

**Understanding the Impact of Urbanization on the Water Crisis in  
Bangalore: Challenges And Opportunities**

**RESEARCH REPORT**

Submitted to the

**National Centre for Good Governance (NCGG),  
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Government Of India**



By

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### **CERTIFICATE**

This is to certify that **Mallipeddi Bhoomika**, a student of **Indira Gandhi National Open University (IGNOU)**, has satisfactorily concluded the research report titled **“Understanding the Impact of Urbanization on the Water Crisis in Bangalore: Challenges and Opportunities”** as part of the internship program at the National Centre for Good Governance (NCGG) under my mentorship.

I, **Professor (Dr) Padmini Pani**, hereby validate the successful completion of the internship report within the internship program at the National Centre for Good Governance (NCGG). The report submitted by **Mallipeddi Bhoomika** is an authentic work carried out by her under my supervision and guidance. I have reviewed and assessed the intern's performance throughout the internship period.

18/06/2024

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## **ABBREVIATIONS**

BBMP - Bruhat Bengaluru Mahanagara Palike

BDA - Bengaluru Development Authority

BMA - Bangalore Metropolitan Area

BMRCL - Bengaluru Metro Rail Corporation Limited

BWSSB - Bengaluru Water Supply And Sewerage Board

BUiS - Bangalore Urban Information System

CAG - Comptroller and Auditor General of India

CGWB - Central Ground Water Board

GDI - Gross Domestic Income

IISc - Indian Institute of Science

IMD - Indian Meteorological Department

KUWSDB - Karnataka Urban Water Supply and Drainage Board

MLD - Million Litres per Day

WWDR - World Water Development Report

WEF - World Economic Forum

## ABSTRACT

### ***Title: Understanding the Impact of Urbanization on the Water Crisis in Bangalore: Challenges and Opportunities***

Urbanization in Bangalore has surged dramatically in recent years, profoundly reshaping the city's landscape and exacerbating its water crisis. This paper delves into the intricate relationship between urbanization and water scarcity in Bangalore, aiming to elucidate the challenges posed by rapid urban growth while exploring potential opportunities for sustainable water management. Urbanization has brought about environmental degradation, with water bodies suffering from pollution, encroachment, and depletion of natural resources, exacerbating the water crisis. By employing qualitative methodology approach, analyses both the primary and secondary data from telephonic interviews with the key stakeholders like Government officials, water management experts, residents etc. and Government sources and reports respectively. The rationale behind conducting this research on the water crisis in Bangalore is rooted in the critical importance of addressing this pressing issue that affects the well-being and sustainable development of one of the India's fastest-growing urban centers. The findings of the research are rising water demand, depletion of groundwater, decline of wetlands and lakes, poor surface water quality, socio-economic consequences and water governance challenges which underscore the urgent need for holistic and sustainable approaches to urban water management in Bangalore. By addressing the challenges of rapid urbanization while harnessing opportunities for sustainable water use, the city can work towards a more resilient and water-secure future. Hence, this study provides a comprehensive analysis of the impact of urbanization on the water crisis in Bangalore and offer valuable insights and recommendations for addressing this pressing issue.

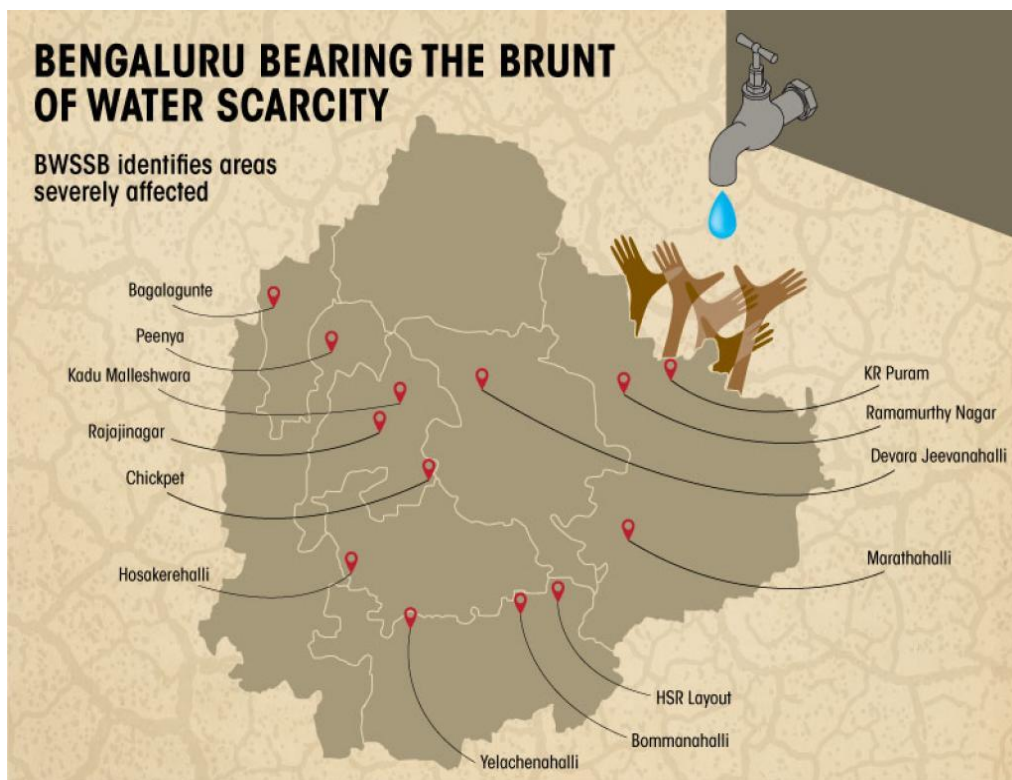
#### **Keywords:**

Urbanization, Water crisis, Sustainable water management, Water bodies, Pollution, Encroachment, Bangalore.



## 1. INTRODUCTION:

Urbanization, a worldwide phenomenon, is changing cities and showing complicated challenges for feasible water administration. Rapid urban growth in Bangalore (or officially Bengaluru), India, has intensified pressure on water resources, exacerbating the city's water crisis. World Economic Forum (2019) has stated that water crisis is one of the biggest challenges facing the century. This research paper examines the multifaceted effects of urbanization on water availability, and governance in Bangalore, by studying the interconnection between urban development and water scarcity. Rapid urbanization poses significant challenges to water resources management in cities worldwide, and Bangalore, stands as an example of the complex interplay between urban development and water scarcity. As Bangalore rapidly expands as one of India's fastly growing urban centers, it has undergone remarkable population increase and economic development in the recent years, putting a significant pressure on its water supply systems.



*Figure-1: A map showing BWSSB identified areas that are severely affected by water scarcity in Bangalore. (Source: A Down To Earth article by Coovercolly Indresh, published on 13 March, 2024)*

Out of whole world's population, one quarter of population living in 25 countries, withdrawing over 80% of their annual renewable freshwater supply, face 'extremely high' levels of baseline water stress and shortages (WWDR 2024; Kuzma et.al.,2023). The rapidly and quickly increasing population of Bangalore has resulted in increase in the water demand, outpacing the capacity of the existing water supply frameworks and systems. Water supplies are under stress due to a number of factors, including population growth, economic expansion, fast urbanization, and changing consumption patterns. (World Bank, 2018). According to recent estimates, the city's population has increased almost three times 1981 to 2011 which is from 2.9 million to 8.4 million (Ramaiah & Avtar, 2019), driven primarily by migration from rural areas and the rapid growth of industries such as information technology and manufacturing. This change in demographics has worsened the strain on water resources, resulting in scarcities and uneven allocation of water. Global demand for water is rising at one per cent annually in due to rapid increase in population and economic progress and development (WWDR, 2018).

Furthermore, urbanization has transformed and reshaped the landscape of Bangalore city, resulting in the depletion of groundwater reserves and degradation of surface water bodies. The transformation of farmland into urban areas, along with uncontrolled extraction of groundwater for industrial and household purposes, has resulted in the depletion of aquifers and subsidence. The area that was once known as Garden City is gradually losing its lung space, or greener areas, as a result of increased urbanization and industrial growth (Central Ground Water Board, 2008). Unplanned urbanization results in erratic expansion that disrupts the local ecology, hydrology, and overall environment. This uncontrolled growth brings about heightened pollution, insufficient infrastructure, and a scarcity of basic amenities in a place (Ramachandra T.V, 2014). Additionally, unchecked expansion of urban settlements has encroached upon lakes and wetlands, vital ecosystems that play a crucial role in recharging groundwater and regulating the city's microclimate (Sudhira et al., 2019). The disposal of solid waste, the encroachment of wetlands, the constant inflow of domestic sewage, and the release of industrial pollutants into surface water bodies have all led to increased anthropogenic stress in urban water bodies, resulting in poor water quality (Ramachandra T.V, 2014).

Given the existing challenges, this research paper intends to thoroughly investigate how urbanization affects the water crisis in Bangalore. By combining existing research findings and empirical data, we aim to uncover the fundamental causes of water scarcity and explore viable approaches for managing water resources sustainably amidst rapid urban expansion.

## **2. HYPOTHESIS:**

The research question of the study is:

“What are the key challenges and opportunities presented by rapid urbanization in Bangalore, and how do they contribute to the water crisis?”

The hypothesis of this research is that there is a significant correlation between urban expansion and exacerbating water crisis in Bangalore. This connection likely arises from various factors such as increased demand for water, inadequate infrastructure for water supply and management, water pollution from urban activities, and encroachment on natural water sources like lakes, ponds etc.

## **3. OBJECTIVES:**

The primary objectives of this study are:

- a) To analyze the impact of urbanization on water availability and distribution in Bangalore.
- b) To identify the key drivers and challenges contributing to the water crisis in the context of rapid urban growth and explore potential opportunities and strategies for mitigating the adverse effects of urbanization on water resources and fostering sustainable water management practices.

#### 4. BACKGROUND AND LITERATURE REVIEW:

The state capital of Karnataka, Bangalore – which is also referred to as India's Silicon Valley, home to many Information Technology industries, has seen a sharp increase in urbanization in recent years due to booming IT sector. Its built-up area expanded significantly over the years: from 130 square km with a population of 1.2 million in 1961 to 366 square km with 2.92 million people in 1981, further growing to 439 square km with 5.8 million inhabitants in 2001. By 2011, the city's built-up area had reached 741 square km, accommodating a population of 8.43 million (Thippiah, 2017).

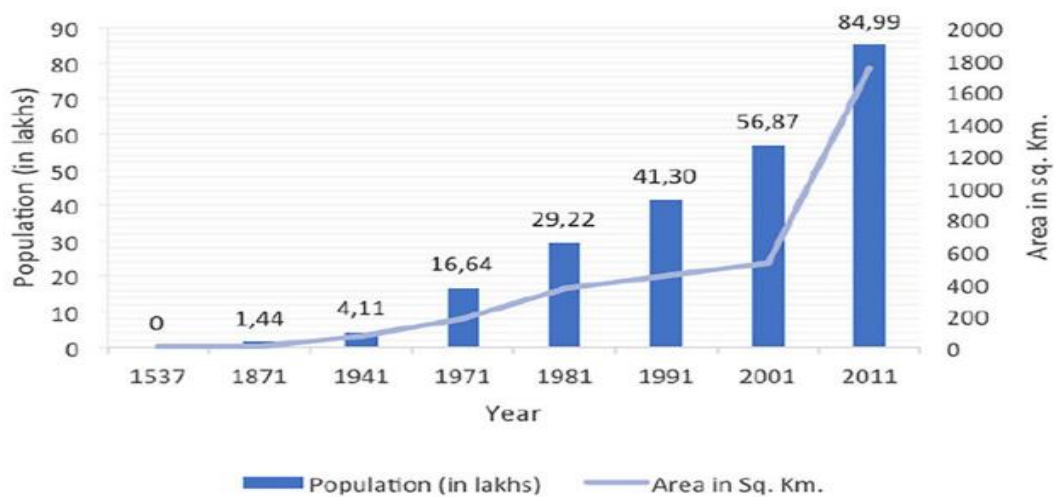


Figure 1: Population growth of Bangalore from 1537 to 2011. (Source: Census of India, 2011).

Water resources in Bengaluru are facing growing pressure due to excessive reliance on a single source, the River Cauvery, and the absence of integrated water management practices (Bengaluru Water Board). As towns develop into cities and urban areas expand, a plethora of governance challenges arise due to the mismanagement of resource systems. Because the Western Ghats mountain range blocks the south-west monsoon, the region experiences a state of drought. Annual rainfall averages around 900 mm, typically ranging between 830 and 970 mm. Historically, the city was renowned for its lush environment as the 'Garden City' and for its numerous water tanks. Early efforts in integrated water management connected lakes and artificial ponds to collect rainwater for irrigation, freshwater storage, and groundwater recharge. However, both the number and size of these tanks and parks have been declining steadily over time (Drangert, 2017). Rapid urbanization results in the rapid population growth in the urban areas. As the demand for water increases, the groundwater recharge abilities and natural land absorption rates are squandered, creating an imbalance in supply and demand wherein water shortages are the general outcome. Cities around the world are grappling with this challenge, especially as economic development and demographic shifts drive higher water demand. The delicate balance between supply and demand is crucial for sustainable water management (Raj, 2013).

**Urban Water Shortage:** The pressure on limited water supplies is increased by rapidly expanding cities. (World Bank Document, 2018). In many places around the world, it's a familiar sight to see water shortages in urban centers. Challenges including aging infrastructure, changing service standards, and urban development characterize the complex world of urban water supply (World Bank document, 2018). The lack of adequate water supply, especially in the heart of towns, is a widespread issue. Apart from increased pollution, changes in climate and ecology, and the absence of basic infrastructure and utilities, unplanned and swift urbanization influences and reshapes the landscape, impacting its functioning (Aithal and Ramachandra 2016a). Insufficient infrastructure for recharging water sources exacerbates the problem, resulting in inadequate supply (KV Raju, 2008). Water shortages will occur in many regions of the world during the next 20 years due to the world's increasing demand for water, which has been rising at a rate of about 1% annually due to factors like rapid population growth, economic development, and changes in consumption patterns (WWDR, 2018, and Chakraborti, 2019). The Indian city, Bangalore is no different but also facing severe water crisis (Sudhira et al., 2007). Situated in a dry area with no major river flowing through it, Bangalore has historically relied on the interconnected lakes within the city limits to meet its continuously rising water demands. Bengaluru is currently witnessing an unprecedented surge in rapid urbanization and expansion, primarily driven by concentrated developmental efforts focused on industrialization to boost regional economic growth. This surge has resulted in significant alterations to land cover, leading to severe environmental degradation and presenting substantial challenges for decision-makers in city planning and management. These challenges include addressing climate change concerns, heightened emissions of greenhouse gases (GHGs), poor infrastructure, congested roads, and shortages of essential services like electricity, water, and sanitary facilities in many places (Ramachandra, T. V., & Aithal, B. H., 2016).

In the recent years, the city has grappled with water governance issues, due to its failure to safeguard and improve its extensive network of lakes (Nath, S. 2021). Bangalore's lake governance is multifaceted and complex (Nath, S. 2021). According to the Bangalore Development Authority's (BDA) 2015 Master Plan, the city of Bangalore originally had 400 lakes. However, throughout time, according to government data, the number of lakes decreased to 260 by the 1940s, and it is currently down to 65 (Kumar, 2022). A study (Mapunity, 2013) on 105 lakes indicates that nearly 98% of them face illegal encroachment issues, with approximately 82% experiencing a reduction in their catchment areas and 38% having unauthorized slums encroaching on their lakebeds (Nath. S., 2021).

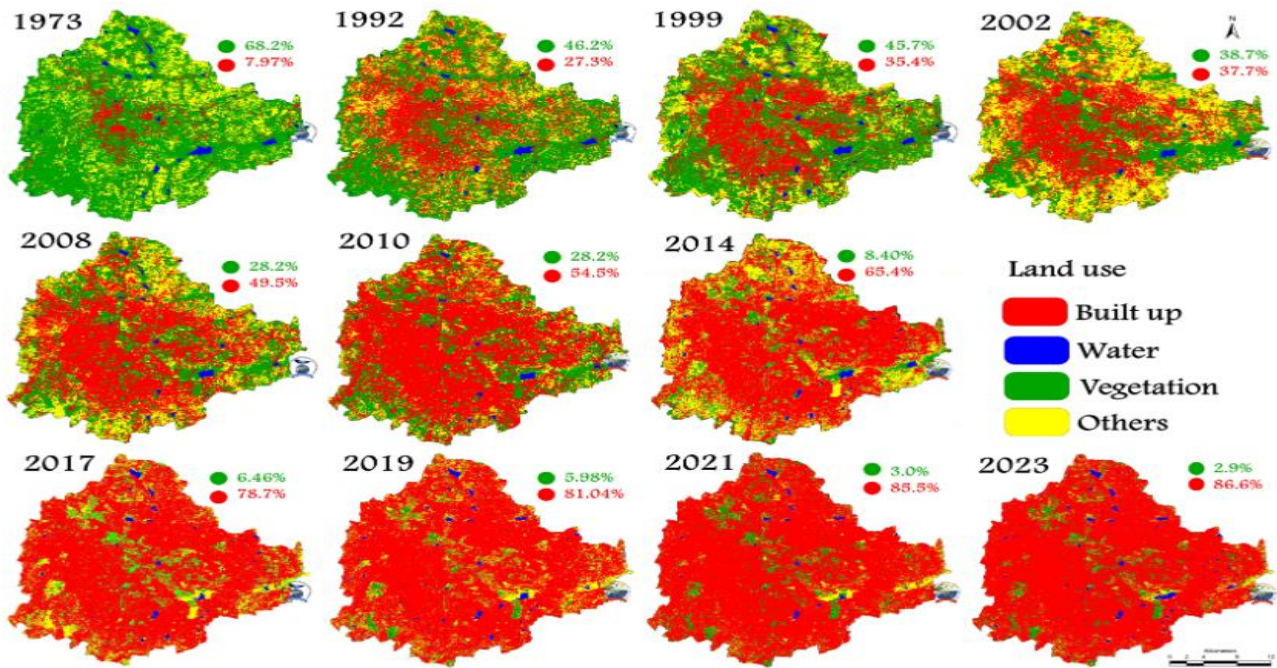


Figure 2: Land use changes in Bangalore from 1973 to 2023 (Source: T V Ramachandra, Bharat H Aithal, Vinay S, Bharat Setturu, Tulika Mondal, Abhishek Baghel – Bangalore Urban Information Sustum (BUiS)).

The above figure shows how the city's landscape has changed over the past 50 years. There is a heavy loss of wetlands and water bodies to concretization in Bangalore. In 1973, the vegetation was 68.2% and the land used for living was only 7.97%. But the vegetation decreased to 2.9% to concretization of 86.6% in 2023. There it is seen more than 1000% increase in the concretization due to cascading urbanization.

Water resources in Bengaluru are facing growing pressure due to excessive reliance on a single water source, the River Cauvery, and the absence of integrated water management practices. Established in 1964, the Bengaluru Water Supply and Sewerage Board (BWSSB) was entrusted with the management of water infrastructure, operations, and maintenance, functioning independently from the state government. It assumed the duty of guaranteeing a sufficient water supply, establishing sewerage networks for the safe disposal of sewage, devising and executing plans to enhance water reserves, managing sewage disposal, and collecting water charges on a "no loss, no profit" basis to promote sustainability. However, the BWSSB's core objectives prioritize water quality and the customer satisfaction over ensuring universal access to water (BWSSB Official website). The BWSSB also utilizes water from three additional rivers—Arkavati, Hemavati, and Shimsha - but in smaller quantities compared to its primary source (Dasgupta, S., 2012). Thara, K. (2017) states that the free water supply might be stopped by a complaint from a middle-class neighbor or a senior BWSSB official. In order to discreetly allow access without drawing attention to individuals who might object, water is therefore frequently supplied irregularly and erratically at various times during the day for a brief period of time.



**Causes of Water shortage:** The main causes of water shortage include over population, over consumption and over extraction of groundwater, water pollution and climate change (Chakraborti, 2019). Heavy population growth is putting heavy stress on water supply and resources. Over extraction of groundwater has led to a drop in the groundwater levels over the last 60 years. Many cities and towns are experiencing summer time water shortages due to insufficient surface water systems brought on by abrupt climate change and altered rainfall patterns (Chakraborti, 2019). And these causes are leading to water shortages and crisis in many Indian cities and towns.

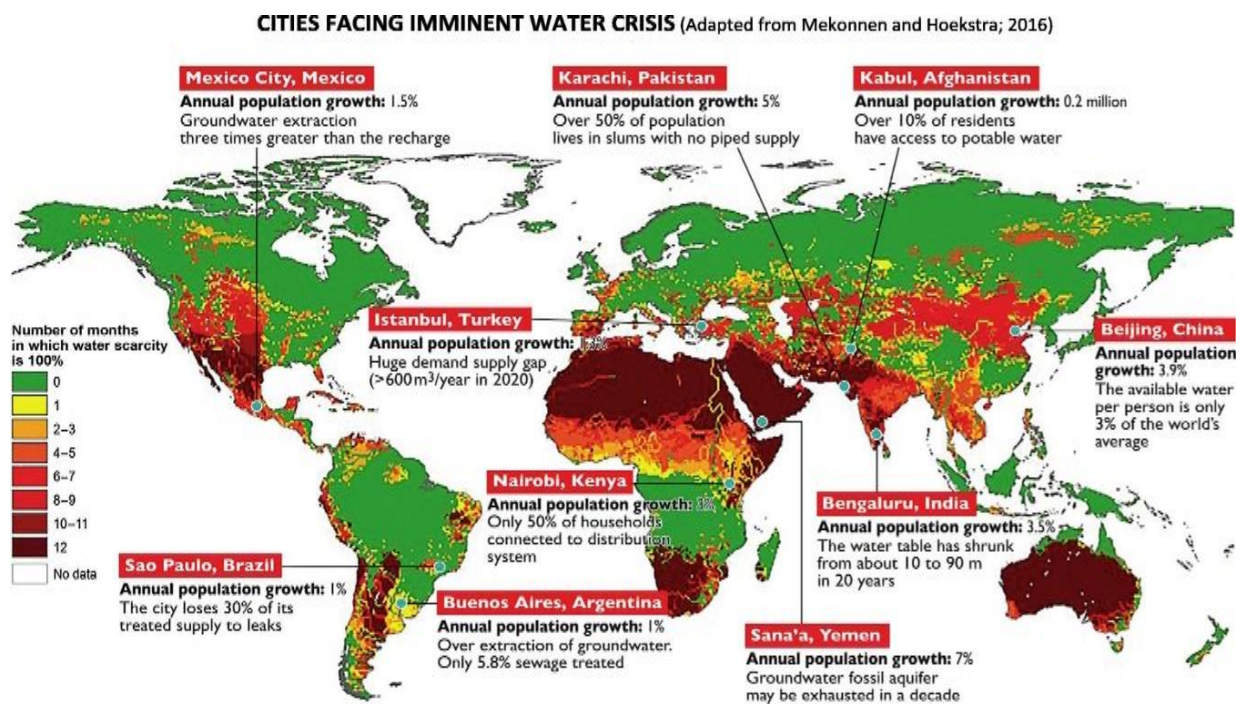


Figure 3: Cities facing imminent water crisis around the world. Bangalore is one of them. (Source: Adapted from Rai S. Kookana et.al, 2020; & Mekonnen and Hoekstra, 2016)

**Urban sprawl in Bangalore:** Bangalore is witnessing rapid urbanization, population growth and administrative transformation. This development places strain on the available water resources, primarily the contested interstate River Cauvery and the hard-rock aquifers, resulting in accessibility challenges (Grönwall, J. T., 2008). The process of urban sprawl in Bangalore leads to a proportional increase in the built-up surface area relative to population (Biswas, V. et.al, 2022).

Bangalore city got expanded in a short span of 50 years. The city is getting expanded very quick along with the industrialization and urbanization. Rapid population growth has changed and reshaped the boundaries of Bangalore and is causing stress on water resources in the city.

## **5. METHODOLOGY AND MATERIALS / DATABASE:**

The research methodology employed qualitative data analysis to assess the impact of urbanization on the water crisis in Bangalore. A systematic literature review was conducted to gather insights from a diverse range of scholarly articles, reports, and research papers focusing on the nexus between urbanization and water scarcity in Bangalore. Criteria for inclusion were relevance to the topic, publication within the last two decades, and empirical evidence-based analysis.

The primary approach to collecting data involved conducting semi-structured telephonic interviews with Bengaluru Water Supply and Sewerage Board (BWSSB), Bruhat Bengaluru Mahanagara Palike (BBMP) officials and collecting the perceptions of residents of Bangalore city through an e-questionnaire - online survey using Google form and telephonic interviews alongside the analysis of secondary data.

The secondary data of demographics, rainfall, groundwater, lakes etc. was collected from various sources like Census 2001, 2011, India Meteorological Department (IMD), Central Ground Water Board (CGWB), Lakes Department, Bruhat Bengaluru Mahanagara Palike (BBMP), Bengaluru Water Supply and Sewerage Board (BWSSB). And the satellite images are collected from the Google pro and Google images.

By analyzing existing literature, empirical studies, and policy frameworks, this research seeks to identify the challenges posed by urbanization and explore opportunities for sustainable water management and conservation initiatives. Through a comprehensive examination of the water crisis in Bangalore, this research aims to contribute to the discourse on urban water governance and inform evidence-based strategies to address this pressing issue, ensuring the city's long-term water security and environmental resilience in the face of rapid urbanization.

### ***Geography and Topography of Bangalore:***

The capital of the state of Karnataka, Bengaluru, is situated at an altitude of 920 meters (3020 feet) above mean sea level and at latitude 12.59° North and longitude 77.57° East. Bangalore receives an average rainfall of 970mm/year. The city is majorly covered by Arkavathy river basin and South Pennar basin. A tributary of the Cauvery River, the Arkavathi River, flows through the northern outskirts of the Bangalore city. Bengaluru city is situated over the ridges delineating four valleys or watersheds, i.e; Hebbal valley to the North, Koramangala & Challaghatta valley to the East and Vrishabhavathi valley to the West. According to the report given by Central Ground Water Board (CGWB), the aquifer system in Bangalore majorly consists of fractured, fissured, and weathered granites and gneisses of Archean age. And the ground water recharge of this type of aquifer is very low.



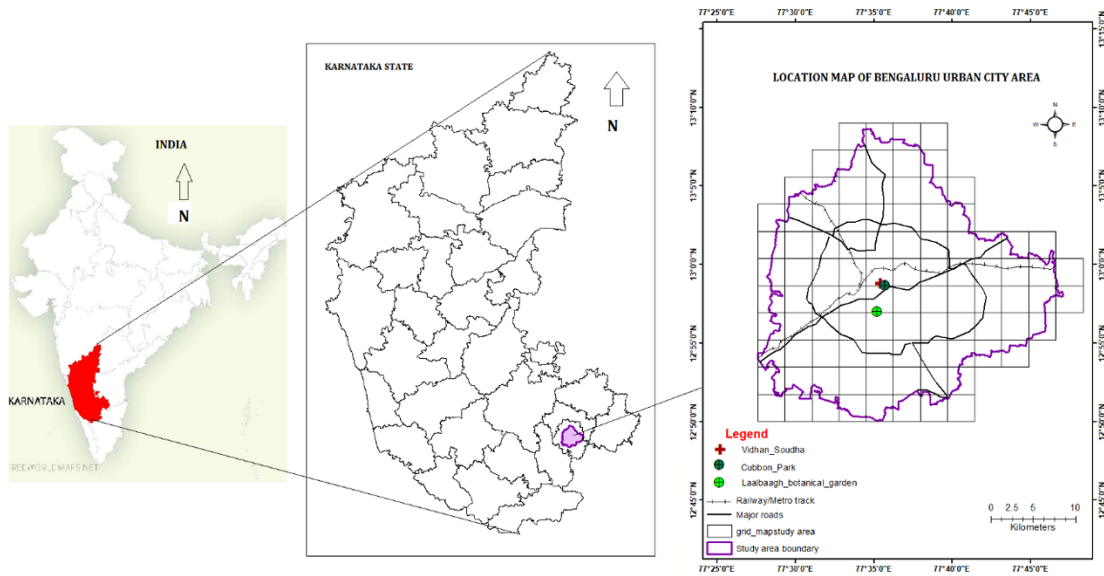


Figure 4: Location map of study area – Bangalore (Source: Central Ground Water Report, 2023)

### Demographics of Bangalore:

Bangalore, officially known as Bengaluru, is the capital and economic hub of Karnataka state. It is situated on South India's Deccan Plateau at an altitude of roughly 920 meters above mean sea level.. The city is spread across 741 square kilometers. The Bengaluru Metropolitan Area has an area of approximately 1,284 square kilometers. Bangalore is one of the three finest metropolitans in India (other two Delhi and Mumbai). With the rapid expansion of several industries, particularly the IT sector, Bengaluru is India's second-fastest-growing cosmopolitan metropolis. Rapid industrialization resulted in fast population growth.

City	Total Population(2011)	Total Population(2001)
Mumbai	12,442,373	11,978,450
Delhi	11,034,555	9,879,172
Bangalore	8,443,675	5,682,293
Hyderabad	6,993,262	5,496,960
Ahmedabad	5,577,940	4,470,006
Chennai	4,646,732	4,343,645
Kolkata	4,496,694	4,580,546
Surat	4,467,797	2,788,126
Pune	3,124,458	2,538,473
Jaipur	3,046,163	2,322,575

Table 1: Top 10 Indian cities by population (Source: Census 2001 & 2011)

According to census 2011, Bangalore city is the third most populated metro city in India with an approximate population of 8,443,675. Mumbai and Delhi were the top 2 populous metropolitan cities according to the census of year 2001 and 2011 respectively. Bangalore is one of the fastest and quickly growing cities in the country with the Gross Domestic Income (GDI) of 6.8 lakh, which is four times more than the national average per capita GDP.

<b>Year</b>	<b>Total Population</b>	<b>Growth rate (%)</b>
1991	4,130,000	-
2001	5,759,987	39.4%
2011	8,749,944	51.9%

*Table 2: Decadal growth of urban population of Bangalore (Source: Census 2011, 2001, 1991)*

The rise in Bangalore’s population has been truly exceptional. Bangalore experienced a rapid population outburst in the last few decades. According to Census of years 1991, population of Bangalore urban was 4.3 million. And the population density has increased to 5.7 million in 2001, just within a span of 10 years, a decade. That wasn’t all, it was observed a rapid growth of population and estimated around 8.7 million population in Bangalore Urban and 8.4 million population in the Bangalore city in 2011. Now, in 2024, the Bangalore Metropolitan area population is estimated around 14 million.

The rapid urban population growth has put stress on the natural resources in Bangalore. The Indian Institute of Science (IISc) reports that since the 1970s, the number of concrete buildings in cities has increased by 1,000%, and that over 93% of lakes and forests have been replaced by concrete structures. The unchecked and rapid growth of population has ultimately resulted in the encroachment of lakes, decline in green spaces, wetlands, deforestation, leading to severe environmental degradation. The population has grown due to the fast urbanization process, which has also caused the built-up area and city to expand.

The main driving forces for rapid urbanization in Bangalore are Industrialization, Globalization, Modernization and Marketization. Rapid growth of industries especially Information Technology industries has attracted more number of people to migrate to Bangalore for businesses, jobs etc. The city is now facing many issues like water shortage, traffic congestion, pollution, sewage and solid waste management issues, and many other urban issues due to rapid urbanization and poor and improper urban planning. Bangalore's fast population increase has also resulted in the city's expansion and the rise of slums and informal settlements, which highlight the socio-economic disparities in the area. Therefore, monitoring the trends of urbanization is the first and foremost task for the planners, administration and Government for implementing policies and schemes related to the usage of resources and to accommodate development simultaneously.

### ***Rainfall pattern of Bangalore:***

Rainfall is the most essential phenomenon which brings water onto earth through precipitation, helps in irrigation and also cater the water needs of people on the earth. Now-a-days, prediction of rainfall has become more challenging due to drastic changes in climate and global warming. Bangalore receives an annual rainfall about 970 mm, with the wettest months being August, September and October. Bangalore city lies on the south of the Deccan plateau. Usually, Bangalore majorly receives rains from the South-west monsoon and a significant amount of rainfall from the North-East monsoon.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total rainfall (in mm)	El Nino (Y/N)	La Nina (Y/N)
2014	0	0.2	4.7	22.7	74.6	172	100.9	102.4	319	343.8	25.7	1	1167	N	N
2015	9	0	37.7	225.8	178.4	85.3	94.1	110	189.8	47	296.4	5.1	1278.6	N	N
2016	4.4	0	19.9	21.9	140.6	191.3	209.4	82.8	33.2	11.5	1.5	74.9	791.4	Y	N
2017	0.2	0	47.8	30.4	241.9	25.1	59	351.8	513.8	385.7	20.6	19.7	1696	N	N
2018	0	1.8	47.6	34.1	140.4	29.5	94.2	70.9	106.9	63.3	12.8	16.2	617.7	N	N
2019	0.8	58	0	41.2	136.7	58.4	93.9	142.8	211.4	196.3	8	12.6	960.1	N	N
2020	0	0	18.4	121.1	128.6	114.8	158.3	75.9	300	204.3	71	20.4	1212.8	N	N
2021	21.2	10.3	0	118.2	130.7	91.1	203.3	98.3	188.5	366.3	277.8	5.4	1511.1	N	Y
2022	3.9	0	0	61.4	270.2	255.5	136.7	378.7	353	296.5	59.8	74.7	1957.7	N	Y
2023	0	0	8.4	28.2	305.5	72.3	141.5	12.6	NA	NA	NA	NA	1020.2	Y	N

*Table 3: Month-wise rainfall data in millimetres(mm) for the last 10 years of Bangalore city (Source: India Meteorological Department, IMD)*

According to the data given in table 3, we can understand that the city receives most of the rains in the months of August, September and October from the South-West monsoon. And the city receives low to no rainfall in the months of December, January and February. North-East monsoon does not bring much rainfall to Bangalore city. Bangalore received a record rainfall with 1,957 mm in the year 2022, which is twice the average annual rainfall of Bangalore. According to India Meteorological Department (IMD), Bengaluru has received 18% deficit rainfall in 2023. Due to a poor North-East and South-West monsoon in 2023, the Karnataka state has received a 34% deficit of rainfall. This deficit of rainfall in Bangalore caused the low storage in rivers dams and drought conditions in the area.

Effect of El Nino is of the reasons for low rainfall in the city and the country as well. El Nino caused the low rainfall and caused the drought conditions in Bangalore city. Water shortage is not new for the residents/people of Bangalore. Water shortage occurs almost every time when the annual or yearly rainfall is low as less than 1,000 mm. And water shortage occurs not only due to drought conditions in the city but also due to the depletion of ground water levels. There has been a significant and rapid decline in the ground water levels of the Bangalore metropolitan city.

***Primary water sources - Bangalore:***

The two main sources of water which serves the needs of people in Bangalore are Cauvery river water, supplied by Bengaluru Water Supply & Sewerage Board (BWSSB) and the ground water extracted through the bore wells which are managed by Bruhat Bengaluru Mahanagara Palike (BBMP). The central and core areas of the city, where the population density is lower than in the rapidly expanding peripheral regions and outer suburbs, are where the majority of BWSSB's water distribution system is found. And the outer areas which are developed in last 5-10 years do not have Cauvery river water supply and the people rely on the ground water extracted from the underground.

According to the Mr. Ramalingappa B.K., Public Relations Officer, BWSSB, the fresh water demand in the city is 2,600 MLD per day. BWSSB states that they are pumping and drawing out almost 1,450 MLD water every day from the river Cauvery, which is 100KM far away from the city, to cater the water needs of the people of Bangalore city. 110 villages which were later added to BBMP donot have Cauvery water supply. The Cauvery stage-V project aims to provide 775 MLD water to 110 villages which donot have the Cavery water connection previously. And the remaining who doesn't have Cauvery water supply, rely on the ground water. Bore wells provide 700 MLD water every day. Additionally, 500 MLD of water which is one-fifth of the fresh water required by the city, is short of supply. 60% of people are receiving regular water supply from Bengaluru Water Supply and Sewerage Board (BWSSB) and 40% of people rely on bore wells. Cauvery water supply is never disrupted at all but the pressure built up when the city never had rain for around 150 days, the bore wells started drying up. Out of nearly 14,000 bore wells in Bangalore, nearly 50% i.e; 7,000 bore wells have dried up. In Bangalore, the shortage of the water was not because of the shortage of the water supply from the river, but because of drying up of bore wells, due to the groundwater depletion. The main reason is urbanization, which is brought about by an increasing number of people relocating to larger cities like Bangalore and an ever-growing need for water. More bore wells are being dug in order to meet the demand for water. The regular recharging of ground water is being neglected by individuals, which is causing a substantial depletion of ground water.

### ***Ground water in Bangalore:***

According to the report given by Central Ground Water Board (CGWB), the area is predominantly underlain by granites and gneisses of Archaean age. The weathered thickness of aquifers varied from 10 to 30 meters. Groundwater in Bangalore is found in the shallow weathered rock and residuum under phreatic condition, and in the deeper jointed and fractured granites and gneisses rocks ground water occurs under semi-confined condition.

Set across three taluks, the 2174 sq. km. Bangalore Urban District is home to a sizable urban population. The district relies heavily on groundwater for drinking, urban, and irrigation needs, with a noted overexploitation leading to a 197% stage of groundwater development. Groundwater quality is affected by industrial and sewage pollution, high nitrate content, and overexploitation is a major concern.

<b>Ground water resource (in hectare meter ham)</b>	<b>2004</b>	<b>2023</b>
Ground water recharge from rainfall (Monsoon Season)	4568	12896.1
Ground water recharge from other sources (Monsoon Season)	7638	407.19
Ground water recharge from rainfall ( Non-monsoon Season)	2384	6106.24
Ground water recharge from other sources ( Non-monsoon Season)	3071	4308.32
Total Yearly Ground Water Recharge	17661	23717.85
Total Natural Discharges	892	2371.78
Annual Extractable Ground Water Resource	16769	21346.07
Present Yearly Ground Water Extraction-Irrigation	31470	20636.4
Present Yearly Ground Water Extraction-Industrial	1557	8025.9
Present Yearly Ground Water Extraction-Domestic		3536.03
Total Present Annual Ground Water Extraction	33027	32198.34
Yearly GW Allocation for Domestic Use as on 2025	2186	3659.66
Net Ground Water Availability for future use	0	0
Stage of Ground Water Extraction (%)	197	150.8

*Table 4: Dynamic Ground Water Resources of Bangalore Urban district of years 2004 and 2023*

*(Source: Central Ground Water Board (CGWB), 2004 & 2023)*

According to table 4, we can understand that the The extraction of ground water exceeds the replenishment of ground water, which resulted in the drop in ground water table. Bangalore's groundwater levels have dropped as a result of overuse of the groundwater resources. It is seen that the annual ground water recharge of year 2004 was less than 2023 and annual groundwater extraction was more in 2004 than in 2023, because the people were not that aware of rainwater harvesting and also industrialization and urbanization were at peak stage during early 2000's.

The stage of Ground Water Extraction (%) was 197 in 2004 and has been decreased to 150.8 in 2023 which is a positive sign, but is categorized as over-exploited. Stage of ground water extraction is the ratio of yearly ground water extraction to yearly extractable resource in an area. This helps us to understand whether the ground water resource in an area is safe, semi-critical, critical or over-exploited.

National compilation on Dynamic Ground Water Resources of India, 2023, by Central Ground Water Board, stated that Bangalore City, Bangalore-East, Bangalore-North, Bangalore-South Anekal, Yelahanka are the over exploited assessment units in the Bangalore Urban district. And Nelamangala, Doddaballapura, Devanahalli, Hoskote are the over-exploited assessment units in the Bangalore Rural district.

According to CGWB, the recommendations include artificial recharge, rainwater harvesting, water conservation, and legislations for sustainable groundwater use in Bangalore (*Source: CGWB Bangalore ground water report,2023*).

- *Artificial Recharge*: Creating artificial structures like recharge wells, percolation tanks, and check dams to ensure rainwater to infiltrate and get percolated into the ground. This helps replenish aquifers and increase the ground water levels.
- *Rainwater Harvesting*: Encouraging individual, community, and institutions to consider rainwater harvesting. Collecting rainwater from rooftops of the buildings and directing it to recharge pits or storage tanks can significantly contribute to increase in ground water levels and aquifer recharge.
- *Watershed Management*: Putting watershed development plans into action to improve groundwater recharge, prevent soil erosion, and preserve rainwater. This includes afforestation i.e; planting of more trees, and soil conservation measures to ensure water gets percolated into the ground.
- *Regulating Groundwater Extraction*: By Enforcing regulations to control excessive groundwater extraction, pumping, over-exploitation and implementing water use permits, metering, and pricing mechanisms can help manage extraction rates in Bangalore.
- *Educating Communities*: Raising awareness on the importance of groundwater conservation, recharge and encouraging responsible water use by initiating awareness programmes. Community participation is very essential for successful and significant recharge of ground water i.e; aquifer recharge initiatives.

### ***Lakes in Bangalore:***

According to Lakes department, BBMP, urbanisation has been quickly rising in the last few years in India, in terms of economic development population and geographical boundaries .It is observed that urban expansions have overtaken the water bodies in their territories and peripheral regions of the city. Water Bodies have been the backbone of resource sustainability in any urban conglomerate as they cater to different human needs - drinking, washing, fishing and irrigation. Also they are an essential resource for storing water, serve as a retention mechanism that would capture flash floods, help maintain ground water levels through recharge from rain water, development of industries, support bio-diversity and avian fauna, and influence a city's micro-climate. But today, the quality of water resources and their availability are under considerable threat due to rapid urbanization.

Bengaluru city was once known as 'city of lakes' due to the presence of large number of lakes in the city. According to IISc report, 2016, there were 1,452 water bodies during early 1800's and these were gradually reduced due to encroachments and concretization. According to Bengaluru Sustainability Forum report, lakes in Bangalore have a rich and historical heritage, dating back to the time of Kempegowda, the founder of Bangalore city. Kempegowda has built a series of lakes and tanks to harness rainwater for cultivation and agricultural purposes. These water bodies, over the years, have evolved from simple tanks to complex lake ecosystems, home to a wide range of flora and fauna. The lakes like Ulsoor, Sankey Tank, Varthur Lake and Bellandur Lake are not only landmarks but also historical witnesses to the growth of Bangalore city.

Bangalore's lakes are grappling with multiple challenges, despite their historical and ecological significance. Rapid urbanization has resulted in encroachments, illegal constructions on and over the wetlands and lakebeds, and the dumping of solid waste into these water bodies. Industrial pollution and effluents from factories and untreated sewage discharge into the lakes, tanks and other water bodies in Bangalore, has resulted in the deterioration of water quality, threatening the survival of life of aquatic animals and posing health risks to the surrounding communities. Bellandur Lake was once known for its scenic beauty and fresh water, now gained notoriety for the froth which is a result from the factories effluents discharge and fire incidents caused by high levels of pollutants and effluents discharged into the water body.

### Custody of Lakes in BBMP Area

Bruhat Bengaluru Mahanagara Palike	167
Bengaluru Development Authority	33
Karnataka Forest Department	5
Lake Development Authority	4
BMRCL/Metro	4
<b>Total</b>	<b>210</b>

*Table 5: Custodian of lakes in Bangalore (Source: BBMP Lakes Department website, 2024)*

According to Table 5, the lakes in Bangalore are under the custody of various government agencies or organizations. There are 210 lakes in Bangalore under the BBMP area. Out of 210 lakes, 167 lakes are under the custody of Bruhat Bengaluru Mahanagara Palike, 33 lakes are under the custody of Bengaluru Development Authority, 5 lakes under the custody of Karnataka Forest Department and 4 lakes each under the custody of Lake Development Authority and BMRCL/Metro. Most of the lakes are managed by BBMP.

Total Extent of Live lakes (in acres)	3622.00
Total Encroachment area of Live lakes	303.00
Total Encroachment Removed of Live lakes	46.00
Balance Encroachment to be removed of Live lakes	258.00

*Table 6: Encroachment removal status in Bangalore (Source: BBMP Lakes Department website, 2024)*

From table 6, we can understand that about 10% of area of water bodies in Bangalore has been encroached. And out of 303 acres area only 46 hectares encroachments were removed by BBMP and the balance of 258 acres is yet to be done. These encroachments have been done due to the rapid population growth, migration from rural and other areas to Bangalore in the wake of industries in the city. This is all done because of rapid and quick urbanization in Bangalore in the past few years. Many people are migrating to Bangalore for education, employment and many other purposes. This over crowdedness and over population has led to the encroachments of lakes, wetlands and other water bodies and now it is posing challenges to the mankind in Bangalore. Due to these encroachments, the catchment areas had come down and a few lakes got disappeared. And it is causing the water shortages due to less recharge of ground water in summer season and causing floods in monsoon season.

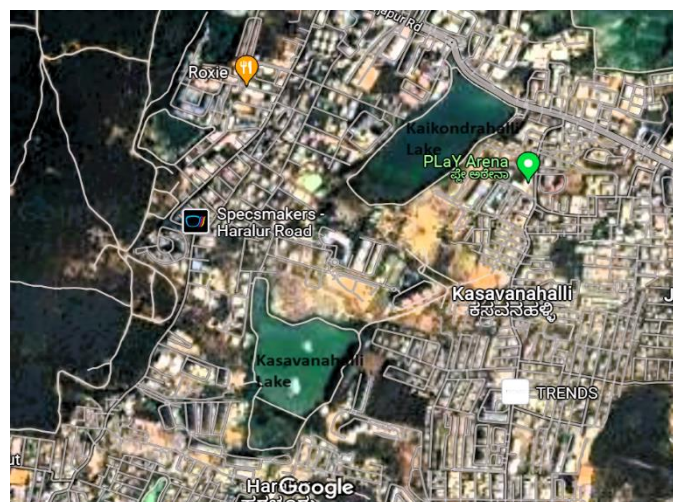


Urbanization has severely effected the lakes in Bangalore. The majority of the city's lakes have been substantially encroached upon in order to build urban infrastructure but it resulted in only 17 good lakes existing among the 51 healthy and good lakes which were present in 1985 in the heart of the city. Urban development in Bangalore has resulted in conversion of 19 lakes into residential colonies, bus stands, Golf courses and playgrounds, stated by Lakes department, BBMP.



*Figure 5: Kasavanahalli and Kaikondrahalli lakes in 2002 and 2016 (Source: Adapted from Sanchayan Nath, 2021)*

Figure shows the lake Kasavanahalli and Kaikondrahalli and how they got transformed from year 2002 to 2016. Earlier the lakes were neat, clean and free from any discharges and encroachments. But in the later stage, buildings and other structures have come up in between both the lakes. This has resulted in the decrease in catchment areas of lakes and sewerage discharge from the residential houses built there, into the lakes causing pollution of the water bodies.



*Figure 6: Kasavanahalli and Kaikondrahalli lakes in 2024 (Source: Google earth, 2024)*

Figure 7 shows the current status of Kasavanahalli and Kaikondrahalli lakes in 2024. The buffer zones and the inlet areas are blocked with the concrete structures like apartments, villas etc. These buildings have been built on the buffer zones of lakes. And this is causing massive flooding during monsoon season and low catchment area caused the reduction in the water storage and percolation into the ground which finally results in drop in groundwater levels in the surrounding areas.

Maximum encroachments were done mostly in the areas which are developed after industrialization in Bangalore. Areas like Mahadevpura, Whitefield etc. tops the list of number of encroachments in Bangalore. BBMP officials has also taken charge and initiated Anti-Encroachment Drive to demolish the structures near the streams, lakes, ponds etc. And also they have initiated Anti-Plastic Drive to ban plastic and discharge of it near the water bodies which automatically reduces the clogging of drains and canals.

***Measures taken by Bengaluru Water Supply and Sewerage Board (BWSSB) and Bruhat Bengaluru Mahanagara Palike (BBMP):***

Bengaluru Water Supply and Sewerage Board (BWSSB) and Bruhat Bengaluru Mahanagara Palike (BBMP) has taken some adequate measures to tackle the water shortage in Bangalore. BWSSB has ensured that every household gets enough Cauvery water every day in the core areas where there is Cauvery water supply. And to the people living in the outer areas which are developed in the last 5-10 years which doesn't have Cauvery water supply are given water by installing syntex tanks in those areas. They have installed around 2,000 syntex tanks in the areas where there was shortage and supplied water through those tanks. And some people used private tanker water for their needs. BWSSB has managed to fill the dried lakes with the secondary treated water from the sewage treatment plants. BWSSB also started an initiative of rain water harvesting in the Bangalore city to prevent the water shortage in future as a long term goal.

According to Mrs. Snehal Rayane IAS, East zone commissioner, BBMP has supplied water through tankers to the people. The private water tankers rates were sky rocketed. Earlier, a 600 liter tanker costed around Rs.500 - Rs.550 which now during water shortage costed around Rs.1500 to Rs.2000. BBMP has regulated the prices of tankers and supplied water through tankers at reasonable rates. BBMP has also regulated the over exploitation of ground water. It has restricted giving permissions to new bore wells as the ground water has declined in the area. They imposed fine/penalty of Rs.5,000 who used water irresponsibly for the non-essential needs like washing cars, swimming pools etc. They ensured that the fresh water is used only for the very essential needs like drinking, cooking etc. And the people are made aware of the conservation of water during this crisis period.

BBMP initiated Encroachment Removal Drive to demolish the structures which have come up in the later years due to rapid urbanization on the lakebeds, near the rivers etc. They have successfully removed some of the encroachments in the heavily populated areas like Mahadevpura etc.

The Central Ground Water Board (CGWB) implemented schemes on artificial recharge projects like check dams and recharge trenches to harness surface runoff and recharge the depleting aquifers. The implementation of ground water legislation at the state level is under consideration to regulate and manage ground water resources effectively. Rooftop rainwater harvesting was facilitated in various establishments, including Bangalore University, to augment ground water resources.

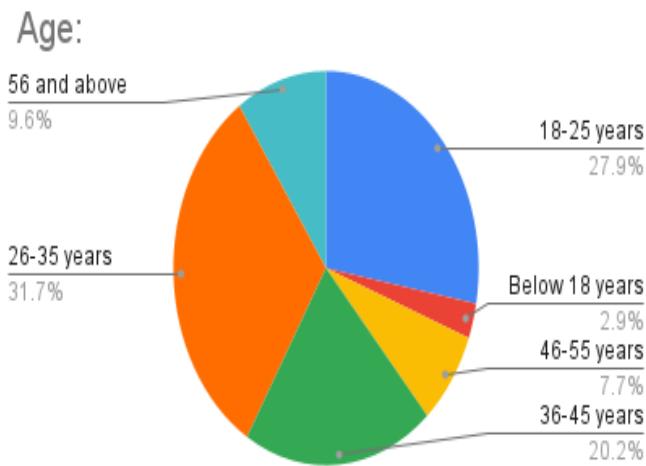
The Bangalore Development Authority (BDA) has mandated that all plots larger than 240 square meters must have rainwater harvesting installed and offered a 5-year property tax rebate for residential properties inside BMA, and a 2-percent rebate for non-residential buildings, when rainwater collecting is incorporated as a fundamental component of building construction. Even though government has put efforts, the community engagement was not up to the mark. Now the public are aware of the water shortage and have been participating in making the sustainable water management possible.

## 6. DATA ANALYSIS AND INTERPRETATION:

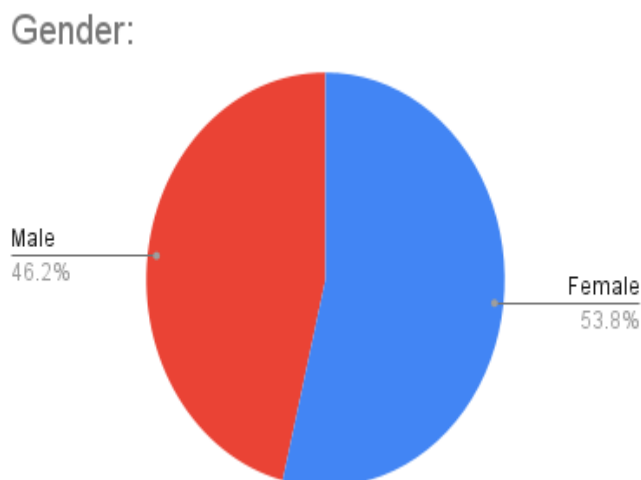
### *Analysis of the questionnaire on Residents' perceptions:*

To understand the impact of Urbanization on the Bangalore's water crisis more in depth and the perceptions of the residents of Bangalore on the water crisis, an online survey questionnaire (google form) was shared to the residents of Bangalore. This online survey was conducted in May 2024. And 104 members had participated and answered the questions. And the questions that were asked are mentioned in the Annexure-I, which is attached at the end of the research report.

### **Profile of respondents:**

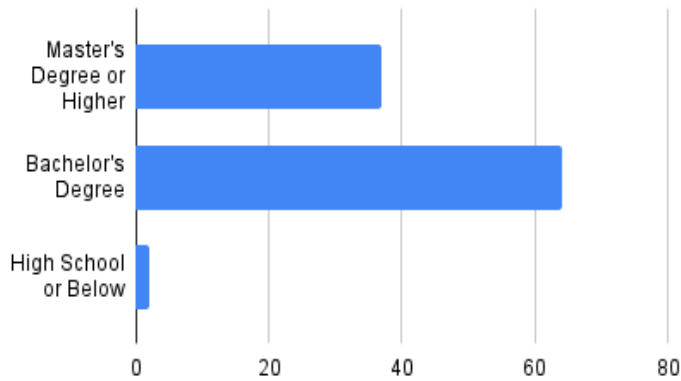


Age is considered as the main factor in the study to analyze the opinions of the respondents. Out of 104 respondents, majority i.e; 33 are from 26-35 years age group, who are considered as the working group. And 29 respondents are from 18-25 age group and least no. of respondents i.e; 3 are from below 18 age group.



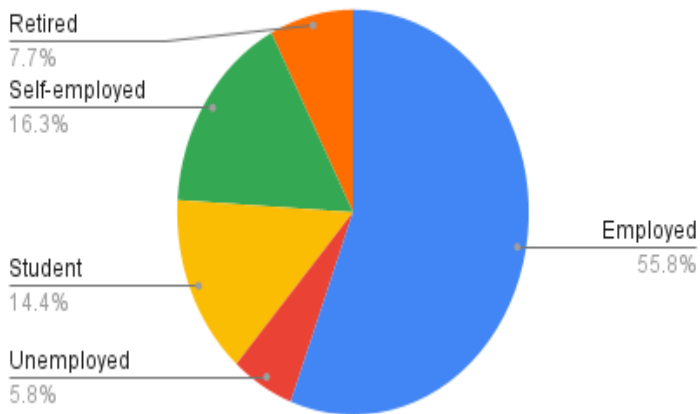
The pie chart shows the percentage of female and male participants of this online survey. Out of 104 respondents, 54% i.e; 56 are female and 46% i.e; 48 are male respondents.

### Education Level:



The graph shows the education level of the participants. Out of 104 respondents, highest no. of people i.e; 65 possess a qualification of Bachelor's degree, 37 people are Master's or higher degree holders and 2 respondents had completed their high school.

### Occupation:



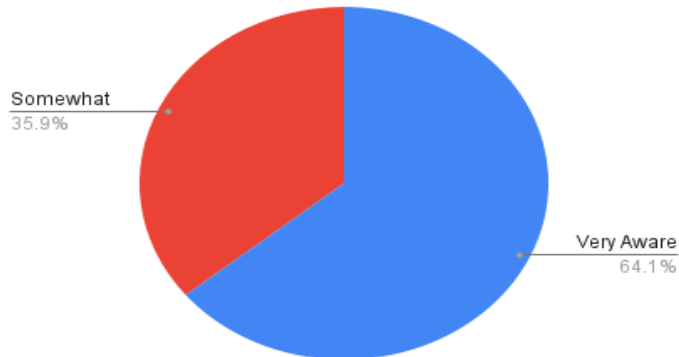
The pie-chart shows various the occupation of the respondents. Out of 104 respondents, 58 are employed, 17 are self-employed, 15 are students, 8 are retired persons and 6 respondents are unemployed. Most of the respondents are are educated and employed.

- Area of residence

People from almost all the parts of Bangalore has participated in this online survey. Most of the respondents are from the places like Whitefield, Electronic city, Koramangala, Indira nagar, Jayanagar, Gottigere, Banashankari, JP Nagar, Hebbal, Nagarabhavi, Marathahalli, Kengeri, Chamarajpet etc. And majority are from the Bangalore East.

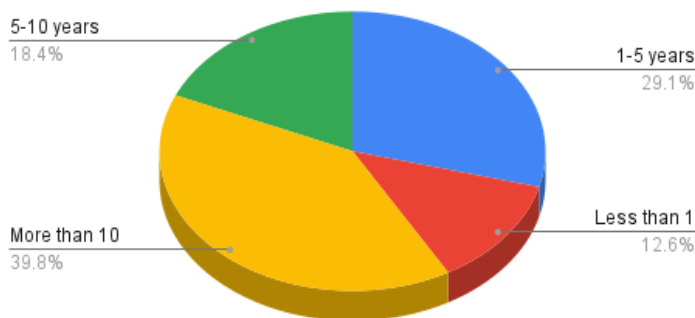
**Responses:**

How aware are you of the current water crisis in Bangalore?



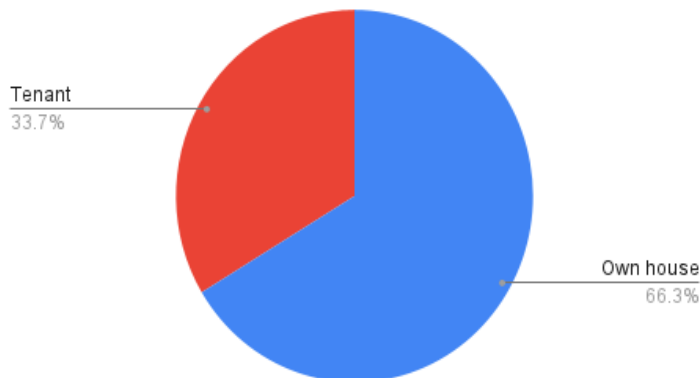
The graph shows the awareness of the respondents on the ongoing water crisis in Bangalore. Most of the respondents are very aware of the water crisis or shortage in the Bangalore city and also the metropolitan area. And almost every respondent is more or less aware of the water crisis in Bangalore.

How long have you been living in Bangalore?



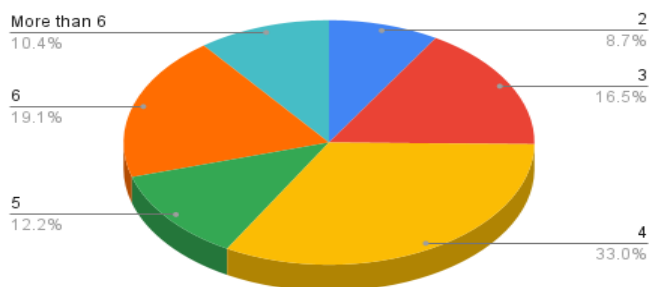
Out of 104 respondents, 39% i.e; 41 people are residing in Bangalore for more than 10 years, 30% i.e; 31 people are staying for last 1-5 years, 19 people are staying since 5-10 years and 13 respondents are living in Bangalore for last few months i.e; less than 1 year.

Whether you live in own/rented house



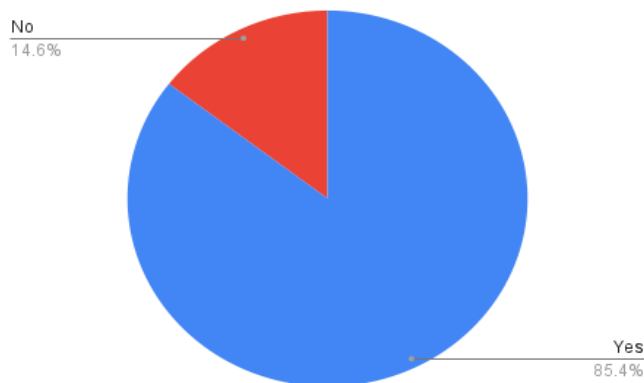
The graph here shows the type of house i.e; own/rented, they are living in. Out of 104 respondents, 66% i.e; 69 people are tenants and live in rented house. 34% i.e; 35 people own a house in Bangalore.

**Your Family size - How many people live in your house?**



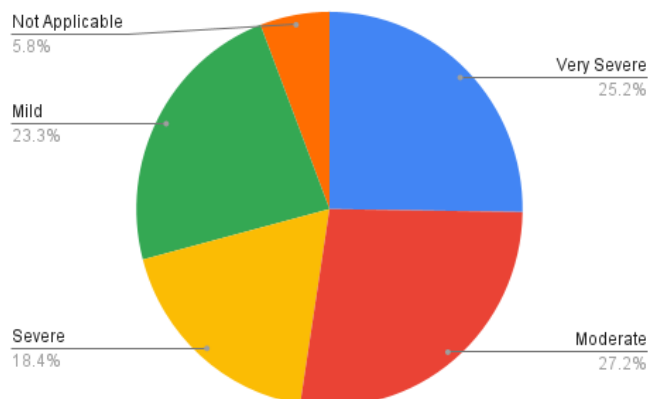
The graph shows the family size of the respondents. Most of the respondents have a family size of 4. Out of 104 respondents, 38 people have a family size of 4, 19 people have a family size of 3, 14 people have a family size of 5, 13 people live in a family more than 6, 10 respondents have a family size of 2 and 10 respondents have a family size of 6.

**Have you faced water shortages or disruptions in your area due to rapid urbanization?**



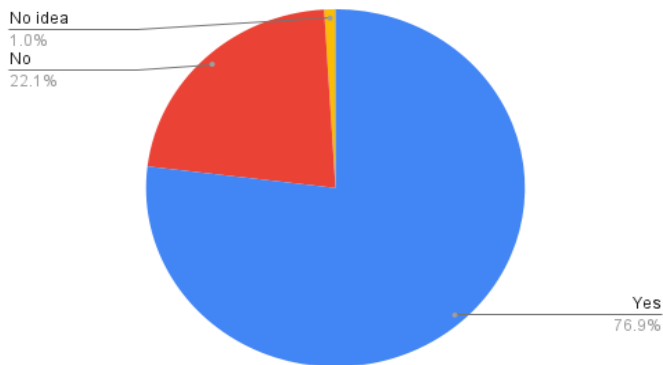
This graph shows how many respondents faced the water shortage in their areas. From the given pie chart we can conclude that most of the respondents faced water disruptions. Out of 104 respondents, 86% i.e; 89 members said that they faced water shortage and 14% i.e; 15 people didn't face any water shortage in their area due to rapid urbanization.

**How severe do you perceive the water crisis to be in your area?**



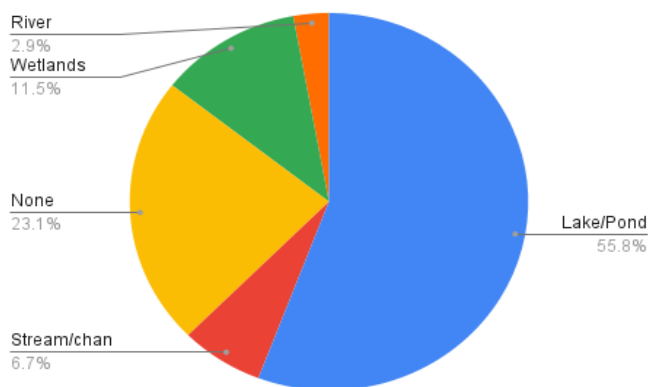
The severity of the water crisis perceived by the respondents is shown in the graph. Out of 104 respondents, 26 people perceive that the water crisis is very severe in their area. 20 people say its severe, 28 people say its moderate and 24 people say its moderate in their areas. And 6 respondents say that there was no shortage and not applicable to their area.

Do you have any surface water bodies around your home/community?



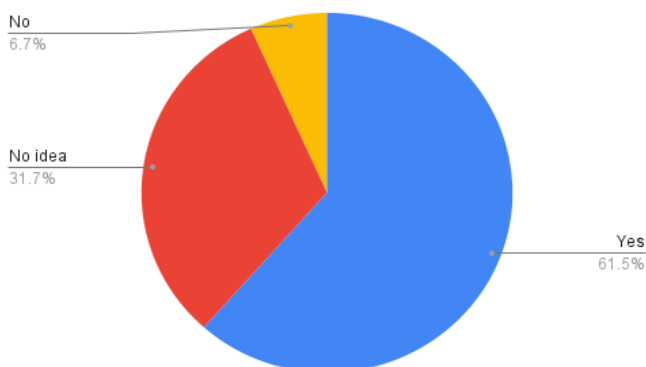
According to the graph, 80 respondents have a surface waterbodies near and around their home/community. And 23 people donot have any surface water bodies around their home.From this we can say that the city Bengaluru has a huge number of lakes but now they have been encroached due to rapid urbanization over the past few years.

What type of water body is around/nearby your home/community?



This graph shows what type of water bodies the respondents have nearby their home/community. 58 respondents have lake/pond near their home/community. 12 people houses are near the wetlands, 7 people houses are nearby streams/channels and 3 respondents liver nearby the river. Arkavathy river flows through the city. And 24 respondents doenot have any type of water bodies near their home/community.

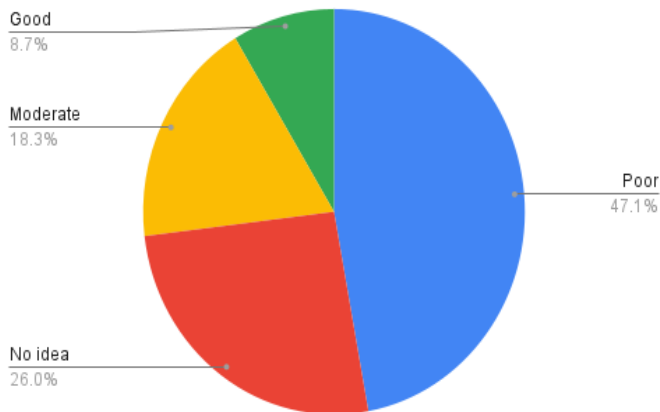
Do you remember any water body loss around your area in the last 5/10/15 years?



This graph shows that many respondents 61.5% i.e; 64 people had reported that they had seen the water body loss in their area/neighbourhood in the past few years. This water body loss is due to the encroachments seen on the water bodies in Bangalore due to rapid population growth.

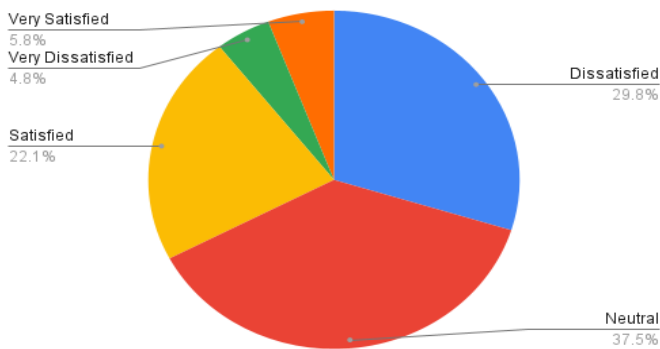


What is your opinion about the quality of the surface water of our city/surroundings?



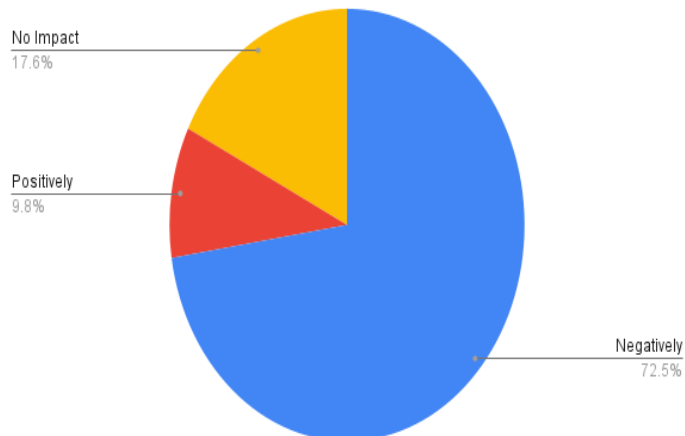
This graph shows the respondents' opinions on the quality of surface water bodies in their city. From the given graph, we can understand that most of the lakes' water quality has deteriorated due to pollution and discharge of effluents and sewerage into the surface water bodies like lakes, channels, rivers etc. 49 respondents said that the water quality of the water bodies in the city is poor.

How satisfied are you with the existing water infrastructure in your area?



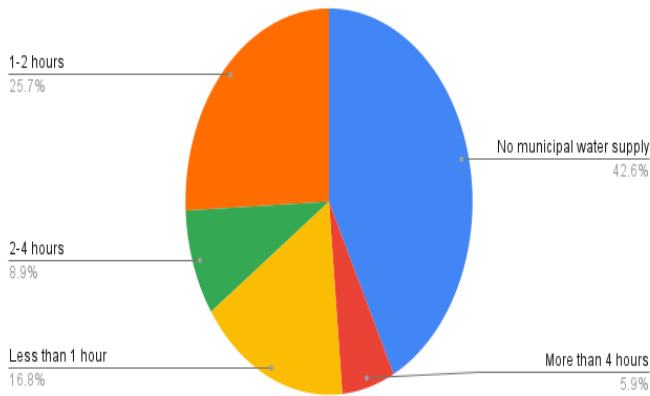
The graph shows how satisfied the respondents are with the water infrastructure in their areas. From the given pie chart, we can understand that most of the people are not satisfied with the existing water infrastructure in their area. And they want some more better water infrastructure for regular and uninterrupted water supply.

How do you feel the water crisis has impacted your daily life?



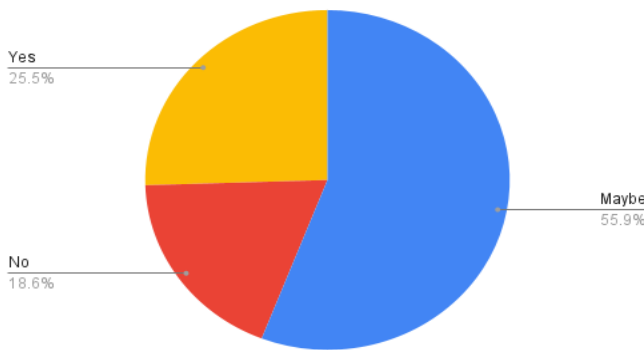
According to the responses from the participants, it is known that the water crisis has impacted their daily life negatively, due to the shortage and no water in some areas. They had to wait in the long queues for the water tankers and had to use water efficiently and limitedly. They also said that they reused the already used water for gardening and flushing in their home.

How many hours of municipal water supply do you typically receive per day?



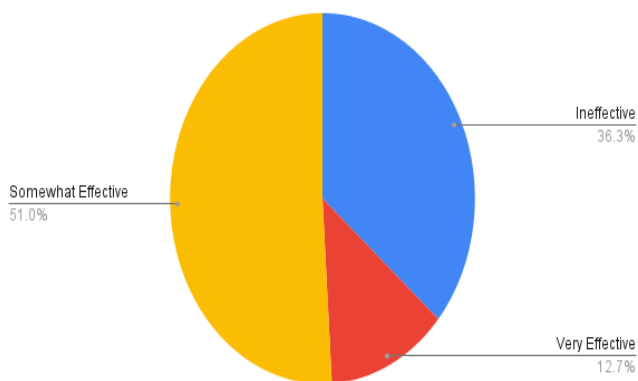
The graph shows the number of hours that the respondents receive water per day. Since most of the responses are from the Bangalore East and the outskirts of Bangalore, many people reported that there is no municipal water supply. And 27 respondents receive 1-2 hours of water supply, 17 members said less than 1 hour of water supply and 9 members get 2-4 hours water supply. Water supply differs from area to area so is the shortage.

Do you feel the government is taking adequate measures to address the water crisis?



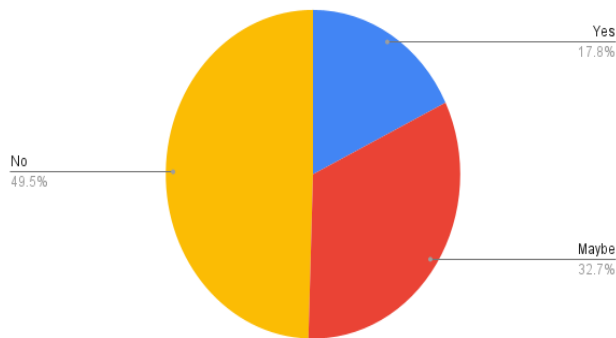
The graph shows the respondents' opinion on the government measures. Most of the respondents feel that the government is not so keen in taking the adequate measures to address the water crisis in Bangalore. And also feel that even though the measures are taken, they are not effective in tackling the situation.

How effective do you consider the government's response to the water crisis in Bangalore?



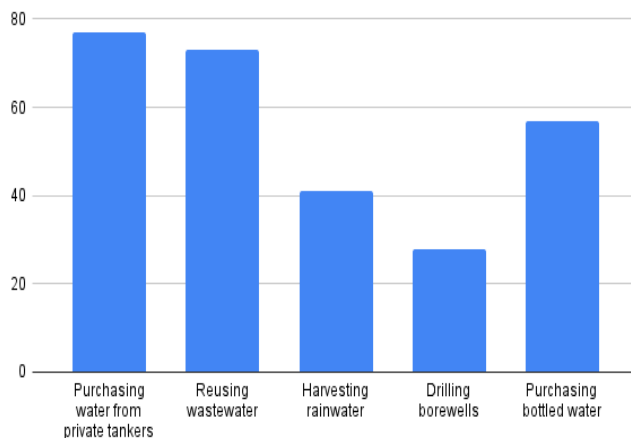
This graph shows how effective was the response from the government to tackle the water crisis in the city. Majority 51% of the respondents feel that the response from the government is somewhat effective and the measures that they are taking are not that effective in tackling the crisis.

Have you or anyone in your household experienced health issues due to water scarcity or poor water quality?



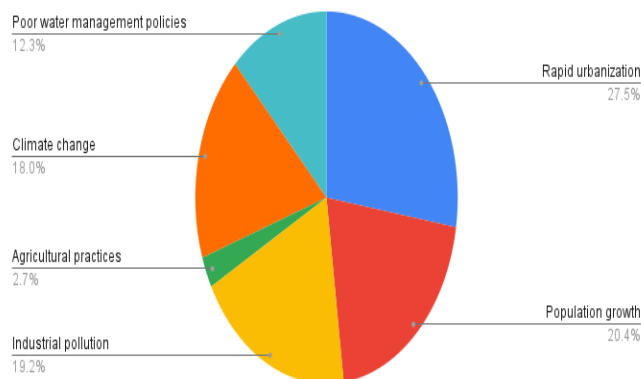
This graph shows whether the people had faced health issues due to shortage and poor quality of water. Even though the people of Bangalore have faced water crisis and relied on the water tankers, most of them had never experienced any health issues due to the water scarcity. A few of them i.e; 18 out of 104 respondents, had suffered from health issues due to poor water quality.

What alternative sources of water do you use during shortages?



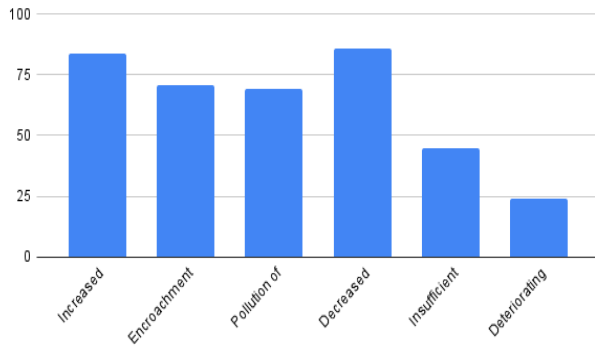
Alternative sources that the respondents opt during shortages of water are shown in the graph. Majority of the respondents i.e; 77 out of 104 had relied on the private tankers for their water needs and some respondents said that they relied on other alternate sources like using wastewater again and harvested rainwater, drilling new borewells and a few relied on the purchased bottled water for their water needs.

What do you believe are the main factors contributing to the water crisis in Bangalore?



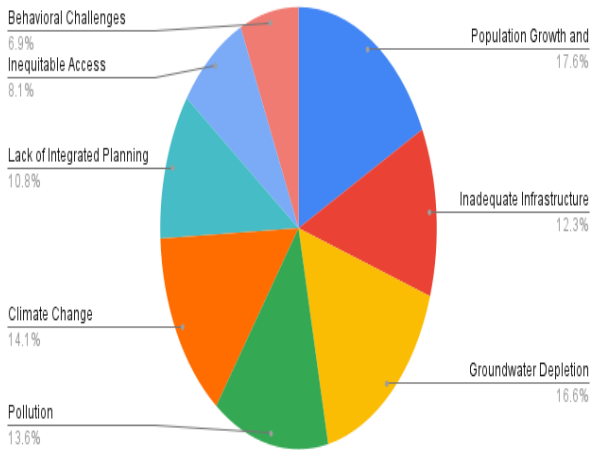
Factors contributing to the water crisis are shown in the graph. Most of the residents feel that the water shortage and crisis is due to Rapid Urbanization, Population growth, Poor water management policies and climate change in Bangalore. 92 respondents feel that the crisis is majorly due to rapid urbanization in Bangalore. And above 60 respondents said that the crisis is due to population growth, industrial pollution and climate change.

In your opinion, how has urbanization contributed to the water crisis in Bangalore?



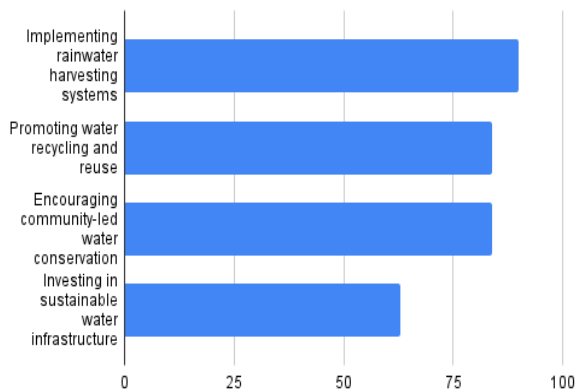
The graph shows how urbanization caused water shortage in Bangalore. Respondents reported that the rapid urbanization has caused the increased water demand, water bodies encroachments, pollution of surface water sources, decline in groundwater levels and deterioration of quality of water. Above 80 respondents felt that urbanization caused depletion of groundwater and increased water demand in Bangalore.

What do you think are the biggest challenges hindering effective water management and conservation efforts in Bangalore?



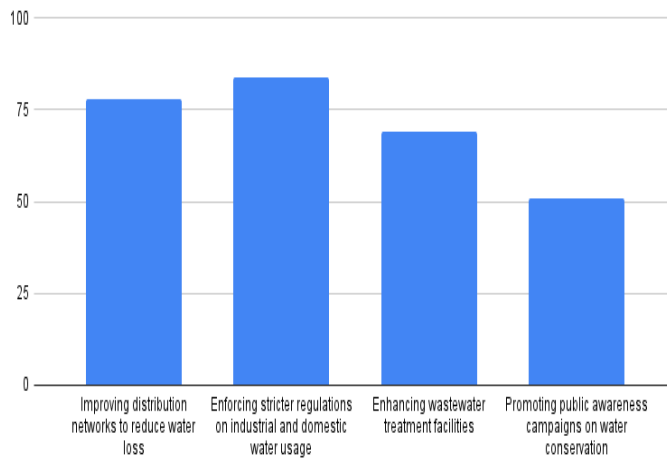
This graph shows the challenges according to the respondents that are hindering water management and conservation. Majority of the respondents feel that the population growth and rapid urbanization, decrease in groundwater, pollution, climate change and a few people feel that the inadequate water infrastructure, lack of integrated and poor planning, inequitable access to water and behavioural challenges are the biggest challenges hindering effective water management and conservation efforts in Bangalore.

What opportunities do you see in urbanization to address the water crisis in Bangalore?



The graph shows the opportunities to address the water crisis in Bangalore. The respondents of the survey had said that promoting water cycling methods and reuse, implementation of rainwater harvesting, encouraging community-driven water conservation programmes would help to reduce the impact of water crisis by improving distribution networks to reduce water loss, enforcing stricter regulations on industrial and domestic water usage, enhancing wastewater treatment facilities.

What improvements would you suggest for better water management in rapidly urbanizing areas?



From the given graph, we can conclude that majority of respondents suggested to enforce stricter regulations on industrial and domestic water usage and to improve distribution networks to reduce water loss and unaccounted for water. And some other had suggested to enhance wastewater treatment facilities and promote public awareness campaigns on water conservation for better water management in the rapidly urbanizing areas.

After analysing all the responses of the residents participated in the online survey, we can conclude that the water crisis or shortage is not in all the areas but in the areas that are on the outskirts where the dependency on borewells is very high and the areas with high population and no Cauvery water supply, for example, areas like Whitefield, Electronic city are developed in the past few years and has seen a lot of urban growth in these areas. Simultaneously a lot of concretization has come into picture by putting the natural resources at risk. This has led to over dependency on groundwater which resulted in ground water depletion and decline in the green spaces and surface water bodies. A lot of people who suffered from the water shortage had largely relied on the private water tankers and bottled water. Most of the lakes and other water bodies in Bangalore have been usurped with the concrete structures. Groundwater levels have been dropped from 300-400 feet to 1200+ feet. The major causes of water shortage are rapid urbanization, population growth, groundwater depletion, insufficient water supply and climate change. Rapid urbanization caused the city to face difficulties like insufficient infrastructure, inadequate water supply, climate change due to pollution and global warming, over exploitation of groundwater. And the opportunities for sustainable water management involves harvesting rain water, conservation of water at all possible chances and to maintaining the lakes and tanks, which helps in the recharge of groundwater. Community engagement is most essential in achieving sustainable water management in the global city like Bangalore.

## 7. FINDINGS & CONCLUSION:

The study on how urbanization affects Bangalore's water crisis highlights several key findings and conclusion. Following is the summary of findings based on the data and sources studied in this research process:

**Rising Water Demand:** The swift urban growth in Bangalore has significantly increased the need for water due to population surge and urban sprawl. The population of Bangalore has rapidly grown from 8.7 million in 2011 to 14 million(estimated value) in 2024. Along with the population, the need and demand for water has also grown. Currently, the demand for water is 2,600 Million Litres per Day but the supply of water is not upto the demand. The BWSSB supplies 1,650 MLD water every day which is less than three-fifth of the demand. 700 MLD water is drawn out from the borewells to cater the water needs but still there comes the shortage for one-fifth of the water demand. The Cauvery stage-V project aims to provide 775 MLD water to 110 villages which donot have the Cavery water connection previously. Even though it provides 775 MLD it would not suffice the water needs due to rising water demand in Bangalore. Population increase directly impacts water demand, stressing the urgency for effective urban water management strategies to cater to the city's expanding needs.

**Groundwater Depletion:** Urbanization has led to a decline in groundwater levels across the Bangalore Metropolitan Area. Due to rapid urbanization in Bangalore, the population increased rapidly and the demand for water has also grown. To cater the water needs people started relying on borewells and draws out about 700 MLD water everyday. They heavily depended on borewells for their water needs and extracted the groundwater in an unregulatory manner. This heavy reliance on borewells led to over extraction and over exploitation of groundwater which ultimately resulted in the decline in groundwater levels. And the groundwater recharge is also very minimal in Bangalore. The stage of extraction of ground water in 2023 is 150% which shows the over exploitation of ground water in Bangalore. Groundwater availability and sustainability are impacted by uncontrolled extraction, which intensifies depletion. Excessive groundwater extraction for urban purposes, along with inadequate recharge mechanisms, poses a serious threat to water security in the region.

**Decline of Wetlands and Lakes:** Urban growth has led to the degradation and loss of lakes and wetlands in Bangalore. According to the Lakes Department, BBMP, currently Bangalore has 210 lakes which are very less compared to the number of lakes that were there previously. Out of 3,622 acres of live lakes, 303 acres were encroached which is 10% of the total extent. Bangalore is now no longer a city of lakes because most of the lakes are encroached and polluted. The total water catchment area of the lakes i.e; area of lakes is also declined. Many lakes suffer from siltation, reducing their storage capacity and affecting water quality. And this has resulted in floods in monsoon and water shortage in summer season. Rapid urbanization has encroached upon these vital ecosystems, causing habitat loss, biodiversity reduction, and diminished water retention capacity, exacerbating the water crisis and

ecological imbalances in the city.

**Surface Water Quality Impact:** Changes in land use due to urbanization have negatively affected the quality of surface water in Bangalore. Untreated waste water and hazardous effluents from factories and industries are being released into Bangalore's surface water bodies, causing pollution. And also from the untreated sewage that is directly released into the lakes and streams. Pollutants such as heavy metals, nutrients, and pathogens degrade water quality and harm aquatic ecosystems. This has made the quality of water in surface waterbodies to deteriorate. And BWSSB is filling some lakes with the treated waste water. Urban expansion has resulted in heightened pollution and deterioration of surface water bodies in urbanizing areas, stressing the necessity for efficient land use planning and pollution control measures to tackle water quality issues.

**Socio-economic consequences:** Water scarcity resulting from urbanization disproportionately impacts vulnerable communities in Bangalore. Low-income communities and informal settlements may face challenges in accessing reliable water supply, relying instead on informal sources or expensive private water tankers. The marginalized group of people could not afford for the private water tankers of Rs. 1,500 each and everytime they need water. This is putting stress on the economically weaker sections people in Bangalore. And this has widened the gap and increased the social disparities among the people. In order to address social inequities and strengthen resilience, inclusive water governance methods are required. The socio-economic effects of water shortage highlight challenges of fair access and livelihoods among vulnerable populations.

**Water Governance Challenges:** Urbanization presents institutional hurdles in water governance in Bangalore. Multiple agencies like Bengaluru Water Supply and Sewerage Board (BWSSB), Bengaluru Development Authority (BDA), Bruhat Bengaluru Mahanagara Palike (BBMP), Karnataka Urban Water Supply and Drainage Board (KUWSDB) are involved in water management, leading to fragmentation and lack of co-ordination, creating challenges in decision-making and implementation. There should be co-ordination between the Governmental organisations, agencies, NGOs, and the communities for better water governance in Bangalore. Insufficient funding and financial sustainability pose challenges to maintaining and upgrading water infrastructure. The tariffs are very less and water is provided to people and industries at subsidized rates. These tariff systems frequently fail to capture the full cost of water, resulting in insufficient investment in infrastructure maintenance and development. Water management and decision-making processes are improved by effective institutional frameworks and participatory techniques, which are advocated due to the complexity of urban water governance, which includes concerns of coordination, regulation, and stakeholder involvement.

## 8. RECOMMENDATIONS:

Based on the research findings on the impact of urbanization on the water crisis in Bangalore, the following recommendations can be made to address the challenges and leverage the opportunities:

**Integrated Water Management:** Implement integrated water management strategies that consider both surface water bodies and groundwater resources. This involves coordination in planning and management of water sources to ensure sustainable usage and replenishment. Integrated water management in Bangalore requires collaborative efforts among government agencies like BWSSB, BDA, BBMP AND KUWSDB, private sector stakeholders and civil society. By adopting holistic approaches that prioritize sustainability, resilience, and equitable access to water resources and developing strategies and policies, Bangalore can effectively address its water challenges and ensure a water-secure future for its residents.

**Water Conservation:** Promote water conservation measures at the individual, household, and community levels. This includes promoting water-efficient technologies, rainwater harvesting, and awareness campaigns to reduce water consumption and wastage. Encouraging rainwater harvesting at individual and community levels helps recharge aquifers during the monsoon season. Rainwater harvesting plays a vital role in enhancing the city's water supply and mitigating water scarcity challenges. Since Bangalore has excellent precipitation, and even if half of the precipitation falls is captured, it still leaves 10-15 TMC of additional resources available. In light of this, BWSSB has made the implementation of rainwater harvesting essential for all building owners and occupants whose site area measures 60' x 40' or more, as well as for newly constructed buildings with dimensions of 30' x 40' or more. To promote the adoption of rainwater harvesting, a number of widely accepted initiatives are launched. Furthermore, BWSSB created a "Rainwater Harvesting Themepark" in Jayanagar with 26 RWH models and recommendations on water conservation. Many residential complexes, educational institutions, and commercial buildings in Bangalore have successfully implemented rainwater harvesting, serving as examples of sustainable water management practices. Even though BWSSB mandated the RWH, it did not implemented holistically.

Rain water harvesting can be done in three ways:

- a) Roof top rain water harvesting
- b) Run off rain water harvesting
- c) Rain water collection and storage through tanks and lakes.

Rainwater harvesting in Bangalore improves resilience against the effects of climate change, encourages sustainable water use habits, and supports environmental conservation initiatives in addition to helping with water scarcity.



**Groundwater Recharge:** Implement measures to enhance groundwater recharge, such as constructing artificial recharge structures like recharge wells, percolation tanks, check dams, and promoting sustainable land use practices that facilitate infiltration and recharge of groundwater. Recharge wells allow rainwater or treated wastewater to infiltrate into deeper aquifers, replenishing groundwater reserves. Percolation tanks capture and store rainwater temporarily and allowing it to slowly percolate into the ground and recharge aquifers. Check dams are specifically constructed to improve groundwater recharge by reducing surface runoff and enabling water to infiltrate into the ground. Sewage Treatment Plants (STPs) are to be expanded and upgraded in order to treat wastewater to tertiary standards so that it can be used again for non-potable uses like irrigation, manufacturing, and recharge of groundwater. The government should implement measures for regulating the extraction of groundwater.

Ground Water Management and Regulation (GWM&R) scheme which is a Central Government scheme should be implemented in a strict manner to regulate the over exploitation of groundwater and take measures to recharge groundwater in Bangalore.

**Urban Planning:** Proper urban planning plays a significant role in the sustainability of a city. BDA prepares and updates Master Plans that guide the growth and development of Bangalore, including land use planning, infrastructure development, and environmental conservation. It should incorporate water management strategies within the Master Plans to ensure sustainable water supply, wastewater management, and stormwater drainage systems. Planning should include the development of infrastructure and maintenance of it. Hence, before developing a city, one must ensure to integrate water-sensitive urban planning principles into city development plans for a sustainable and water-resilient future.

**Pollution Control:** Pollution control in Bangalore is a critical issue due to the city's rapid urbanization, industrial growth, and increasing vehicular traffic. Implement stringent pollution control measures to mitigate the degradation of surface water quality. This includes enforcing regulations on industrial discharge, sewage treatment, and solid waste management to prevent pollution of water bodies. Upgrading and expanding STPs to treat domestic and industrial wastewater before discharge into water bodies. Regulating and monitoring industrial discharges through effluent treatment plants (ETPs) and enforcing compliance with pollution control norms. Planting trees, developing green spaces, and promoting rooftop gardens to enhance biodiversity, absorb pollutants and mitigate climate change effect. Implementing these pollution control measures would result in green, clean and water secure city.

**Ecosystem Restoration:** The lakes, and other water bodies are encroached and filled with pollutants and sewage. This had led to degradation of ecosystem in Bangalore. Cleaning and de-silting of lakes and tanks would automatically helps to enhance the storage capacity. Removing the structures that have come up on the buffer zones of lakes and lakebeds would help the water to flow into the lakes and mitigate flooding of storm water during Monsoon season and would help to recharge groundwater through lakes and lessen the water shortage during the summer season. BBMP has initiated a few programmes to rejuvenate lakes and restore them. Those programmes should be implemented in a more holistic manner. Restore and conserve lakes, wetlands, and other natural ecosystems to enhance water retention capacity, biodiversity, and ecological resilience. This involves reclamation of encroached water bodies, habitat restoration, and green infrastructure development.

**Community Engagement:** Encourage community participation and stakeholder engagement in water governance processes. This entails including regional associations, non-governmental organizations, and other relevant stakeholders in the formulation, organizing, and execution of water management programs. Engage local communities through participatory planning processes, citizen forums, and educational initiatives to increase public awareness of pollution mitigation, water conservation, and sustainable methods of water management. And provide training and capacity building programs for stakeholders, water managers, and urban planners to enhance skills in integrated water resource management. This would bring awareness in citizens and also increases the accountability and transparency.

**Inclusive Governance:** Ensure inclusive and participatory water governance processes that prioritize the needs and perspectives of all stakeholders, including marginalized communities. This involves promoting equity, access, and social justice in water allocation and distribution. Conduct public consultations and participatory workshops to gather feedback, suggestions, and concerns from the community on issues affecting their neighborhoods and livelihoods. Empower marginalized communities through inclusive development projects, access to basic services (e.g., water, sanitation, healthcare), and economic opportunities to improve their quality of life and ensure their voices are heard in decision-making processes.

By implementing these recommendations, Bangalore can tackle the water crisis, enhance water security, and promote sustainable urban development amidst rapid urbanization in the long term.

## **9. LIMITATIONS OF THE STUDY:**

The study focuses exclusively on Bangalore Metropolitan Area i.e; Bangalore Urban district. And besides primary data from telephonic interviews and online survey, most of the study conducted is based on the secondary data collected from various official websites, reports, research papers, and journal/news articles. However, this heavy reliance on secondary sources could impact the accuracy and reliability of the study's findings. The respondents to the survey is limited. The study is based on certain assumptions or hypotheses regarding the causal links between urbanization and the water crisis. These assumptions lack robust statistical validation, potentially leading to speculative conclusions.

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## ANNEXURE - I

### Questionnaire for understanding the community perceptions on "Bangalore Water Crisis"

This study aims to understand the community perceptions, knowledge on the ongoing water crisis in Bangalore and practices related to water use and conservation, which is essential for developing inclusive and effective watermanagement strategies.

#### Demographic Information:

1. Age:

- Below 18 years
- 18-25 years
- 26-35 years
- 36-45 years
- 46-55 years
- 56 and above

2. Gender:

- Male
- Female
- Prefer not to say
- Other:

3. Education Level:

- High School or Below
- Bachelor's Degree
- Master's Degree or Higher

4. Occupation:

- Student
- Employed
- Unemployed
- Retired
- Self-employed
- Other:

5. Area of Residence in Bangalore:

- Indiranagar
- Koramangala
- Whitefield
- Jayanagar
- Electronic City
- Other:

**Awareness and Perception:**

6. How aware are you of the current water crisis in Bangalore?

- Very Aware
- Somewhat Aware
- Not Aware

7. How long have you been living in Bangalore?

- Less than 1 year
- 1-5 years
- 5-10 years
- More than 10 years

8. Whether you live in own/rented house

- Own house
- Tenant

9. Your Family size - How many people live in your house?

- 2
- 3
- 4
- 5
- 6
- More than 6

10. Do you have any surface water bodies around your home/community?

- Yes
- No
- No idea

11. What type of water body is around/nearby your home/community?

- River
- Stream/channel
- Lake/Pond
- Wetlands
- None

12. What is your opinion about the quality of the surface water of our City / surroundings?

- Poor
- Moderate
- Good
- No idea

13. Do you remember any water body loss around your area or neighbourhood in the last 5/10/15 years?

- Yes
- No
- No idea

14. Have you faced water shortages or disruptions in your area due to rapid urbanization?

- Yes
- No

15. How severe do you perceive the water crisis to be in your area?

- Very Severe
- Severe
- Moderate
- Mild
- Not Applicable

16. How satisfied are you with the existing water infrastructure in your area?

- Very Satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very Dissatisfied

17. How do you feel the water crisis has impacted your daily life?

- Positively
- Negatively
- No Impact

18. What do you believe are the main factors contributing to the water crisis in Bangalore?

(Select all that apply).

- Rapid urbanization
- Population growth
- Industrial pollution
- Agricultural practices
- Climate change
- Poor water management policies
- Other:

19. In your opinion, how has urbanization contributed to the water crisis in Bangalore? (Select all that apply)

- Increased demand for water
- Encroachment of water bodies
- Pollution of water sources
- Decreased groundwater levels
- Insufficient water supply
- Deteriorating water quality
- Other:

20. What opportunities do you see in urbanization to address the water crisis in Bangalore?

(Select all that apply)

- Implementing rainwater harvesting systems
- Promoting water recycling and reuse
- Encouraging community-led water conservation initiatives
- Investing in sustainable water infrastructure
- Other:

21. What improvements would you suggest for better water management in rapidly urbanizing areas? (Select all that apply)

- Improving distribution networks to reduce water loss
- Enforcing stricter regulations on industrial and domestic water usage
- Enhancing wastewater treatment facilities
- Promoting public awareness campaigns on water conservation
- Other:

**Water Usage:**

22. How many hours of municipal water supply do you typically receive per day?

- Less than 1 hour
- 1-2 hours
- 2-4 hours
- More than 4 hours
- No municipal water supply

23. What alternative sources of water do you use during shortages? (Check all that apply)

Purchasing water from private tankers

- Reusing wastewater
- Harvesting rainwater
- Drilling bore wells
- Purchasing bottled water
- Other:

24. Have you made any changes to your water usage habits due to the crisis? If yes, please describe.

25. How satisfied are you with the quality of water supplied by the municipality?

- Very satisfied
- Satisfied
- Not satisfied

26. Have you or anyone in your household experienced health issues due to water scarcity or poor water quality?

- Yes
- No
- Maybe

27. In your opinion, what are the most significant social and environmental impacts of the water crisis in Bangalore?

- Social unrest
- Health issues
- Displacement of communities
- Ecosystem degradation
- Other:

**Government Response and Policy Measures:**

28. Do you feel the government is taking adequate measures to address the water crisis?

- Yes
- No
- Maybe

29. How effective do you consider the government's response to the water crisis in Bangalore?

- Very Effective
- Somewhat Effective
- Ineffective

30. What specific policy measures do you believe should be implemented to address the water crisis? (Select all that apply)

- Improved water infrastructure
- Strict regulations on water usage
- Promotion of water conservation practices
- Investment in alternative water sources (e.g., rainwater harvesting)
- Other:

**Community Engagement and Awareness:**

31. How informed do you feel about water conservation practices and initiatives in your community?

- Very Informed
- Somewhat Informed
- Not Informed

32. Have you participated in any community-led initiatives or campaigns related to water conservation?

- Yes
- No

33. If yes, please describe your involvement and its impact.

**Future concerns:**

34. How concerned are you about the long-term availability of water in Bangalore?

- Very Concerned
- Concerned
- Neutral
- Not Concerned

35. What do you think are the biggest challenges hindering effective water management and conservation efforts in Bangalore? (Select all that apply)

- Population Growth and Urbanization
- Inadequate Infrastructure
- Groundwater Depletion
- Pollution
- Climate Change
- Lack of Integrated Planning
- Inequitable Access
- Behavioural Challenges
- Other:

36. What improvements would you suggest for better water management in rapidly urbanizing areas?

## ANNEXURE – II

### **Questions asked to the Bengaluru Water Supply and Sewerage Board (BWSSB) Officials:**

1. What is the current status of water availability and demand in Bangalore, considering the rapid urbanization the city has experienced?
2. How has urbanization contributed to the water crisis in Bangalore, particularly in terms of increased water demand and stress on existing water sources?
3. What are the main challenges faced by BWSSB in ensuring adequate and sustainable water supply to meet the needs of Bangalore's growing population?
4. Can you elaborate on the strategies and measures implemented by BWSSB to address the water crisis in Bangalore in light of urbanization?
5. What role does infrastructure development play in mitigating the impacts of urbanization on water resources and addressing the water crisis?
6. How does BWSSB manage and regulate groundwater extraction, especially in rapidly urbanizing areas, to prevent depletion and contamination?
7. Are there any innovative technologies or approaches that BWSSB is exploring to optimize water management and usage in urbanized areas?
8. How does BWSSB collaborate with other government agencies, stakeholders, and community organizations to address the challenges posed by urbanization on water resources?
9. What are the key policies and regulations implemented by BWSSB to promote water conservation and sustainable water use in the face of urbanization?
10. Can you provide insights into the challenges and opportunities for rainwater harvesting and wastewater recycling initiatives in Bangalore's urban areas?
11. How does BWSSB monitor and assess the effectiveness of its interventions in addressing the water crisis in Bangalore caused by urbanization?
12. What are the long-term plans and strategies of BWSSB to ensure water security and resilience in Bangalore amid ongoing urbanization trends?



## ANNEXURE - III

### **Questions asked to Bruhat Bengaluru Mahanagara Palike (BBMP) Officials and Lakes Department Special Commissioner:**

1. How would you describe the current state of the water crisis in Bangalore, particularly in areas affected by urbanization?
2. What are the primary factors contributing to this crisis, and how significant is the role of urbanization?
3. How has urbanization specifically exacerbated the water crisis, and what are its most significant impacts?
4. What infrastructure and policy initiatives has BBMP implemented to address the water crisis in urbanized areas of Bangalore?
5. Can you highlight any specific projects or programs aimed at mitigating the effects of urbanization on water resources?
6. How does BBMP plan to balance the competing demands of urban development and water conservation?
7. How does BBMP collaborate with other governmental agencies, NGOs, and private sector entities to tackle the water crisis in urban areas? And what role do you believe collaboration plays in finding holistic solutions to this complex issue?
8. What efforts does BBMP undertake to raise public awareness about water conservation and the impacts of urbanization on water resources? And how important is public education in fostering behaviour change and promoting sustainable water use practices?
9. How has urbanization directly impacted the lakes in Bangalore, and what are the specific challenges it has posed to their conservation and management?
10. What role does the Lakes Department play in coordinating with other city agencies and stakeholders to prevent further encroachments and restore encroached areas around lakes?
11. What are some of the key initiatives undertaken by the Lakes Department to address the impacts of urbanization on Bangalore's water bodies, particularly concerning water quality, quantity, and encroachments?
12. How does the Lakes Department balance the need for urban development with the imperative to protect and restore the city's lakes and water bodies?

13. What legal and regulatory mechanisms are in place to prevent encroachments on lakes, and how effectively are they enforced?

14. What role do community engagement and public awareness campaigns play in combating lake encroachments and promoting sustainable water management practices in Bangalore?

15. Finally, what are the long-term goals and objectives of the Lakes Department in addressing the twin challenges of urbanization's impact on the water crisis and lake encroachments in Bangalore, and how do you envision the future of water management in the city?

# water 2

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