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REVIEW ARTICLE

Water auditing and recycling as a tool for management of water resources: an Indian perspective

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Abstract
Water is limited and is unevenly distributed globally. India being home to approximately 18% of the global population accounts for only 4% of global renewable water resources, making it the world's 13th most water-stressed country. The increase in human population coupled with accelerated economic activities and climate change has put enormous pressure on government and policymakers in India to find different innovative and smart ways to manage the demand–supply gap in the water sector. Despite having the largest water infrastructure in the world and concerns raised about increasing water crisis in national discourse at academic, policy and governance levels, the tangible outcome does not resonate adequately on the ground level. Identification of alternate tools, calibration and fine-tuning relevant policy and planning necessitate the need of implementing water auditing and water recycling to meet the ever-increasing water demand as far as the water footprint in India is concerned. Based on the principle of what gets measured gets managed, water auditing best caters to the water management needs and is yet to become a top priority to curb the water crisis. Public acceptance seems to be one of the major barriers in universalizing water recycling in India which is aggravated by the uneven and/or absence of a proper and adequate water governance approach and structure. This paper tries to highlight the major challenges water resources management is facing in India and aims to illustrate how well planned water auditing and water recycling as a tool can deliver in effective and rational utilization and distribution of water.

Keywords Urban water resources · Water auditing · Water recycling · Water policy

Introduction

Water auditing is the means to improve the understanding of the level of water governance needed in a country and the costs incurred to deliver sustainable water services to all (Food and Agriculture Organization 2018). A water audit is a field-based survey using specific apparatus, installation, instruments, and administrative procedures to discover the efficiency of water use to formulate recommendations for ameliorating water-use efficiency (Newcomb 2008; Kubade et al. 2017). It is a usual and frequently accepted practice internationally and has been accentuated recently with the gradual course of water becoming a valuable resource (Ministry of Water Resource 2017a, b). Non-Revenue water is a pressing global issue; around 45 million m^3 of water is lost almost every day (World Bank 2019) with Asia alone losing half of its supplied water due to leakages in pipes that add strain to government funding depriving potable water to a considerable amount of population (Dalton 2019; International Water Association 2019a, b). Water audit provides a solid architecture for systematically obtaining, supervising, and examining water relevant details and evidence (Anderson et al. 2012) and helps to raise awareness concerning water problems to achieve the goals of water governance (The International Organization of Supreme Audit Institutions 2004).

Water recycling is also considered to be a highly recognized tool that can provide a workable solution to meet the heightened global demand for water in the age of dwindling freshwater supplies (Glick et al. 2019). The idea of water recycling to manage freshwater scarcities existed in the Minoan civilization in ancient Greece 5000 years back (Patil et al. 2013). Wastewater is an ancillary water resource, especially for water-deficit countries, and is no

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longer perceived as a waste, but a source of drinking water when recycled and/or reclaimed (Tchobanoglous 2012). In recent times, wastewater has been increasingly recognized as a possible source of clean water for potable and non-potable uses and recycling of water can be considered as a sustainable source of water (Tortajada 2020). Water reclamation, recycling, and reuse are vital components of sustainable water use especially in the context of integrated water resources management. With the increase in water demand and rising pollution of water bodies, wastewater reclamation seems to be a positive response throughout the world (Sala and Serra 2004). Recycled water is a valuable resource which instead of being discarded could be recycled and reused to minimize the pressures on freshwater sources (Anderson 2003). Agricultural irrigation constitutes the highest use of recycled water on a global scale, while as other end uses such as industrial and nonpotable urban uses have also made great advancements in recent years, especially in countries such as Australia, Asia, Southern and Western America, Europe, and the Mediterranean countries (Chen et al. 2013a, b). There has been a global trend to create more room for water reuse practices beyond agricultural and landscape irrigation, to recreational and environmental use, industrial reuse, groundwater recharge, and potable reuse (Zhang et al. 2017). Recycling initiatives are under scrutiny due to the ambiguities or absence of a coordinated scientific approach, along with growing public anxiety about the risks associated with utilizing recycled water (Anderson et al. 2001). Water recycling is recognized as one of the means to increasingly reduce the demand for potable water, but its potential benefits are identified as one of the prominent challenges of present times (Dimitriadis 2005). The prevailing global scenario of water demand, supply, consumption patterns, shoddy government policies, and poor implementation of water management strategies draws the global attention toward the importance of implementation of various water management tools, viz. water auditing and water recycling. The emergence of these tools is completely based on the most indelible water crisis that is believed to be evolved from misgovernance and mismanagement of water resources.

Water use has sextupled over the last 100 years and is rising by about 1% per year due to poor water management of water resources and climate change (The United Nations World Water Development Report 2020). Domestic global water use currently accounts for 10% of the total water available and is expected to increase significantly between 2010 and 2050 in most parts of the world except Western Europe. An increase of with the greatest increment of 300% is projected in Africa and Asia (Boretti and Rosa 2019). The water footprint of the top five water consuming nations is shown in (Fig. 1), and the sectorial water footprint globally is shown

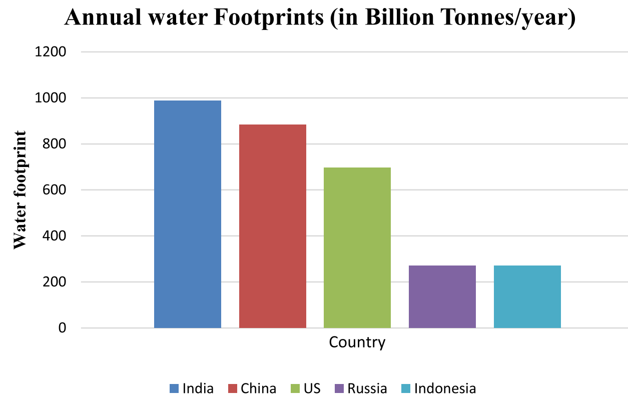

Fig. 1 Annual water footprints (in billion tons/year) of top 5 water consuming nations of the world (c.f. The World Counts 2023)

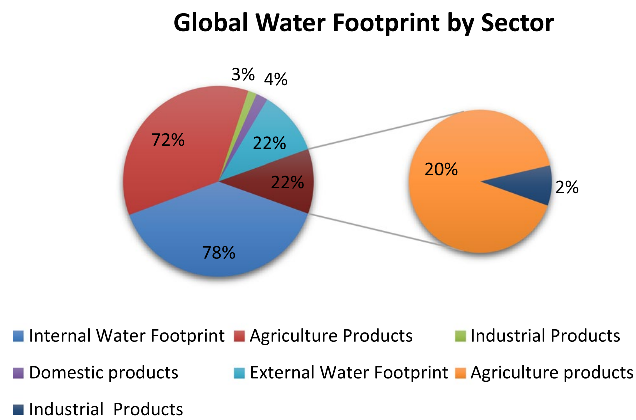

Fig. 2 Global water footprint of different sectors globally (c.f. Hoekstra and Mekonnen, 2012)

in (Fig. 2). Water shortages consistently rank among the global threats of utmost concern to policymakers and business leaders (The Global Risks Report 2019).

The perception of freshwater being an abundant and unlimited resource continues to persist even though not more than 1% of the Earth's freshwater is accessible to mankind (Kamble et al. 2018). The importance of water to all life on Earth and many forms of socio-economic developmental activities has led it to its course of becoming the most widely discussed issue at the International level (Cosgrove and Louck 2015). The contemporary relationship between water supply and demand and its spatial distribution continues to remain ambiguous under the current policies, leading to a wide accountability lag (Chen et al. 2020). Water is a basic need for the continuation of life and welfare of all, which makes it imperative to provide ample quantity and potable quality of water to all (Chawre 2020). The impression of water being of low-cost nature has failed to consider its innate environmental and social worth (Barrington and Ho 2014). Rapid urban sprawl has also emerged to be one of

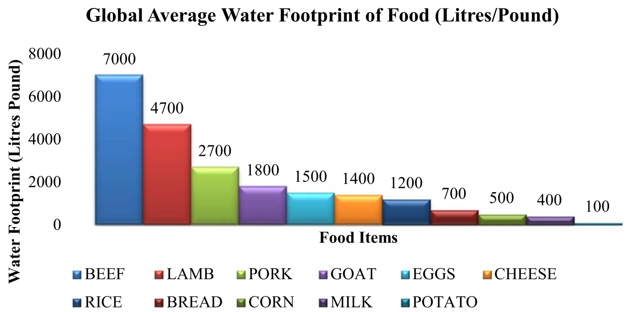

Fig. 3 Global average water footprint of food (liters/pound) (Walker et al. 2019)

Table 1 Classification of countries in context of water stress and scarcity (c.f. Lal 2001)

AWR (Per capita water availability in cubic meters)	Classification of countries
1700	Rarely water scarce
< 1700	Water stressed
< 1000	Moderately water scarce
500 and < 500	Extremely water scarce

the main reasons for the depletion of local water resources, leading to unevenness in its distribution (Chen et al. 2020). Water scarcity has engulfed many parts of the world, a condition wherein water demand of all sectors, along with the environment cannot be met entirely due to the reckless use and/or decrease in quality of water (Alcamo et al. 2007). Reportedly, of the total water withdrawn from surface and groundwater, global water use for domestic, irrigation, and industry accounts for 10%, 70% and 20% respectively (Wisser et al. 2008).

As per reports, the water footprint of beef is 7000 L per pound that stresses the fact to decrease the usage of water-intensive foods which can reduce the pressures on global water resources (Fig. 3). Four billion people deal with severe water shortages across the globe making the world's water demand increase rapidly with a simultaneous decline in water supply (Mekonnen and Hoekstra 2016). In most parts of the world, over 70 percent of freshwater is utilized in the production of food via irrigation of crops and livestock feeding and it is estimated that, by 2050, feeding a planet of 9 billion people will lead to a 50 percent increase in agricultural production and a 15 percent hike in water withdrawal rate (Khokhar 2017). The increased global hunger shoots up water demand along with a contribution from households and industry, thereby, increasing the global water stress (Walker et al. 2019).

Water stress caused by unprecedented urbanization, demographic growth, increasing water demands, water scarcity, and institutional failures at the global level call for efficient water management and good governance practices (Leeuwen et al. 2019). Therefore, as recognized, the world water crisis is an outcome of governance crisis at a global level (Castro 2007) and what makes water governance particularly so challenging is the ambiguity about the yearly gap in amount and quality of water, in terms of both stocks and flows (World Bank 2006). The per capita annual water resource has been used to classify countries concerning water stress and scarcity (Table 1). Ten countries in the world account for 60% of the world population without access to clean and safe water (Fig. 4) which emphasizes that providing water to all underwater governance. Therefore, water governance has captured increased attention as a policy matter in recent years (Woodhouse and Muller 2017). It is a set of collaborative actions which aim at achieving a common goal and invite coordination among various stakeholders (Lubell et al. 2008). Goodwater governance ensures that supervision of water resources should be done in an equitable, transparent, and accountable manner (Abu-Zeid and Shuklomanov 2003). It is high time to make use of the authoritative water policies to manage the water crisis. Water governance if allowed to function properly can make strategic use of all water resources and tackle the current water scarcity in all the regions due to the globally accepted that reflects water crisis is rooted in power, poverty, and inequality in its availability (Rogers 2006; UNDP 2006).

Surface water resources in India account for only 4% of global renewable water resources making it the 13th most water-stressed country in the world (Central Water Commission 2015; Pandey 2019). The rising population of India has already surpassed China in April 2023 (Silver et al. 2023). Currently, the population of India is 1.38 billion and is anticipated to cross 1.6 billion by 2050 that can result in stress on water reserves in the country (Prabhu 2012; United Nations Department of Economic and Social Affairs 2019). About 100 million people across India are facing the nationwide water crisis and 21 major cities are reported to be deprived of groundwater in 2019 (Yeung et al. 2019). Given that India is primarily an agrarian country, irrigation by far is the largest user of India's water reserve with hooping usage of 78% of total water reserve, followed by domestic sector (6%) and industrial sector (5%) (Press Information Bureau 2013) which puts immense pressure on water resources.

National Institute for Transforming India Aayog (NITI) in 2018 reported that India is facing a water crisis with about 600 million citizens facing water stresses, resulting in two lakh deaths per year (Hassan 2018). The per capita surface water availability was reported to have reduced from 2309 m^3 to 1902 m^3 from 1991 to 2001, respectively, and is projected to reduce further to 1401 m^3 and 1191 m^3 by 2025 and 2050, respectively (Gangwar 2013). Water demand will grow annually by 2.8% to reach a whopping 1500 billion

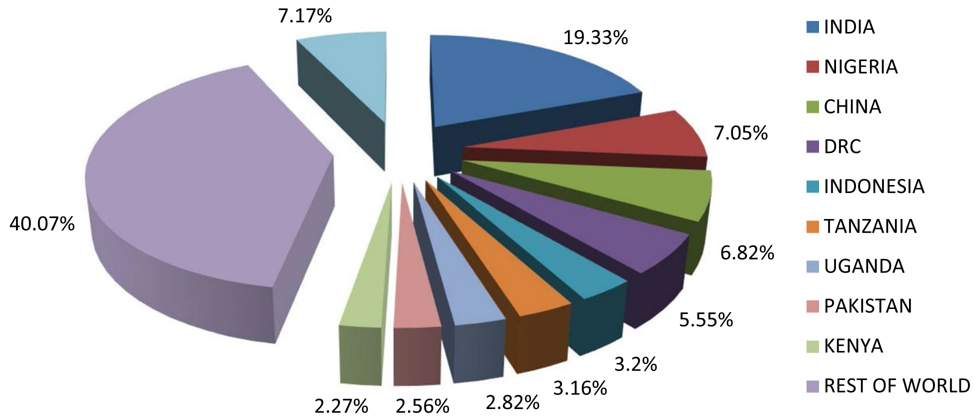

Fig. 4 Countries without access to clean water (c.f. Water Aid 2018)

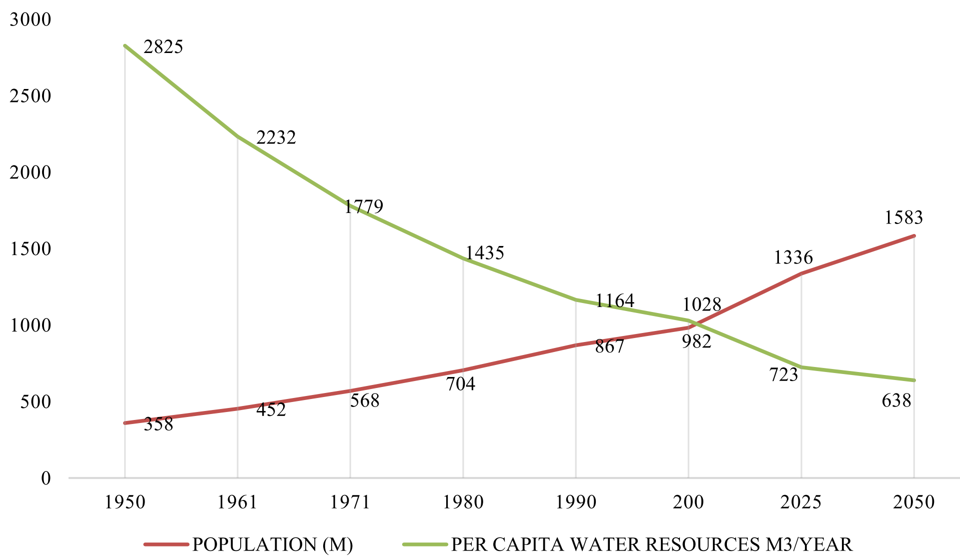

Fig. 5 Growth of Population and Declining per Capita Water Availability in India (c.f. Amarsinghe et al. 2008)

cubic meters by 2030, while as the water supply is projected to remain at 744 BCM, that is, just half of the total demand (The Energy and Resources Institute TERI 2014), which will further increase to 1.4 trillion cubic meter by 2050 (Sengupta 2006). India's water demand will surpass the supply a few decades from now based on the current water use and population therein (Fig. 5).

The water crisis of India is an outcome of decreasing per capita water availability coupled with the mismanagement of its water resources reflected by the fact that India ranks as the third-largest exporter of groundwater through virtual water trade, while 52% of its wells are diminishing (Water Aid 2019). In recent years, the idea of water resource management has emerged to treat water as an economic and public good (Hellegers 2002). To manage water stress in India, there is a need to adopt several methods for monitoring and reserving water (Bhattacharya et al. 2015). As the water demand is projected to escalate in the coming years in all the sectors of India (Table 2), water governance will

Table 2 Sector-wise projected water demand in India (c.f Kumar and Goyal 2020)

Sector	Year wise water demand in BCM		
	2010	2025	2050
Irrigation	688	910	1072
Drinking water	56	73	102
Industry	12	23	63
Energy	5	15	130
Other	52	72	80
Total	813	1093	1447

direct India toward a workable and sustainable water policy between the center and state (Prabhu 2012; Kumar and Goyal 2020).

Within India, states are paying attention to massive water losses from public water systems and are endorsing sensible policies for communities to report and reduce the water losses (Natural Resources Defense Council 2018). The role of water pricing, water recycling, water auditing, community participation and management, involvement of panchayats and municipalities have been emphasized to recognize water as a productive good (The National Water Policy 2012). As far as the regional water stress in India is concerned, the maximum change in the water stress situation observed in Northern and Western regions (Table 3) requires the immediate attention of authorities to reduce the ongoing water crisis. The various water stress categories include low water stress (< 25%), medium water stress (25–50%), high water stress (50–75%), very high water stress (75–100%), and water deficit (> 100%) (Hegde 2012). Since, water scarcity involves water strain, water shortage or deficits, water crisis due to poor management of resources, lack of government attention and awareness, there is an urgent need to initiate appropriate arrangements for holistic water administration, and rethinking by various authorities in the water sector (Bhatt and Bhatt 2017; Mamta and Vishal 2018).

Therefore, to decrease water usage and save unnecessary over-use of water, water auditing could be practiced to assess water availability vis-a-vis consumption needs of any given community, group, or locality to ensure a balance between water use and supply (Nayak 2020). It is a practice that attempts to survey water stocks, demand, attainability, and use in the wider perspective of governance, institutions, public–private expenditure, legislation, and the political economy of water (Food and Agriculture Organization 2012). The fact that some water loss is inevitable and there are no accurate statistics available for calculating the amount of water lost in India, it becomes difficult to calculate wastage of every drop escaping our systems for which water audit becomes an important tool (CWC 2005). A total of 200 + water audits have a potential of saving 160 billion liters annually, which is the same as supplying freshwater to the whole rural population of India for 2 days (CII- Triveni Water Institute 2019). Rapid amplification of population and escalating water demand has reduced per capita water availability in India. In this context, the introduction of water recycling becomes one of the feasible options to achieve long-term sustainability of water supplies (Miller 2006). It is another key strategy that can augment the existing water resources in both developing and developed countries (Mekala et al. 2008). Wastewater recycling is also important in terms of economy, practicality, and safety and has the potential to alleviate water problems caused due to the decline in the availability of freshwater sources, climate change, increase in urban population, and demand for water from competing sectors (Mandal et al. 2011).

It is an established fact that lack of conduct and control in managing water resources of India is a pressing issue that makes it a prerequisite to tackle the water scarcity. The authorities, however, continue to do little at the grass root level to deal with this issue in a practical and consistent manner. This paper demonstrates how water auditing and water recycling could possibly improve water governance and lead to long-term sustainability of the India's freshwater systems. India needs to reconsider the institutional processes for dissemination of knowledge about water management as there is a certain amount of risk associated with the mannerism of dissemination of this knowledge in legitimizing and consuming water resources. There is an urgent requirement to identify that water crisis in India and take steps to ensure adequate quality water supply to all. Failure of water governing bodies to manage the water resources is a clear indication of the fact that India is facing water crisis not due to lack of water resources but due to policy amnesia. Under the ambit of integrated water resources management, the practice of water recycling is important to ensure the sustainability of our water resources while as water auditing profoundly boosts water-sustainability efforts by enabling vibrant framework of systematic acquisition, quality control and analysis of water-related information which, in turn, provides information required in water governance, accountability and transparency.

Table 3 Regional Water Stress in India (percentage wise) under Business as Usual Scenario (The Energy and Resources Institute 2014)

Year	North	East	West	Central	South	North–East	National
2011	70.1	28.9	41.2	23.2	29.3	4.8	37.1
	High	Medium	Medium	Low	Medium	Low	Medium
2021	74.2	30.7	45.7	26.7	31.4	5.8	40.4
	High	Medium	Medium	Medium	Medium	Low	Medium
2031	77.7	32.6	48.7	27.8	33.7	6.8	42.9
	Very high	Medium	Medium	Medium	Medium	Low	Medium
2041	80.8	34.8	51.2	29.1	35.8	8.6	45.3
	Very high	Medium	High	Medium	Medium	Low	Medium
2051	84.0	37.3	54.1	30.3	38.2	10.8	47.9
	Very high	Medium	High	Medium	Medium	Low	Medium

Water auditing and governance in India

Water audit came into the picture in the late 80s to control drought-related problems, shortages, leakages, losses of water, to decrease water usage and save money (Ganorkar et al. 2013). The present water availability of India stands at 1820 m^3 per capita per annum which got reduced from 6000 m^3 since 1947, due to which a water audit becomes an unavoidable exercise in India (Kumar and Kumar 2019). A water audit is a holistic approach toward total water resource, its distribution and its efficient use to lessen the capital and operating cost (Ganorkar and Khedikar 2011). A water audit assists in identifying and quantifying the pathways to reduce water use and loss thereby saving valuable resources and public money (Ganorkar et al. 2013). The main elements of water audit comprise of water production record, water delivery to metered and unmetered users, water loss or thefts, proposed initiatives to address water losses via leakages and other unaccounted for the same (Fig. 6).

For water audits, a zone-wise bulk metering system must be framed, which would facilitate identification of areas where the actual wastage of water is occurring (Ministry of Water Resources 2014). In India, an environmental audit is being carried out in three stages:

1. Pre-Audit Process which includes establishing a plan for auditing
2. Field processing that includes sampling, observations and meetings of staff, and
3. Post-audit process where in an environmental audit report is prepared and measures to execute the plan are proposed

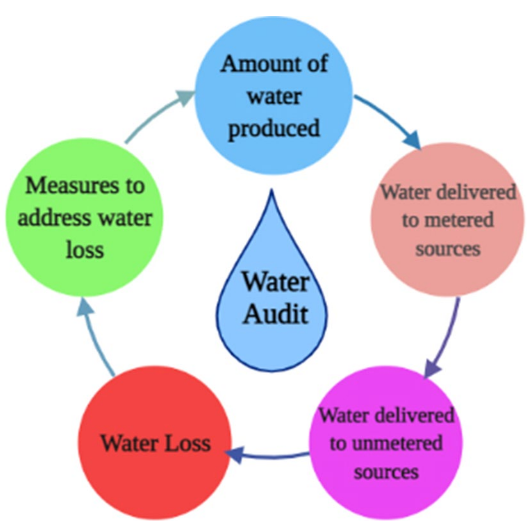

Fig. 6 Elements of water auditing (CWC, 2005)

Generally, a water audit consists of 5 major steps given by American Water Works Association (AWWA) and International Water Association (IWA) (2000).

1. Source evaluation/system input volume

The first step in completing the standard water balance is to determine the System Input Volume which includes multiple wells, springs or surface water intakes to balance the amount of water input. The amount of water input to the balance is determined by metering at the source.

Water supplied = System input volume − Water exported

Water Exported is the bulk water supplied to adjacent water systems that are located outside of the service region.

2. Calculation of authorized consumption

Authorized consumption means the volume of authorized consumption that is metered/ the volume of water used by registered customers. Authorized consumption is either metered or unmetered and either billed or unbilled.

Authorized consumption = Billed authorized consumption – Unbilled authorized consumption

The calculation of Authorized Consumption involves determining the category of Revenue Water that generates income for the water service. Revenue Water is made up of two components: Billed Metered Consumption and Billed Unmetered Consumption. Billed Authorized Consumption refers to the volume of authorized consumption that is billed and comprises both billed metered consumption and billed unmetered consumption. Billed Metered Consumption refers to the volume of authorized consumption that is both metered and billed, including usage by residential, commercial, and industrial customers.

3. Evaluation of apparent losses

Water losses that occur due to inaccuracies in water flow measurement, errors in water accounting, and unauthorized usage are known as Apparent Losses. Sometimes they are called "paper losses" since they consist of water that is not properly recorded on paper.

4. Evaluation of real losses

Real Losses are the physical escape of water from the distribution system and include leakage and overflows prior to the point of end use. Real losses typically account for a greater volume of water lost in comparison to apparent losses. The marginal cost of real water loss occurs at the cost of production—the expenses associated with extraction, treatment, delivery, operations and maintenance.

5. Performance measurement

Performance measures helping the customers to comprehend the goals and progress achieved through the water auditing process.

Water balance = System input volume − Authorized metered consumption

Percent water balance = (Water balance/System input volume) × 100

If the water balance exceeds 15% of the system input volume, the water system is required to complete a water audit and response plan (Choudhary et al. 2021).

India is one among the top 12 water-poor countries with per capita of water availability of 1850 m^3/person/year against the world average of 7690 m^3/person/year emphasizing the need to form well-informed documentation and monitoring for efficient and beneficial utilization of finite water resources (Sarda 2011). Water loss in the water allocation system is a significant event in India as up to 50–60% of treated and pumped water is lost during conveyance from source to the consumer end (Tembhurne et al. 2017). Though water audit is not a recent idea or documentation, yet, no regulations or Bureau of Indian Standards codes for water audit are available in India. Taking this into consideration, the "General Guidelines for Water Audit" have been made available covering three main aspects of water use, viz. irrigation, domestic and industries intending to promote introduction, standardization, and familiarization of a water audit to improve water use efficiency (Central Water Commission 2005). According to reports, the water crisis could lead to World War III, and to avoid the same, a water audit needs to be practiced (Dhariyal 2017). Water Audits should become routine exercises and institutionalized based on the fact "what gets measured gets managed" and could also identify water conservation strategies, ideally leading to zero liquid discharge (Barrington and Ho 2014; TERI 2014). Companies might soon have to do a water audit as the government plans to frame a policy to assess the per unit consumption of water for creating sustainable water resources in the country (Chitravanshi 2019). To carry out water auditing, additional information also needs to be collected that can be achieved by identifying the leaks and losses by reviewing billing records, assessing flow observation, visual inspection or leak detection, and analysis of the state of tools including visual inspection (e.g., periodic walk-over and inspections of exposed mains), technologies for internal visual inspection (e.g., camera inspections of closed-circuit television (CCTV), etc. (The United States Environmental Protection Agency 2009). Comprehensive audits are an important step toward water conservation and, if combined with a leak detection plan, can save both resources and time (Kulkarni et al. 2014). As per the recommendations, Water Audit Cells under Monitoring Units and Water Tracking and Monitoring Unit of Water should be formed by the state governments in their Water Resources Departments to shoulder the responsibility of performing a water audit (CWC 2005). In the context of the prevailing scenario, a water audit becomes an important tool in India to identify the monetary loss of the public on account of water losses and unauthorized water connections (U.S. EPA 2009).

Guidelines for water auditing strongly advocate that a water audit system is used for all water resources projects to make it a routine activity (Central Water Commission CWC 2005). Implementing water use efficiency has been accorded the highest priority under National Water Mission and simultaneously asks for water audits across the industrial and commercial sectors (National Water Mission 2017). Further, guidelines have been provided to improve the functionality of water audits to prepare water balance to fulfill water use rights from its source to its applications, create historical water consumption pattern that can help in pointing out fluctuations in water use (Water Resources Department 2019). For instance, the state of Maharashtra in India has conducted annual state-level water audits on more than 1200 irrigation systems since 2003. This number has rapidly increased from 1200 to 2500 and has managed to bring out valuable information like water availability, state-wise water use, regional water losses, details of areas planned and irrigated, unutilized water from storage, and percentage of evaporation (Water Resources Department 2019). The scale of implementation of water auditing shall not be limited to educational institutions and industrial sector but of wide coverage. The Indian government is encouraging a trend in which all educational institutions must have green campuses that address water audits, water footprints, and water recharge to save water resources.

The community-led water audits and water security planning are crucial to reduce the real and apparent losses in the water supply distribution system. IT-based technology, metering of water, installation of flow control valves in water connection, water budgeting, community surveillance, water conservation measures are some of the programs being taken up to strengthen water supply management for all (Ministry of Jal Shakti 2017). To encourage efficient water usage, a system should be established to create benchmarks for different purposes such as water footprints and water auditing. To encourage cost-effective and efficient use of water and timely completion of projects, the financing of such projects should be structured appropriately. Water Users Associations (WUAs) should be given legal authority to collect and retain a portion of water fees, manage the allocated water amount, and maintain the distribution system within their jurisdiction. This will provide incentives for WUAs to use water in a sustainable manner and ensure the efficient use of financial resources, while also promoting the timely completion of projects.

Community participation should be encouraged in managing water resources projects and services. Urban domestic water systems should publish water accounts and water audit reports that identify leakages and pilferages (National Water Policy 2012). Also, the Central Government can direct states and local urban bodies to implement water auditing at all levels where water is used and encourage all sectors to adopt this practice on a national scale.

Therefore, the other states of India need to practice the method of water auditing with the sole purpose of conservation and management of water resources to deal with the water stress across the country. Water auditing is a profound necessity as it unifies diverse water users from different backgrounds, lifestyles, and strata of education, creating thereby a common 'water' language for all avoiding confusion over issues such as 'water use' and 'water consumption.' A comprehensive water audit must be a vital part of policy in India as it facilitates a comprehensive outline of water allocation and user system and aims to achieve national benchmarks of water consumption, thereby facilitating effortless, effective, and efficient management of the resources with enhanced reliability. The audit exercise provides decision-making tools to the concerned people by identifying inefficient uses, troubled areas wherein water conservation and remedial measures can be undertaken. The lack of water auditing practice in our current water management system despite its guidelines having been given by the Ministry of Water Resources shows the poor governance of water in our country. The importance of water auditing lies in controlling the wastage of water which is of vital importance concerning the present water crisis in India making it mandatory for every water conservation project to make use of water auditing. Also, thefts and unauthorized use of water are rampant in India that fails the very purpose of a water audit owing to the lack of water governance in the country. For India, a water governance framework should include revamping the legal regulation of water by putting water on top of their agenda. There are allegations that numerous multinational beverage and bottled water companies steal groundwater all over the world. Hotels, wedding venues, recreation centers, manufacturing companies, and construction companies in many regions illegally pump water from surrounding ponds and lakes, usually at night. This decreases the amount of water available to the underprivileged and cattle. The majority of people who steal water live in unlicensed multi-story structures and large slums that are not connected to any official water infrastructure. According to reports, between 2000 and 10,000 private water tankers apparently run erratically every day, delivering cargoes of water largely to enterprises (The Hindu 2018). According to the Centre for Science and Environment (CSE), around 20,000 illegal bore-wells were dug by tankers in Gurgaon. The main cause of theft and poor management in India is the accessibility of inexpensive water. Water needs to be handled as an economic good and priced so that the system recovers the whole capital investment as well as all operating and maintenance costs (IAS Parliament 2018). In the worst cases, water theft might even result in a shortage of drinking water. Around 48 million cubic meters of potable water, enough to serve 200 million people with water in poor nations, is lost every day from official supply networks (World Bank 2006).

In our country, water conservation is the most talked about topic but if we genuinely have to strive for saving water, every state should have its water audit that needs to be incorporated and made mandatory by the concerned authorities. In this hour of crisis when water stock is decreasing, water audit should be made an integral part of all water-related assessments in India as it will not only quantify water consumption but will also give an idea of how much water can be used, reused, conserved and wasted- information that is profoundly vital for a country dealing with a looming water crisis.

Water recycling and governance in India

There is an immense potential for treated wastewater reuse in India as studies reveal that the treatment of 80% of urban wastewater could increase the volume of available wastewater for reclamation by 400% (Kumar and Goyal 2020). The concept of water reuse is not unheard of in India as records show the first instance of wastewater reuse in India goes back to 1964–65 (Arceivala 1969). One of the biggest challenges faced by India is accelerated pollution of both surface and groundwater (Mekala et al. 2008). Water recycling derives its impetus from many factors that may involve the inadequate water environment, cost approach using recycled water, or very stiff regulations on water quality discharge (Kamizoulis et al. 2003). But in a country like India, the main driver for water recycling is water stress (IWA, 2019). The advancement in technology for wastewater use from industries and municipal corporations accounts for the largest percentage of the total environmental market in India (Winrock International India 2007). Based on the extent of the treatment and availability of freshwater, reclaimed water can have multiple uses in industrial processes, irrigation, and human consumption (Krishnan 2006). The factors like wastewater quantity and quality, public consciousness, market viability, costs incurred, treatment type and distribution system, etc., enable several feasible options to be incorporated for reusing of treated wastewater. The reclaimed water reuse is mainly classified into five main categories (Fig. 7).

The genesis of wastewater recycling in a country like India surfaced from the early 90s as the architect of maximum Indian urban drainage systems is designed in a way that wastewater received by the water bodies without treatment

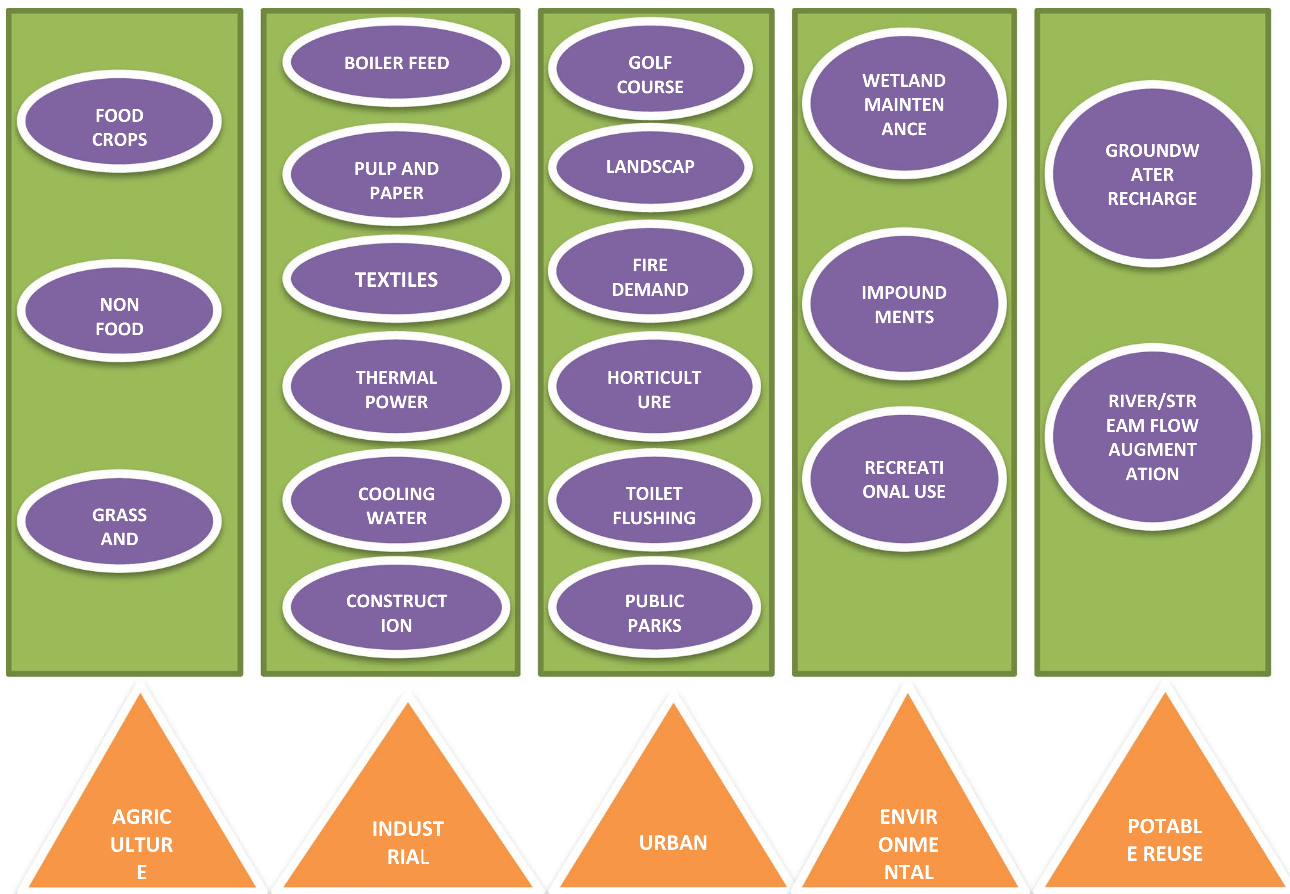

Fig. 7 Various classes of reclaimed water reuse in India (Kumar and Goyal 2020)

signifies the negligence in following regulations for safe handling, transport, and disposal of wastewater (Kaur et al. 2012). Further, adding to the quagmire is the much prevalent imprecise concept that water is an inexhaustible natural resource that has prevented water conservation or recycling from becoming a part of Indian culture (Hegde 2012). In India, by 2025, one person in three will have to live in conditions of absolute water scarcity (International Water Management Institute 2003) paving a way for water recycling to overcome the problem of reduced water availability (Mandal et al. 2011). The wastewater generated in the urban sectors of India during the time of independence (1947) was estimated at 5 billion liters per day which touched the mark of about 30 billion liters per day in 1997 (Winrock International India 2007). An integrated effort needs to be formulated for water quality management to balance the infrastructural and socio-economic measures which include construction of new wastewater treatment systems, advancement of the existing wastewater treatment systems, technological improvement in wastewater systems, and renewal of the sewerage system (Sahasranaman and Ganguly 2018). Therefore, compulsory recycling and reuse of wastewater from water-intensive activities should be introduced to lessen the ongoing and upcoming pressures on freshwater resources (CWC Ministry of Water Resources 2014). The limitation of various water-related data sets like water supply–demand gaps, wastewater volumes, and water consumption, etc., are sprouting due to the fragmentation of the water sector in India (Kumar and Goyal 2020). A growing set of viable but unconventional water resources, such as wastewater, present a promising opportunity to address the growing gap between water demand and supply toward a more water-secure future (Jones et al. 2021). Wastewater is increasingly recognized as a reliable and cost-effective source of freshwater, particularly for agricultural applications; however, wastewater remains an "untapped" and "undervalued" resource (WWDR 2017), especially in India. This policy lacuna and the absence of a distinct regulatory framework lead to water resources mismanagement and there could be serious complications without a prompt response (Nath and Parmar 2022). The rate of demand for clean water is increasing at a faster pace than wastewater treatment solutions and technological developments that ensure the safe distribution and management of wastewater (Sato et al. 2013). Ensuring safety is the main challenge in promoting re-use as it is crucial for both human and ecosystem health. If that is not achieved, wastewater is considered as waste and is not treated, recycle or reused (Qadir et al. 2020). The apathy with regard to treatment of wastewater in India is visible from how its sewage systems have been designed which are struggling for efficiency as most of urban India's sewage systems lead directly to rivers or lakes (Dutta and Bhaskar 2017). The Sustainable Development Goal 6.3 is focused on wastewater and has a target to reduce the proportion of untreated wastewater and substantially increase its safe reuse and recycling globally (NITI Aayog 2022). The number of STPs has almost doubled, and the capacity increased by 41% in 2020 as compared to 2014 (Table 4). So, currently, the total treatment capacity is 36,668 MLD; however, only 26,869 MLD is the operational capacity (CPCB 2021b). According to this recent report published by Central Pollution Control Board (March 2021), India's current water treatment capacity is 27.3% and the sewage treatment capacity is 18.6% (with another 5.2% capacity being added).

While India face numerous challenges in setting up and operation, the challenges are grouped under the following issues: (i) Institutional challenges, (ii) Regulatory challenges, (iii) Economic challenges, (iv) Technological challenges and (v) Social challenges. Despite having reasonable institutional capacity, the expected outcomes with regard to water management are not encouraging largely due to lack of accountability, cooperation, long-term planning, adequate human resource etc.

Challenges in relation to regulation are in the form of, standards, monitoring, and jurisdiction. The lacunae present in the monitoring system and the standards used to determine the treatment requirements are concerning, particularly given the current limited treatment capacity (NITI Aayog 2022). Economic challenges related to STPs include the high cost of more advanced treatments. However, the direct economic benefits from the STP derived from the use of treated water in agriculture or fisheries are considerably low. Therefore, municipalities often choose less efficient technologies in terms of environmental performance. This creates a trade-off between environmental performance and economic viability (Kumar and Tortajada 2020). Since, India is over-dependent on older technologies for handling wastewater (FICCI Water Mission and 2030 Water Resources Group 2016). The Government due to limited funds and higher expenditures tends to choose technologies with lower capital costs despite their poor performance. This can lead to limitations in the ability of municipalities to handle wastewater, impairing treatment functions, and a further increase in avoidable repair costs (Nikore and Mittal 2021). Social hurdles are that the citizens are usually not well informed about the issues related to water scarcity and the positive outcomes of water reuse and recycling. Although awareness has been created about the use of reclaimed water, people are reluctant to use it (Kakwani and Kalbar 2020). This may require a cultural shift through education and sustained awareness campaigns. Recycled water is very less likely to be accepted for drinking purposes compared to its non-potable purposes like irrigation of parks (Rodriguez et al. 2009; Villarín and Merel 2020). People often have negative emotions of fear and disgust when it comes to the usage of recycled wastewater. These are deeply entrenched within individuals but are also linked with wider societal processes and social representations (Smith et al. 2018).

The cumulative wastewater production from Class I cities and Class II cities in India is around 35, 558 million liters per day (MLD) and 2,697 MLD, respectively (Table 5), with a cumulative treatment capacity of 8040 MLD only. An estimated 61,754 MLD sewage is generated in India, while the treatment capacity is only 22,963 MLD, or 37.18% of the total sewage generated. Major pollution of India's surface water resources is credited to incessant dumping of untreated sewage directly into water bodies, (Fecal Sludge Management Report 2009). The water situation is so precarious

Table 5 India's wastewater treatment capacity (c.f. Roy 2020)

	Class I cities	Class II cities
Sewage generation (million liters per day)	35,558	2,697
Installed capacity (million liters per day)	11,553	233
Capacity gap	68%	91.3%

Table 4 Status of Sewage Treatment Plants in India (CPCB 2021b)

S No	STP status	2014		2020	
		No of STPs	Capacity (MLD)	No of STPs	Capacity (MLD)
1	Operational	522	18,883	1093	26,869
2	Non-operational	79	1237	102	1406
3	Under construction	145	2528	274	3566
4	Proposed	70	628	162	4827
	Total installed (1 + 2 + 3)	746	22,648	1469	31,841
	Total treatment (1 + 2 + 3 + 4)	816	23,276	1631	36,668

reflecting greater reuse of treated wastewater (Sahasranaman and Ganguly 2018).

India's National Water Policy advocates conservation, augmentation, and recycling water in view of the looming water-scarce future (Amerasinghe et al. 2013). The fact that less than 50 percent of wastewater is being treated or reused in India calls for a drastic change from the current centralized water management approach to address the problem of water scarcity (Mattoo and Singhal 2020). The option of recycling water has been around for quite some time, but one doesn't find it suitable to consume the 'used water' for drinking or any other household usage due to the unsuitable treatment of water leaving behind odor and discoloration, not to mention the economic and technical factors being another main group of factors that tend to affect the adoption of water-recycling technology (Hegde 2012). A National Reclaimed Policy with targets, regulatory, and financial/fiscal measures is needed to be devised in India as treated wastewater reuse is still an evolving concept in India but lacks the institutional and regulatory structure that hinders its establishment (Kumar and Goyal 2020). Recycled water can help satisfy most water demands, as long as it is adequate to ensure appropriate water quality for the intended use (Patil et al. 2013). If the water recycling system is correctly managed over the ensuing decades, Indians will benefit from using reclaimed water as a key resource for the long-term development of new commercial initiatives or economic prospects (Banerjee 2021). There is the need to integrate the existing water and wastewater policies and programs into a National Water Framework which will establish general principles to govern water issues and will be implemented by the Central Government, the State Governments and the local governing bodies (Breitenmoser et al. 2022). Currently, water scarcity in India is not due to its reduced availability of adequate quantity, but due to poor water quality that has not been actively addressed in India till date (Chaudhuri 2019). Therefore, in India, there is a need to reach the stage of `zero water' industries wherein industrial units would take charge of all their water needs by adopting recycling techniques without being dependent on other outside sources (Venkateswaran and Singh 2017).

Despite a long history of wastewater reuse in many parts of India, the question of the safety of reused wastewater remains an enigma primarily because of concerns regarding the quality of reused water and the functionality of wastewater treatment plants. The process possesses several loopholes, we cannot deny the fact that water recycling and reuse are a much-needed water resource management tool that can augment water resources and help improving water quality. Seeing the apathy of government policies in the context of wastewater treatment along with the design of its sewage systems, there is an urgent need to plan strategies and design policies that give equal weightage to augmentation of water supplied and development of wastewater treatment facilities in facilitating water management practices. Wastewater is a reliable alternative source of water, as it can transform the approach of wastewater management from 'treatment and disposal' to 'reuse, recycle and resource recovery' highlighting the need to frame and/or reframe water reuse policies to manage the impending water crisis in India. The government of India needs to make use of this effective water management practice at all levels to help contribute to the formation of water use alternatives.

Conclusion

The rising population of India which has already surpassed China in April 2023 is likely to stress water resources as India is the world's 13th most water-stressed country. This will require to calibrate and fine tune the infrastructure, technical, human resource and governance aspects to pave the way for achieving sustainable water management goals. Besides, water needs to be handled as an economic good rather than a cheap resource.

In this scenario, water recycling and auditing together can improve the understanding of the level of water governance needed to deliver sustainable water supplies to all sectors. Through water recycling, treated wastewater can be used for non-potable purposes, thereby reducing the demand for freshwater sources. Additionally, water auditing could provide a means of assessing water usage and identifying areas of improvement, allowing for more efficient use of existing water resources. We argue here if water audit is promoted on the lines of financial audit in the country, it has the potential to revolutionize to the large extent the reforms that will encourage this practice of water audit in all sectors thereby leading to wise and judicial use of water for safeguarding water resource.

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