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Intermittent water supply in Indian cities: considering the intermittency beyond demand and supply

Suchismita Satpathy and Rohit Jha*

Department of Humanities and Social Sciences, Birla Institute of Technology and Science Pilani, Hyderabad Campus, Jawahar Nagar, Kapra Mandal, Hyderabad 500 078, India
*Corresponding author. E-mail: p20170439@hyderabad.bits-pilani.ac.in

SS, 0000-0001-9553-7203; RJ, 0000-0002-6742-5906

ABSTRACT

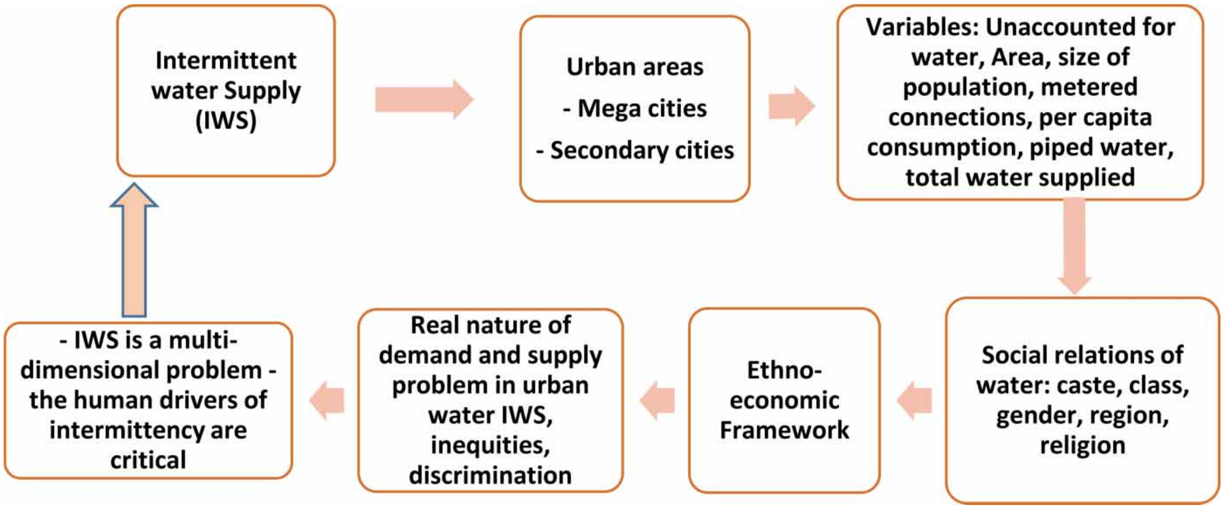
Intermittent water supply (IWS) is a typical characteristic of cities in developing countries like India. One of the factors responsible for IWS is unaccounted for water (UFW). Factors like increase in population, upward trends in water demand, water scarcity due to climate change, and asymmetric distribution of water resources are also equally important. However, social relations of water are poorly understood and camouflaged under technicalities associated with IWS. Thus, in this paper, we examine IWS in Indian mega cities and secondary cities with an ethno-economic framework by bringing the data together from various administrative sources like government agencies, allude to its parameters from logistical perspectives, e.g. distances, capacities, population strength, etc., and try to position the water issue with challenges associated with caste, class, gender, religion, region, and governance. The ethno-economic perspective is an attempt to not only complement but also supplement the scientific studies from other disciplines by understanding the real nature of demand and supply problems in urban water management. This paper demonstrates IWS as a multi-dimensional problem and stresses the human drivers of intermittency.

Key words: ethno-economic approach, equitable water distribution, Indian cities, intermittent water supply, unaccounted for water, water supply systems

HIGHLIGHTS

- The paper assesses the intermittent water supply (IWS) situation in mega cities and secondary cities of India.
- It is considering the understanding of IWS beyond the supply and demand factors to the people who deal with the problem on a day-to-day basis.
- It uses a framework combining the ethnographic and economic aspects which are important for equitable urban water distribution in IWS situation.

GRAPHICAL ABSTRACT



INTRODUCTION

The sixth goal of the United Nations Sustainable Development Goals (SDGs) lays emphasis on providing clean drinking water and sanitation to all by 2030. However, the water sector is still struggling to improve water resource management and to increase the coverage and quality of water. The extent of coverage remains in question as millions continue to be out of formal networks of water supply in cities of Africa and Asia (Charalambous & Laspidou 2017). Along with coverage, intermittent water supply (IWS) is an additional challenge. The IWS system is defined as any piped system which provides water for less than 24 h in a day (Mokssit *et al.* 2018). Inadequate coverage, intermittent supplies, low pressure, water theft, poor infrastructure and poor quality are some of the most prominent features of water supply in Indian cities. The Indian urban water situation is such that 64% of the urban population is covered by individual connections and stand posts, duration of water supply ranges from 1 to 6 h, per capita supply of water in cities ranges from 37 Litres Per Capita Per Day (LPCD) to 298 LPCD for a limited duration, most cities do not have metering for residential water connections, 70% of water leakages are from pipes for consumer connection and due to malfunctioning of water meters, non-revenue water (NRW) or unaccounted for water (UFW) accounts for 50% of water production (Ahluwalia *et al.* 2011). With the rapid increase in urban population and continuing expansion of city limits, insufficient municipal budget, low cost recovery, etc. the challenge of delivering water in Indian cities is growing rapidly.

Though the commitment under SDGs 6 to 'leave no one behind' requires increased attention on disadvantaged groups and efforts to monitor elimination of inequalities in drinking water services, discriminations conspicuously exist. Categories of caste or class or community somehow determine where water does or does not go (Björkman 2015). The long-held belief that private participation can be a game changer by making public utilities more efficient and profitable has not yet materialized. On contrary, the situation in a few cities is such that the water mafia (Ranganathan 2014) and land mafia are collaborating as a nefarious nexus, thus adding new and unwelcome dimensions to the already existing water management problems. The inefficiency of the private sector is not only attributed to the failure of the age old water systems, but also to the intertwined discriminatory practices which show a wide range of intersectionality. For a private player, to navigate through these issues and ensure an equitable access to water seems impossible for now. Thus, apart from the supply-side economic issues, demand side population identities, awareness, and political power of the categories are also critical factors.

Various studies have identified the causes and the consequences of IWS worldwide (Klingel 2012; Ameyaw *et al.* 2013; Kumpel & Nelson 2014; Galaitsi *et al.* 2016; Mokssit *et al.* 2018; Simukonda *et al.* 2018; Ghorpade *et al.* 2021). The issue of equity emerges frequently in studies focusing on IWS (Galaitsi *et al.* 2016). The IWS results in inequitable supply, increased NRW, and deteriorated water quality (Ayoub & Malaeb 2006; Ghorpade *et al.* 2021). Insufficient metering, poor extent of coverage, leakages, water thefts, storage and distribution challenges, problems with access to water resources are responsible for IWS. UFW is one of the important causes and consequences of IWS. NRW or UFW is the water which does not make it from the source of the distribution network to the consumers due to leakages, wastage or theft. However, monitoring NRW and the differential impact of IWS on different sections of the population are problematic in an IWS regime (Al-Washali *et al.* 2019). Thus, understanding the problem of UFW is very much essential in the discourse of IWS. The present study aims to describe the existing intermittent urban water supply and distribution conditions of India's mega cities and secondary cities, linking them to the diverse impact this has on different sections of society. Using the ethno-economic framework, we attempt to further extend the understanding of IWS in social science.

Water Supply Systems (WSSs) are seen as a symbol of modernity and a way to have a better quality of life. However, in the context of UFW and IWS, modernity has failed and has resulted in commodification of water. The formal water networks not only challenged the notion of procuring water from streams, wells, rivers, and canals but also struggled to overcome the barriers of caste, class and religion to some extent. There are varied social actors and multiple power structures in the society that shape the nature of the social interactions in bureaucracy, community and among the people at large. Thus, the ethno-economic approach helps us interpret the situation of IWS better in the light of diverse social-economic categories.

In the following discussion, first we identify if there is any link between size of population, area of city and the existing intermittent water situation in the mega cities and secondary cities. The second part of the paper is the analysis of the social factors complicating the existing water situation in urban India and making it inequitable, inaccessible and scarce.

INTERMITTENT URBAN WATER SUPPLY SITUATION AND UFW IN INDIAN MEGA CITIES

Water problems have already gripped the Indian mega cities (cities with population of 10 million or more) such as Mumbai, Delhi, Bengaluru, Kolkata, Hyderabad and Chennai. The secondary cities (population between 1–5 million) like Ahmedabad, Surat, Indore, Jaipur, Vadodara, Nagpur, Lucknow, Coimbatore, Nashik, Thiruvananthapuram, Varanasi and Visakhapatnam are not exempt from water issues. In India, where IWS is the norm, among the total connections available with all the water service providers only 43% of them are metered as of 2009 (Danilenko *et al.* 2014). The report by the Ministry of Urban Development indicates that in 2012, 13.3% of metered connections with 69.2 LPCD and 32.9% of NRW exist in the country against 100% metering, 132 LPCD and 20% NRW targets (Ghorpade *et al.* 2021). The average annual per capita water availability in the years 2001 and 2011 in India was assessed as 1,816 and 1,545 m^3, respectively, which may further reduce to 1,486 and 1,367 m^3 in the years 2021 and 2031, respectively (Ministry of Jal Shakti 2021). Only 47% of urban households have individual water connections in India, and about 40–50% of water is reportedly lost in the distribution system for various reasons. It is in this context that there is a need to examine the existing water systems and their social networks.

Table 1 contains the water profiling of the six mega cities. Over the decades, the population of Mumbai has grown enormously, giving rise to the sprawling slums within the city and suburbanization in the periphery, making it notorious for its congested living facilities. The situation for Delhi, and its periphery including Gurgaon and Faridabad which constitute the National Capital Territory, is complex due to the daily movement of a large number of people into and out from the city. This migratory population complicates the supply of all of the basic amenities, not just water. In part due to such complications, the current demand for water in the city is projected at 4,769 Million Litres per Day (MLD), whereas only 3,546 MLD is supplied. In Hyderabad, the HMWS&SB estimated the demand and supply of water at 2,312 and 1,343 MLD, respectively, for the year 2015. If the current trends of growth continue, then by 2021 the demand is projected to be at 3,172 MLD and supply at 2,214 MLD (Safe Water Network- Hyderabad 2016a). Thus, there is an obvious and large gap between the demand and the supply. This gap is closed by the means of exploiting groundwater. Groundwater in about 56% of the assessment units in Delhi was found to be overexploited. Its level is declining by 0.5–2 m annually in most parts of Delhi, and in Mumbai it is considered unfit for drinking. But the supply gap is met at household levels by accessing the groundwater (Safe Water Network -Delhi 2016b).

Kolkata, having a considerably high population, actually has the lowest quantity of water supplied out of all the mega cities with a considerable per capita consumption. The benchmark notified by the Ministry of Housing and Urban Affairs, Government of India is 135 LPCD for urban WSSs (2 March 2020). The per capita consumption for Kolkata is approximately 134 LPCD, which is close to the national average consumption and is further closer to the national goal of 150 LPCD for mega cities. However, it has been observed that the supply of water is erratic. In Chennai, per capita consumption of

Table 1 | Water supply profile of the six mega cities

City	Mumbai	Delhi	Kolkata	Chennai	Bengaluru	Hyderabad
Population	1,84,14,288	1,67,87,941	1,41,12,536	86,96,010	84,99,399	77,49,334
Area (km^2)	603.4	1,484	206.08	426	709	625
Quantity of water supplied (MLD)	3,350	3,546	599	830	970	1,287
Ground water (%)	NA[a]	9	11	9	40	30
Piped water (%)	76	81.3	92	98	93	70
Per capita consumption (LPCD)	135	274	134	90	100	162
Percentage UFW	20	52	35	40	40	40
Metered connections (%)	81	55	1	NA[b]	95.5	30
Nodal Agency	The Hydraulic Engineer Department	Delhi Jal Board (DJB)	Kolkata Municipal Corporation (KMC)	Chennai Metropolitan water supply and sewerage Board	Bengaluru water supply and sewerage Board (BWSSB)	Hyderabad Metropolitan water supply and sewerage Board (HMWS&SB)

Source: Census handbook 2011, websites of respective municipal authorities, CGWB report, TISS, Safe Water Network- Delhi Hyderabad 2016a.
[a]In Mumbai, though the percentage of ground water usage is not available, the GMMC reports 3,950 dug wells and 2,514 bore wells under operation for water supply purpose in the city.
[b]Metering water is not seen as commonly in Chennai as in Bengaluru, Mumbai or New Delhi.

water is 90 LPCD which is quite low. In November of 2019 Chennai Metro Water increased its water supply by about 100 MLD (Viswanath 2019). This benefit has not yet been received by the peripheral areas of Chennai which are heavily dependent on groundwater and informal sources of water like tankers.

Figure 1 reveals that Bangalore and Mumbai have done considerably well in metering of connections, thereby recovering the utility cost to a certain extent. In stark contrast, it appears that Delhi has one of the lowest percentages of metered

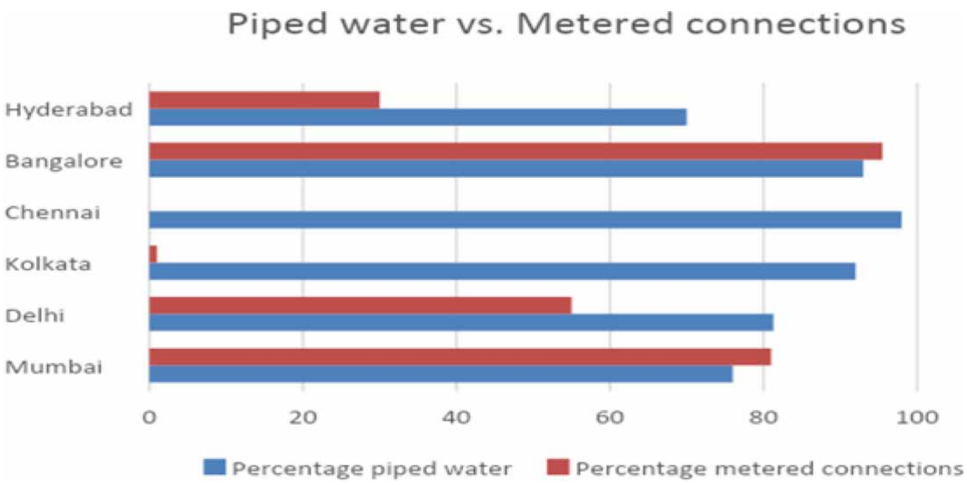


Figure 1 | Piped water and metered connections.

connections among the mega cities. In 2011 the Delhi High Court exhorted in an order that there should be 100% metering in Delhi. Additionally, consumers should be asked to pay for the actual consumption. If citizens have a fundamental right to water, it is also important for them to pay for the water they use. But in reality, as much as 20% of the total 2 million connections in NCT of Delhi are unmetered. Most metered connections are also charged only a flat-rate tariff. Similarly, in Hyderabad, the piped water supply percentage stands at 70%, which is low compared to the other mega cities. There is a deficient piped supply of water to peripheral areas of the city, including the slums which mainly get their water supply through water tankers. Kolkata has an abysmally low number of metered connections, namely only 1% of households. Chennai recently started metering household and commercial water connections. This not only affects the utility's cost recovery but also gives scope for widespread wastage of water and UFW (Figure 2).

Total UFW is measured by the volume of the water lost (in litres) as a percentage or share of the total water supplied during the same time period. The tangible losses of existing intermittent supply in Indian cities are leaks and breaks in the pipes along with spill overs whereas the non-tangible losses are broken and tampered meters, inaccurate and improper readings, and outright water theft. The leaks and breaks which allow the water to seep through affect the quality of the water. UFW is the biggest problem in Delhi with almost 52% of water supplied being unaccounted for and this is not affordable where lesser quantities of water are supplied. Like most UFWs, the treated water supplied by the Delhi Jal Board (DJB) is lost during transmission and distribution due to pipeline leakage. The city also has a problem with illegal pilferage of water by tanker supply companies and illegal tapping of water. Piped water supply coverage in Delhi slums is 84.3% and of them, only 50.9% of the slum population have connections within their households, while the others share their source of drinking water.

In Mumbai, UFW accounts for 20%. It also boasts a higher percentage of metered connections at 81% and piped water supply coverage at 76%. The large slum-dwelling population causes a great amount of inequity in terms of distribution. Most slum residents have access to poor quality of water, inadequacies in the number of hours the water is supplied for, and so mostly resort to informal systems. The unaccounted-for water of about 20% comprises mainly pilferage and leakage from often 100-year-old pipes during transmission. The total water supplied is approximately 3,350 MLD and the unaccounted-for water is about 20% of this total, which is 670 MLD, a figure that can actually meet the demand and supply gap of water in the city to a large extent. Water supply through tankers is a vital support of water supply to the urban poor in Delhi. Over 800 tankers are owned and hired by DJB. But tanker water supply is quite costly for poor residents. There is always a risk of water getting contaminated, and it is difficult to purify it in order to make it drinkable. So, DJB in Delhi and VUDA in Visakhapatnam have started the treated-water kiosks throughout their cities to make drinking

Figure 2 | UFW vis-a-vis total water supplied.

water accessible for the urban poor. According to the BWSSB's Handbook of Statistics, in Bengaluru, 37–40% of the total water is lost in distribution itself, which may have improved due to the change in infrastructure, although the official latest numbers are not readily available. The high amount of unaccountable water has always plagued the BWSSB which incurs high losses (Mehta *et al.* 2013). Hyderabad faces about 20% of UFW issues mainly because of extensive and frequently occurring valve leakages, and under-maintained water supply infrastructure. Kolkata also has similar problems because of excessive distribution losses and poorly maintained pipelines.

Table 2 indicates the linear regression of the quantity of water supplied vis-à-vis variables like piped water, UFW and per capita consumption for mega cities. The relationship between the quantity of water supplied and piped water is strong with a correlation value of 0.994 and R^2 value of 0.988 and this indicates that an increase in the quantity of water supplied corresponds to an increase of piped water supply. The relationship between the quantity of water supplied and UFW is not so strong and this illustrates that an increase in the quantity of water supplied does not result in an increase in UFW. In this respect, the correlation is strong whereas the R^2 value of linear regression is not strong at 0.813 and 0.662. The per capita consumption of water and the quantity of water supplied exhibits a non-linear relationship with correlation value of 0.694 and R^2 value at 0.482, indicating that increased quantities of water need not lead to increase in per capita consumption. The second half of the table (Table 2) reveals the relationship between UFW and variables like piped water, area of the city, population and quantity of water supplied in six mega cities. On the basis of the p-values obtained for UFW vis-à-vis the piped water, water supplied and area, the relationship is statistically significant as the p-value is less than 0.05. An increase in values of piped water and quantity of water supplied does not necessarily result in the increase of UFW. However, in the context of area, any increase in the area shall cause an increase of UFW. The correlation determined between the population growth and the UFW has no inference as the p-value is higher than 0.05 and the correlation is statistically insignificant. This indicates that the growth in population does not necessarily contribute to an increase in the UFW. As per the dataset available, the effect of population growth on UFW is trivial.

IWS SITUATION AND UFW IN INDIA'S SECONDARY CITIES

The secondary cities of today are the mega cities of tomorrow and the state of water infrastructure in these cities is a worry. An assessment of the water supply and distribution systems in selected secondary cities of India reveals that cities like Lucknow, Coimbatore, Visakhapatnam, Ahmedabad, Surat, Nagpur, etc. are also facing similar problems of urban water management, due to a rapid increase in population, resulting in the need for better urban planning, regulated growth, and decrease in environmental degradation (Ramachandra & Aithal 2013). Table 3 displays that Jaipur has almost 100% coverage in metering whereas Ahmedabad, Indore, and Lucknow have no metered connections. Metering of connections is a salient parameter to understand the patterns of usage of water, develop strategies to minimize the wastage of water, and assist in the financial recovery of the water utilities as consumers will be charged based on usage. It is to be noted that these cities have relatively higher percentages of piped water supply and their per capita consumption is more or less similar. Vishakhapatnam and Indore have lower piped water supply. Water tankers are used to provide water in Trivandrum's non-piped areas despite having 78% coverage of pipes and 100% metering. Nagpur supplies water to the urban residents at the cost of the irrigation potential as it is water-stressed and has significant metering.

Comparing the amount of water supplied to the city with the amount of water that is unaccounted for, we can see that the cities of Lucknow and Coimbatore have close to 55% water unaccounted for, which is extremely high. Most other cities have

Table 2 | Correlation and linear regression of piped water, UFW; per capita consumption and area, population and UFW

Mega cities (sample size: 6 cities): Independent variable – Quantity			Predicted variable: UFW			
Dependent variable	**Correlation value**	**Linear regression: R^2**	**Independent variable**	**Correlation value**	**p-Value**	**Linear regression R^2**
Piped Water	0.994	0.988	Piped water	0.842	0.035	0.709
UFW	0.813	0.662	Water supplied	0.813	0.048	0.662
Per capita	0.694	0.482	Area	0.954	0.003	0.911
			Population	0.529	0.279	0.28

Table 3 | Water situation in secondary cities

City	Quantity of water Supplied – MLD	Percentage piped water	Per capita consumption – LPCD	Percentage UFW	Percentage metered connections
Ahmedabad	1,210	90	140	23	0
Surat	980	95	140	15	NA
Indore	323	46	98	10	0
Jaipur	374	98.7	125	22	98
Vadodara	401.8	78	156	32	3
Nagpur	625	80	135	19	91.6
Lucknow	675	71	179	54.7	0
Coimbatore	137	88	125	56	30
Nashik	350	95	150	25	NA
Thiruvananthapuram	268	78	100	35	100
Varanasi	276	77	150	35.5	NA
Vishakhapatnam	291	54.9	113	30	2.16

Source: The data are collected from each city's municipal corporations.

close to the national average, i.e. 30%. High quantities of UFW are one of the biggest inefficiencies to plague the water utility system with dissatisfied consumers and poor infrastructure.

Table 4 reports the correlation and linear regression analysis of quantity supplied with the variables of piped water, UFW and per capita consumption of water in secondary cities. It highlights that the quantity of water indicates a strong relationship with piped water but a weak relationship with the UFW. The quantity of water increases with an increase in piped water and not necessarily with an increase in UFW. This observation in secondary cities is similar to the mega cities in India. Similarly, an increase in the quantity of water does not guarantee increased per capita consumption as the two variables have a poor linear relationship.

Similarly, the analysis of relationships between UFW and the other variables like piped water, area of the city and water supplied in secondary cities is predicted in Table 4. Observing the R^2 and correlation value of the three variables of piped water, water supplied and area, we can see that all three have a poor linear relationship with UFW and hence we cannot establish with certainty that a change in one of the variables can explain a corresponding change in UFW.

The examination of the intermittent water situation in urban India reveals that it is highly uneven and inequitable. Some cities like Meerut, Pune, Delhi, and Mumbai, which have the highest per capita water supply, appear to have access to a higher percentage of water than the percentage of the population that they account for (Malakar *et al.* 2018). But at the same time, these cities are among the most vulnerable to extreme water crises. Urban authorities often mention scarcity as the cause of IWS, but it is a multi-dimensional problem since intermittency is often human-driven. The urban water crisis is mediated by other aspects of the population in India like class, religion, region, gender, and caste. Thus, we link IWS with varied social categories.

Table 4 | Correlation and linear regression of piped water, UFW and per capita consumption in secondary cities – UFW in secondary cities

Secondary cities Independent variable: Quantity			Predicted variable: UFW		UFW: Secondary cities (Sample size: 12 cities)	
Dependent variable	Correlation value	Linear regression R^2	Independent variable	Correlation value	*p*-Value	Linear Regression R^2 value
Piped Water	0.98	0.962	Piped water	0.602	0.038	0.362
UFW	0.674	0.455	Water supplied	0.674	0.016	0.455
Per capita	0.359	0.129	Area	0.355	–	0.126

IWS AND THE SOCIAL CATEGORIES: HUMAN-DRIVEN INTERMITTENCY

Social equity in IWS is primarily about people, not water. Water may be allocated equitably, distributed equitably, and even accessed equitably, but if people are unable to derive benefits from it, the end result is not social equity. So, water equity should be judged by the final situation of people, and the distribution of the totality of benefits from water (Peña 2011). Irrespective of the region in an IWS situation, the consumers mostly secure their water supply through storing water during the time of supply. In such conditions, water quality is also affected as pipes are regularly drained and left without pressure between supply cycles, causing contamination. Nevertheless, intermittent supply and its effects on water quality can vary greatly between and within distribution networks as well. The problem of unequal distribution of water is more severe when there is IWS. So, the issue of equity in water supply is one of the major problems. However, equity in water supply is significantly affected by the location of the water tanks and the layout of the network (Gottipati & Nanduri 2014). Various empirical studies comment on how the access, quantity and quality of water vary when overlapped with caste, religion and income levels. The mitigation procedures undertaken by the households to overcome the scarcity and shortage of water are also linked to the socio-economic status. Though access to water is a basic human right and the key to achieve gender equality, and food security at the household level, water shortage continues to persist in the cities across the world. Water scarcity has affected the population of approximately 1.1 billion people. Intermittent hours of water supply force customers to rely on black markets (water mafia) or informal vendors, often serving higher-income citizens, thereby exacerbating inequalities among users and leading to commodification. The commodification of water affects the poor and the vulnerable groups in terms of housing, drinking water, sanitation and drainage facilities. IWS service costs more than regular service, and users bear the brunt of having to pay more to access water services via alternative routes (Charalambous & Laspidou 2017). It also weakens the social contract between governments and their communities when water utilities fail to deliver basic water services, perpetuating a downward spiral of water insecurity and fragility in many developing countries. We experienced this in South Africa in 2002. Riots broke out in Algeria in 2002, civil unrest erupted over use and allocation of water in China in 2000 and riots in Bolivia in 2000 were against privatization of the water system; conflicts over water shortages were reported in Chile, Lebanon, and Mexico in 2021.

Class and IWS

The 69th round of the National Sample Survey (NSS) mentioned that in the year 2012, 94.1% of the households in the Indian slums had improved sources of drinking water. The report also highlights that the cost for procuring water is more for the poor and vulnerable groups as they are not connected to any grid systems or formal water supply networks. These sections of the population are dependent on private water suppliers and they end up paying more than required for the exact quantity of water they have access to. This is visible not only in Indian cities of Delhi but also in the UK where more than 3% of total expenditure to access water is termed as hardship. Empirical work on Asian and African cities illustrates that 11–20% of the total income is spent on access to water. The bargaining power and the political ideology also determine the ease of access to water. Thus, class as a social category does relate to the IWS.

Intermittency also roots a high risk of contamination leading to substantial health hazards. The consumers have to pay the costs, so called coping costs, for additional facilities, such as storage tanks, pumps, alternative water supplies, and household treatment facilities (Totsuka *et al.* 2004). The poor who cannot afford such facilities spend their time fetching water from public taps or vendors at comparatively high total costs.

In Mumbai, lower income households do not have adequate supply of water provided by the municipal corporation and have to resort to illegal measures, most commonly called water theft by the privileged sections of society (Graham *et al.* 2013). Similarly, in the city of Patna, many slum residents are still dependent upon informal sources of water like shallow wells to fulfill their demand for water (Sell 2013). However, the examples of Kerala and Rajasthan in India illustrate that informal settlements have better access to water. This intersectionality between water and class can be best seen in the urban and peri-urban areas of India (Das & Safini 2018) as exemplified by the inequality in access to water. In addition to poor accessibility, the low level of clean drinking water and a lack of information on healthy drinking water practices affect people's immunity and health. The upper- and middle-class community members get access to water by pressurizing and convincing the city officials to sanction water connections in the demanded areas. Migrants, on the other hand, were not a part of the original city plans, hence only receiving municipal services when political representatives perceive them as vote banks. Thus, access to water depends on the social relation to water that is based on the ability of residents to be recognized by city agencies through legitimate water services (Anand 2011, p.8).

IWS along with inequitable water distribution further worsens the status of the vulnerable class as the supply varies from 30 to 40 LPCD in low income neighbourhoods when compared to the 400 LPCD in high income neighbourhoods in Indian cities. On the one hand, there is implicit subsidization of tariffs for the rich through low water rates; on the other hand, there is inadequate coverage of water supply to the poor, hence forcing the urban poor to buy water at higher rates from private sources, turning the essential element for survival into an unaffordable luxury for them. The liberalized real estate market has further exacerbated the water demands. Thus, the main challenge according to Björkman 'is to make water flow to the unpredictable and constantly changing *location* of demand'. While policy perspectives tend to approach urban water questions with engineering and technological solutions, Björkman (2010) foregrounds the politics and power relations embedded in certain configurations of water access and flow across cities like Mumbai.

Religion and IWS

Religious belief plays a significant role in shaping people's opinion about the environment (Jones 2014). Though water is considered precious by every religion, differential religious world views lead to over consumption, pollution, and scarcity. Furthermore, religion can also be a point of conflict in access to water among different religious communities where poor water access may be a deliberate state-led intent to discriminate against a particular religion (Mawani 2019). The 'Muslimness' of Mumbai slums complicates residents' access to water, a fairly commodified and politicized amenity; where water mafia plays an important role in making the state accessible, through the act of supervision and collaboration (Contractor 2012). Similarly, Muslim areas have poor access to municipal water in Ahmedabad. Water forms an essential part of most religious practices in almost all religions. Despite that, there is a paucity of literature on water and its relation to various religions. Today we have moved from sacred to secular water policy management. It has resulted in ignoring the intersectionality of religious sentiments with water (Priscoli 2012). Nevertheless, in India, Srilanka and South Africa, the intersectionality of religious philosophy with water management has produced some interesting case studies on awareness programmes about water conservation and management practices. But from the supply-side religious difference mediates decision-making and outcomes embodied by water distribution related technical plans. Thus, not only IWS but also religion and ethnicity influence the ability of communities to access water (Mawani 2019).

Region and IWS

Intermittency generates inequitable water distribution due to pressure-dependent flow conditions, with obvious disadvantages for consumers located far away from the supply points or at higher altitudes in the area. The location and spatiality of the territories have influence on the appropriation, distribution and exploitation of the water resources. Nevertheless, the state is responsible for formal water supply and distribution networks to ensure everyone is provided with a fair quantity of water, which is safe and clean and in an equitable way. In India, despite focus on cities' water infrastructure, 24×7 continuous water supply in the cities is a distant dream and IWS further makes it inequitable given the uneven pressure conditions especially in the localities away from the reservoirs or the pumping stations. Those consumers farthest away from supply points will always collect less water than those nearer to the source. However, the physiographic constraints resulting in IWS are already discarded by technological developments. Additionally, regional or spatial unequal water access is believed to be human-driven (Anand 2011; Björkman 2015). The work of Anand (2011) highlights that provisioning of water relies on which sections of society demands, fights and receives the usage rights and not simply which altitude the consumer is in. This invokes the narratives of core-periphery, formality versus informality, and explains the 'fluid' nature of the territories and the access to natural resources associated with it.

Gender and IWS

IWS affects women the most both in rural or urban areas as they are the primary users, providers and managers of water in households. Water is often associated with inherent femininity (Joshi 2011). So, men fetching water for the home is uncommon due to the traditional norms, stereotypes and fear of ridicule by other males (Crow & Sulthana 2002; Arouna & Dabbert 2010; Asaba *et al.* 2013).

Where intermittent access to clean water for drinking, hygiene and sanitation purposes exists the communities become more vulnerable to communicable diseases. Women's concerns in the water sector are articulated around their domestic roles and subsumed under notions of household and social equity. The larger questions of the water rights of women, both

Table 5 | SC and ST population

Tap water from untreated source, all India data focussing SC and ST population

S. no.	Locality		Total in India	Total SC	Total ST	% SC from the total	% ST from the total	% SCST
01.	Urban	Near the premises	2,454,542	498,155	141,739	20.29	5.77	26.06
		Away from the premises	638,625	137,990	49,558	21.60	7.76	29.36
02.	Rural	Near the premises	10,566,863	2,365,760	1,118,870	22.38	10.58	32.97
		Away from the premises	2,643,920	594,708	333,673	22.49	12.62	35.11

Source: Office of the Registrar General & Census Commissioner, 2011. https://censusindia.gov.in/nada/index.php/catalog/8480#metadata-description.

in terms of access and control over decision-making, remain unaddressed (Paul 2017). Women have to walk long distances in areas where water is not easily accessible and the fear of sexual assault, particularly at night, is a limitation to water access. So, the impact of differential supply and insecurity is more on women, especially from the poor and marginalized sections, illustrating that the women residents in slums and illegal settlements of Indian cities are affected most by the water problems (Das & Safini 2018, p. 191). Denial of water rights to women results in their deprivation of education, employment and social development. Much literature exists to back the gender-based inequalities in water management in rural areas of India, a similar if not more serious situation exists in the urban informal settlements. The sources of water in most informal Indian settlements like stand pipes, community hand pumps, wells and bore wells are inadequate, unreliable, and time consuming. Thus, the responsibility for the collection of water does in fact act like a roadblock to the wellbeing of women.

Caste and IWS

Caste-based discrimination leading to human rights violations regarding drinking water makes it an important social issue. The hierarchical caste structure within the Indian society affects almost every aspect of life including the access to water. Given the intrinsic IWS system existing in India, caste-based water access complicates the water crisis further. The amount of time spent and the distance travelled for water collection has been consistently higher for the Scheduled Caste and Scheduled Tribe (henceforth SC & ST) communities when compared with other communities (Dutta *et al.* 2018). Access to water is a daily struggle for residents in rural and urban India due to the caste-based discrimination. Krishnaraj (2011) argues that, despite the policy initiatives and attendant programmes to expand access to water users, given our hierarchical society, the conversion of drinking water into a private good adversely affects women and the lower castes and classes.

Table 5 indicates the distance travelled by the residents of the SC and ST communities to fetch water from untreated sources which are either near or far from their homes. It clearly indicates that though the percentage of SC's and ST's accessing water from the untreated source away from premises in rural areas in India is higher than in urban areas, it is not significant when compared with the proportion of other castes in the rural area thereby busting the myth that discrimination with respect to distribution of water is only higher in rural areas.

DISCUSSION

From the review of the IWS situation and social relations of water in India it is clear that the state is pivotal in the water space because it decides the mechanisms of appropriation, distribution and expropriation of water. The state provides access, provision, and distribution of drinking water, sanitation and drainage facilities. With liberalization and privatization, there is a shift in water governance. Though the state has a central role in the social relations of water, water governance has been problematized for over three decades now with changes in the role of the state in water provisioning post-liberalization.

The analysis of social relations and access to water in Indian cities have unpacked relationships that residents have with urban specialists. With water shortages increasingly cutting across class lines and legal statuses, access to municipal water supply in Indian cities is mediated by group identities like caste, gender, religion, space, etc. and actors such as state, political leadership and urban planners are playing very important roles. Thus, IWS is not simply an infrastructural problem but is partly human-driven where social factors are complicating the existing water situation.

Presenting an inquiry of this nature, the account of inequitable water access and severity of effects of IWS based on caste, class, gender and religion offered here is illustrative of how IWS seen as an infrastructural problem of scarcity and availability needs to be understood as a culmination of intense mediations between actors, identities, state and non-state actors with varying interests.

LIMITATIONS

The study is mostly relying on the review of literature to substantiate the claim that social relations of water is crucial in IWS. Though it identifies the human drivers of intermittency, it is not providing any solution to the problem. An inquiry of this nature can only help understate the problem of IWS in a better way providing a fertile ground for future investigation on social drivers of IWS.

CONCLUDING REMARKS

The question which still continues is if there exists a guarantee to provide safe water to the people in the developing countries by resolving the challenges of IWS systems or UFW. The focus of studies and the approaches of the state continue to be intensive towards creation of infrastructure in the form of the water supply networks which further perpetuate the challenges associated with inequality, power structures associated with caste, class and gender. This reinforces the central theme of Björkman and Nikhil Ananda's ethnographic works on the water situation in Mumbai which illustrate that access to water is beyond the economic dimension of water supply. Therefore, the need to merge the economic and ethnographic accounts is crucial to complement the technological interventions to improve the water accessibility and efficiency in the urban water distribution system. This ensures the fundamental right of access to water is upheld and the allocation of water resources and access to water facilities will be beneficial for all members of societies, regardless of their class, race, caste or sex.

DATA AVAILABILITY STATEMENT

All relevant data are available from an online repository or repositories. Population finder | Government of India (censusindia.gov.in), Census tables | Government of India (censusindia.gov.in), India - HL-06 (SC): Households (excluding institutional households) from scheduled castes by main source of drinking water and location, India - 2011 (censusindia.gov.in), India - HL-06 (ST): Households (excluding institutional households) from scheduled tribes by main source of drinking water and location, India - 2011 (censusindia.gov.in), Greater Visakhapatnam Municipal Corporation (gvmc.gov.in), Home - Bangalore Water Supply and Sewerage Board (karnataka.gov.in), Home: Hyderabad Metropolitan Water Supply and Sewerage Board (hyderabadwater.gov.in), Official Website of Delhi Jal Board, Government of NCT of Delhi, India|, About Mumbai - MyBMC - Welcome to BMC's Website (mcgm.gov.in), Home page | Smartcities, Amdavad Municipal Corporation (ahmedabadcity.gov.in), Smart City Indore | Water Supply.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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