https://doi.org/10.26565/2410-7360-2024-61-30
UDC 911.3:351.778.3(540.35-21Гув)
Received 3 August 2024
Accepted 9 September 2024

Water security status and associated challenges in Guwahati city (India)

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ABSTRACT

Introduction. Although cities are becoming increasingly developed in all spheres, there occur formidable multidimensional challenges associated with urban development. One such challenge is the water security, as water in the urban areas is the hotspot in regard to its consumption due to fast growing population on small geographical extent. Moreover, the development of urban water system is unable to keep pace with the rapid growth of population in cities, leaving majority of the dwellers lacking access to water supply system.

The purpose of article. This study intends to identify the problems associated with the urban water systems, its challenges in effective supply of water and the resultant water insecurity at households. It examines the water infrastructures in the city since its development in 1930 on a spatio-temporal context. The impact of prevailing water infrastructures on the status of households' water insecurity has also been assessed.

Research Methods. Google earth engine software was used to visualize the spatial spread of urban water networks in the city. A kml file generated from the Google earth was converted to compatible layer in ArcGIS. Purposive sampling technique was adopted for household survey in three different zones, based on distance from reservoirs, slope, reservoir capacity and number of household connections from reservoirs. Selection of households from different zones under each scheme was done on the basis of consumers of urban water system and water security status. Water security status at households has been assessed through its components, quantity, quality, reliability and accessibility.

Main findings. Water infrastructures have been inadequate since a very long time with just one third of the population having access to the urban water systems. Households reported that enhancing the quantity and quality of water, which constitute vital aspects of water security, requires resorting to diverse strategies, incurs considerable cost and compromises welfare. Moreover, there exists a spatial variation in quantity and quality of water obtained from a shared scheme with increasing distance from service reservoirs/plants. Further, along with poor reliability and accessibility from water supply schemes at households, disparities among different water supply schemes have also been revealed.

Scientific novelty and practical value. The article analyzes for the first time the status of urban water security and associated challenges in the city through primary data and information on water infrastructures. The practical value of the study is the possibility of revealing the spatial variation in quantity and quality of water obtained at households despite a shared scheme or system that can be conducted in other studies of developing countries. The results of the study are significant in the context of justifying measures to strategize security of water at individual level.

Keywords: *Guwahati, water supply scheme, quantity, quality, water security.*

In cites: Hazarika Bharati, Kar Bimal K. (2024). Water security status and associated challenges in Guwahati city (India). Visnyk of V. N. Karazin Kharkiv National University, series "Geology. Geography. Ecology", (61), 377-391. https://doi.org/10.26565/2410-7360-2024-61-30

Introduction

Water supply system forms the backbone of sustainable urban development. However, it is often challenged with multifarious issues particularly in developing countries [40, 5]. Basically, the failure in water supply systems in large cities has been associated with fast growth of population, lack of adequate investments in water infrastructures and declining trend of water resources [12, 15]. These factors exert immense pressure on the existing water infrastructure, if they are mostly obsolete and worn out [19]. Lack of investment in augmenting water supply systems has become a common problem in most of the developing countries, as such it hinders the target of achieving the SDG-6 of "water and sanitation for all" under the umbrella of millennium development goals [36, 41]. Many large cities of developing countries are confronted with lack of universal coverage of municipal water, inadequate water supply, poor water quality, intermittent and unreliable water supply, power cuts, water theft, low pressure in pipes, leakages in distribution system, etc [18, 24]. These challenges are linked with the inefficient water infrastructure system. The obstacles that come on the way towards assured water supply include lack of adequate water source, suboptimal location for setting up of water plant, obstruction in setting up of pipeline network, poor management of the water supply system, lack of adequate monitoring in the supply system, poor quality of supply network materials, etc [22, 38].

Centralized water system and its governance have been the focus areas of research in the recent times particularly in the global south cities considering SDG-6 [3, 40]. Failures in urban water gover-

nance push the city dwellers to increased intensity of water insecurity, basically involving inadequate quantity and quality of water. Ageing urban water systems has considerably reduced its production due to continuous wear and tear of the components, affecting the consumersby gradual decrease in water obtained at households over the years [19]. On the other hand, inadequate information and insufficient monitoring in the distribution system results in frequent leakages of the pipes including disastrous bursts in few cases [21]. Such deficiencies in the distribution system results in substandard water supply, leading to decrease in quantity and deterioration in quality of water, reaching the consumers [42]. A developed country like the United States was reported with approximately 18 per cent of the outbreaks caused from water quality failure due to contaminants entering into the distribution system through leakages [8]. A progressive society in all aspects depends on the reliable quality ~~in~~ and adequate quantities of water. Wastage of water through cracks, leakages, faulty valves, illegal connections, thefts in the distribution system was estimated to be more than 40 % in developing countries, leading to remarkable volumes of water loss [42]. Water quantity, one of the prime components of water security, tends to be inadequate with decreased pressure in pipes due to flaws in the distribution system as evident in Delhi [23]. Temporary and prolonged suspension of water supply from a centralized water system has become a common phenomenon in cities of developing countries [21]. Households strategize alternate source of water along with municipal water systems due to reduced accessibility and reliability from the same [44]. It is therefore important to investigate and understand the challenges encountered by the providers and consumers to effectively address the issue of water insecurity, significantly hindering societal and well being of the residents [6].

Urban water provision and governance constitutes vital aspects of development, supposedly ensures water security to the populations. Guwahati city, characterized by rapid urbanization during the last few decades has posed a challenge on the urban water system. Presently the city has populations of more than a million as per estimation. The city is located at the southern banks of Brahmaputra. At the initial development of the city population were concentrated in the north central part of it, along the immediate banks of Brahmaputra, indicating water needs fulfilled by it. The earliest form of the city was a small town with a geographical area of 2.68 sq. km, consisting of only 8wards with 11,661 population~~s~~ during 1901 Census [7]. At that time the town was confined to the north central part of the present Guwahati. With the development of communication networks and establishment of provincial institutions and divisional offices the town began to assume commercial, educational and administrative importance in attracting population from the neighboring districts and other states of India. The growing population and subsequent spatial expansion–contributed expansion of municipal area to 7.68 sq. km in 1903 by including three more wards to its earlier eight wards. Accordingly the water plants got constructed in those areas and its governance was also confined to the places of important establishments. The town grew to double in its geographical area by including three more wards to its earlier 11wards, totaling to reach a total area of 14.24 sq. km in 1961. In response to growing population by inclusion of large areas into municipal boundary the water infrastructures also got developed, although not in tandem as per demands. Again in 1974, after converting the town into municipal corporation the total jurisdiction of the city area rose to 216.79 sq. km with 34 wards. The shifting of the state capital from Shillong (Meghalaya) to Dispur area of Guwahati (Assam) in 1972 had set the trend of rapid growth of the city. Thus the inclusion of villages into the city limit has indeed increased the demand for water supply services. It may be noted that during the process of growth, the city expansion of the town took place towards south, east and west in a semi-circular way. In this way as per demands the water infrastructures also got constructed in the city since 1930; but multiple challenges stood on the way of smooth operation of the water supply. Moreover, spatial variation in quantity and quality of water at households has been an alarming cause of concern in the city since long. Inadequate fund has been identified as the prime obstacle to restore, renovate, manage and augment the municipal water systems. Such challenges are faced by both the providers and consumers of water supply, and in this way both parties often get criticized on the ground that municipal water authorities are often deemed irresponsible and consumers are also frequently criticized as it is hard to satisfy their demands. It may be noted that water supply services in the city are able to cater only just one-third of the population [16]. Therefore, understanding the challenges of both the parties is essential to address the issue in a more sustainable manner.

Materials and Methods

This study has been based on primary and secondary data collected during 2022-2024. Primary data was collected at household level with respect to household size, frequency of households obtaining water per week, average liters of water obtained, hours of water supply, frequency of water supply per day, time of water availability (morning or evening), alternate sources of water to supplement shortages, etc. The secondary data collected from different institutions in the context of the study area includes location and number of water plants and its service

reservoirs, capacity and production of water, ground water information, etc. The primary survey was conducted using a structured schedule-cum-questionnaire ~~at~~in506 households through a purposive sampling method covering different categories of water supply systems. Data were collected from three different categories of households, such as households near to reservoirs (Zone I), households located in midpart of the distribution system (Zone II) and households located at the extreme or tail end of the distribution system (Zone III). The sampled schemes were 25, which include different types such as old and new schemes including DTWS. The sampled schemes were chosen systematically based on their types of schemes such as capacity, number of connections, locations of reservoirs, distance and elevation to represent the consumers of urban water systems. From each water supply schemes on an average ~~of~~21 households were selected from three different parts of the distribution system (Zone I, II & III). This method represents the total consumers of water supply system who experience inequalities in obtaining water from such urban water systems. This method was followed to understand inequalities of water obtained at households away from the service reservoirs.

The collected data were processed and tabulated using Excel software to compare and contrast among different water supply schemes for different aspects of water security. Google Earth was used to locate the water plants and their service reservoirs. A kml point data (keyhole markup language) as a file was converted to vector file in the ArcGIS platform to visualize the spread of different water supply systems in the city. Water samples taken from the household taps were analyzed in the laboratory, which were then summarized and presented in tabular form for different categories of households (Zone I, II & III) to see variation in water quality with distance from service reservoirs. The parameters include pH, total dissolved solids (TDS), total hardness, calcium, residual chlorine, magnesium, iron, fluoride and turbidity which were analyzed in Public Health Engineering Department Division I, located at Bamunimaidam, Guwahati, Government of Assam. A combination of physical and chemical analysis was performed on the samples using turbid meter, litmus paper and titration method for determining concentration of turbidity, pH, hardness and chlorine. The other parameters were analyzed using conductivity or UV detection, titration method using EDTA (chelating agent) and spectrophotometer for TDS, fluoride, magnesium and iron respectively.

Study area

Guwahati city, located in the north-eastern part of India is one of the largest and fastest growing cities in the region. The city currently accommodates more than a million population~~s~~ (estimated based on 2001-2011 growth rate) in 216.79 sq. km and it is bordered by Brahmaputra in the north. Apart from the presence of mighty river, large and small wetlands are dotted sporadically including three small rivers (tributaries of the Brahmaputra) in the city, suggesting ample water resources for the dwellers. On the other hand, ground water deposits found at shallower depths has been a great resource for the dwellers considering the spatial variation of municipal water networks.

The city draws water from two sources, the Bramaputra and ground water within its municipal boundary. Although other small rivers such as Bharalu, Mora Bharalu, Khanajan, Basistha and Bondajan flowing through the city are not being directly used for water supply, but plays a significant role in recharging of ground water, by more than 65 % of the city dwellers. Similarly wetlands either big (including Deeporbeel, Ramsar site of India) or small in different parts of the city also elevates the ground water level, beneficial for constructing deep tube well schemes (DTWS) to supply water to households deprived from the Brahmaputra-based schemes. The city has 135 water plants, but only 34% of the city population has access to the urban water system.

Results and Discussion

Challenges among the Providers

Water infrastructures are essential investments for a livable city, a pre-requisite for health, prosperity and security of a nation. Reliable and secured water infrastructures require~~s~~ long-term economic inputs that are planned, designed and constructed over time considering current and future growth and development of the city [10]. An urban water infrastructure generally consists of three basic components: the source of water supply, the processing or treatment of the water (water treatment plant) and the distribution of piped network to the users. Water infrastructure/services in Guwahati are numerous, which are maintained by the municipal authorities and a few by the local communities. A total of 135 water plants, large and small are operating in different parts of the city and while distributing to the consumers various challenges occurs.

Obsolete water plants

Water plants in developing countries are characterized by old, poor, and broken components, resulting in reduced production of water than its designed capacity [46]. In fact, the water plants have outlived its engineering life (functioning for more than 30 years) [19]. Similarly, in Guwahati the water plants are unable to produce water as per its designed capacity (Table 1). Except for the newly established water plants (SWGWSP & SCGWSP) others are unable to produce as per designed capacity due to malfunctioning of important components. Therefore, lack of renovating the vital components of water plants has often resulted in interrupted and reduced quantity of

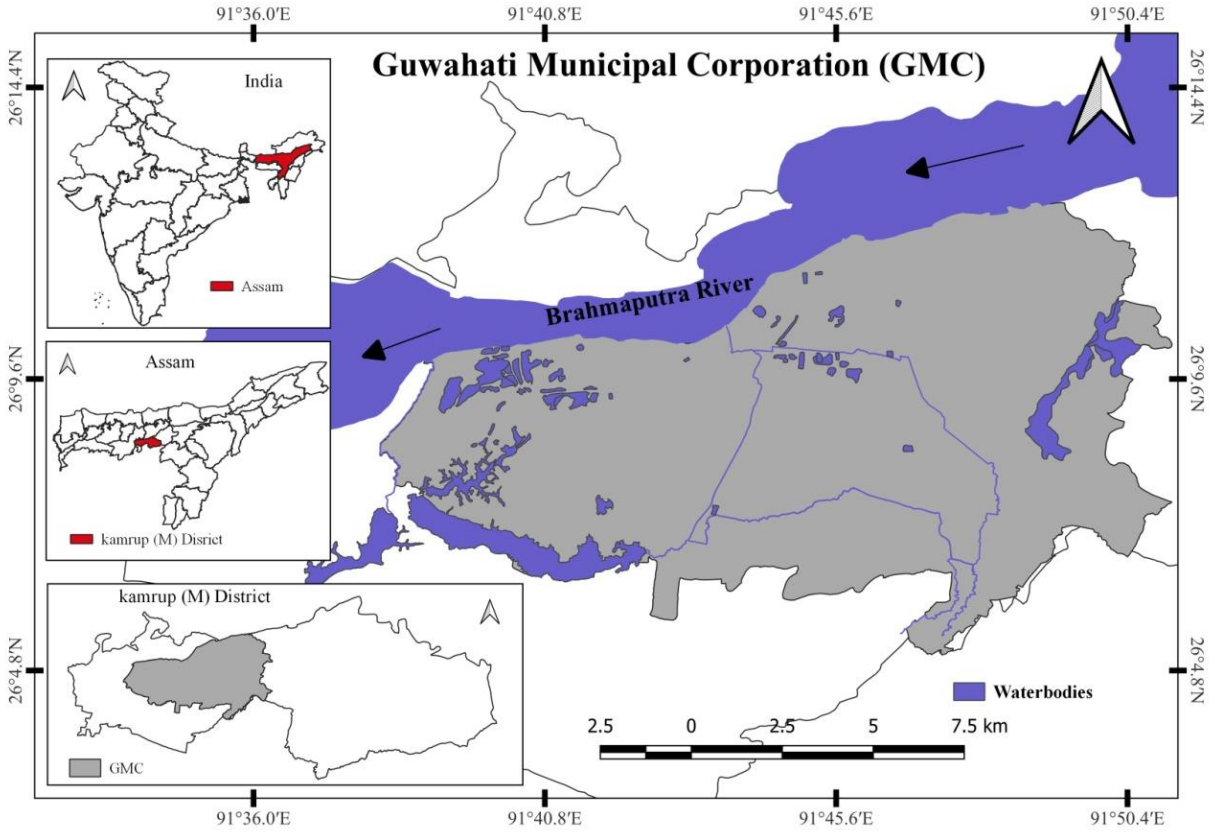

Fig. 1. Location of the study area

Table 1

Capacity and production status of water plants in Guwahati

Location of water treatment plants	Year of Commissioning	Designed Capacity (in MLD)	Production of water (in MLD)	Gap of production (in MLD)
Panbazar	1963	45.00	25.00	20.00
Satpukhuri	1930 (Renovated in 1984)	22.50	15.00	7.50
Kamakhya	1992	4.50	3.50	1.00
Lichubagan, Hengerabari (GMDW& SB)	1996	12.60	7.50	5.10
Sadilapur, Jalukbari (SWGWSP)	2018	107.00	20.00	87.00
Kharghuli, Uzanbazar (SCGWSP)	2022	191.00	63.00	128.00
DTWS-GMC-WWW	Since 1983	1.50	1.16	0.34
DTWS- PHED-I	Since 1957	14.19	8.63	5.56
DTWS- PHED- II	Since 1960	8.97	4.67	4.3
Total		**400.10**	**148.46**	**258.80**

Source: Different water supply agencies in Guwahati Metropolitan Corporation, 2024

water supply, low production of water leaving many households deprived of water supply network.

Pipeline cracks/ leakages/ bursts in the distribution system

Leakages in the distribution network are a common phenomenon in Guwahati which have a significant impact on the quantity and quality of water supply. Another compromising effect is the suspension of water supply, when repairs are undertaken, otherwise innumerable cracks and leakages are left unde-

tected which considerably tends to decrease pressure in pipes. On the other hand, such leakages are the pathways for transmission of unwanted and contaminated elements into the pipelines, resulting in inadequate quality of supply water [13]. The faulty valves lying along the drain is also frequently identified upon receiving complaints of poor water quality. The old water supply schemes are challenged with frequent occurrence of either cracks or leakages; the SWGWSP and SCGWSP however are associated with bursting of pipeline network due to poor quality of materials. Bursting of pipes or valves can result in a significant upward flow of water, consequently damaging loss of human lives and property in different parts of the city along with occurrence of flash floods, traffic disruption, etc. In May 2023 a disastrous bursting incident from SCGWSP resulted in the loss of two human lives and left around 30 people injured including loss of property of at least 40 houses [28]. Thereafter also multiple bursting occurred in different parts of the city causing infrastructural and property damage.

Fig. 2. Pictures depicting pipeline leakages and bursts in Guwahati
(Source: Internet and author, 2022-24)

Illegal water connection or water theft

There are many unauthorized connections from water networks of municipal water supply system in Guwahati. This type of water theft frequently goes undetected by water authorities and it has consequent effect on pressure in pipes in the adjacent areas [28]. Water is stolen by installing water pumps or booster to enhance pressure in pipes in an attempt to obtain desirable quantity of water. Despite residents' suspects and complaints about installation of water pumps for water theft leading due to unusual pressure fluctuation in the pipes, the concerned water authorities are unable to detect such malpractice in most cases. Although water suppliers have the authority to locate and remove water pumps, the residents hide so effectively that detection remains challenging.

The water authorities have introduced grievance cell to manage water theft complaints including imposition of penalties on the people involved in such theft. But, the number of thefts has not declined as reported in various print and electronic media. It may be mentioned here that water theft has been addressed in many cities of developing countries by strict metering system and proper field audit [25]. However, it remains a matter of great challenge to overcome the issue of water theft in Guwahati city due to lack of metering system and unskilled man power in recording audit system.

Inadequate funds

Maintenance of the infrastructure necessitates timely renovation and augmentation that demands consistent flow of funds [5]. It is observed that a considerable number of households in the south-central, south-western and eastern parts of Guwahati city are deprived of urban water networks due to huge cost involved in setting up of water plants. However, in other large cities of India majority of the populations has access to the urban water supply system [33, 44]. Moreover, renovation activities are greatly affected due to lack of requisite funds from the concerned authorities. Even the leakages occurring in the distribution system are not concealed due to lack of funds

until they go beyond control. Moreover, the outlived water plants that require thorough renovation have also not been considered, otherwise it could have produced water as per its designed capacity (Table 1). The Brahmaputra carries high silt and it affects materials of water pumps during procurement of the silt-laden raw water. In view of this, the water pumps get damaged and defunct leading to temporary suspension of water supply. The shortage of required funds has also delayed scheduled completion and full commissioning of SCGWSP & SWGWSP in the city. In fact, although there has been continuous efforts with respect to these two projects to extend the supply network in the proposed command areas, shortage of funds stands on their way of completion and commissioning. Power cuts is also an added problem in ensuring uninterrupted pumping of raw water, which could have been mitigated provided there is dedicated power supply exclusively for pumping operations. Therefore, in totality lack of funds pose long-term challenges, which the old schemes are facing at present.

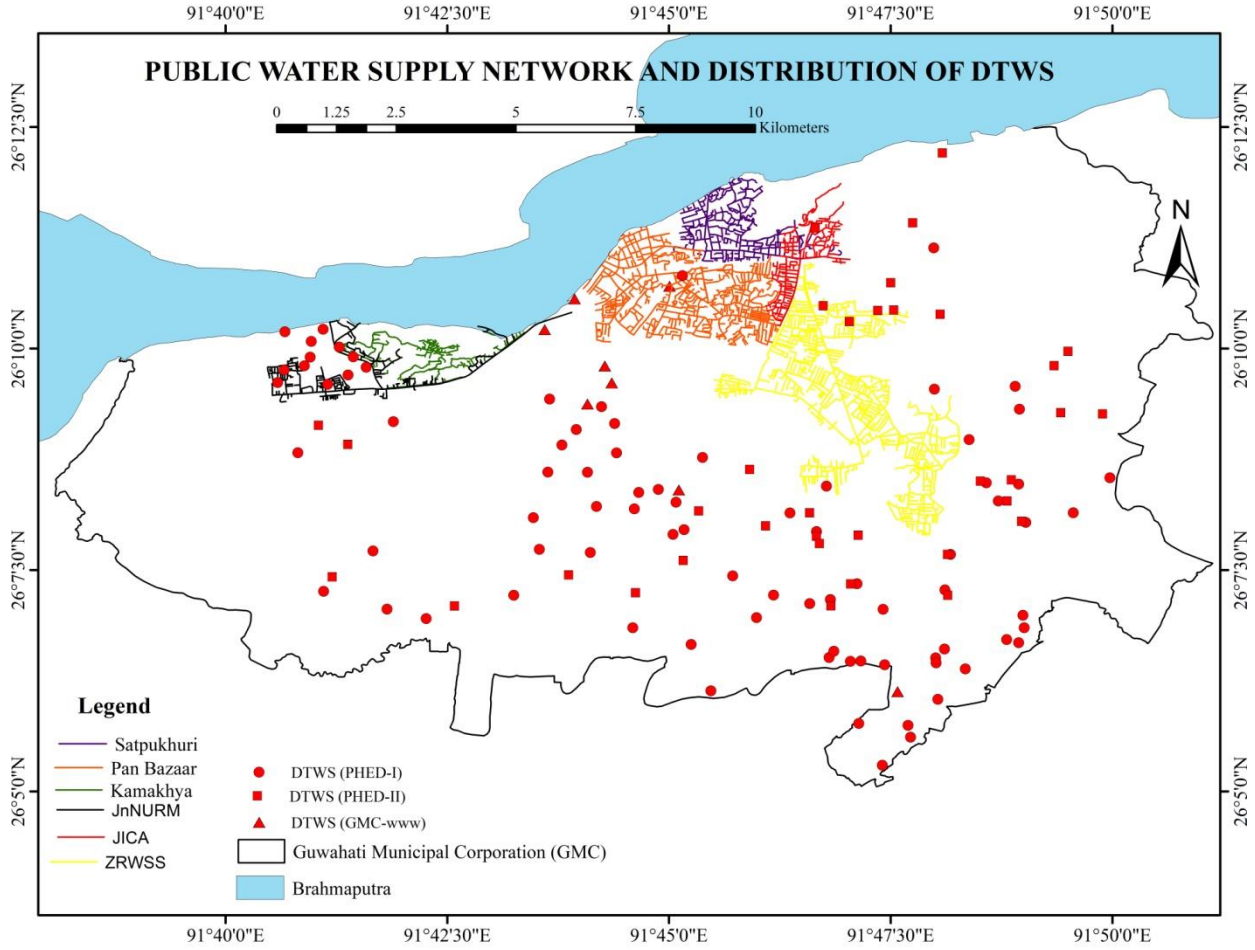

Fig. 3. Public water supply network and distribution of DTWS

Natural calamities

Most of the water infrastructures in Indian cities lack resilience to disasters due to their poor engineering design and management [9]. Occurrence of heavy rains followed by landslides damages the vital components, such as main pipeline through which water is pumped to various reservoirs. Restoration work of such damaged pipeline in the landslide hit area takes a considerably longer time leading to suspension of water supply for more than sixty days [37].

Declining water resources

The Deep Tube Well Schemes (DTWS) being developed in the course of time indicates that such small schemes are important in areas devoid of mega public water supply systems. This has led to heavy extraction of ground water to cater to the needs of ever increasing demands consequent upon declining ground water levels. The declining trend of ground water resources results in uninterrupted supply of water to households and even temporary suspension of supply. Some of the DTWS, particularly in the eastern part of the city, get defunct over time due to lowering of water table and authorities takes the responsibility to find another location of water source to resume water supply. It however takes a considerable time for resumption of water supply and no alternate supply is available during such period of restoration.

In this way a variety of challenges emerges before the providers of urban water supply, viz. political, natural, manmade, etc, towards aiming at ensur-

ing water security for the dwellers of Guwahati city.

Problems of Water Security among the Consumers

Quantity of Water Supplied at households

In developing countries water quantity received at households from the urban water system varies across its different command or supplied areas [2, 44]. The water supply patterns in Guwahati vary among different water supply schemes as testified by consumers during field survey. Nature of water supply to households is intermittent as all the schemes operating in the city are able to provide three or four times only per week, except the SWGWSP and SCGWSP. In the past (at least 10-15 years back) respondents obtained water daily, but now water is supplied to households thrice a day or sometimes twice (during various crisis situation) due to increasing household connections from water supply system. To maintain equity for all households intermittent supply strategy is adopted by providing water in phases at different time period (morning and evening) of the day with limited hours of supply. Sometimes due to scarcity of water resources intermittent supply service has become the norm [20]. However, in the present study intermittency has been associated with inadequate infrastructures. Earlier the frequency of water supply in a day was twice, but now for the last many years it has reduced to just once and that too with uncertain time of the day. As the water supply to households is not regular, the city dwellers often have to reschedule their activities or to wait for resumption of water flow in taps.

Table 2

Daily water availability patterns at household level in Guwahati city

Water supply schemes	Number of sampled households	Average number of days water received per week	Average range of number of liters in a single supply per day	Average hours of water supply (in minutes)	Frequency of water supply in a day	Time of water availability
Panbazar	67	3	400- above 3000	45-90	1	Morning & evening
Satpukhuri	84	3	300-3000	40-90	1	Mid-morning & evening
Kamakhya	23	4	500-2500	30-50	1-2	Mid-morning & evening
Lichubagan, Hengerabari (ZRWSS) (GMDW& SB)	19	4	800-4000	60-120	1	Morning & evening
Sadilapur, Jalukbari (SWGWSP)	25	7	1500	60-90	1-2	Morning & evening
Kharghuli, Uzanbazar (SCGWSP)	24	7	1500	60-80	1-2	Morning & evening
DTWS-GMC-WWW	19	3	500-1500	40-50	1	Morning & evening
DTWS-PHED-I	178	3	200-1500	30-60	1-2	Morning & evening
DTWS-PHED-II	67	3	200-1500	40-60	1-2	Morning & evening

Source: Primary Survey, 2022-23

The households obtaining volume of water from a shared scheme varies in such a way that some households receive more than 3000 liters in a single supply, while some others with less than 500 liters. Such a low quantity of water to some households is found in the case of Panbazar and Satpukhuri water supply schemes. The households close to the water reservoir get adequate pressure in pipes and therefore receive water more than the national standard (135 lpcd). However, in the middle part and tail end part of the distribution system water availability gradually reduces due to poor pressure in the pipes. This phenomenon is attributed to household connection more than its designed capacity, water theft in the upper part (zone I) by installing booster in taps, illegal connection and unnoticed cracks and leakages in pipes. Water availability at the households for the tail end part goes down to 300-400 liters per day for a 4-5 family size, and also provided only thrice a week, demanding family members to use water conservatively and compromise sanitation. Water is provided once for a maximum of 90 minutes to the tail end part of the distribution system, while the households close to reservoir receives water more than 3000 liters in less

than 45 minutes. The remaining water in the pipes of distribution system flows to the tail end with least pressure which last for 90 minutes to those households. Similar is the case with respect to Kamakhya water scheme and ZRWSS, where quantity of water obtained at households varies significantly. The DTWS also provides water in similar pattern. Sometimes it is provided twice a day. This practice however allows recharging of ground water. Contrastingly, the consumers of new water supply projects get adequate volume of water daily. The SWGWSP and SCGWSP provide water twice a day so that all households of these this projects get equal volume of water unlike the old schemes in the city. Moreover, these two projects are supplying water daily to ensure water security. Therefore, it is evident that there exists a marked disparity of water availability among the households even drawing water from similar shared schemes.

The prevalence of disparities in household water availability, measured in liters per capita per day (lpcd) sourced from municipal supplies, is a notable phenomenon observed not only in India but also in other developing nations [38]. Guwahati city is facing uneven distribution of water supply with substantial variation in per capita, supply hours and water pressure. This inequality in water availability is a function of slope and distance from the service reservoirs. The households located at higher elevation than the reservoir receive relatively less volume of water due to decreased pressure. However, mechanical water pumping system can help address this issue, a practice which is confined to only few locales due to the cost implications. The households located at higher elevation than the service reservoirs adopt this technique to maintain adequate pressure in pipes.

Table 3

Disparity in water availability at households within a scheme in Guwahati city

Water supply Schemes/Project	Zone I		Zone II		Zone III	
	No. of sampled households	Average water obtained (in lpcd)	No. of sampled households	Average water obtained (in lpcd)	No. of sampled households	Average water obtained (in lpcd)
Panbazar	24	188	20	100	23	50
Satpukhuri	27	170	30	80	27	38
Kamakhya	7	157	7	125	9	63
Lichubagan, Hengerabari (ZRWSS) (GMDW& SB)	7	182	6	110	6	80
Sadilapur, Jalukbari (SWGWSP)	10	250	7	188	8	167
Kharghuli, Uzanbazar (SCGWSP)	8	220	8	180	8	165
DTWS- GMC-WWW	6	120	7	95	6	45
DTWS- PHED-I	61	110	59	78	58	43
DTWS- PHED- II	23	125	21	100	23	65
Total	**173**	**170**	**165**	**118**	**168**	**80**

Source: Primary Survey, 2022-23.

The households categorized as Zone I generally tend to have desired pressure in pipes and therefore obtain adequate water. These households on an average obtain 170 lpcd, which is above the national standards (135 lpcd) for maintaining proper health, sanitation and hygiene (Table 3). Although water is not provided daily, the households located in this zone are able to suffice their daily water needs by collecting and storing it for dry pipe days. The intermediate zone (Zone II) tends to have decreased pressure in pipes with consequent decrease in volume of water obtained by the households. This decreased pressure is attributed to increased number of house service connection in the initial part (Zone I) of the distribution system. The average water obtained in this intermediate zone is 118 lpcd. However, there is marked disparity between the schemes, where the water obtained is less than 100 lpcd in the Satpukhuri and DTWS (GMC and PHED-I) (Table 3). Moreover, the households connected to the SWGWSP and SCGWSP are able to obtain adequate water despite increasing distance from service reservoirs due to their efficient supply system. It has become a challenge for the households to cope with low volume of water obtained in zone II. In contrary to Zone I, the Zone III (tail end) part of the distribution system has the least pressure in pipes due to greater number of connections and leakages in the upper part. The

households falling into this zone endure with the supply system as they obtain the lowest volume of water with an average of 80 lpcd. Hence, the distance from the service reservoirs plays an important role in keeping inequality of water quantity per capita and the challenges of inadequacy within an urban water system.

Quality of Supply Water at households

The health and wellbeing of an individual depends upon the quality of water consumed. However, lack of adequate supply of safe drinking water among the people in most of the developing nations greatly affects their welfare and development. [31]. But the irony is that today more than 50% of the global city dwellers do not have access to safe water [41]. In the case of Guwahati city its distribution network is characterized by ageing pipelines, corrosion and leaching of pipe materials, intrusion of contaminants and unwanted solid particles through cracks and leakages, formation of biofilm in the pipes, etc. All these issues affect the water quality in varying spatio-temporal terms [11, 35]. The water quality is also found to vary within the distribution systems of three supply zones (Table 4) from service reservoirs to the consumer taps.

The most common pollutants and problems detected in the supply water of Guwahati city include Total dissolved solids, Total hardness, Calcium, Residual chlorine, Magnesium, Iron, Fluoride and Turbidity as well as bacterial contamination [16]. The pH value, another crucial parameter in water chemistry, was also analyzed to measure its alkalinity level. The above mentioned issues in supply water are not visible to the naked eyes, excepting chlorine, iron and turbidity, which can be distinguished by the consumers. The ageing water networks are the pathways for intrusion of unwanted contaminants (solid and liquid particles) through cracks and leakages and formation of biofilm due to intermittent nature of water supply [4,35].

Table 4

Spatial variation in water quality at households within a distribution system

Water Quality / Zones		Water Supply Schemes/Project									Total
		Panbazar	Satpukhuri	Kamakhya	Lichubagan, Hengerabari (ZRWSS) (GMDW& SB)	Sadilapur, Jalukbari (SWGWSP)	Kharghuli, Uzanbazar (SCGWSP)	DTWS- GMC-WWW	DTWS- PHED-I	DTWS- PHED- II	
		Mean Concentration (mg/L and NTU)									
Zone I	Chlorine	7.5	9.7	6.8	5.4	2.4	2.6	3.4	3.5	3.9	**5.02**
	Turbidity	3.91	3.66	3.1	3.61	3.47	3.12	0.34	0.97	0.95	**2.57**
	Iron	0.14	0.21	0.1	0.15	0.08	0.11	0.64	0.87	0.74	**0.33**
Zone II	Chlorine	0.31	0.54	0.26	0.37	0.38	0.29	0.54	0.46	0.27	**0.49**
	Turbidity	4.87	3.74	2.98	2.58	4.11	4.16	0.74	0.81	0.84	**2.76**
	Iron	0.1	0.1	0.07	0.07	0.05	0.08	0.59	0.47	0.64	**0.24**
Zone III	Chlorine	0.09	0.02	0.19	0.21	0.26	0.21	0.31	0.28	0.11	**0.18**
	Turbidity	4.91	5.24	4.1	3.14	4.13	3.97	0.81	0.72	0.87	**3.10**
	Iron	0.08	0.11	0.1	0.07	0.06	0.08	0.61	0.56	0.63	**0.25**

Source: Primary survey, 2022-23

Reliability of supply at households

Reliability of supply water is measured with respect to its adequacy in quantity and quality. Unreliability in water supply is mitigated through various coping strategies adopted by the consumers [44]. Many of the households in the city have devised some alternative ways to enhance water security besides municipal water, which illustrate about the responses to unreliability of water supply in Guwahati.

Extraction of ground water in Guwahati city has exceeded the safe limit with more than 65% of the populations derive water from it, as a common pool resource [19]. Many residents go for digging of wells as their first option and this strategy is being employed exclusively by majority of the households across the city (Table 5). As there are numerous options, the city residents use more than one strategy, some are adopted by larger number of households and others are chosen by only a few depending on their feasibility. Although zone I obtains adequate

Table 5

Accommodating water supply unreliability at household level in Guwahati

Zones	Coping Mechanisms	Water Supply Schemes/Project								
		Panbazar	Satpukhuri	Kamakhya	Lichubagan, Hengerabari (ZRWSS) (GMDW& SB)	Sadilapur, Jalukbari (SWGWSP)	Kharghuli, Uzanbazar (SCGWSP)	DTWS- GMC-WWW	DTWS- PHED-I	DTWS- PHED- II
		Households (in %)								
Zone I	Dug wells	37.51	39.14	3.61	21.36	14.21	31.24	31.21	11.31	32.14
	Tube wells	9.62	14.52	0.00	11.27	15.63	21.62	21.52	16.53	28.74
	Communal bore hole	0.00	0.00	0.00	2.31	0.00	11.21	0.00	0.00	0.00
	Buying of water	0.00	1.24	9.54	15.21	0.00	14.21	10.24	15.21	3.64
	Storing of water	14.21	13.62	17.52	0.00	0.00	0.00	14.12	8.52	6.74
	Rain water harvesting	12.17	1.32	21.19	19.87	0.00	13.25	9.87	17.21	15.42
	Conserva-tional be-havior of water use	0.00	0.00	15.87	12.31	0.00	8.87	15.24	12.36	27.21
Zone II	Dug wells	46.31	51.26	6.21	38.12	19.87	43.64	26.63	16.34	33.34
	Tube wells	11.62	21.63	3.51	21.23	8.63	19.51	8.62	18.54	16.92
	Communal bore hole	6.37	8.74	0.00	8.74	0.00	10.26	0.00	0.00	25.34
	Buying of water	15.62	21.63	8.30	25.10	0.00	21.60	12.31	18.67	18.54
	Storing of water	31.52	27.58	38.24	37.21	0.00	21.14	26.54	30.25	26.34
	Rain water harvesting	19.64	25.87	31.25	30.21	0.00	18.79	18.63	27.89	31.25
	Conserva-tional be-havior of water use	9.87	6.87	20.14	10.35	0.00	10.32	20.31	13.64	25.17
Zone III	Dug wells	65.21	68.76	20.15	50.16	10.24	45.64	35.16	40.12	37.25
	Tube wells	18.67	20.85	8.74	30.24	15.23	30.14	14.26	25.87	21.37
	Communal bore hole	14.32	25.14	0.00	20.10	0.00	18.96	0.00	0.00	3.54
	Buying of water	20.62	30.14	5.34	35.45	0.00	27.56	13.65	24.63	26.36
	Storing of water	35.63	37.28	53.31	68.78	10.34	35.60	41.25	63.32	58.25
	Rain water harvesting	15.60	15.58	23.34	38.25	0.00	35.63	48.35	46.36	35.37
	Conserva-tional be-havior of water use	33.32	35.63	34.85	41.25	10.36	27.89	25.28	23.68	29.68

Source: Primary survey, 2022-23 and water supply agencies, 2023.

water from municipal supply, dug-well is used to enjoy liberal washing and cleaning by a large number of households than other options. But, with increasing distance from service reservoirs the dependence on dug wells/tube wells increases due to decrease in the quantity of water obtained from municipal supply (Table 5). These sources supplement shortages to some extent on daily basis. Storing of water and rain water harvesting are also found to comparatively higher in zone II. Small storages like drums, cans and buckets are used to store municipal water for emergency requirement or at the times of supply interruption. The use of strategies among the consumers in zone III is found to be more than the other zones (Table 5). Conservational attitude of water usage is also much higher at the extreme parts of water supply networks. The households categorized in this zone practice storing of water as a precautionary measure for dry pipe days. It needs to be mentioned here that the households connected to the SWGWSP are equipped with sufficient water provisions, and to supplement shortages in the case of extreme events the shallow depths of ground water in western part of the city suffice the crisis.

The study reveals that more than 63% city dwellers use~~s~~ electronic water purifiers. Of these households, 56% use chlorination (bleaching powder) in their over head tanks to prevent bacterial contamination and this is more prevalent in households with increasing distance from the service reservoirs. These households practice this method, because the officials of water authorities have suggested them to use it to prevent possible contamination. Another 20% of the households filter~~s~~ water through conventional filtration systems, typically equipped with candles. Around 14% of households purify water through boiling in view of its health outcomes. More than 3% of the city households spend extra money on purchasing packaged mineral water exclusively for drinking purposes with a view to remain safe from waterborne diseases. The packaged mineral water has so far reported no adverse effects and hence some rich people confidently consume this packaged water. It is therefore clear that the city dwellers practice different alternative ways to enhance water quality depending on their capability, feasibility and practicability.

Accessibility of water supply

One of the key determinants of health outcomes

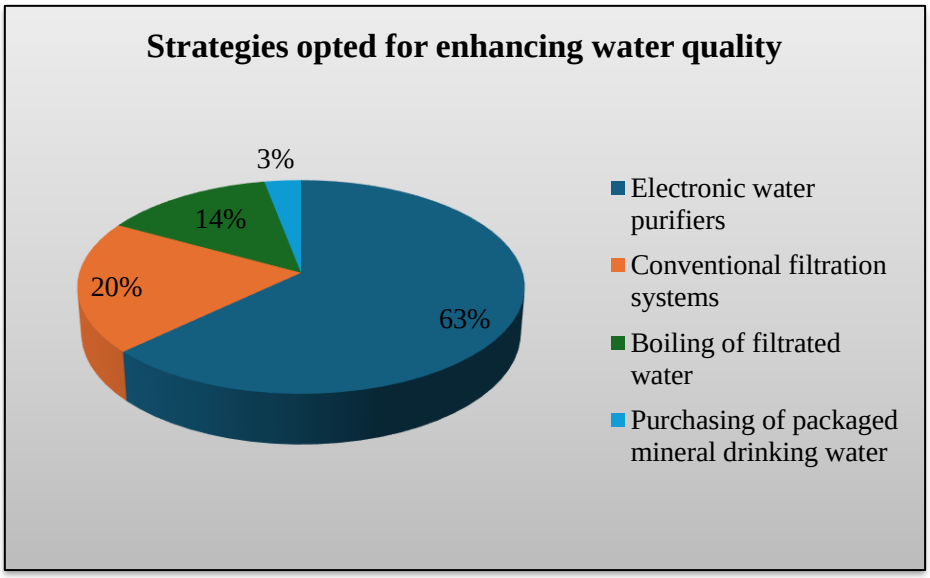

Fig. 4. Strategies devised by households to enhance water quality

is access to clean and adequate water among the city dwellers in relation to socio-economic background. However, there remains a challenge among the consumers in achieving equitable access to water. Empirical studies conducted in this respect reveal that economic differentials are the root cause of such unequal access to municipal water, apart from location of households away from water supply systems [26, 29]. Although municipal water supply network is confined ~~in~~to some parts of the city, all households within the command area has do not have access to it. In fact, a large proportion of low income households is deprived of required access to municipal water. Contrastingly, although the high income households can easily afford the cost of water supply, the water supply networks still remain~~s~~ inaccessible to those households. Such circumstances indicate that affordability alone cannot necessarily be always correlated with accessibility.

The household survey further reveals that the socio-economic factors like education, household size, age and gender of the household head, income, etc play~~s~~ a significant role in procuring municipal water connection [1, 26]. However, in Guwahati city accessing water from the urban water supply systems is primarily determined by wealth of the households.

However, there are few households in the city which despite low income have access to water supply. In fact, such households took municipal water supply connection long back during the periods of comparatively better incomes. It is further observed that the higher income households with large family size or large number of water users, such as tenants in rental properties, avail water service connection with larger diameters in attempt to ensure adequate volume of water for all. Hence, variation in income level among the city dwellers greatly influences the degree of access and adequacy of water in different parts of Guwahati city.

Water accessibility, which is defined as the ability of households to ensure adequate quantity of water at an affordable price, [1, 2] varies spatially at household level across Guwahati city among different water supply schemes. The household survey reveals that more than 50% are challenged with inadequacy of required water (Table 6). It is observed that the newly established residential high rise complexes in the western and north-eastern parts of the city are benefited with adequate supply of water from SWGWSP and SCGWSP respectively. But, the remaining water supply schemes in the city can hardly provide sufficient water to 50% of the households under their command. As the old and conventional water supply schemes are functioning mostly below their designed capacity, to supply water to the consumers exceeding the production capacity, the volume of water supply mostly remains insufficient to the users leading. Hence, to ensure equitable access to water, the supply schemes should be thoroughly renovated and properly maintained by overcoming all challenges arising from their infrastructural inadequacy.

Table 6

Spatial variation in accessibility of water supply at households

Water supply Schemes/Project	Households obtaining adequate water (in %)
Panbazar	41.80
Satpukhuri	32.14
Kamakhya	34.78
Lichubagan, Hengerabari (ZRWSS) (GMDW& SB)	42.10
Sadilapur, Jalukbari (SWGWSP)	100.00
Kharghuli, Uzanbazar (SCGWSP)	100.00
DTWS- GMC-WWW	31.57
DTWS- PHED-I	55.06
DTWS- PHED- II	32.83
Total	**48.62**

Source: Primary Survey, 2022-23.

Besides the above, an analysis of multiple dimensions of water security status in Guwahati city reveals that the municipal water supply system is still inadequate for the city households particularly in terms of quantity.

Conclusion

The foregoing analysis reveals that the urban water system in Guwahatihas been struggling with multiple deficiencies, resulting in low accessibility, poor quality and compromised reliability of water supply. The water production level is significantly below their designed capacity due to ageing of water plants and lack of proper management practices contributing to only 34% of the city population having access to urban water system. Additionally, leakage in the distribution system has greatly affected the quantity and quality of water obtained at households, reducing reliability on urban water supply. Such a situation is indicative of the fact that the water supply system is given least priority in the development agenda of the city corporation. Considering the outlived urban water systems and slow development of supply network in the recently commissioned water supply projects, the city authority can propose a policy for decentralization of the water supply network to cover more area and population. Such attempts can address the sustainability of the system and ensure water security among the city dwellers.

This study presents a detailed account on the cause and effect of water insecurity with a view to explore necessary coping strategies to overcome the prevailing challenges of water deficiencies in the city [21, 44]. The study based on household survey reveals the deficiency of the water supply system such that 48% households in zone I do not meet the required minimum water supply standard of 135 lpcd. This has been largely attributed to lowering of water table in the DTWS. This deficiency is even more alarming in zone II and zone III, where around 90% households fall short of required standard of water supply in the city.

It is, however, encouraging to find that the SCGWSP and SWGWSP are in continuous effort to expand the supply network in the areas deprived of

urban water supply systems in Guwahati city. The would certainly help increase household level water supply connections and enhance access to urban water for domestic use in the city. Moreover, the very recent commissioning of more than 100 DTWS under GMC-www can also increase the degree of access to urban water supply in the city. However, there has been great challenge on the part of the urban water authorities concerned to keep track with continued increase in the demand of water due to rapid city population growth along with the issues of industrialization and climate change. In view of such situation efforts should be on to increase utilization of huge Brahmaputra river water along with concerted measures for rainwater harvesting, protection of surface waterbodies and optimal use of groundwater in the city. It is thus expected that such efforts along with awareness campaign against wastage of water and possible measures for waste water recycling would go a long way in ensuring water security in Guwahati city.

Acknowledgements

The authors are thankful to the University Grants Commission (UGC), Government of India, for providing financial support in the form of a Fellowship (3165/NET-DEC 2018).

References

1. *Abubakar, I. R. (2019). Factors influencing household access to drinking water in Nigeria. Utilities Policy, 58, 40-51. https://doi.org/10.1016/j.jup.2019.03.005*
2. *Adams, E. A. (2018). Intra-urban inequalities in water access among households in Malawi's informal settlements: Toward pro-poor urban water policies in Africa. Environmental Development, 26, 34-42. https://doi.org/10.1016/j.envdev.2018.03.004*
3. *Bakker, K. (2007). The "commons" versus the "commodity": Alter-globalization, anti-privatization and the human right to water in the global south. Antipode, 39(3), 430-455. https://doi.org/10.1016/j.envdev.2018.03.004*
4. *Barros, D., Almeida, I., Zanfei, A., Meirelles, G., Luvizotto Jr, E., & Brentan, B. (2023). An Investigation on the Effect of Leakages on the Water Quality Parameters in Distribution Networks. Water, 15(2), 324. https://doi.org/10.3390/w15020324*
5. *Biswas, A. K. (2013). Water management for major urban centres. In Water Management in Megacities (pp. 3-17). Routledge. https://doi.org/10.4324/9781315878645*
6. *Boakye-Ansah, A. S., Ferrero, G., Rusca, M., & Van Der Zaag, P. (2016). Inequalities in microbial contamination of drinking water supplies in urban areas: The case of Lilongwe, Malawi. Journal of Water and Health, 14(5), 851-863. https://doi.org/10.2166/wh.2016.258*
7. *Census of India. (1971). District census Handbook, Kamrup (M) District, Assam.*
8. *Craun, G. F., Nwachuku, N., Calderon, R. L., & Craun, M. F. (2002). Outbreaks in drinking-water systems, 1991-1998. Journal of Environmental Health, 65(1), 16.*
9. *Deshkar, S. (2019). Resilience perspective for planning urban water infrastructures: A case of Nagpur City. Urban Drought: Emerging Water Challenges in Asia, 131-154. https://doi.org/10.1007/978-981-10-8947-3_9*
10. *Dong, X., Du, X., Li, K., Zeng, S., & Bledsoe, B. P. (2018). Benchmarking sustainability of urban water infrastructure systems in China. Journal of cleaner production, 170, 330-338. https://doi.org/10.1016/j.jclepro.2017.09.048*
11. *Fontanazza, C. M., Notaro, V., Puleo, V., Nicolosi, P., & Freni, G. (2015). Contaminant intrusion through leaks in water distribution system: experimental analysis. Procedia engineering, 119, 426-433. https://doi.org/10.1016/j.proeng.2015.08.904*
12. *Gleick, P. H., Wolff, G. H., Cooley, H., Palaniappan, M., Samulon, A., Lee, E., ... & Katz, D. (2013). The World's Water 2006-2007: The Biennial Report on Freshwater Resources. Island Press.*
13. *Gupta, A.., &Kulat, K. D (2018). Leakage reduction in water distribution system using efficient pressure management techniques. Case study: Nagpur, India. Water Science and Technology: Water Supply, 18(6), 2015-2027. https://doi.org/10.2166/ws.2018.023*
14. *Gupta, A., &Kulat, K. D. (2018). A selective literature review on leak management techniques for water distribution system. Water resources management, 32, 3247-3269. https://doi.org/10.1007/s11269-018-1985-6*
15. *Hansen, R. D. (2009). Water-related infrastructure in Medieval London. nd). http://www.waterhistory.org/histories/london/ (accessed 10 January 2015).*
16. *Hazarika, B., & Kar, B. K. (2024). Water security in Guwahati City (India): examining present status and emerging challenges. GeoJournal, 89(3), 1-18. https://doi.org/10.1007/s10708-024-11103-9*
17. *Hazarika, N., &Nitivattananon, V. (2016). Strategic assessment of groundwater resource exploitation using DPSIR framework in Guwahati city, India. Habitat International, 51, 79-89. https://doi.org/10.1016/j.habitatint.2015.10.003*
18. *Jayakar, A., Sudharsan, S., Veewin, M., & Rishi, M. (2022). Water Theft and Leakage Identification in Distributed System. In 2022 Smart Technologies, Communication and Robotics (STCR) (pp. 1-4). IEEE. https://doi.org/10.1109/STCR55312.2022.10009563*
19. *Kang, H. (2019). Challenges for water infrastructure asset management in South Korea. Water Policy, 21(5), 934-944. https://doi.org/10.2166/wp.2019.005*
20. *Kumar, A. (1998). Technologies to improve efficiency in distribution system with intermittent supplies. Water Supply-International Water Supply Association, 16(1), 576-579.*

21. Lee, E. J., & Schwab, K. J. (2005). Deficiencies in drinking water distribution systems in developing countries. Journal of water and health, 3(2), 109-127. https://doi.org/10.2166/wh.2005.0012
22. McIntosh, A. C. (2003). Asian water supplies reaching the urban poor. Asian Development Bank.
23. Misra, K., & Malhotra, G. (2011). Water management: the obscurity of demand and supply in Delhi, India. Management of Environmental Quality: An International Journal, 23(1), 23-35. https://doi.org/10.1108/14777831211191575
24. Mustafa, D., & Reeder, P. (2009). 'People is all that is left to privatize': water supply privatization, globalization and social justice in Belize City, Belize. International Journal of Urban and Regional Research, 33(3), 789-808. https://doi.org/10.1111/j.1468-2427.2009.00849.x
25. Mutikanga, H. E., Sharma, S. K., &Vairavamoorthy, K. (2011). Assessment of apparent losses in urban water systems. Water and Environment Journal, 25(3), 327-335. https://doi.org/10.1111/j.1747-6593.2010.00225.x
26. Nastiti, A., Sudradjat, A., Geerling, G. W., Smits, A. J. M., Roosmini, D., &Muntalif, B. S. (2017). The effect of physical accessibility and service level of water supply on economic accessibility: a case study of Bandung City, Indonesia. Water International, 42(7), 831-851. https://doi.org/10.1080/02508060.2017.1373323
27. Neelkamal Das, N. D., & Goswami, D. C. (2013). A geo-environmental analysis of the groundwater resource vis-α-vis surface water scenario in Guwahati city. https://doi.org/10.12944/cwe.8.2.13
28. Northeast Now. (2023). Assam water supply pipe burst in Guwahati, one dead. Northeast Now. Available at: https://nenow.in/north-east-news/assam/assam-water-supply-pipe-burst-guwahati-one-dead.html. Accessed May 22, 2024.
29. Osei, L., Amoyaw, J., Boateng, G. O., Boamah, S., &Luginaah, I. (2015). The paradox of water accessibility: understanding the temporal and spatial dimensions of access to improved water sources in Rwanda. Journal of Water, Sanitation and Hygiene for Development, 5(4), 553-564. https://doi.org/10.2166/washdev.2015.029
30. Parkinson, S. C., Johnson, N., Rao, N. D., Jones, B., van Vliet, M. T., Fricko, O. &Flörke, M. (2016). Climate and human development impacts on municipal water demand: A spatially-explicit global modelling framework. Environmental Modelling & Software, 85, 266-278. https://doi.org/10.1016/j.envsoft.2016.08.002
31. Patki, V. K., Jahagirdar, S., Patil, Y. M., Karale, R., &Nadagouda, A. (2021). Prediction of water quality in municipal distribution system. Materials Today Proceedings, 13. http://dx.doi.org/10.1016/j.matpr.2021.02.826
32. Pawe, C. K., & Saikia, A. (2018). Unplanned urban growth: land use/land cover change in the Guwahati Metropolitan Area, India. GeografiskTidsskrift-Danish Journal of Geography, 118(1), 88-100. https://doi.org/10.1080/00167223.2017.1405357
33. Ray, B., & Shaw, R. (2018). Coping with Urban Water Insecurity in the Colonial City of Kolkata. Urban Drought: Emerging Water Challenges in Asia, 209. http://dx.doi.org/10.1007/978-981-10-8947-3_13
34. Romero-Lankao, P., &Gnatz, D. M. (2016). Conceptualizing urban water security in an urbanizing world, Current opinion in environmental sustainability, 21, 45-51 https://doi.org/10.1016/j.cosust.2016.11.002
35. Sadiq, R., Kleiner, Y., & Rajani, B. (2007). Water quality failures in distribution networks–risk analysis using fuzzy logic and evidential reasoning. Risk Analysis: An International Journal, 27(5), 1381-1394. https://doi.org/10.1111/j.1539-6924.2007.00972.x
36. Shipman, H. R. (1967). Water supply problems in developing countries. Journal-American Water Works Association, 59(7), 767-772.
37. The Times of India. (2022). After 2 months, water supply from Satpukhuri to resume. The Times of India. Available at: https://timesofindia.indiatimes.com/city/guwahati/after-2-months-water-supply-from-satpukhuri-to-resume/articleshow/93147568.cms. Accessed May 24, 2024.
38. Tholiya, J. J., Chaudhary, N., & Alam, B. M. (2022). Determinants of geographical inequalities in domestic water supply across city of Pune, India. Water Supply, 22(2), 2148-2169. https://doi.org/10.2166/ws.2021.364
39. UN Water. Water and urbanization. (2021). Available at: https://www.unwater.org/water-facts/water-and-urbanization. Accessed May 1, 2024.
40. Van der Bruggen, B., Borghgraef, K., &Vinckier, C. (2010). Causes of water supply problems in urbanised regions in developing countries. Water resources management, 24, 1885-1902. https://doi.org/10.1007/s11269-009-9529-8
41. (2018). Urban water security dashboard: Systems approach to characterizing the Water, U. N. (2018). Sustainable Development Goal 6 synthesis report on water and sanitation, Published by the United Nations New York, New York, 10017 https://doi.org/10.1061/(ASCE)WR.1943-5452.0000997
42. WHO & UNICEF 2000 Global Water Supply and Sanitation Assessment 2000 Report. Iseman Creative, Washington, DC https://iris.paho.org/handle/10665.2/45503
43. WHO/UNICEF. WASH (water, sanitation, and hygiene). (2023). Available at: https://www.unwater.org/water-facts/wash-water-sanitation-and-hygiene. Accessed May 1, 2024.
44. Zérah, M. H. (2000). Household strategies for coping with unreliable water supplies: the case of Delhi. Habitat International, 24(3), 295-307. https://doi.org/10.1016/S0197-3975(99)00045-4

Authors Contribution: All authors have contributed equally to this work
Conflict of Interest: The authors declare no conflict of interest

Стан водної безпеки та пов'язані з цим проблеми в місті Гувахаті (Індія)

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Розвиток міської системи водопостачання не встигає за швидким зростанням населення в містах, через що більшість мешканців не мають доступу до системи водопостачання. Це дослідження має на меті виявити проблеми, пов'язані з міськими системами водопостачання, проблеми з ефективним водопостачанням і, як наслідок, відсутність водної безпеки в домогосподарствах. Воно розглядає водну інфраструктуру в місті з моменту його розвитку в 1930 році в просторово-часовому контексті. Також було оцінено вплив існуючої інфраструктури водопостачання на стан водної безпеки домогосподарств. Для візуалізації просторового розподілу міських водопровідних мереж у місті було використано програмне забезпечення Google Earth Engine. Для обстеження домогосподарств у трьох різних зонах було прийнято методику цілеспрямованого відбору на основі відстані від водосховищ, нахилу, місткості водосховища та кількості підключень домогосподарств до водойм. Вибір домогосподарств з різних зон за кожною схемою здійснювався на основі споживачів міської водопровідної системи та стану водозабезпеченості. Стан водної безпеки домогосподарств оцінювався за її складовими, кількістю, якістю, надійністю та доступністю. Водна інфраструктура була неадекватною протягом дуже тривалого часу, лише одна третина населення мала доступ до міських систем водопостачання. Домогосподарства повідомили, що підвищення кількості та якості води, які є життєво важливими аспектами водної безпеки, вимагає застосування різноманітних стратегій, спричиняє значні витрати та ставить під загрозу добробут. Крім того, існують просторові варіації в кількості та якості води, отриманої за спільною схемою зі збільшенням відстані від резервуарів обслуговування/заводів. Крім того, поряд із низькою надійністю та доступністю схем водопостачання домогосподарств, також були виявлені відмінності між різними схемами водопостачання. У статті вперше аналізується стан міської водної безпеки та пов'язані з цим виклики в місті за допомогою первинних даних та інформації про водну інфраструктуру. Практична цінність дослідження полягає в можливості виявлення просторової варіації кількості та якості води, отриманої в домогосподарствах, незважаючи на спільну схему або систему, яку можна проводити в інших дослідженнях країн, що розвиваються. Результати дослідження є значущими в контексті обґрунтування заходів щодо стратегії водної безпеки на індивідуальному рівні.

Ключові слова*: Гувахаті, схема водопостачання, кількість, якість, водозабезпеченість.*

Внесок авторів: всі автори зробили рівний внесок у цю роботу
Конфлікт інтересів: автори повідомляють про відсутність конфлікту інтересів

Надійшла 3 серпня 2024 р.
Прийнята 9 вересня 2024 р.