

Effective Strategies for Sustainable Water Management in Butibori Town

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Abstract: Butibori is a bustling industrial municipality located in proximity to Nagpur, India, currently grappling with a significant issue pertaining to water scarcity. The purpose of my study is to devise an inclusive approach for the stewardship of water resources in Butibori, accommodating both existing and anticipated demands. As of the year 2021, the town boasts an approximate population of 49,500 inhabitants who receive merely 34 to 45 liters of water daily. This allocation substantially deviates from the prescribed 135 liters, culminating in a deficit of roughly 7.32 million liters per day. With projections indicating a population surge to 169,653 by the year 2053, the demand for water is anticipated to escalate to 31.20 million liters per day. Such an increase will impose considerable strain on the town's constrained water infrastructure, which presently encompasses a water treatment facility capable of processing only 3.6 million liters and a 55 km water distribution network. To fulfill future requirements, this distribution network would necessitate an extension to 102.09 km. Moreover, over 25% of the water is lost due to leaks and inefficiencies, while pollution in the Vena River, the principal source of water for the town, exacerbates the scenario.

Employing the methodology known as Integrated Water Resource Management (IWRM), I utilized Geographic Information Systems (GIS) for analytical purposes, collaborated with local stakeholders, and examined successful water management approaches from other municipalities such as Jaipur, Patiala, and Nablus. My proposed strategy encompasses the enhancement of water treatment and storage facilities, the extension of the water distribution network, the reduction of water loss through metering and audits, as well as the promotion of rainwater harvesting and the recycling of wastewater for non-potable applications. This proposal aspires not only to secure equitable access to safe drinking water and curtail environmental decline but also to establish a practical blueprint for other cities confronting analogous water-related predicaments.

Keywords- Sustainable water management, Integrated Water Resource Management, Water loss, Rainwater harvesting, Wastewater recycling, Urban water supply, Butibori.

1. INTRODUCTION

Water is essential for communities, businesses, and nature. However, managing water in a way that keeps it safe and available for everyone is getting harder around the world. Many cities are growing quickly, and because of climate change, the water supply is mismanaged, and India is facing this problem, too. Over 600 million people in India do not have enough water, especially in cities that need to provide clean and dependable water to their increasing populations.

In my research, I focused on Butibori, a busy industrial town close to Nagpur in Maharashtra. This town is a clear example of the struggles many places are facing. The water supply in Butibori is not enough—people get only 34 to 45 liters of water per person each day, while the recommended amount is 135 liters. Right now, there is a shortage of 7.32 million liters of water every day. This problem is made worse by old water systems, pollution from the Vena River caused by factories, and losses in the water supply that are more than 25% due to leaks and other issues. bigger global problem. More than 2.2 billion people around the world do not have safe drinking water, and cities have the hardest time dealing with this scarcity. The population in Butibori is expected to grow a lot, from 49,500 in 2021 to 169,653 by 2053. This makes it very important to find a sustainable plan for managing water. India's water issues are part of a

Figure 1. Projected gross water demand in Butibori from 2021 to 2053, showing an increase from 9.10 million liters per day (MLD) to 31.20 MLD, reflecting population growth and highlighting the need for sustainable water management strategies.

Since India became independent, it has made great progress in managing water resources, which has helped the economy and improved access to drinking water. However, rapid city growth and industrial activities, particularly in areas like Maharashtra that do not have much rainfall, have increased the demand for water beyond what is sustainable.

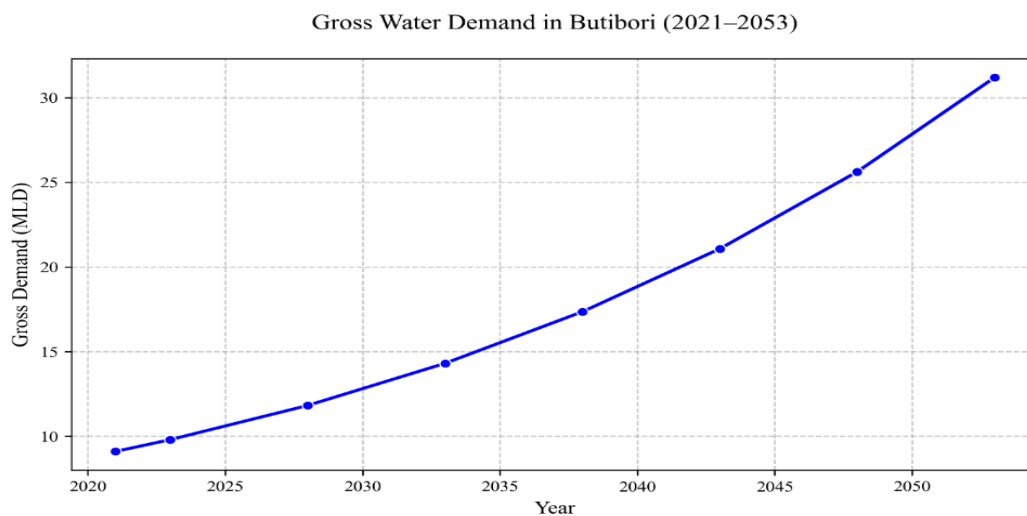


Figure 1Graph: Gross Water Demand in Butibori (2021–2053)

In Butibori, the water system is not up to the task: the network of pipes is only 55 km long when it needs to be over 102 km, and the water treatment plant can only handle 3.6 million liters per day. Additionally, pollution from the Maharashtra Industrial Development Corporation (MIDC) is harming the Vena River, and too much groundwater is being used without enough rain to refill it.

To tackle these problems, I looked into using Integrated Water Resource Management (IWRM). This approach brings together science, policies, and community involvement to make sure that water supply meets demand while also protecting the environment. Some practical steps include reducing water losses, recycling wastewater, and collecting rainwater, which are relevant for Butibori.

I also observed successful examples from other cities, like Jaipur, which improved its ability to handle droughts by using different water sources, and Patiala, which effectively combined surface water and groundwater. International examples, like a helpful planning tool called WEAP used in Nablus, show how to predict water needs for growing towns like Butibori.

In my study, I planned a strategic water management plan for Butibori that addresses the current water shortage and prepares for future needs. I had done this by mapping the town's water resources, finding the gaps in the current water infrastructure, predicting future population growth and water needs, and suggesting effective conservation and distribution solutions.

To accomplish this, I used tools like Geographic Information Systems (GIS) to analyze the town, consult with important local groups like the Butibori Municipal Council and local residents, and learn from case studies of other cities. My plan will suggest expanding the water treatment and storage capacities, extending the water distribution network, reducing water losses through better monitoring, and using rainwater harvesting and recycled wastewater for non-drinking uses, like maintaining parks.

This study is important not only for Butibori but also offers a model for other towns facing similar water challenges. By combining improvements in water infrastructure with programs that engage the community, we can develop a system that is sustainable and can be repeated in other places. My approach follows both national standards and successful international practices to ensure that everyone has access to reliable and fair water supplies.

2. LITERATURE REVIEW

Rapid urban growth, demographic expansion, and climatic variability are presently undermining the sustainability of urban water systems. This survey synthesizes foundational scholarly works in relation to prospective interventions to alleviate water scarcity in Butibori, where existing supply consistently lags behind demand.

Cosgrove and Loucks (2015) endorse the implementation of integrated water-resource management (IWRM) as the principal antidote to the cumulative pressures of growth, climate perturbation, and

anthropogenic degradation. This paradigm is directly germane to Butibori, where a daily supply shortfall of 7.32 million litres, coupled with per capita delivery of 34 to 45 litres per capita per day—significantly beneath the 135 litres stipulated by the Central Public Health and Environmental Engineering Organisation—mandates immediate and comprehensive institutional reform. Loucks et al. (1982) further advance a systems synthesis that interweaves hydrological, economic and sociocultural variables, thereby enhancing the precision of allocation decisions. Complementarily, Chaturvedi (1987) underscores the necessity of demand management, arguing that interventions to curb consumption are equally obligatory alongside supply augmentations in contexts of chronic deficit.

Empirical investigations substantiate these theoretical propositions. Dass et al. (2012) document drought preparedness in Jaipur, underscoring the dual imperatives of source diversification and non-revenue water (NRW) attenuation; the latter is particularly germane to Butibori, where current NRW levels surpass 25%. Brar et al. (2011), analysing Patiala, advocate the conjunctive use of surface and groundwater; their findings offer a replicable schema for Butibori, which presently relies heavily on the Vena River and a declining aquifer network.

Internationally, Abdo's (2009) deployment of the WEAP modelling tool in the Nablus case study illustrates the effectiveness of scenario-based water resource planning, a methodology equally essential for responding to Butibori's anticipated water demand escalation to 31.20 million litres per day by 2053. Daykin (2011) illustrates the dual advantage of stakeholder participation and modern leakage-control technologies, directly informing measures required to rectify Butibori's current distribution inefficiencies. The Asian Development Bank (2012) identifies non-revenue water reduction via comprehensive metering and systematic water audits, actions that squarely confront the infrastructural deficiencies observed in Butibori's water supply system. Spuhler et al. (n.d.) advocate for the deployment of circular-supply solutions including wastewater recycling and rainwater harvesting, strategies that resonate with Butibori's capacity to reclaim 5.77 million litres per day of treated effluent for secondary uses, notably the augmentation of a municipal green belt. Concurrently, the Central Ground Water Board (2002, 2007) recommends rainwater harvesting and artificial recharge techniques that attend to Butibori's groundwater depletion and the variable yield character of the monsoon recharge.

Robust demand forecasting remains pivotal in the planning cycle. Nishanth et al. (2023) and Shankar Lal (2023) present refined population-growth models robust across various Indian contexts, while Sarwah and Aziz (2023) employ multivariate forecasting in Erbil; the cumulative insights emphasize tailored projections for Butibori, where the diffusion of industrial activity is a principal driver of accelerated demographic change.

The policy and institutional landscape, as represented by the CPHEEO guidelines, establishes supply and service benchmarks that presently elude Butibori; current household connection coverage stands at 33.16% and supply is provided on an intermittent basis.

The City Development Plan (2021) advocates the engagement of private sector investment and the implementation of targeted public awareness initiatives as dual levers for improving both the protection of water resources and the operational efficiency of supply networks. This multifaceted strategy provides a structured approach for mitigating the persistent challenges of water quality degradation and intermittent supply facing the Butibori urban agglomeration.

3. PROBLEM FORMULATION

Butibori, an industrial hub near Nagpur, India, faces a critical water supply deficit driven by rapid urbanization, population growth, and environmental degradation. The Central Public Health and Environmental Engineering Organization (CPHEEO) mandates a minimum water supply of 135 liters per capita per day (LPCD) for urban areas with full sanitation systems, including 15% additional demand and 15% losses. However, the Butibori Municipal Council delivers only 34–45 LPCD intermittently (every 2–3 days), resulting in a 7.32 million liters per day (MLD) shortfall against the 9.10 MLD required for the 2021 population of 49,500. The existing water supply system, designed to deliver 10.92 MLD, is undermined by multiple constraints. The Vena River, the primary water source, is polluted by untreated effluents from the Maharashtra Industrial Development Corporation (MIDC), compromising water quality and availability. Non-revenue water (NRW) losses exceed 25%, surpassing the CPHEEO benchmark of 15%, due to an outdated distribution network spanning only 55 km against a required 102.09 km. The water treatment plant (WTP) capacity of 3.6 MLD is inadequate, and only 33.16% of households have piped connections, leaving 66.84% reliant on hand pumps, open wells, or MIDC-

supplied water, which fails to meet domestic and industrial demands. Ward No. 4 lacks a piped system, depending on wells and borewells that dry up in summer, necessitating tanker deliveries of 400 liters per household every two days. Ward No. 7 receives metered MIDC water at Rs. 11 per 1000 liters, while Ward No. 8 (Choti Bori) relies on insufficient open wells with small-scale filtration for drinking water. Population growth, fueled by in-migration due to employment opportunities in Butibori MIDC, infrastructure, and social amenities (notably during 2001–2011), exacerbates the crisis. Projections estimate 94,393 residents by 2038 and 169,653 by 2053, increasing water demand to 17.36 MLD and 31.20 MLD, respectively.

The Vena River cannot meet future needs, and the proposed Wadgaon Dam reservation, under review, covers only 55% of 2021 demand, leaving a 3.32 million cubic meters (MM³) gap, projected to widen to 6.34 MM³ by 2038 and 11.39 MM³ by 2053. Groundwater depletion from over-extraction and poor monsoon recharge, coupled with the absence of a sewage treatment plant (STP), leads to untreated sewage discharge into the Vena River, further degrading water quality. The research problem centers on developing a sustainable water resource management plan to address the current 7.32 MLD shortfall, projected to grow significantly by 2053, while ensuring equitable access to clean water and mitigating environmental degradation. This requires reconciling escalating demand with limited resources, upgrading infrastructure, reducing NRW, and integrating alternative water sources to support Butibori's growing population and industrial needs.

4. OBJECTIVES

The goal is to provide a technical solution for water distribution and conservation while also creating a strategic water resource management plan for the town of Butibori based on an assessment of the town's current water resources. Study of topography of town by using GIS.

- To identify and evaluate present water resources for Butibori town.
- To evaluate existing water supply and issues towards distribution.
- To evaluate and project the future population of the town using two different methods of population forecasting.
- To estimate the town's future water demands based on projected population figures.
- Study of remedial measures for water conservation for Butibori town.

5. METHODOLOGY

To craft an efficient resource management plan for Butibori, an industrial town located close to Nagpur, India, I conducted research toward a suitable water resource plan for the town. Butibori's water supply issues necessitate a combination of an extensive water resource appraisal, infrastructure gap analysis, evaluating resource management frameworks, and formulating advanced conservation as well as distribution mechanisms. The proposed approach for methodology and practical measures to be taken, as well as reasons for Butibori's water management needs are elucidated in the following summary.

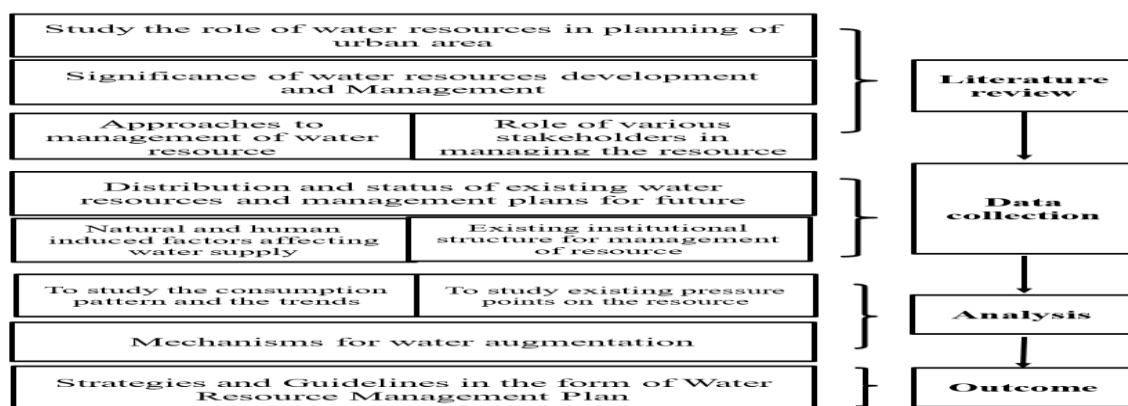


Figure 2 Hybrid Hierarchical Structure of Water supply management

Literature Review: My focus and interests led me delve in case studies of Patiala and Jaipur in India and also Nablus in different parts of the globe to get a better handle on water resource management in towns and cities. I drew insights from other studies as well, such as the ones by Dass et al. (2012) and Abdo

(2009) which discussed the non-revenue water (NRW) along with other management frameworks. My study framework was Butibori's water scarcity issues, limited infrastructure, and an ever-growing demand, which was significantly aided by those studies.

Data Collection: To contextualize my study, I sought to gather secondary data from Butibori Municipal Council along with other key documents, namely the City Development Plan (2021), City Sanitation Plan (2021), and Water Supply Detailed Project Report (DPR). These documents provided comprehensive data pertaining to the region's water supply infrastructure including the treatment capacity, distribution networks, storage systems, and population and demand projections. To enrich my understanding, I conducted field visits to the Vena River and other groundwater sources. Through my interviews with BMC officials and other locals, I gathered useful information regarding the operational and water quality challenges, as well as the needs of the underprivileged, unserved, and underserved populations residing in Ward No. 4 and Choti Bori.

Butibori Water Resources and Infrastructure Evaluation: To evaluate Butibori's water resources and infrastructure, I analyzed data relevant to the region. In 2021, the supply shortfall was 7.32 million liters per day, NRW losses were greater than 25%, and household connection coverage was 33.16%. Additionally, the region's water treatment plant had a capacity of only 3.6 MLD, which is significantly lower than what is presently required. To estimate future demand, I employed two population forecasting techniques based on the works of Nishanth et al. (2023), and Shankar Lal (2023), projecting water demand to be 17.36 MLD in 2038 and 31.20 MLD in 2053. Utilizing Geographic Information Systems (GIS), I mapped the town's topography along with the distribution of water resources to identify where infrastructure improvements could be spatially located. I also assessed the environmental Vena River pollution caused by MIDC effluents, as well as the groundwater depletion from over-extraction.

BMC cadre, MIDC representatives, and local community members are the relevant stakeholders. Based upon their needs, I organized the primary challenges, which included unequal water distribution, a limited storage capacity, and over-reliance on hand poll water sources or MIDC supplied water. Their feedback aided in the realization of prioritized interventions, such as NRW restructuring, wastewater recycling, and equitable supply. In meeting the underlying needs of the community, as well as local and institutional capacities, these recommendations are responsive to local realities.

Proposal Development: From my review of the literature, my analysis of the data, and the feedback collected from stakeholders, I created a strategic plan for water management. The plan includes both supply-side and demand-side solutions: expanding treatment and storage capacities as well as extending the current distribution network from 55 km to the required 102.09 km for supply-side and metering as well as public awareness initiatives for demand-side. I also propose harvesting rainwater, artificially recharging groundwater supplies, and reusing wastewater to reclaim 5.77 MLD of treated effluent, thereby closing the 7.32 MLD gap and addressing future demand.

6. CURRENT SCENARIO OF WATER SUPPLY IN BUTIBORI

The water supply system in Butibori, an industrial hub near Nagpur, India, relies solely on the Vena River water supply scheme, commissioned in 2015 by the Zilha Parishad, Nagpur, and transferred to the Butibori Municipal Council (BMC) in 2018 after a trial period. This scheme draws water from the Vena River, a left-bank tributary of the Wardha River, but faces significant challenges due to pollution and inadequate infrastructure, resulting in a persistent water supply deficit across the town.

Table 1 Details of Vena River Water Supply System

| Sr. No. | Parameters | Description |
|---------|-----------------------|---|
| 1 | Vena River | It is left bank tributary of river of the river Wardha. |
| 2 | RWRM | 250 mm DI pipe having 3.44 Km length |
| 3 | Water Treatment Plant | Conventional WTP of capacity 3.6 MLD |
| 4 | Storage Capacity | 11.50 Lakh Litres |

| | | |
|---|---------------------|--|
| 5 | Pure water | |
| | A) PWRM | 200 mm dia DI pipe and 180 mm PVC Pipe. |
| 6 | Distribution System | HDPE and PVC pipe of about 75 mm to 160 mm |

The system comprises a raw water rising main (250 mm DI pipe, 3.44 km), a conventional water treatment plant (WTP) with a capacity of 3.6 million liters per day (MLD), and a storage capacity of 11.50 lakh liters across two elevated storage reservoirs (ESRs) located near the WTP (7.50 lakh liters) and Jijamata School (4.00 lakh liters). Pure water is transmitted via a 280 mm HDPE pipe (1.26 km) using four centrifugal pumps—two 30 HP (one working, one standby) and two 15 HP (one working, one standby). However, pollution from untreated effluents discharged by the Maharashtra Industrial Development Corporation (MIDC) into the Vena River compromises water quality, rendering the WTP underutilized. To compensate, the BMC purchases water from MIDC, but this supply is insufficient to meet current or projected demands, exacerbating the town’s water scarcity. The distribution network, consisting of HDPE and PVC pipes (75–160 mm diameter), is uneven and limited, contributing to significant non-revenue water (NRW) losses and supply shortages throughout the year. Only a fraction of the population benefits from piped water, with 66.84% of households relying on hand pumps and open wells due to inadequate infrastructure coverage.

Table 2 Details of Choti Bori water Supply Scheme

| Source | ESR | Transmission Line Details |
|----------------------|----------------|---------------------------|
| Choti Bori Open Well | Near ZP School | 75mm PVC |
| Juni vasti Open Well | Near ZP School | 75mm PVC |

Ward-specific disparities further highlight the system’s limitations. Ward No. 7 receives metered water from MIDC on a daily basis, with consumers charged Rs. 11 per 1,000 liters, a cost collected directly by MIDC. In contrast, Ward No. 8 (Choti Bori) depends on a water supply scheme established in 1995, utilizing two open wells (Choti Bori and Juni Vasti) connected by 75 mm PVC pipes. This source is inadequate for the ward’s needs, providing water primarily for non-potable uses, with a small-scale filtration system installed near the Choti Bori ESR to supply drinking water. Ward No. 4 lacks any piped distribution system, relying entirely on wells and borewells, which dry up during summer months. To address this, the BMC provides tanker deliveries of 400 liters per household every two days, an insufficient and unsustainable solution.

Analysis of Existing Water Supply System

Total Water Demand

As per the guidelines outlined in Section 2.2.8.3 of the CPHEEO Manual on Water Supply and Treatment, the minimum water supply requirement for households equipped with a full flushing system for waste disposal is stipulated at 135 liters per capita per day (LPCD). This allocation accounts for domestic water use, an additional 15% for miscellaneous demands, and a further 15% to compensate for water losses. Additionally, the manual recommends a provision of 15–25 LPCD for the floating population to meet their basic water needs.

As per below table current Gross Demand of water (i.e. for year 2021) is 9.10 MLD and for the year 2038 & 2053, demand is 17.36 and 31.20 MLD respectively.

Table 3 Demand and Gap for Total Water Demand

| Particulars | 2021 | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
|---|--------|--------|--------|--------|--------|----------|----------|----------|
| Population projection | 49,500 | 53,281 | 64,278 | 77,814 | 94,393 | 1,14,652 | 1,39,398 | 1,69,653 |
| Demand (MLD) = 135 LPCD + 15% other demand and 15% losses | 9.04 | 9.73 | 11.74 | 14.21 | 17.24 | 20.94 | 25.46 | 30.99 |

| | | | | | | | | |
|--|------|------|-------|-------|-------|-------|-------|-------|
| Floating population (5% of total population) | 2475 | 2664 | 3214 | 3891 | 4720 | 5733 | 6970 | 8483 |
| Demand for floating at 25 LPCD | 0.06 | 0.07 | 0.08 | 0.10 | 0.12 | 0.14 | 0.17 | 0.21 |
| Gross Demand (MLD) | 9.10 | 9.80 | 11.82 | 14.31 | 17.36 | 21.08 | 25.63 | 31.20 |

Water Reservations

Drawing upon the data supplied by the Barshi Nagar Parishad (BNP), a formal recommendation to secure a reserved water allocation from the Wadgaon Dam has been submitted to the state government and is now pending deliberation. Regrettably, the quantum of water proposed is inadequate to satisfy the requirements of the municipality. Specifically, the water entitlement established for the year 2021 meets only 55 per cent of the total consumption forecast. The table that follows details the evolving requirements for water reservation, revealing a present volume deficit of 3.32 million cubic meters (MM³) from the dam reservoir. Experts predict that the water shortage will grow to 6.34 million cubic meters by 2038 and reach 11.39 million cubic meters by 2053. This shows that it is very important to take action now to ensure a reliable and sustainable water supply for everyone.

Table 4 Demand and Gap for Water Reservation

| Water Reservations from Dam | 2021 | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
|--|------|------|------|------|------|------|------|-------|
| Required demand for reservation (MM ³) | 3.32 | 3.58 | 4.31 | 5.22 | 6.34 | 7.70 | 9.36 | 11.39 |
| Actual Reservation (MM ³)(for 5 MLD) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gap (in MM ³) | 3.32 | 3.58 | 4.31 | 5.22 | 6.34 | 7.70 | 9.36 | 11.39 |

Capacity of WTP

A field survey conducted in Butibori revealed that the water treatment plant (WTP) is not being operated by the local council due to the unsatisfactory quality of raw water. The total water demand for the WTP was determined by accounting for gross demand and assuming 20 hours of daily pumping. The current water demand for WTP, as of 2021, is estimated at 10.92 million liters per day (MLD). Projections indicate a significant increase in demand, reaching 20.83 MLD by 2038 and 37.44 MLD by 2053, underscoring the need for improved water treatment infrastructure and raw water quality management to meet future requirements.

Table 5 Demand and Gap for WTP

| Water Treatment Plant | 2021 | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
|---|-------|-------|-------|-------|-------|-------|-------|-------|
| Demand for treatment plant capacity (in MLD) considering 20 hours pumping | 10.92 | 11.76 | 14.18 | 17.17 | 20.83 | 25.30 | 30.76 | 37.43 |
| Available treatment plant capacity (in MLD) existing WTP | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| Gap (in MLD) | 7.32 | 8.16 | 10.58 | 13.57 | 17.23 | 21.70 | 27.16 | 33.83 |

Capacity of existing WTP is about 3.6 MLD which is insufficient to suffice the present demand. As it was constructed in year 2018, it's design period will be completed in the year 2033. (as per CPHHEO manual)

Water distribution network

Analysis conducted using data from the Brihanmumbai Municipal Corporation (BMC) and the Bombay Natural History Society (BNP) indicates that the present water distribution network spans roughly 55.00 kilometers. Anticipated future requirements for the network have been derived from an exhaustive road length evaluation, guided by a comprehensive road gap study. Comparison with the benchmarks

articulated by the Central Public Health and Environmental Engineering Organization (CPHEEO) reveals that the current distribution system lacks 15.09 kilometers of pipeline infrastructure necessary to meet the projected service demand.

Gross Water Demand in Butibori (2021–2053)

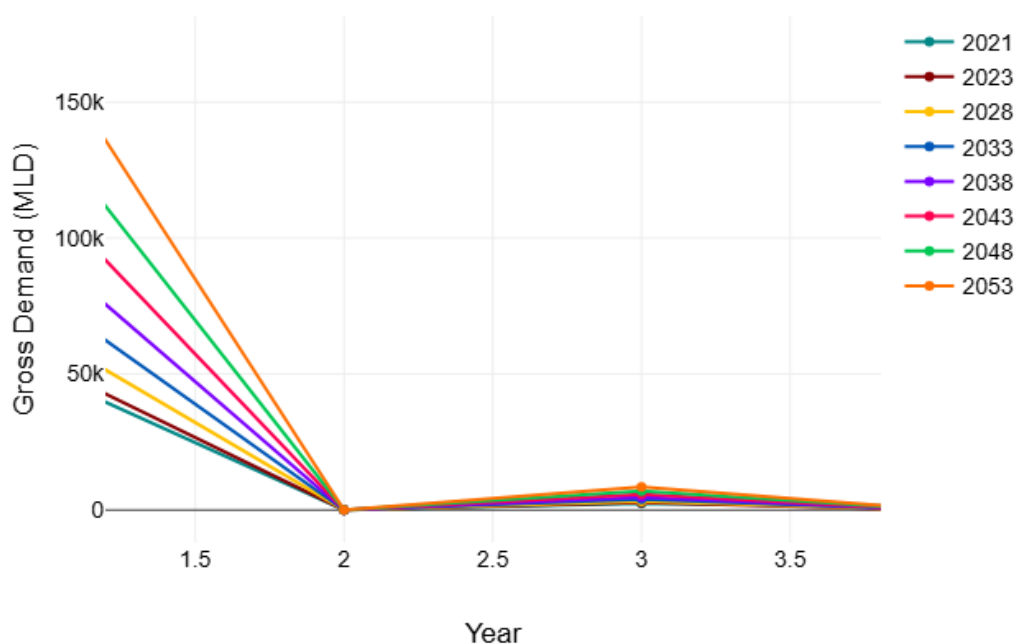


Figure 3 Water Treatment Plant Capacity Gap (2021–2053)

Figure 3. Line graph illustrating the capacity gap of the water treatment plant (WTP) in Butibori from 2021 to 2053, showing an increase from 7.32 million liters per day (MLD) to 33.83 MLD, highlighting the urgent need for infrastructure upgrades to meet projected demand.

Table 6 Demand and Gap for Water Distribution Network

| Water Distribution Network | 2021 | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
|--|--------|--------|--------|--------|--------|--------|--------|--------|
| Road length required as per gap assessment (in km) | 102.09 | 102.09 | 115.70 | 140.07 | 169.91 | 206.37 | 250.92 | 305.37 |
| Existing distribution network (in km) as per NP record | 55.00 | 55.00 | 55.00 | 55.00 | 55.00 | 55.00 | 55.00 | 0.00 |
| Gap (km) | 47.09 | 47.09 | 60.70 | 85.07 | 114.91 | 151.37 | 195.92 | 305.37 |

The present water distribution network, commissioned in 2018, will reach the conclusion of its design life of thirty years—following the guidelines set forth in the CPHEEO manual—in the year 2048. According to data provided by the BNP, routine maintenance activities on the network have been executed in a timely manner. The tabulated projections indicate that the total length of distribution pipelines needed by the years 2038 and 2053 will be 114.91 km and 305.37 km, respectively.

Water storage tank

As per CPHEEO manual, design period of Storage tank is 15 years. Hence, the calculated age of ESR is shown in following table.

Table 7 Details of Existing Water Storage Tanks (Capacities in Lakh Litre)

| Location | Capacity | YOC | 2021 | 2023 | 2028 | 2033 |
|---------------------------------|----------|------|------|------|------|------|
| Choti Bori Near ZP School | 0.30 | 1995 | 0.00 | 0.00 | 0.00 | 0.00 |
| Near WTP ESR | 7.50 | 2016 | 7.50 | 7.50 | 7.50 | 0.00 |
| Near Zizamata School | 4.00 | 2016 | 4.00 | 4.00 | 4.00 | 0.00 |
| Near Khaparde School | 1.00 | 1995 | 0.00 | 0.00 | 0.00 | 0.00 |
| Navin Vasahat Near Durga temple | 1.30 | 1983 | 0.00 | 0.00 | 0.00 | 0.00 |
| Juni Vasahat Kumbhar Pura | 1.00 | 1990 | 0.00 | 0.00 | 0.00 | 0.00 |

| | | | | | | |
|-------|-------|--|-------|-------|-------|------|
| Total | 15.10 | | 11.50 | 11.50 | 11.50 | 0.00 |
|-------|-------|--|-------|-------|-------|------|

The data presented in the preceding table indicate that the Elevated Service Reservoir (ESR) situated near the Water Treatment Plant (WTP) and the ESR located in the vicinity of Jijamata School are anticipated to reach the end of their design lifespan by approximately 2028. The remaining four ESRs, having been installed within the 1983 to 1995 timeframe, have already surpassed their respective design periods; thus, their storage capacities are disregarded in any future demand projections. Consequently, it may be inferred that Butibori town currently possesses inadequate water storage to satisfy the requirements of its extant population. According to the Central Public Health and Environmental Engineering Organization (CPHEEO) guidelines, the storage requirement is quantified at 50 percent of the total water demand.

Water service connection

The data presented indicates that roughly 33.16% of properties currently enjoy direct house connections, while the remaining 73.47% rely on hand pumps or alternative water sources. Certain commercial establishments need not secure dedicated water connections owing to their comparatively modest consumption, which they are able to satisfy through on-site provision. At present, there exist 2,820 water connections within the study area; however, projected demand by the year 2053 reaches 31,809 connections. Accordingly, the anticipated shortfall, when measured against that demand, totals 28,989 connections to be addressed prior to the year 2053.

Table 8 Demand and gap for Water Service Connections

| Water Service Connections | 2021 | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
|--|--------|--------|--------|--------|--------|--------|--------|--------|
| No. of properties | 10,629 | 11,489 | 13,993 | 17,112 | 21,005 | 25,881 | 32,015 | 39,761 |
| 80% Properties to have Water connection | 8,503 | 9,191 | 11,194 | 13,689 | 16,804 | 20,705 | 25,612 | 31,809 |
| Existing service connections (as per ULB record) | 2,820 | 2,820 | 2,820 | 2,820 | 2,820 | 2,820 | 2,820 | 2,820 |
| Total Gap | 5683 | 6371 | 8374 | 10869 | 13984 | 17885 | 22792 | 28989 |

Table 9 Demand and Gap for Storage Tank

| Water Storage Tank | 2021 | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
|---|-------|-------|-------|-------|-------|--------|--------|--------|
| Storage tank demand capacity (LL) 50% storage of total demand | 45.20 | 48.65 | 58.70 | 71.05 | 86.20 | 104.70 | 127.30 | 154.95 |
| Existing storage tank capacity (LL) (as per field survey) | 11.50 | 11.50 | 11.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gap (LL) | 33.70 | 37.15 | 47.20 | 71.05 | 86.20 | 104.70 | 127.30 | 154.95 |

As per above table demand of storage tank for year 2053 is 154.95 LL.

Ministry of Urban Development (MOUD) service level benchmarks (SLBs) for water supply

Table 10 SLBs for Water Supply

| Sr. No. | Indicator | Benchmark | Actual |
|---------|--|--------------|----------------------------------|
| 1 | Coverage of Water Supply Connections | 100% | 33.16% |
| 2 | Per Capita Supply of Water | 135 LPCD | 35-45 LPCD |
| 3 | Extent of Non- revenue Water | 15% | >25% |
| 4 | Extent of Metering | 100% | 35.46% |
| 5 | Continuity of Water supplied | 24 hrs daily | Intermittent once after 2-4 days |
| 6 | Efficiency in redressal of customer complaints | 80% | < 80% |
| 7 | Quality of Water Supplies | 100% | 50-60% |
| 8 | Cost Recovery in Water Supply Services * | 100% | 72.65% |

| | | | |
|---|--|-----|--------|
| 9 | Efficiency in Collection of Water Charges ** | 90% | 25.92% |
|---|--|-----|--------|

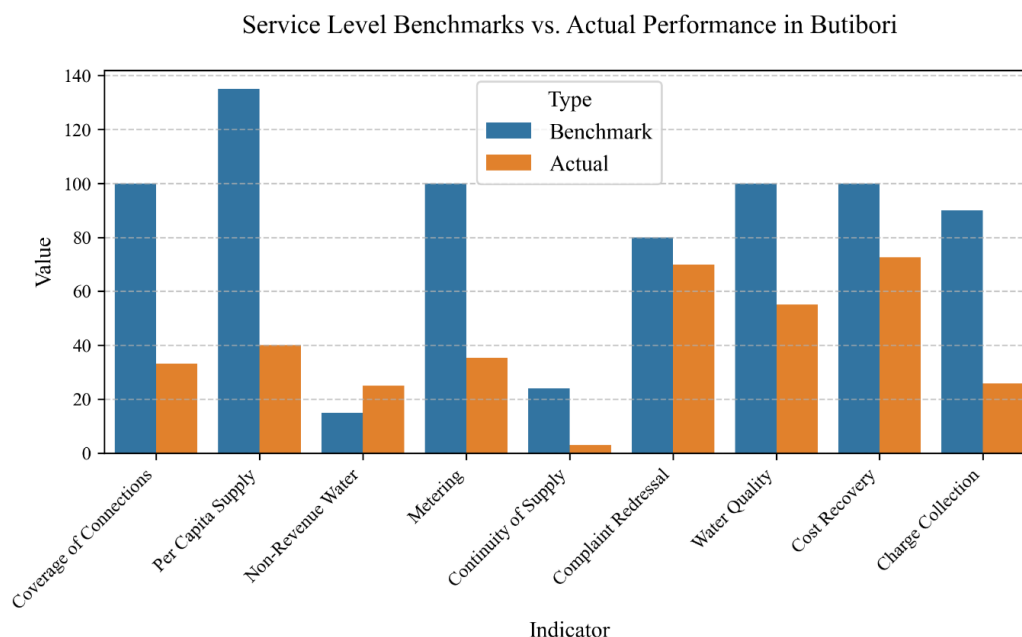


Figure 4 Service Level Benchmarks vs. Actual Performance in Butibori

"Figure 4. Comparison of Ministry of Urban Development (MOUD) service level benchmarks and actual performance in Butibori across indicators such as coverage of water supply connections (100% vs. 33.16%) and per capita supply (135 LPCD vs. 35-45 LPCD), illustrating significant infrastructural gaps." The data presented indicate pervasive shortcomings in the water supply system, where delivered outcomes markedly trail the prescribed performance standards. Critical deficiencies pertain to the extent of network coverage, the average volume of supply per capita, metering penetration, and the efficiency of complaint-handling mechanisms. Elevated proportional losses of water not generating revenue, combined with inadequate recovery of operating costs, signal both managerial and infrastructural vulnerabilities.

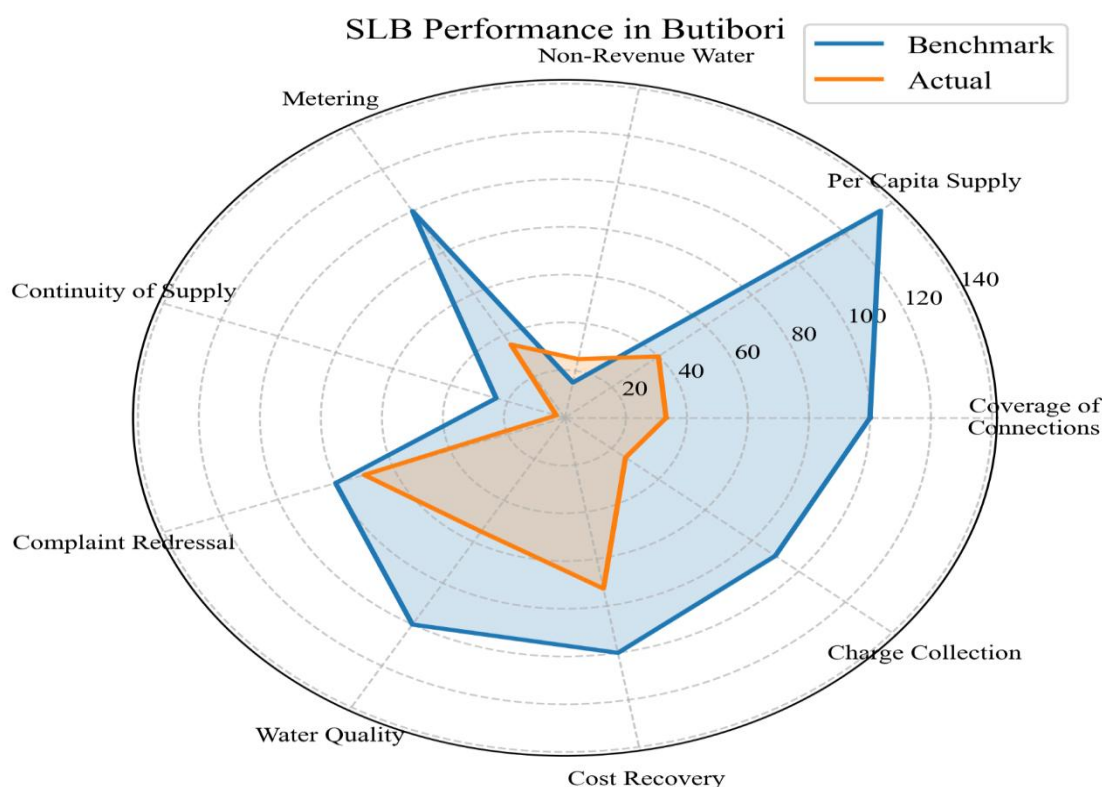


Figure 5: SLB Performance in Butibori

"Figure 5. Radar chart depicting service level benchmark (SLB) performance in Butibori, comparing benchmark (blue) and actual (orange) values across indicators like non-revenue water (>25% vs. 15%) and water quality (50-60% vs. 100%), emphasizing the need for remedial measures."

Moreover, the prevalence of episodic supply and the deterioration of water quality underscore the necessity for prioritized, informed remedial measures. Rectifying these vulnerabilities is indispensable for achieving resilient and just water governance, securing universal, reliable access to safe drinking water.

7. PROPOSAL & STRATEGIES FOR FUTURE

Factors Influencing Water Resources Proposals & Strategies

Water resource management requires a comprehensive appraisal of both the availability of water and the patterns of consumption over time. Management begins with the identification of the source waters, an assessment of the integrity and sustainability of their recharge zones, a review of distribution efficiencies, and an evaluation of the existing infrastructure's capacity to satisfy projected demand. The interplay of these elements determines the volume of potable water that can be supplied to a community with an acceptable level of reliability. Conversely, demand assessment entails a detailed examination of usage patterns, demographic trends that reconfigure these patterns, and the price incentives or disincentives that condition water-using behavior. The dynamic interrelation of these supply and demand variables is, therefore, the cornerstone of management plans that aspire to both ecological sustainability and social equity, ensuring current consumption does not impair future resource availability. The appended table enumerates the critical supply and demand variables that should be integrated into any comprehensive planning exercise directed at achieving water management that is both ecologically responsible and socially just.

Table 11

| Factors Influencing Water Resources Proposals And Strategies | |
|--|---|
| Supply side factors | Demand side factors |
| 1. Water Sources | 1. Population |
| ✓ Type | ✓ Frequency |
| ✓ Capacity | ✓ Per Capita Demand |
| ✓ Climate Change | ✓ Connection Types |
| | ✓ Water Pricing |
| 2. Distribution Network Design | 2. Water Usage Issues |
| ✓ Efficiency of design | ✓ NRW Losses, Illegal Connections, Unaccounted Water, Theft |
| 3. Storage Capacity | |
| 4. Pumping Capacity | |
| 5. Distribution Network Capacity | |
| ✓ Coverage Inadequacies | |
| 6. System Losses | 3. Operation and Maintenance Related Issues |
| ✓ NRW Losses | ✓ Water Quality |
| ✓ Pipe Breakages | ✓ Maintenance Challenges |

Distribution of Water Management Strategies by Scope

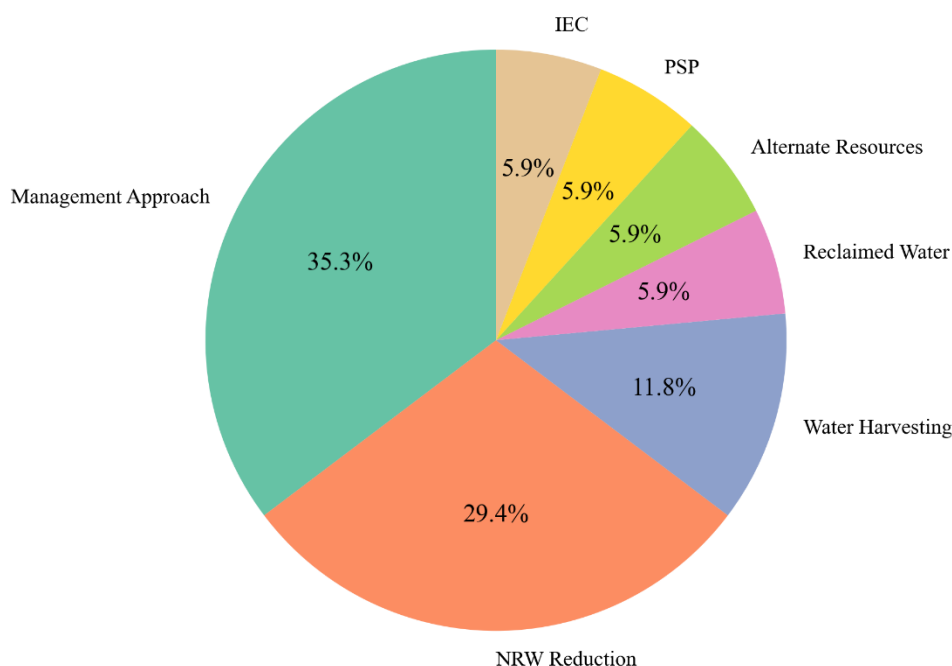


Figure 6: Distribution of Water Management Strategies by Scope

"Figure 6. Pie chart illustrating the distribution of water management strategies by scope in Butibori, with 35.3% allocated to Management Approach, 29.4% to NRW Reduction, and other categories like Water Harvesting (11.8%), reflecting a balanced strategic framework."

Strategies for Water Resource Management

Effective water resource governance requires a holistic framework that aligns total demand with available supply under varying hydrological and anthropogenic pressures. The matrix below summarizes a suite of mutually reinforcing interventions designed to enhance system performance, refine allocation processes, and embed a culture of conservation. Key measures include retrofitting volumetric flow sensors across abstraction and distribution points, deploying real-time telemetry networks to detect and characterize leakage, expanding cistern-integrated rainwater capture at both household and institutional scales, and initiating participatory outreach programmed that frame water use as a shared civic responsibility. When these components are synergistically applied, they compress abstraction gaps, curtail avoidable wastage, and secure equitable, continuous access to safe drinking water for all constituencies. Consequently, their systematic adoption forges a cohesive governance architecture that bolsters community resilience and aligns with the adaptive imperatives of a warming climate and fluctuating population densities.

Table 12 Strategies for Water Resource Management

| Sr. No | Strategies | Major Scope |
|--------|---|------------------|
| 1 | Implement metering in all types of water connections to regularize the water supply process and increase revenue. | NRW Reduction |
| 2 | Use computer applications and software to monitor the water supply process. | |
| 3 | Leakage Control – Water Auditing, Fix overflow sensors. | |
| 4 | Detect and regularize illegal connections. | |
| 5 | Optimum usage of produced water. | |
| 6 | Harvesting of rainwater and other water sources. | Water Harvesting |

| Sr. No | Strategies | Major Scope |
|--------|--|---------------------|
| 7 | Artificial recharge. | |
| 8 | Develop systems and technologies for recycling and reuse of wastewater. | Reclaimed Water |
| 9 | Restoration and rejuvenation of surface water bodies. | Alternate Resources |
| 10 | Optimum use of conserved water. | Management Approach |
| 11 | Maximum usage of storage reservoirs and tanks. | |
| 12 | Improvement of water supply in scarce locations. | |
| 13 | Integration of surface water management and groundwater management. | |
| 14 | Transfer the approach from water supply management to water demand management. | |
| 15 | Watershed-level management approach. | |
| 16 | Private sector participation in water supply projects. | PSP |
| 17 | Public awareness campaign and IEC activities for the economic use of water. | IEC |

8. CONCLUSION

A systematic examination of the town's water supply infrastructure reveals an urgent need to revisit the planning and design of both water storage and distribution components. Because the municipal supply currently relies predominantly on the adjacent river and seasonal rainfall, the incorporation of water conservation strategies—such as rainwater harvesting and the minimization of non-revenue water—has become imperative. Additionally, the reclamation and reuse of treated wastewater for industrial applications represent an effective conservation strategy, as it alleviates the demand for potable supplies. The unit cost of reclaimed water, which ranges from Rs. 5 to 8 per kiloliter, remains consistently lower than the treatment and delivery cost of sourcing new freshwater supplies. Presently, the township generates 7.80 million liters per day of sewage. In the absence of a dedicated sewage collection and treatment network, this effluent is discharged directly to the Vena River via an open drain. The treatment system currently receives 8.56 million liters per day and delivers 5.77 million liters of effluent that meets reuse standards. The reclaimed effluent can be directed to the municipal green belt, thereby contributing indirectly to the town's sustainable development objectives. By integrating a spectrum of water management interventions, the municipal authority can mitigate supply shortfalls and enhance the resilience of the system.

Surface water and groundwater systems are hydraulically linked through natural hydrological pathways. Optimal management of these interrelated resources—often referred to as conjunctive use—can significantly bolster water provision and allocation in the region. Nevertheless, over drafting groundwater aquifers diminishes downstream surface water flows, while inadequate aquifer recharge diminishes the groundwater baseline that supports surface water features. The Butibori council is therefore advised to concentrate on increasing rainwater-harvesting capacity to bolster aquifer recharges, thereby safeguarding water supplies in anticipated dry years. Balanced governance and synchronized management of both storages can elevate regional water supply resilience; however, unsustain dependence on pumped groundwater may elevate salinity, mineralization, and pathogen levels, thereby compromising water quality. Comprehensive strategies must consequently emphasize the maximization and judicious regulation of surface water reservoirs to secure future irrigation, domestic supply, and ecological integrity.

REFERENCES

1. Abdo, R. U. K., 2009. *Evaluation of Urban Water Supply Options Using WEAP: The Case of Nablus City*. Master's thesis. An-Najah National University, Nablus, Palestine.
2. Asian Development Bank, 2012. *Non-Revenue Water Reduction Toolkit*. New Delhi: Asian Development Bank.
3. Brar, T. S., Jain, R. K. and Khare, D., 2011. Water resource management plan for an urban area - Patiala. *International Journal of Earth Sciences and Engineering*, 4(6), pp. 997-1003.
4. Butibori Nagar Parishad, 2021. *City Development Plan Butibori*. Butibori: Butibori Nagar Parishad.
5. Butibori Nagar Parishad, 2021. *City Sanitation Plan Butibori*. Butibori: Butibori Nagar Parishad.
6. Central Ground Water Board, 2002. *Rainwater Harvesting and Conservation Manual*. New Delhi: Ministry of Water Resources, Government of India.
7. Central Ground Water Board, 2007. *Manual on Artificial Recharge of Ground Water*. New Delhi: Ministry of Water Resources, Government of India.
8. Central Public Health and Environmental Engineering Organization, n.d. *Manual on Water Supply and Treatment*. New Delhi: Ministry of Urban Development, Government of India.
9. Chaturvedi, M. C., 1987. *Water Resources Systems Planning and Management*. New Delhi: Tata McGraw Hill.
10. Cosgrove, W. J. and Loucks, D. P., 2015. Water management: Current and future challenges and research directions. *Advancing Earth & Space Sciences* [online]. Available at: [Insert DOI or URL if available].
11. Dass, A., Jethoo, A. S. and Poonia, M. P., 2012. Impact of drought on urban water supply: A case study of Jaipur City. *International Journal of Engineering and Innovative Technology*, 1(3), pp. 170-173.
12. Daykin, A. D. S., 2011. *Review of Water Resources Management Plan Process - Final Report*.
13. Government of India, 1993. *Indian Standard IS 1172:1993*. New Delhi: Bureau of Indian Standards.
14. Loucks, D. P., Stedinger, J. R. and Haith, D. A., 1982. *Water Resources Systems Planning and Analysis*. Englewood Cliffs, NJ: Prentice Hall.
15. Nishanth, K. P., Massand, A. and Roy, M., 2023. Forecasting population in India. *International Journal of Research Publication and Reviews*, 4(9), pp. 2801-2804.
16. Raftery, A. E. and Ševčíková, H., 2023. Probabilistic population forecasting: Short to very long-term. *International Journal of Forecasting*, 39(1), pp. [page range not specified].
17. Sarwah, O. I. and Aziz, S. Q., 2023. Population forecasting till 2050 using various methods and water supply strategy for Erbil City. [Journal or publisher not specified].
18. Shankar Lal, 2023. Mathematical modeling of population forecasting in India. *Journal of Interdisciplinary*, 12(1), pp. [page range not specified].
19. Spuhler, D., Germann, V., Kassa, K., Ketema, A. A., Sherpa, A. M., Sherpa, M. G., Maurer, M., Lüthi, C. and Langergraber, G., n.d. Developing sanitation planning options: A tool for systematic consideration of novel technologies and systems. [Journal or publisher not specified].
20. Survey of India, n.d. *District Planning Map Series*. [Place of publication not specified]: Department of Survey of India.
21. Water Supply DPR, Butibori, n.d. *Water Supply Detailed Project Report*. Butibori: [Publisher not specified].