess fertilisers, pesticides and dung to flow into the reservoirs. Moreover, people from the city had built weekend holiday homes on the shore of the reservoirs in large numbers and the untreated sewage and used water from these was seeping into the reservoirs and causing the water quality to deteriorate even further.

Studies showed that buying up land near the reservoirs, installing sewage and used water treatment plants there and paying the farmers not to cultivate land or graze cattle near the streams would cost about $ 1-2 billion initially and later have a recurring cost of as little as $ 10 million annually. This would ensure that the water flowing into the reservoirs remained potable. Thus, New York City Corporation raised the money through municipal bonds and carried out this environmental restoration project instead of going for the much more costly option of installing a water filtration plant. All filtration does is solve a problem. Preventing the problem, through watershed protection, is not only faster and cheaper but also has lots of other benefits. Weighing the costs and benefits, watershed protection and decentralised treatment implemented as part of a CWE was a better decision for New York (Heal, 2000).

Similarly, urban Australia, especially the cities of Adelaide and Melbourne, faced the two problems of inadequate stormwater drainage infrastructure leading to flooding and increasing water needs that could not be met anymore from the Murray and Yarra Rivers respectively. A large investment was required in improving the stormwater drainage system and in augmenting the water supply. This was when the Australian Government thought of combining the two and the result was a composite urban water management programme based on the concept of Water Sensitive Urban Design (WSUD) (Melbourne Water, 2022), which is defined as "an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff, drinking water and used water to protect water related environmental, recreational and cultural values,
- Storage, treatment and beneficial use of runoff,
- Treatment and reuse of used water,
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity, and
- Conserving water within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non-drinking water supplies."

Thus, by reusing stormwater through appropriate water harvesting techniques involving both surface and aquifer storage and the treatment and reuse of used water, the need for expensive drainage and water supply systems is reduced considerably. The design of buildings is done in such a way, so as to save on water use and increase water storage and reuse. In the process, the environment is also conserved as extensive soil conservation and plantation activity is undertaken in the unbuilt environment. The crucial point of note in these changes coming about in the international urban water management scenario, is the realisation on the part of policy makers and planners that working with nature is beneficial both financially and environmentally. This can bring about substantial benefits at less cost compared to further investments in solutions that rely only on centralised technological fixes for water supply and used water management problems. In the urban water management context this involves an optimal use of both groundwater and surface water sources and where feasible recharging and reuse of storm and used water (Veolia, 2021, UNESCO & ICWSSM, 2020).

Given this trend in developed countries, which have the resources for centralised urban water management, of switching to decentralised water management systems so as to become CWE compliant, it is even more important for India, where the ULBs and Governments are facing a severe resource crunch, to do so too.

7. Detailed Plan of Decentralised Urban Water Management

The Government of India has taken note of the emerging global trend for implementation of CWE and the guidelines for urban water conservation published under the Jal Shakti Abhiyan (GoI, 2019d) stress the following towards achieving this:

"Sustainable Development Goal 6 (SDG 6) envisages availability and sustainable management of water for all by 2030. India is facing the challenge to serve 17 percent of the world population with 4 percent of the world's freshwater resources. Presently designated as a water stressed nation, India stores less than one-tenth of its annual rainfall. In order to address water scarcity, it is important to undertake efforts for conservation, restoration, recharge and reuse of water".

All States must necessarily follow these guidelines and so even though the Government of Chhattisgarh has not yet notified its own guidelines in this regard, it will follow the Central ones for implementing CWE.

7.1 Circular Water Economy Principles

The detailed guidelines for urban areas in the Jal Shakti Abhiyan for achieving a circular water economy are as follows:

7.1.1 Rainwater Harvesting

1. Cities need to ensure that Rainwater Harvesting (RWH) provisions are incorporated in their Building Bye-Laws (BBLs). Thereafter, an effective enforcement mechanism should be put in place for providing RWH structures in all buildings as stipulated under BBL of the city.
2. Urban Local Bodies (ULBs) should constitute a Rainwater Harvesting Cell which will be responsible for effective monitoring of Rainwater Harvesting in the city. The cell should monitor the extent of ground water extraction and ground water aquifer recharge. This information should be displayed at prominent locations for public awareness.
3. ULBs should ensure that all government buildings (Central/State/ULB) must have RWH structures. If such structures are there, but not functional, then they should be made functional. If they are not there, as a special drive, RWH structures should be constructed in these buildings.
4. ULBs should check that all public buildings like educational institutions, commercial establishments, hospitals, etc have got RWH structures. If they are found non-functional, then they should be made functional. In case they are not there, action needs to be taken to develop such structures.
5. ULBs should check whether Group Housing Societies have RWH structures available or not. If they are there, they should be made functional. In case they are not there, Resident Welfare Associations (RWAs) should be persuaded to take up their development.
6. ULBs should ensure that in future all building permissions granted must have RWH structures incorporated, as per BBLs, and same should be checked before issuing Occupancy-cum-Completion Certificate (OCC).
7. Urban public spaces such as road side footpaths and walkways in parks are being concretised. These measures have adverse effect on natural water percolation. Concretisation increases surface run-off and restricts natural percolation of water contributing to urban flooding. ULBs should undertake de-concretizing of pavements and increase recharge.

7.1.2 Reuse of Treated Used water

1. Optimisation of the use of water, by undertaking treatment of used water and reusing it. Treatment of used water at source and its reuse provides an alternative to fresh water where water is required for non-potable use. The water reclaimed from used water can be used for toilet flushing, agriculture/horticulture, fire hydrants, industries, construction activities, power plants, etc and Building Bye laws should include these provisions.
2. Provision of dual piping under Building Bye-Laws should be checked in all levels of government (Central/State/UT/ULB) buildings, commercial complexes, public buildings like educational institutions, hospitals, and Group Housing Societies, whether the same is available, so that the treated used water can be used for horticulture, toilet flushing and fire hydrants. If it already exists, then its functionality should be checked, and made fully operational. If it is not there, then action should be taken to ensure that these buildings have dual piping systems.
3. In all new government buildings/Group Housing Societies, public buildings, whenever building plan is approved, it should be ensured that there should be treatment of used water at source and dual piping as has been provided in City/State/UT BBLs. At the time of inspection for issuance of Occupancy-cum-Completion Certificate, compliance of provision of Building Bye-Laws for used water treatment at source and dual piping to reuse the treated used water should be checked thoroughly.

7.1.3 Rejuvenation of Urban Water Bodies

1. Water bodies should be cleaned through bio-remediation measures, de-silting, aeration, removal of floating and other invasive aquatic plant-species or any other technology suiting local conditions.
2. Shore-line of the water bodies should be properly fenced to protect them from encroachment. Inlet and outlet of the water body should be strengthened.
3. Inflow of domestic/industrial sewage into the water body should be arrested and only treated effluent adhering to standards prescribed by CPCB may be allowed into the water body.
4. Catchment area treatment via afforestation, stormwater drainage management, silt traps, etc. may be undertaken.
5. Water front development around the water body may be taken up, keeping in view the eco-system based approach for the aquatic body, conforming to prevalent environmental legislation and maintaining social and cultural sanctity of the place.
6. ULBs should monitor quality of water in the water bodies on a weekly basis and undertake appropriate action to improve wherever necessary.

7.1.4 Plantation for Water Recharge

1. Such places where plantation could be done during the rainy season like roadside, around water bodies or available public spaces, should be identified at the earliest. Water hardy indigenous variety of trees should be identified for plantation and preferably tall plants (4-6 feet) may be used.
2. Adequate measures need to be taken up to protect and nurture such plants to ensure their survival.
3. Special drives may be taken up to motivate the Resident Welfare Associations (RWAs), Civil Society Organizations (CSOs), National Cadet Corps (NCC), National Service Scheme (NSS), Nehru Yuva Kendra (NYK), etc to plant trees at large scale in the residential colonies, schools, public buildings etc.

7.1.5 Awareness Campaigns

1. There is a need for public awareness regarding water conservation. Greater public participation in the efforts being undertaken by Centre/States/UTs/ULBs has to be ensured. Local communities need to be mobilized to play a vital role in efforts for urban water conservation. ULBs should undertake measures to encourage collective ownership in management of water available locally.
2. ULBs should engage RWAs, schools, businesses, Civil Society Organizations (CSOs), Nehru Yuva Kendras (NYKs), NSS volunteers, NCC cadets, SHGs formed under DAY-NULM, elected representatives, Swachhagrahis to organize door to door outreach, community events, workshops, flyers, banners, wall paintings, street plays, social media campaigns, etc. for dissemination and building awareness for all four above listed Water Conservation measures in urban areas. Leading personalities in films, sports, social work or public life may be invited to the campaigns.

7.1.6 Monitoring and Documentation

1. Effective monitoring needs to be done by establishing a clear baseline and benchmark for State/UT/ULB level performance on implementation of rainwater harvesting, rejuvenation of water bodies, reuse of treated used waterwater and Plantation. The progress needs to be monitored on a real-time basis to ascertain the progress of ULBs and gaps in each of these thrust areas.
2. State/UT/ULB level reporting of progress
3. Video Conferencing with State/UT governments at the Centre level and ULBs at the State/UT level
4. Print, Pictorial, Audio and Video documentation of achievements will be done.

Thus, these guidelines set out a clear roadmap for implementation of conjunctive decentralised urban water management which is unfortunately not being followed in practice anywhere in this country.

7.2 Aquifer Management

The built environment in urban areas has drastically reduced the possibilities of natural recharge leading to higher runoffs during monsoons causing waterlogging on one hand and, lesser availability of water in the unconfined and confined aquifers for post monsoon withdrawal of water. Depending on the hydrogeological characteristics, the underlying aquifers can be artificially recharged to a greater or lesser extent thus augmenting water storage. Done in a scientific manner this can obviate the need to access water from distant sources for water supply even in arid and semi-arid regions of the country (CGWB, 2013d). The Central Groundwater Board has prepared a detailed Masterplan for Artificial Recharge to Groundwater based on a mapping of the hydrogeological characteristics of the underlying rocks to identify the potential storages in the confined aquifer (CGWB, 2020). Storage in the unconfined aquifer generally poses little problems where there are soils. Thus, the following steps need to be taken for enhancing aquifer recharge:

1. Estimation of sub surface storage space and quantity of water needed to saturate it.
2. Quantification of surface water requirement and surplus annual run off availability as source water for artificial recharge in each area.
3. Working out design of suitable recharge structures, their numbers, type, storage capacity and efficiency considering the estimated storage space and available source water for recharge.
4. Cost estimates of artificial recharge structures required to be constructed in identified areas.
5. Planning of afforestation initiatives in open spaces to increase natural recharge.

7.3 Decentralised Used Water Management

The Government of India has also published detailed guidelines for decentralised used water management (GOI, 2012b) and the principles detailed in it are as follows:

1. Decentralized Used Water Management (DUWM) may be defined as the collection, treatment, and disposal/reuse of used water from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation.

2. Flows at any point in the system will be small, implying less environmental damage from any mishap and less cost of treatment.
3. System construction will result in less environmental disturbances as treatment is done locally.
4. The system expansion is easier as new treatment centres can be added without routing ever higher flows to distant treatment centres.
5. Entry of industrial waste can be eliminated due to the possibility of better monitoring.
6. Treatment units will be close knit and free from odours and insects.
7. Community participation will ensure better monitoring of the system performance.
8. Quality of treatment will be better and cheaper than in centralised systems due to accurate estimation of lower quantity of used water generation and its separation into grey and blackwater at source.
9. Reuse of treated used water will be easier as long pipelines and pumping stations will not be needed to supply the treated water from centralised STPs.

However, despite these advantages, DUWM is not being implemented because of the following:

1. Policies regarding installation, operation and maintenance of these systems at the household and community level are not yet well established by ULBs.
2. Standardization of the systems is difficult as significant variation exists with regard to technical design to suit the local geography and climatic conditions and consequently there is a lack of a skilled ecosystem of installation and maintenance.

7.4 Design of Decentralised Urban Water Management Systems

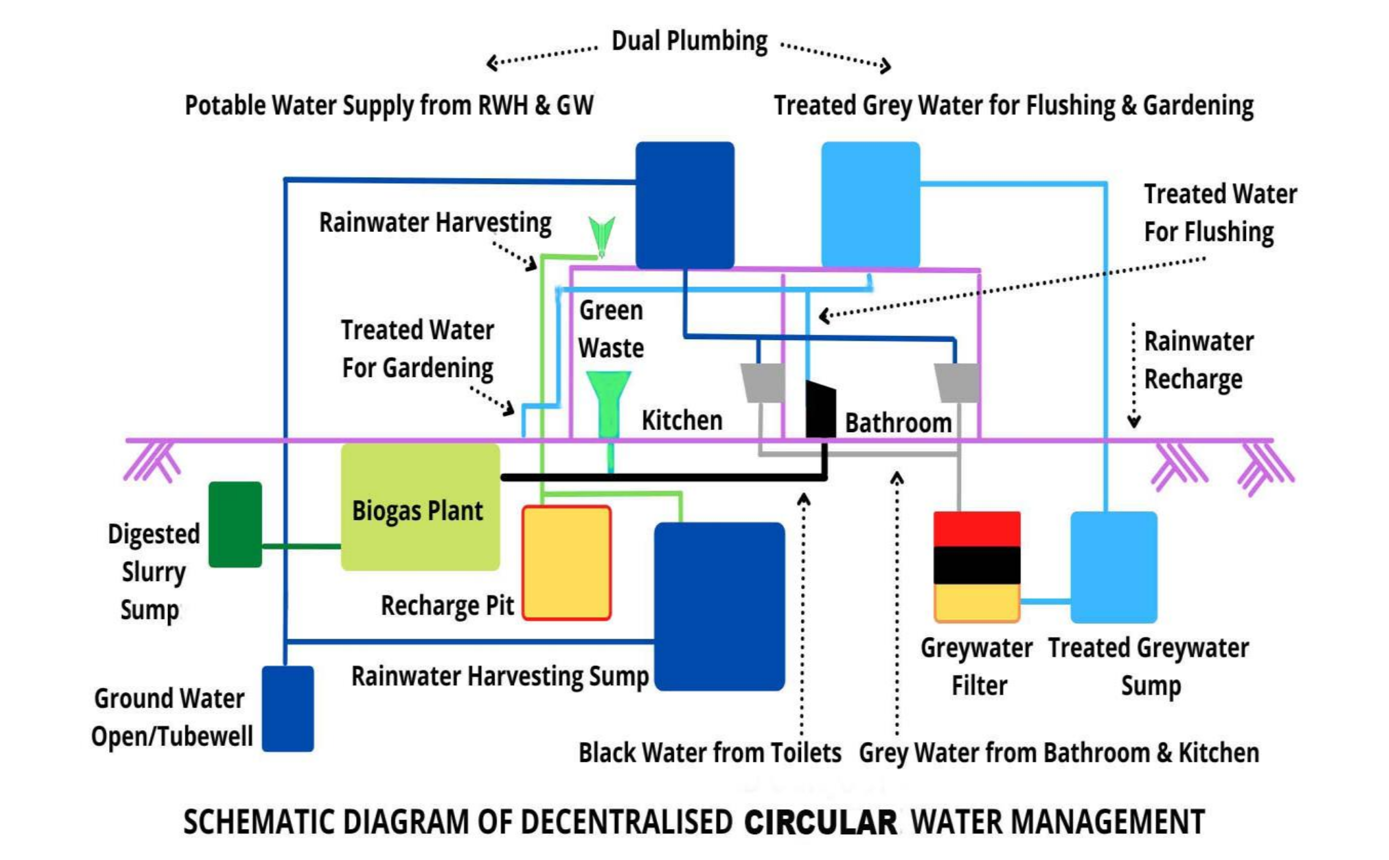
The above detailed discussion of the various Government guidelines shows clearly that implementation of CWE involves a considerable amount of decentralised urban water management to complement CUWM as it is both difficult and costly to achieve CWE through CUWM alone.

Chhattisgarh is ideal for planning and implementation of DUWM because apart from Naya Raipur and the steel plant campus of the town of Bhilai, nowhere else are there sewerage systems. Neither are any sewerage systems planned for implementation. Instead STPs are being proposed to be built near the confluence of drains with rivers and the used water flowing in these drains is to be diverted into these STPs for treatment. This is an extremely inefficient way to treat used water and it does not address the problem of polluted used water flowing in the drains in the urban area itself. While, water supply on the average is adequate in cities, the cost of supply is not being recovered as the financial analysis of the study towns has revealed. This adversely affects the equity of supply as lack of finances results in poorer households not getting adequate water as is clear from the data for water supply in slums in Raipur discussed earlier. Therefore, a decentralised plan can be implemented at the household and community level involving the following:

1. Rainwater harvesting, which will improve potable water availability through constructed storage and recharge, which will improve groundwater availability in the shallow aquifer through recharge and enable tapping of groundwater locally for water supply. While recharge into the confined aquifer will require the identification of recharge zones and the construction of appropriate recharge structures to direct the stormwater from the public spaces to these recharge zones, saturation of the shallow aquifer, which mostly has deep soils with good water storage potential in Chhattisgarh (CGWB, 2012), can be done in a decentralised manner at the household or community level.
2. Separate collection and treatment of greywater from the bathroom and kitchen through filtration, aeration and chlorination.
3. Re-use of the treated greywater in flushing of toilets and in gardening to obviate the use of costly potable water for the same.
4. The blackwater from the toilets is to be mixed with the green waste from the kitchen in a bio-gas plant. The gas generated, after being scrubbed of the hydrogen sulphide in it, is to be used for heating water and also for cooking. The slurry is to be oxidised and used as manure in the garden.

This has been represented schematically below in Fig. 34

Fig. 34: Schematic Diagram of Decentralised Circular Water Management



The detailed features of the various components of this scheme are as follows:

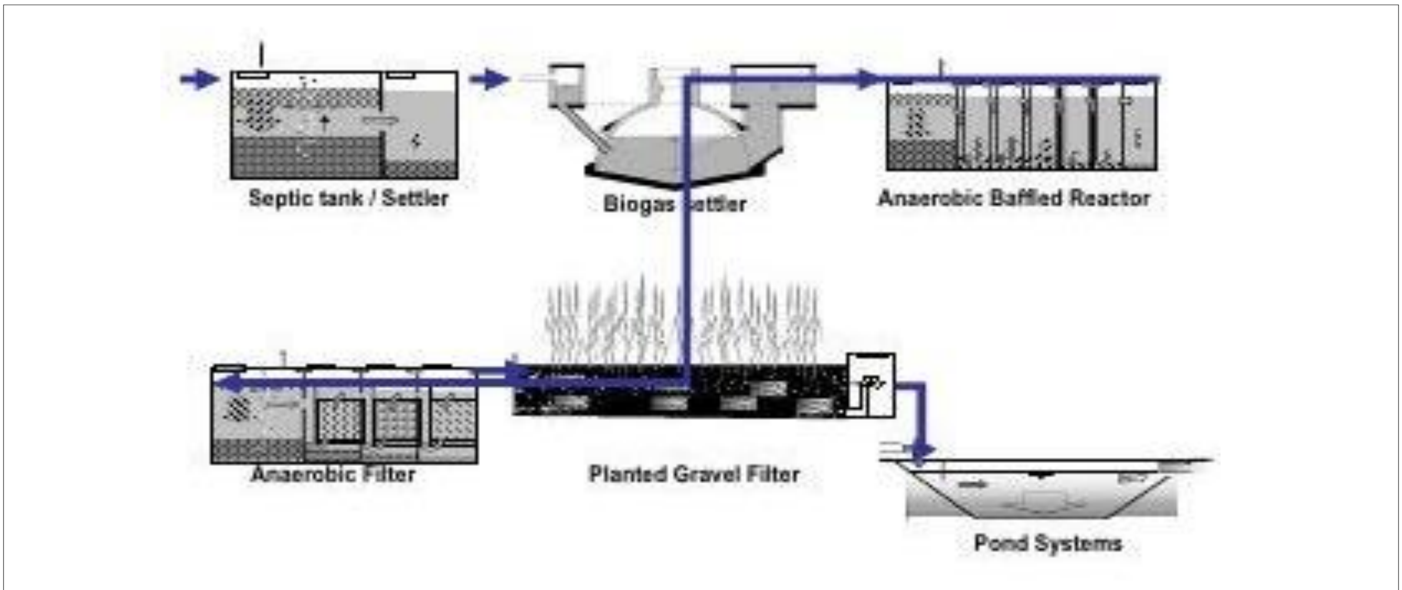
1. The rainwater falling on the roof of the building is either harvested or recharged. Harvesting is more costly as it involves the construction of an underground sump to collect the water. Thus, an optimisation has to be done as to how much of the rainfall is to be harvested and how much recharged depending on the groundwater yield in a particular area, which in turn depends on the underlying hydro-geological characteristics, as recharging is much cheaper. However, if there is water recharging done on a mass scale throughout the urban area both in a decentralised and a centralised manner, then most towns in the country will have adequate water in the confined aquifer. In alluvial plains, like in the Mahanadi, Ganga and Godavari basins of Chhattisgarh, even the shallow aquifer will have adequate water in summer if water recharging is done. That is why in the diagram two options have been provided and there is also a recharge pit alongside the harvesting sump. This pit is filled with a mixture of gravel and sand and is designed to be of a size to absorb the flow of rainwater coming to it from the roof. The rainwater falling on the ground too will be recharged either directly through the soil or the water falling on the paved area will be directed to the recharge pit. The rainwater falling on the roof is filtered through a mixture of gravel and sand before being collected in the harvesting sump. The first one or two showers are bypassed to the recharge pit as the water is dirty with dust gathered on the roof and so about 80 percent of the rainfall can be collected if so required but usually to optimise on storage construction costs, less is collected.
2. The harvested rainwater and the groundwater provide the potable water supply for drinking, washing and bathing uses. There is need for dual plumbing system to use the water for flushing of toilets and gardening, which is to be supplied from treated grey used water.
3. The greywater from the bathroom and that from the kitchen, which latter has to first pass through an oil and grit trap, are directed to a filtration tank consisting of gravel, sand and charcoal. After filtration the water is collected in a sump where it is aerated and chlorinated to clean it further. This water is then used for flushing of toilets and gardening through a separate plumbing system. In this way the use of potable water for these uses is obviated which is a considerable saving because as per the CPHEEO norms, of the 135 lpcd of water supply as much as 25 lpcd is for gardening and 40 lpcd for flushing of toilets and only 70 lpcd is for potable uses. Since the blackwater does not have to be carried in sewers, the

quantity of water needed for flushing is greatly reduced and low-flush toilets can be installed that require less water. Sensors have to be placed in the sump and the overhead tank to automatically regulate the pumping of water from the former to the latter so as to prevent over flow in the former.

4. The blackwater from the toilets and the green waste from the kitchen are sent to a biogas plant. The gas generated from this plant contains mainly methane and some hydrogen sulphide also. The latter being harmful, has to be removed through a scrubber. The gas generated can be used for cooking and for heating water in a gas geyser. In case of four storied or higher buildings, the gas produced can be used to generate electricity which can be reused in the operation of the aerators for grey and blackwater treatment. The digested slurry is collected in a two chambered sump in which one chamber is alternatively filled up and the sludge further digested by anaerobic decomposition to be turned into manure that can be used in the garden while the other chamber fills up much like a two-pit latrine but with the water not leaching into the ground but drying up slowly in the chamber that has filled up as an aerator runs in it to both oxidise the slurry and dry it up. The energy required for this is much less than that needed to run the heavy blowers in large sized STPs of centralised systems. In fact, if the pits are built large enough then even aerators can be dispensed with as the retention time increases allowing for natural drying up of the sludge.

There are some households in slums that do not have enough area for implementing the used water treatment part of this scheme (According to building bye-laws all buildings must leave open space, even though these byelaws are mostly not being followed, nevertheless they need to be strictly implemented for efficient DUWM in particular and urban planning in general). For such low-income households, a community used water treatment system called DEWATS (Decentralised Water Treatment Systems) has to be implemented as shown in Fig. 35 below.

Fig. 35: Schematic Diagram of a DEWATs System (Source: CDD 2020)



The principles are the same as in the household model but in this case the reuse of treated used water, gas and compost will require some more investment and involvement in the community level. These community systems will have to be implemented by the ULBs but the investments and operating expenses required will be similar as for the household model.

The most important positive aspects of this decentralised model are as follows:

1. When implemented at a household level in standalone houses of up to four storeys it requires only minimal energy for used water treatment for aeration of the greywater after filtration which is more than compensated by the generation of gas from the blackwater and green waste. So, the overall used water treatment system is energy and carbon positive. The amount of net energy generated and carbon emission reduced depends on the quantity of used water treated. This is much better than having sewer lines and STPs for community housing layouts because then the capital cost, operating cost and energy use increases exponentially with the size of the layout. In case of high-rise buildings, however, there have to be community STPs of the second type but even in those, the separation of grey and blackwater will reduce the energy consumption which will be required only for aerating the grey water. The energy required for this can be met by generating electricity from the biogas produced by digestion of the blackwater and green waste.

2. The problem of disposal of the green kitchen waste, which is a major expense for ULBs, is also solved very efficiently by directing it to the biogas plant and generating energy and manure from it. The huge expense and carbon emissions involved in transporting the green waste from the households to trenching grounds will also be obviated.
3. Potable water is sourced in situ and in most areas of the country the amount of rainwater recharged will be more than the amount of water drawn from the ground for water supply though this will have to be locally determined through a detailed water balance calculation as prescribed in the AMRUT 2.0 guidelines cited earlier (MoHUA, 2021b). So, the water availability in both the confined and unconfined aquifers will increase if this scheme is implemented over the whole urban area. This too results in savings in energy costs for pumping of water because the water level is much higher and there is consequent reduction of carbon emission. Even greater are the savings in energy and costs at the urban level because as we have seen even in cities like Raipur and Kolkata which are situated near perennial rivers, the water supply cost is so high that it is not met by user charges. In the case of cities like Indore and Bengaluru which have to rely on distant water sources, these savings will be huge and considerably improve the financial health of the ULBs.
4. A persistent problem facing ULBs is that of non-revenue water. A considerable amount of the water is lost through leakages and theft. The leakages and theft are difficult to control because this requires more capital and operating expenditure which are difficult to come by given the precarious financial situation of the ULBs. This is a Catch 22 situation wherein losses and theft take place because of lack of resources with ULBs and these then aggravate the financial situation of the ULBs even further and they are more unable to remedy the situation. This is where the decentralised systems will make a major impact.
5. Rainwater harvesting and recharging also means that there is no stormwater exiting from the house premises. Even though the quantum of recharge into the confined aquifer depends on underlying hydro-geological conditions, the fact that the precipitation is being recharged in a decentralised manner, the amount of water to be recharged is manageable. This will considerably reduce the stormwater load during monsoons. If the stormwater falling on roads is also recharged along the sides of the roads or directed to nearby recharge zones of the confined aquifer through appropriately designed recharge trenches and structures instead of to the stormwater drains that are now there, then there will be less possibilities of water logging during monsoons and instead the water availability in the unconfined and confined aquifers will increase substantially, further reducing energy costs for water supply.
6. The average installation cost of rainwater harvesting is about Rs 8 per litre of water harvested inclusive of piping and underground sump. Recharging costs much less at about Rs 1 per litre as the water is transferred to the aquifer through a recharge pit instead of being stored in a sump. Thus, for a roof area of 1 sq m, assuming a 75 % collection efficiency and annual rainfall of 1000 mm, the cost of installing a rainwater harvesting system would be -

1000 litres x 0.75 x Rs 8/litre = Rs 6000 per sq m of roof area

and the cost of installing a rainwater recharging system would be

1000 litres x 0.75 x Rs 1/litre = Rs 750 per sq m of roof area.

As mentioned earlier, the precipitation falling on the roof can be partly harvested to cater for the summer months when groundwater availability may be low and most of it can be recharged. Assuming a 20% harvesting and 80% recharging ratio the installation cost comes to -

6000x0.2+750x0.8 = Rs 1800 per sq m of roof area.

A 100 sq m single storeyed house will have a water supply of 540 litres per day assuming a household size of four persons. Of this 80 percent would become used water or 432 litres. Therefore, the used water per sq m is roughly 4.3 litres. Assuming a similar installation cost per litre of piping and sump as for water supply, the installation cost comes to Rs 35 per sq m. Another Rs 165 per sq meter can be added on for the dual plumbing, separate overhead tank and bio-digester to arrive at a total installation cost of Rs 200 per sq m for used water treatment and reuse. Thus, for a single storey building, the cost of installing a decentralised water system is Rs 2000 per sq m of roof area.

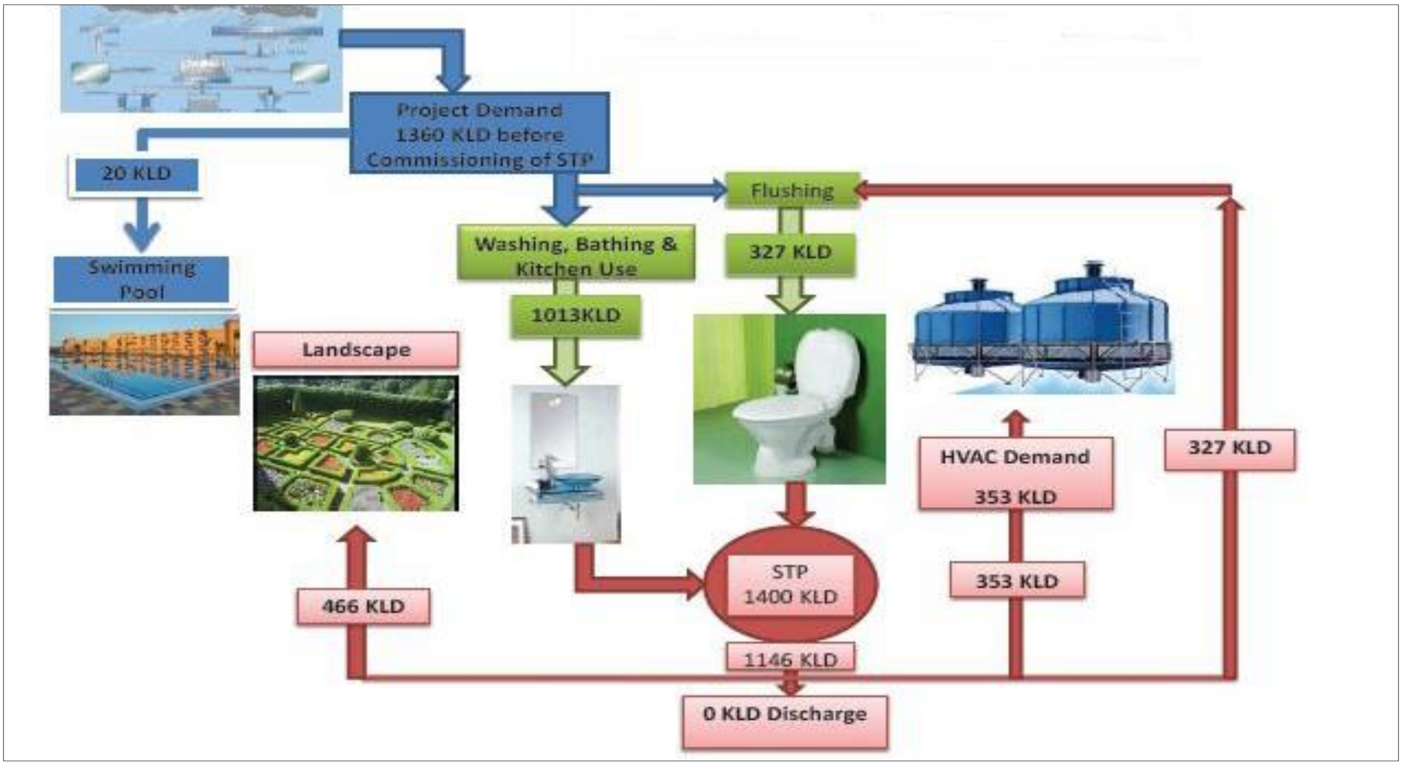
The prevailing market cost of building construction of standard specifications is about Rs 15000 per square metre. Thus, the installation cost of a decentralised water management system at Rs 2000 sq m of roof area is only 13.3 percent extra of the standard building cost and this proportion will go down with more floors being added to the building as the roof area remains constant and even though the used water load increases, the installation costs for the used water system are much less. These estimates are indicative only as actual costs will of course vary depending on the rainfall and the local specificities of construction.

Most of the buildings in an urban area belong to either the Government, commercial establishments or middle, upper middleclass or upper-class households, who can easily undertake this extra cost given that in the long run they will recover this initial outlay from reduced user charges to be paid to the ULB for water supply and waste management. Not only do these decentralised systems need to be made by the norm in new building construction but they should also be retrofitted in already constructed buildings which occupy most of the space in cities. Thus, the ULBs will be left only with the responsibility of supplying potable water to and collecting and treating the used water and green waste from the poorer households who are not able to incur these expenses. However, since this too will be done in a decentralised manner in the localities in which the resource poor live, the huge expenses involved in constructing and operating city-wide centralised water supply and used water management systems will be considerably reduced.

7. The ULBs can also free themselves from the onerous and expensive task of collecting the non-biodegradable waste since this has immense recyclable value which can be unlocked and reaped by cooperatives of waste collectors. There are many successful examples of such cooperatives operating in urban areas to collect and process the recyclable waste with some minimal support from the ULBs (SWaCH, 2021). Transportation costs and carbon emissions will also be reduced as the collection and processing of recyclable waste will be done in local communities instead of in a centralised manner.
8. Another problem in CUWM is contamination of water supply due to leakages in both the water supply lines and sewerage lines. This too is a problem that is aggravated by the lack of financial resources of ULBs like the one of leakages and thefts in water supply. This problem will be reduced considerably with decentralised systems, as all the used water will be properly treated and reused in situ. The associated problem of cleaning the sewers, which results frequently in the death of workers who are deployed for this purpose will also be solved.
9. The CPHEEO manual on sewerage and sewage treatment lays considerable stress on reuse of treated used water from STPs and energy generation from sludge and its use as manure. However, in reality this is difficult because STPs are located at a distance and downstream from the reuse areas. Therefore, pipelines have to be laid back to the city from the STPs and the treated water has to be pumped back. This is a huge capital expenditure and the operating cost of running the reuse system is also quite high making it uneconomical to reuse. However, with decentralised systems, since the reuse is in situ it is much less costly and it also reduces the potable water demand by taking care of the two biggest water uses – toilet flushing and gardening. Moreover, energy generation and the extraction of manure from the sludge is also much easier and results in reducing the cost.
10. There is a considerable reduction in carbon emissions also as not only is the fossil fuel energy use reduced and most of the energy is recouped from digestion of the sludge in decentralised systems, but also the huge energy involved in transportation of water, used water and green waste is also considerably reduced. In this way decentralised systems are carbon positive as opposed to centralised systems which are highly carbon negative. This is an important consideration given the need for mitigating climate change.
11. The biggest problem is the inequity in provision of water supply and used water management services by ULBs due to the financial crunch that they are in. Invariably, the well to do are provided with much better water supply and waste management services than the economically weaker sections of the urban areas. Often the latter have to pay exorbitant rates for tanker supply in the summer months when there are acute water shortages. Decentralised systems will put the onus of water supply and used water management for most of the urban areas on the well to do residents, commercial establishments and the government offices, thus freeing the ULBs of a major responsibility. They can then concentrate on facilitating decentralised water supply and used water management to the economically weaker sections at a much lower cost than in centralised systems.

There are no examples presently in India of such decentralised water management at the town or city level but there are a few examples of residential layouts, institutional campuses and individual buildings that are either water positive or net zero. The Rainbow drive layout in Bengaluru has banned individual borewells and has water supply only from the community borewells with metering and progressive per unit water charges which increase with increase in per household consumption so as to optimise the use of water. There is complete recharging of all the rainwater falling in the layout to enhance the aquifer storage. Most importantly, the STP is functioning properly and the treated water is being reused for non-potable use, substantially reducing the demand for potable water (Biome, 2010). The campus of the Indian Institute of Technology, Jodhpur has been designed to eventually become net zero in water through a combination of water harvesting and natural and artificial water recharging and treatment and reuse of used water as shown in the water balance diagram in Fig. 36 below (Shift Architects, 2013).

Fig. 36: Water Balance for Net Zero Water Management of IIT Jodhpur (Shift Architects, 2013)



There are many examples of individual buildings in cities that are water positive and one very good example is that of the office of the NGO, Dhas Gramin Vikas Kendra in Indore which has rainwater harvesting, natural and artificial recharge, separation of grey and blackwater and their treatment and reuse for non-potable uses through dual plumbing. This office also recharges the rainwater falling on the road in front by directing it into its garden (Pillai, 2012)

7.5 Decentralised Urban Water Management in Study Towns of Chhattisgarh

The crucial aspects of DUWM for it to be feasible and water positive are the rainfall and the aquifer storage potential of a particular area. Therefore, once the water balance is estimated based on these parameters, the planning of DUWM follows from it. The DUWM water balances for the three study towns are detailed below.

7.5.1 Raipur

The annual rainfall in Raipur is 1325 mm and it has black loamy soils with an underlying unconfined aquifer of alluvium and sandstone and the confined aquifer is also of shale, limestone and sandstone with annual natural recharge of 300 mm and a good potential for artificial recharge and aquifer storage (CGWB, 2012 & 2020). Thus, a combination of natural recharge through afforestation in parks and harvesting and artificial recharge of roof top and other water through structures can be undertaken. The planning area of Raipur city is 175 sq km. The minimum run off is 25 percent (CGWB, 2020), the water availability for harvesting and recharge can be estimated as follows -

- Water Availability in MLD = (Area in sq. km x 1000000) x (Rainfall in mm/1000) x 0.75 x 1000/365
- Water Availability = (175 x 1000000) x (1325 / 1000) x 0.75 x 1000 / 365 ≈ 476 MLD

20 percent of this water is to be harvested in sumps and 80 percent recharged. The current population of Raipur is 1590000. Thus, the household potable water demand at 70 lpcd and non-potable water demand at 65 lpcd are –

- Household Potable Water Demand - 1590000 x 70 ≈ 112 MLD
- Household Non-potable Water Demand – 1590000 x 65 ≈ 104 MLD

The industrial, commercial and landscaping water demand, which too is to be met with treated used water, can be assumed to be 15 percent of the household water demand (Joseph et al, 2019) and so this will be –

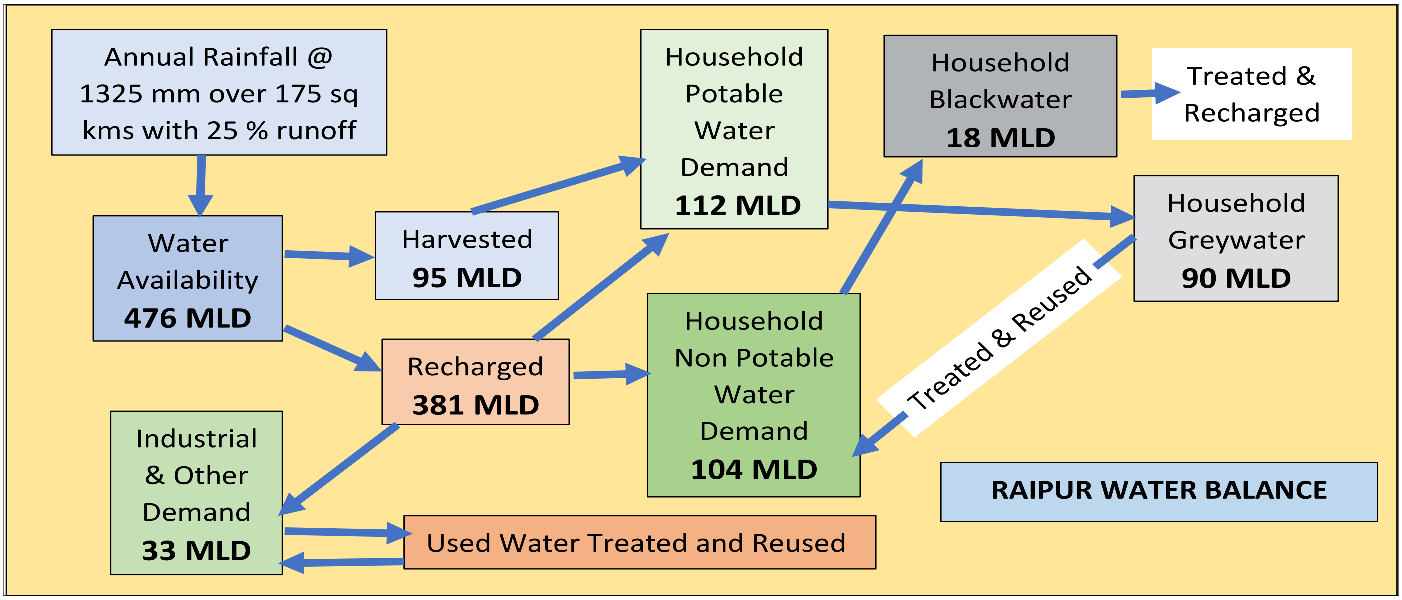
- Industrial, Commercial and Landscaping Water Demand (112 + 104) x 0.15 ≈ 33 MLD

80 percent of the potable water supply becomes grey water. The blackwater generated is equivalent to 20% by volume of the grey water.

- Greywater Generation – 112 x 0.8 ≈ 90 MLD
- Blackwater Generation – 90 x 0.2 ≈ 18 MLD

The Water Balance Diagram for Raipur based on these estimates is shown in Fig 37 below.

Fig. 37: Water Balance Diagram for DUWM in Raipur



Thus, the water availability is almost double of the total water demand and more than three times the potable water demand and most importantly, 65 percent of the non-potable water demand is met by treated grey water. So DUWM can easily be implemented in Raipur as per the guidelines of the Jalshakti Abhiyan, SBM 2.0 and AMRUT 2.0 that have been described earlier.

7.5.2 Jagdalpur

The annual rainfall in Jagdalpur is 1387 mm and it has sandy, loamy and gravelly soils with an underlying unconfined aquifer of alluvium and sandstone and the confined aquifer is also of fractured gneisses and shales and cavernous limestone and sandstone with annual natural recharge of 350 mm and a good potential for artificial recharge and aquifer storage (CGWB, 2013b). Thus, as in the case of Raipur, combination of natural recharge through afforestation in parks and harvesting and artificial recharge of roof top and other water through appropriate structures can be undertaken. The planning area of Jagdalpur town is 20 sq kms. Assuming that minimum run off is 25 percent (CGWB, 2016), the water availability for harvesting and recharge is as follows -

- Water Availability - (20 x 1000000) x (1387 / 1000) x 0.75 x 1000 / 365 ≈ 57 MLD

20 percent of this water is to be harvested in sumps and 80 percent recharged. The current population of Jagdalpur is 150000. Thus, the household potable water demand at 70 lpcd and non-potable water demand at 65 lpcd are –

- Household Potable Water Demand - 150000 x 70 ≈ 11 MLD
- Household Non-potable Water Demand – 150000 x 65 ≈ 10 MLD

The industrial, commercial and landscaping water demand, which too is to be met with treated used water, can be assumed to be 15 percent of the household water demand (Joseph et al, 2019) and so this will be –

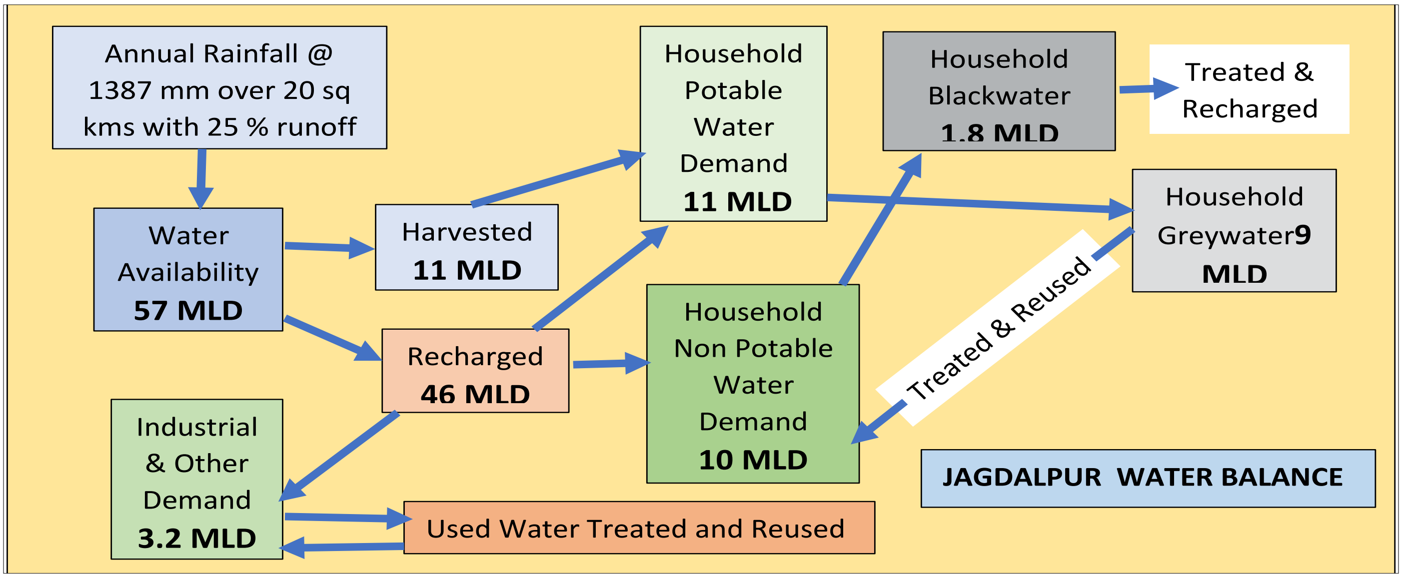
- Industrial, Commercial and Landscaping Water Demand (11 + 10) x 0.15 ≈ 3.2 MLD

80 percent of the potable water supply becomes greywater and the blackwater is equivalent to 20% by volume of the grey water.

- Greywater Generation – 11 x 0.8 ≈ 9 MLD
- Blackwater Generation – 9 x 0.2 ≈ 1.8 MLD

The Water Balance Diagram for Jagdalpur based on these estimates is shown in Fig 38 below.

Fig. 38: Water Balance Diagram for DUWM in Jagdalpur



Thus, the water availability is more than double of the total water demand and more than four times the potable water demand and DUWM can easily be implemented in Jagdalpur.

7.5.3 Surajpur

The annual rainfall in Surajpur is 1130 mm and it has loamy soils with an underlying unconfined aquifer of alluvium and the confined aquifer is of fractured Gondwana rocks with annual natural recharge of 300 mm and a good potential for artificial recharge and aquifer storage (CGWB, 2013c). Thus, as in the case of Raipur earlier, combination of natural recharge through afforestation in parks and harvesting and artificial recharge of roof top and other water through appropriate structures can be undertaken. The planning area of Surajpur town is 10 sq kms. Assuming that minimum run off is 25 percent (CGWB, 2016), the water availability for harvesting and recharge is as follows -

- Water Availability - (10 x 1000000) x (1130 / 1000) x 0.75 x 1000 / 365 ≈ 24 MLD

20 percent of this water is to be harvested in sumps and 80 percent recharged. The current population of Jagdalpur is 25000. Thus, the household potable water demand at 70 lpcd and non-potable water demand at 65 lpcd are –

- Household Potable Water Demand - 25000 x 70 ≈ 2 MLD
- Household Non-potable Water Demand – 25000 x 65 ≈ 1.7 MLD

The industrial, commercial and landscaping water demand, which too is to be met with treated used water, can be assumed to be 15 percent of the household water demand (Joseph et al, 2019) and so this will be –

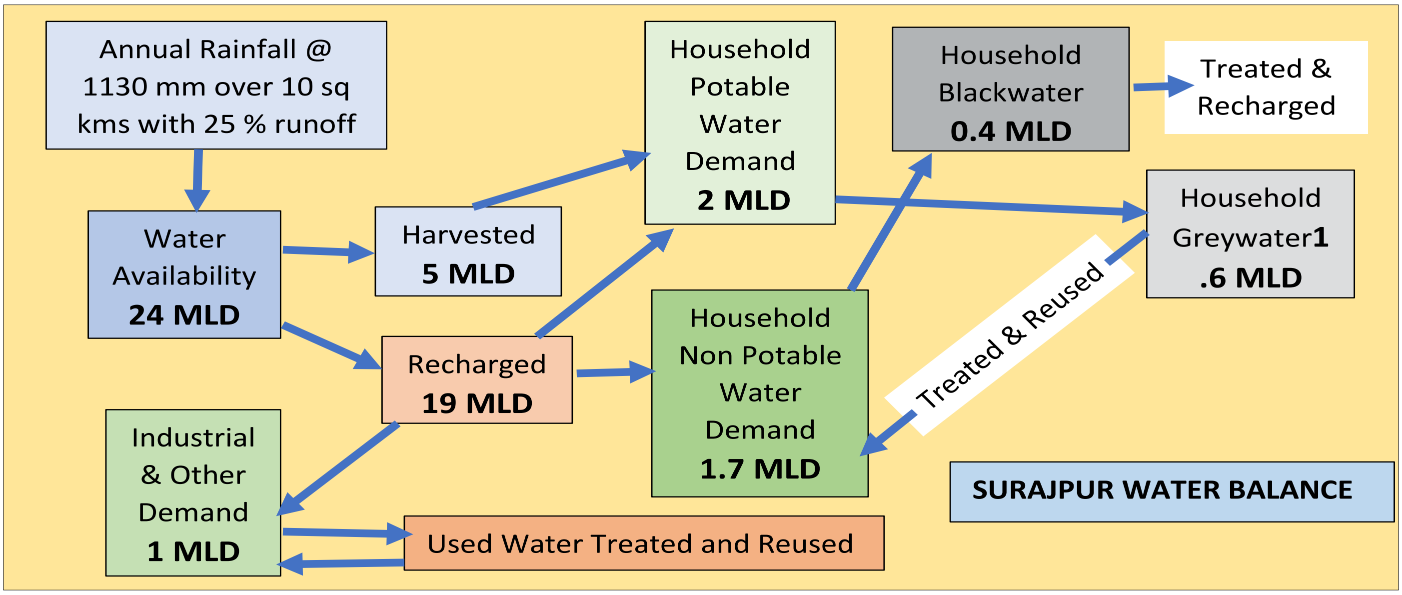
- Industrial, Commercial and Landscaping Water Demand (2 + 1.7) x 0.15 ≈ 1 MLD

80 percent of the potable water supply becomes grey water. The blackwater is equivalent to 20 percent by volume of the water.

- Greywater Generation – 2 x 0.8 ≈ 1.6 MLD
- Blackwater Generation – 1.6 x 0.2 ≈ 0.4 MLD

The Water Balance Diagram for Surajpur based on these estimates is shown in Fig 39 below.

Fig. 39: Water Balance Diagram for DUWM in Surajpur



Thus, the water availability is more than four times of the total water demand and twelve times the potable water demand and DUWM can easily be implemented in Surajpur.

Chhattisgarh being well endowed with rainfall and capacity to store water in aquifers is ideal for the implementation of CWE compliant DUWM which will not only provide water cheaply to the citizens but also recharge the aquifers while mitigating climate change through huge savings in energy use.

7.6 Comparison of Operating Costs of CUWM and DUWM

The per capita costs of CUWM increase exponentially with the size of the city because the handling of larger volumes is costlier per unit than for lower volumes. Moreover, the distance of the source for water supply is also a major factor. Therefore, the costs of CUWM of the city of Raipur which is situated close to a river and the city of Indore which is larger and is situated at a distance from its source are compared with the costs of DUWM.

The cost of water supply through decentralised systems can be estimated as follows:

We have seen from the water balance estimates that out of the norm of 135 lpcd water supply, about 35 percent is met from treated grey water. The rest of the demand is met from a combination of a rainwater harvesting sump and from an open/bore well. Assuming a 1 HP pump supplying at 50 litres per minute, the electrical energy required for pumping 1000 litres of water will be –

- 0.750 kilowatts *1000/(50*60) hours = 0.25 Kwh or units.

Assuming a domestic tariff of Rs 6 per unit the cost of energy per kilolitre comes to Rs 1.5. The maintenance of rainwater harvesting and recharging structures cost very little amounting to just Rs 500 per year for a house of 150 square meters.

Assuming such a house has five persons inhabiting it the yearly water supply would be around 250 kilolitres for a norm of 135 lpcd. Thus, the maintenance cost is Rs 2 per kilolitre of water and the total operating cost of decentralised water supply is Rs 3 per kilolitre. This compares very favourably with the cost of centralised water supply in Raipur of Rs 6.14 per kilolitre and in Indore of Rs 18.73 per kilolitre which were derived earlier.

The main cost in decentralised used water treatment is in aeration of the used water and the slurry. A 0.5 HP air pump can aerate the combined greywater and the slurry volume of 1 kilolitre by running 3 hours at night when there is little or no flow. Thus, the energy expended will be –

- 0.375 kilowatts*3 hours = 1.13 Kwh or units of electricity.

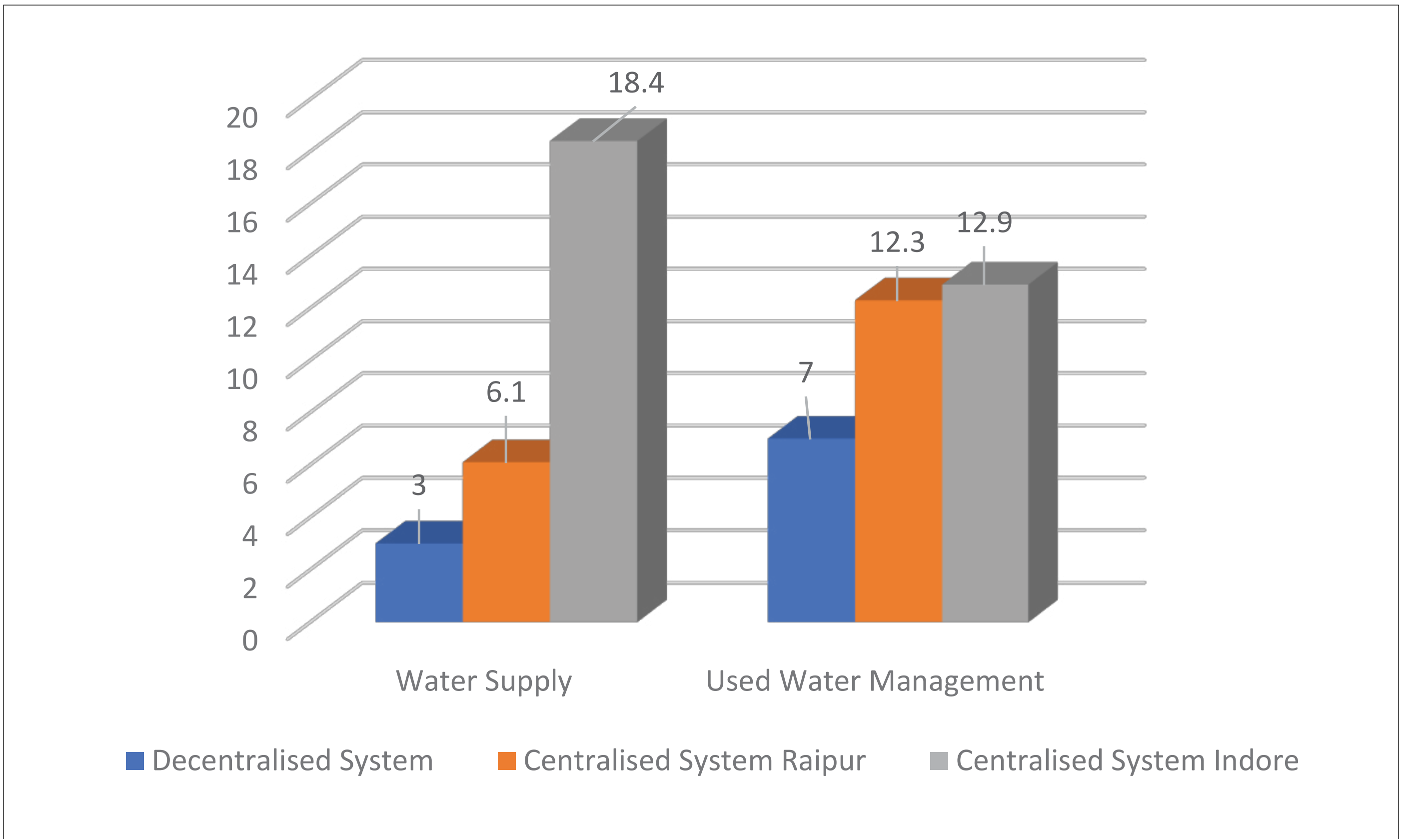
The energy produced from the biogas plant by digesting the blackwater and green waste is 6 Kwh per m3 (Energypedia, 2021). Assuming that 0.1 m^3 of gas is produced we get 0.6 Kwh of energy from the digested biogas. Therefore, the net electricity requirement is only 0.53 units. The cost of electricity being Rs 6 per unit, the cost of energy per kilolitre of used water is Rs 3.2. The cost of maintenance of the digesters and aerators is a little more than for the rainwater recharging units and along with the cost of chlorination will be about 3.8 per kilolitre. So, the total operating cost of a decentralised used water system is Rs 7 per kilolitre at the most.

Raipur currently does not have a centralised sewerage and sewage treatment system so we will take the average annual cost for India which we estimated earlier as Rs 45 lakhs per MLD per year. This works out to Rs 12.3 per kilolitre. The cost for proper used water management in Indore according to prescribed standards, as we have seen earlier, is Rs 12.9 per kilolitre. Thus, decentralised used water management is much cheaper than centralised used water management.

Simultaneously, the cost of transportation of green waste is greatly reduced and the dry waste is recycled by cooperatives of waste collectors at no operating cost to the ULBs. The per household cost of solid waste management from collection to disposal averaging across various sizes of towns is Rs 360 per capita per annum which is a substantial amount (DTE, 2016). This operating cost comparison of CUWM and DUWM is summarised in Fig. 40 below.

This analysis of operating costs clearly establishes that DUWM is much more cost effective than CUWM and can provide considerable benefits in terms of equity and financial sustainability of ULBs along with ecological benefits in terms of water security, conservation of surface and ground water sources and reduction in carbon emissions.

Fig. 40: Comparison of Operating Costs of DUWM and CUWM in Rs/Kilolitre



7.7 Awareness Campaigns

Finally, there is a dire need for awareness building among the people for implementing a circular water economy with the greater adoption of decentralised water management in the Indian context, where it is difficult for ULBs to mobilise resources. Years of operation of the centralised systems, however dysfunctional they may be, have habituated the people to expect the ULBs to take care of their water supply and used water. The ULBs, too, stoke these expectations by pouring more money into the dysfunctional centralised systems. Therefore, it is very difficult to get even well-off individuals, who can very easily do so, to make the extra capital investment and also bear the operational expenses of a decentralised water management system instead of paying minimal or no user charges to the ULBs to do so. The implementation of decentralised water management requires some space to be left open in accordance with the provisions of building byelaws. However, the tendency these days is to build up every bit of space in violation of building rules in collusion with the officials of ULBs. Penal action alone cannot bring about a change in this attitude. Therefore, the following steps need to be taken to improve awareness among citizens to make them proactive participants in DUWM based CWE as follows:

1. The operational, financial and ecological challenges of centralised water management must be explained in detail through media campaigns and community workshops to citizens.
2. The advantages of decentralised water management and a circular water economy must also be publicised and pilot projects must be implemented in a few households in selected wards so that citizens can gain confidence that this is a viable alternative.
3. Capacity development is also required among water sector professionals, academics and policy makers to develop an ecosystem of DUWM right from design and implementation to operations and maintenance to make it easy to implement.

8. Conclusions and Recommendations

The foregoing discussion has brought out the difficulties in implementing a Circular Water Economy and ensuring water security to achieve Goal 6 of the Sustainable Development Goals regarding universal and equitable access to water and sanitation through Centralised Urban Water Management alone. Therefore, there is a need for CUWM to be supplemented by Decentralised Urban Water Management in Chhattisgarh in particular and in India in general.

8.1 Conclusions

1. Centralised water supply suffers from the problems of distant sources, leaking delivery pipelines, poor quality of water, high costs, high levels of non-revenue water, low recovery of user charges and inadequate supply to poor households.
2. Centralised sewage systems suffer from the problems of inadequate flow and consequent blockage and corrosion of sewers, deaths of manual cleaners and low recovery of user charges.
3. Faecal sludge from onsite systems is mostly being disposed of untreated into the environment creating health hazards because it is uneconomical to transport the sludge to FSTPs which are situated at a distance from the city. Moreover, even where ULBs are providing a subsidised desludging service, the efficiency is very low as septic tanks are cleaned at intervals of 10 years on an average instead of the prescribed interval of 2 years. The only operational FSTP in Chhattisgarh in Ambikapur is functioning at only 40 percent of its limited treatment capacity of 5 KLD which is well below the required capacity of 189 KLD.
4. STPs are not being run properly because of the high O&M costs of treatment of used water, the volume of which is greatly increased by the mixing of grey and blackwater in sewers. The disposal of the sludge is also not being done properly and this poses a health hazard and also leads to the reduction of treatment efficiency of the STPs. Whatever amount of treated used water is generated is not being reused due to the lack of pipelines to carry the treated water back to the city from STPs.In the case of Chhattisgarh, most cities and towns do not have sewers or STPs. Some STPs are being built but these are going to treat used water that is diverted to them from open drains which is a very inefficient process when done on a large scale. Even the only such interception and diversion system in Chhattisgarh for sullage in Kawardha town is not functional.
5. Stormwater drains are either non-existent or are not properly designed. Stormwater is conveyed by the open drains for used water resulting in waterlogging during monsoons when these drains overflow.
6. The ULBs are not able to recover the costs of water supply and used water treatment from user charges because the costs of properly implemented CUWM are unaffordable for most citizens as demonstrated by the analysis of CUWM implementation in Indore. This results in huge shortfalls and so ULBs are heavily dependent on grants from the Central and State Governments for both capital expenditure and O&M expenditure. Even with this grant support the levels of expenditure are well below then required for proper CUWM and so the delivery of service is poor and affects adversely the poor who are unable to pay high prices for securing these services from private providers.
7. The ringfencing of water supply and used water treatment functions of ULBs in separate boards has not resulted in substantially better urban water management and financial buoyancy of these boards, which are still dependent on state and central government subsidies.
8. Internationally too, CUWM is facing challenges as it is becoming increasingly difficult to source water and dispose of used water. The costs of renewal and augmentation of existing systems and their operation are increasing beyond the point where it can be recovered from user charges and so decentralised options are being explored and implemented.
9. Adequate measures are not being taken for rainwater harvesting and recharge and decentralised treatment and reuse of used water despite there being numerous legal and policy provisions for promoting the same.
10. There is a woeful lack of public awareness regarding the need for conserving rainwater and treating used water at the household level and neither of the ULBs are doing much to enhance awareness levels, so as to reduce the burden on centralised urban water management.

11. Detailed water balance plans show that towns in Chhattisgarh are ideally situated to implement DUWM due to abundant rainfall and good aquifer storage characteristics. The costs of DUWM are much lower than that for CUWM and to be borne privately, thus, reducing the burden of providing water services on the ULBs.
12. DUWM combined with green waste digestion and localised non-biodegradable waste recycling also relieves the ULBs from the provision of costly solid waste management services.
13. DUWM saves considerable energy required in the pumping and transportation of water and solid waste and thus mitigates global warming and also replenishes the aquifers and surface water bodies resulting in substantial ecological gains.
14. The latest guidelines of the Union Ministry of Housing and Urban Affairs for the Swachh Bharat Mission Urban Phase II and the Atal Mission for Rejuvenation and Urban Transformation Phase II along with the earlier guidelines of the Jal Shakti Abhiyan, all stress on the implementation of DUWM to complement CUWM so as to bring about a CWE and ensure water security.

8.2 Recommendations

The legacy of colonial policies of centralised water management is so well entrenched that it is difficult to complement it with decentralised systems. Thus, despite building and town planning byelaws having made the implementation of DUWM mandatory and the latest policies of the Union Government for urban development having stressed this as a means of implementing a circular water economy, not much is being done on the ground to implement these provisions. Therefore, strong policy measures are required by Union and State Governments and ULBs, not just in Chhattisgarh but across the country, to bring about a greater emphasis on the implementation of DUWM and CWE and also to improve the level of public awareness. Following are the recommendations from the study;

1. First and foremost, the public health and environmental engineering technocracy, including the engineers involved in design and implementation and the academics who teach and research in universities and colleges, must acknowledge the need for decentralised urban water management in India and the importance of using it to complement centralised urban water management which is faced with the problems of increasing economic costs and ecological unsustainability. The recently published guidelines of the Government of India for Urban Water Conservation and Decentralised Used Water Management must be well publicised and strictly implemented. The CPHEEO in collaboration with the State Public Health Engineering Departments and the local engineering colleges, must come up with detailed plans for decentralised water management specific to each ecological zone of the country in the same way as the Central Ground Water Board (CGWB) has come up with a master plan for artificial recharge.
2. Urban planners too must be made aware of the need to implement decentralised water management systems and plan urban development with this as the centrepiece. Water Sensitive Urban Design involving rainwater harvesting, recharging and used water treatment, and reuse and generation of energy from faecal sludge and waste, waste at the household level must be made mandatory. Urban planning rules and regulations are already in place to make this possible but they are followed mostly in the breach currently. Strict implementation of Building Byelaws and Planning Rules must be done as mentioned in the MoHUA Guidelines after first explaining the rationale behind these laws and rules. There is currently a woeful lack of awareness among both city planners and citizens about the appropriateness of these laws and rules.
3. Architects must be sensitised to the need for incorporating decentralised water management in their designs of houses and layouts as there will be a big shift of responsibility in this regard from ULBs to individual households and residential colonies.

4. The Union and State Governments must make it mandatory for the ULBs to implement decentralised water management,and a greater part of the grants which are now going to shore up the unsustainable centralised water management systems, must be directed towards promotion of decentralised water management with Government offices taking the lead.
5. The laws and rules already in place with regard to prevention of water pollution must be strictly enforced. The pollution control boards must be empowered to take prompt action against offenders who violate these laws and rules. All industrial and commercial outlets that are generating used water must have effluent treatment plants installed and operational.
6. Currently, there is no widespread ecosystem for the implementation of decentralised urban water management. Therefore, individuals and NGOs are trying to implement it on their own with marginal impact (Biome Environmental Trust, 2021). This will be possible only if the Governments take the lead in making decentralised urban water management the norm rather than the exception as it is now, by both strictly enforcing the rules and also providing subsidies where necessary for its implementation.
7. Property taxes must be enhanced and the tax base must be completely identified by using geographical information systems as this is the most progressive way to improve the finances of ULBs without which it will not be possible to provide adequately for the economically weaker sections of the urban population. Currently, own tax revenue mobilisation by ULBs is abysmally low and they depend heavily on grants from the Union and State Governments.
8. Public awareness regarding the benefits of DUWM in particular and a circular water economy in general, both for individual households and for urban areas as a whole, must be enhanced because it is not possible to implement these through laws and rules alone without active public participation as has become abundantly clear both in India and internationally.
9. Specifically, in the case of Chhattisgarh, despite being well endowed with water resources, as has been demonstrated in this study and having traditionally used the favourable aquifer characteristics for exemplary decentralised water management, currently, there is a disjunction from these practices in the state. Therefore, detailed water balance plans have to be drawn up at the household, community and town level and DUWM has to be implemented in accordance with these plans. It is recommended to take small town like Surajpur as a model town for implementation of DUWM on a pilot basis by getting on board all stakeholders from citizens and elected representatives to ULB officials and commercial establishments.

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Annexures

Table A1: Zone and Ward details of Raipur Municipal Corporation (RMC 2021)

Zone No.	Ward Name	Ward No.	No. of Households	Population 2011	No. of Notified Slums	Slum Population	
						Number	Prop (%)
1	Yatiyatan Lal	4	5144	17458	7	4790	27.4
	Banjari Mata Mandir	5	4318	14655	6	1906	13.0
	Veerangana Avantibai	6	2734	9279	6	3498	37.7
	Veer Shivaji	7	5392	18300	6	3470	19.0
	Netaji Kanhaiyalal Banjari	8	4462	15143	5	4384	28.9
	Thakkar Bapa	9	3875	13151	17	12239	93.1
	Baal Gangadhar Tilak Nagar	10	2370	8043	1	668	8.3
	Daanveer Bhamshah	11	1157	3927	2	584	14.9
2	Indira Gandhi	20	3008	10209			0.0
	Raman Mandir	21	1869	6343	2	3758	59.2
	Rajiv Gandhi	22	1965	6669	1	520	7.8
	Rani Laxmibai	23	3166	10745	3	3617	33.7
	Pandit Ravishankar Shukla	24	1699	5766	1	2090	36.2
	Mahatma Gandhi	25	2657	9018	4	5490	60.9
	Khshabhau Thakre	26	13895	47158	2	649	1.4
	Doctor Bheemraav Ambedkar	27	10513	35680	4	2652	7.4
	Netaji Subhashchandra Bose	29	3161	10728	4	1693	15.8
	Shaheed Hemu Kalani	35	2408	8172			0.0
3	Maharshi Valmiki	28	10379	35225	6	1547	4.4
	Kalimata	30	2295	7789	4	2051	26.3
	Shankar Nagar	31	2628	8919	1	862	9.7
	Shaheed Veer Narayan	32	2116	7181	3	747	10.4
	Lalbahadur Shastri	33	1804	6123	4	2088	34.1
	Guru Govind Singh	34	1984	6733	3	1196	17.8
	Civil Lines	42	2129	7226	2	269	3.7
	Guru Ghasidas	44	3871	13138	3	1123	8.5
4	Havaldar Abdul Hamid	36	2287	7762	2	2975	38.3
	Babu Jagjeevan Ram	40	3100	10521	3	2187	20.8
	Mother Teresa	43	3016	10236			0.0
	Rani Durgawati	45	6436	21843	5	2901	13.3
	Doctor Rajendra Prasad	46	16231	55086	4	2271	4.1
	Lieutenant Arvind Dixit	47	2076	7046			0.0
	Pandit Bhagwati Charan Shukla	48	1833	6221	2	1013	16.3
	Pandit Motilal Nehru	49	2701	9167	3	1656	18.1
	Shaheed Brigadier Usman	55	1982	6727	4	275	4.1
5	Shaheed Chudamni Nayak	16	2181	7402	8	2756	37.2
	Thakur Pyarelal	60	1536	5213	1	832	16.0
	Mahant Laxinarayan	61	2126	7215	3	314	4.4
	Comrade Sudhir Mukherjee	65	1774	6021	3	649	10.8
	Pandit Sunderlal Sharma	66	2783	9445	3	1014	10.7
	Doctor Kubchand Baghel	67	8915	30256	6	5604	18.5
	Madhavrao Sapre	68	9709	32951	9	3627	11.0
	Pandit Deendayal Upadhay	69	7075	24012	3	1317	5.5

Zone No.	Ward Name	Ward No.	No. of Households	Population 2011	No. of Notified Slums	Slum Population	
						Number	Prop (%)
6	Shaheed Pankaj Vikram	50	2505	8502	2	4134	48.6
	Ravindranath Tagore	51	13016	44175	5	4242	9.6
	Chandrashekher Azad	52	11155	37859	3	1040	2.7
	Moreshwar Rao Gadrae	53	3713	12601	4	1442	11.4
	Shaheed Rajiv Pandey	54	2636	8946	1	72	0.8
	Doctor Bipin Bihari Sur	56	1377	4673	2	208	4.5
	Mahamaya Mandir	62	4293	14570	5	3023	20.7
	Doctor Shyama Prasad Mukerjee	63	9219	31288	6	1216	3.9
	Vamana Rao Lake	64	3305	11217	5	2279	20.3
7	Swami Aatmanand	15	2202	7473	4	2158	28.9
	Ramsagar Para	17	2240	7602	3	1564	20.6
	Pandit Jawaharlal Nehru	37	3419	11604	1	805	6.9
	Tatyapara	38	2100	7127	3	1679	23.6
	Sadar Bazar	39	3144	10670	1	368	3.4
	Maulana Abdul	41	1667	5658	3	1537	27.2
	Swami Vivekanand	57	1961	6655	1	368	5.5
	Bramhanpara	58	1392	4724			0.0
	Kankaali Para	59	1486	5043	3	1968	39.0
8	Veer Savarkar Nagar	1	7457	25308	4	2464	9.7
	Ramkrishna Paramhansa	2	15858	53820	5	3419	6.4
	Sant Kabir Das	3	3779	12825	3	1519	11.8
	Sheed Manmohan Singh Bakhshi	12	3158	10718	4	906	8.5
	Shaheed Bhagat Singh	13	5846	19841	2	1417	7.1
	Pandit Ishwaricharan Shukla	14	4837	16416	3	1717	10.5
	Sardar Vallabh bhai Patel	18	3941	13375	6	1657	12.4
	SantRam Das	19	1804	6123	5	952	15.5
	Sant Ravi Das	70	3351	11373	4	863	7.6
	Total	70	297621	1010087	244	134299	13.3

Source: Raipur Municipal Corporation 2021

Table A2: Population of Jagdalpur (Census 2011)

Sl. No.	Ward No.	No. of Households	Population
1	1	777	3260
2	2	534	2280
3	3	585	2438
4	4	459	3600
5	5	549	2310
6	6	567	2303
7	7	586	3211
8	8	892	3874
9	9	529	2431
10	10	390	2056
11	11	368	1847
12	12	805	3358
13	13	353	1609
14	14	875	3723
15	15	410	1913
16	16	434	2100
17	17	440	2138
18	18	855	3842
19	19	415	2078
20	20	818	3592
21	21	557	2651
22	22	819	3561
23	23	656	2923
24	24	806	3661
25	25	780	3595
26	26	853	3704
27	27	906	4348
28	28	784	3377
29	29	1245	5121
30	30	453	1943
31	31	606	2589
32	32	703	2836
33	33	787	3332
34	34	1000	4046
35	35	661	2942
36	36	991	4363
37	37	1155	5135
38	38	1092	4536
39	39	1089	4305
40	40	600	2532
	Jagdalpur	**28184**	**125463**

Table A3: Persons Interacted with as part of Primary Research

Sl. No.	Name of Organisation	Designation	Date of Meeting	Purpose
1.	Raipur Municipal Corporation	Staff of RMC ranging from the Commissioner, Accounts Department, Sanitation Department and Water Supply Department.	July 26th to 30th 2021, September 16th to 18th 2021, February 17th to 19th 2022	Interviews of staff and getting data of RMC WSS operations
2.	Raipur City	People's representatives, citizens, activists and journalists	July 26th to 30th 2021	Interviews for getting views regarding functioning of WSS in Raipur
3.	Private Septic Tank Cleaning Operators in Raipur	Owners and staff of the private operators	February 18th 2021	Interviews regarding their operations
4.	Jagdalpur Municipal Corporation	Staff of JMC ranging from the Commissioner, Accounts Department, Sanitation Department and Water Supply Department.	August 2nd to 4th 2021, September 22nd to 24th 2021, February 21st to 22nd 2022	Interviews of staff and getting data of JMC WSS operations
5.	Jagdalpur Town	People's representatives, citizens, activists and journalists	August 2nd to 4th 2021	Interviews for getting views regarding functioning of WSS in Jagdalpur
6.	Surajpur Municipal Council	Staff of SMC ranging from the Commissioner, Accounts Department, Sanitation Department and Water Supply Department.	August 6th to 7th 2021, September 28th to 30th 2021, February 23rd to 24th 2022	Interviews for getting views of staff and getting data of SMC
7.	Surajpur Town	People's representatives, citizens, activists and journalists	August 6th to 7th 2021	Interviews for getting views regarding functioning of WSS in Surajpur
8.	Indore Municipal Corporation	Staff of SMC ranging from the Commissioner, Accounts Department, Sanitation Department and Water Supply Department.	November 16th to 18th 2021	Interviews for getting views of staff and data of JMC WSS operations
9.	Ambikapur FSTP	Staff of FSTP	February 25th 2022	Interviews for getting views on operation of FSTP
10.	Kawardha STP	Staff of STP	February 26th 2022	Interviews for getting views on operation of STP

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