Volume 1, 2024 (Maiden Edition)

ANALYSIS OF THE PATTERN AND CHALLENGES OF PUBLIC WATER SUPPLY WITHIN SELECTED RESIDENTIAL NEIGHBOURHOOD IN MAKURDI TOWN, BENUE STATE, NIGERIA

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Abstract

Public water systems play a crucial role in providing clean and adequate water for domestic, commercial, and industrial use. However, many urban areas in Nigeria, including Makurdi Town, face significant challenges in ensuring consistent and equitable water supply. The study examines the pattern and challenges of public water supply across selected residential neighbourhoods in Makurdi Town, Benue State, Nigeria. Using a survey research design, data were collected through closed-ended questionnaires and field observations, focusing on water infrastructure, distribution, and coping mechanisms. A total of 400 households were sampled, and data were analyzed using descriptive statistics and cross-tabulations. Findings reveal that only 10% of residents receive a daily water supply, while 40% experience availability once a week. Reliability is low, with 75% of respondents rating the supply as unreliable or very unreliable. Cross-tabulation results indicate that only 17.7% of water reticulation channels and 24.4% of pipelines across all locations are in good condition. Old G.R.A. has the highest number of functional water reservoirs (80) and pipelines (48), while low-density areas report the poorest conditions, with only 10 functional reservoirs and 5 reticulation channels. The findings further shows that 70% of residents rely on water vendors, 60% on boreholes and only 15% engage in rainwater harvesting. Key challenges include infrastructure decay (40%), population pressure (45%), and poor maintenance (35%). Recommendations include investment in infrastructure rehabilitation, development of a comprehensive water management plan, and promotion of sustainable alternative water sources. The study highlights the need for targeted interventions to address infrastructure gaps and ensure equitable water access across Makurdi Town.

Keywords: *Infrastructure Decay, Neighbourhoods, Makurdi, Public Water Distribution and Urban Water Supply.*

Introduction

Adequate and safe water supply is a fundamental service that drives the economic progress of human settlements and promotes the health of residents. While household water demand constitutes the least proportion of global water use approximately 6% (Hutton & Chase, 2018). It remains irreplaceable, as domestic water use such as drinking, cooking, washing, and sanitation has direct health implications (Crouch *et al*., 2021). In Africa, domestic water supply often relies on traditional water sources, which pose significant challenges due to factors such as income levels, household size, and distance to water points (Okesanya *et al*., 2024). This reliance is further exacerbated by infrastructure deficiencies. A functional water supply system comprises storage reservoirs, pipelines, pumps, and other critical components designed to deliver water from treatment facilities to consumers reliably (Renwick *et al*., 2019). However, most developing countries, including Nigeria, face challenges such

as infrastructure decay, inadequate management, and insufficient investment in public water systems (Balogun *et al*., 2017).

Makurdi, the capital of Benue State, exemplifies these challenges. Rapid urbanization and population growth have increased pressure on the existing water infrastructure, leading to an uneven and unreliable water supply. Public water utilities in the area are constrained by technical inefficiencies, poor governance, financial limitations, vandalism of water pipelines, and population growth outpacing infrastructure development (Balogun *et al*., 2017; Akinde *et al*., 2019). As a result, residents in many parts of Makurdi Town are compelled to rely on alternative water sources such as boreholes and wells, which are often of questionable quality. Water availability directly influences urban planning and population distribution, as areas with modern water supply networks are typically concentrated along trade and transportation corridors (Akanni, 2018). Unfortunately, as residential populations increase, service efficiency tends to decline due to poor planning, resulting in disparities in water supply distribution (Akoteyon, 2016). Addressing these issues requires a comprehensive understanding of the water supply patterns to inform strategies for improved delivery, particularly in rapidly urbanizing cities like Makurdi.

Statement of the Problem

Public water supply in many urban centers has not kept pace with the rapid growth of populations, particularly in developing countries. Public water supply in Makurdi Town has not kept pace with the rapid population growth, leading to significant disparities in water distribution across residential areas of varying densities. While some areas, such as Old G.R.A., Wadata, Lobi Quarters and High-Level, receive intermittent water supply, other parts of the town are underserved or entirely neglected. This uneven distribution is largely attributed to poor planning, outdated and inefficient infrastructure, and a lack of comprehensive water reticulation networks. As a result, many residents are forced to rely on alternative water sources like boreholes, wells, and water vendors, which are often of questionable quality and impose additional financial burdens on households. Further compounding the problem are issues such as vandalism of water pipelines, inadequate maintenance of ageing infrastructure, and the lack of a functional database to monitor water demand and consumption patterns. The growing population has outpaced the capacity of the existing public water system, leading to increased pressure on available resources. These challenges not only affect residents' access to safe water but also impact their health, productivity, and overall quality of life. This study, therefore, aims to examine the pattern of public water supply within residential neighbourhood in Makurdi Town, identify the factors affecting its efficiency and provide strategies for improving water access and distribution.

Literature Review

Theories of Water Demand and Supply

Theories of water demand and supply provide a foundation for understanding the dynamics of water availability and consumption. These theories highlight the relationship between water resources, population growth, and consumption patterns. According to Hutton and Chase (2018), household water demand, though constituting only about 6% of global water use, remains critical due to its non-negotiable role in meeting basic domestic needs such as drinking, cooking, and sanitation. The supply side of this equation emphasises the importance of infrastructure, governance, and sustainable resource management to meet these demands effectively (Renwick *et al*., 2019).

Systems Theory for Understanding Water Infrastructure

Systems theory offers an integrated approach to understanding the complexities of water infrastructure. It posits that water supply systems consist of interrelated components, including storage facilities, pipelines, pumps, and treatment plants, which must function cohesively to deliver water effectively (Janke *et al*., 2013). The theory further explains how technical, social, and economic subsystems interact, often leading to inefficiencies when one or more components are neglected. For instance, Balogun *et al*. (2017) identified factors such as urbanization, poor governance, and inadequate investment as systemic issues that disrupt water supply networks.

Public Water Supply

Public water supply refers to the provision of potable water by government or authorized agencies to meet domestic, industrial, and institutional needs. This supply is typically managed through a centralized system of infrastructure, designed to ensure equitable distribution to urban and peri-urban populations (Renwick *et al*., 2019). Access to water is critical for urban areas, as it directly influences public health, economic activities, and overall quality of life. Crouch *et al*. (2021) emphasized that access to safe and reliable water significantly reduces health risks associated with waterborne diseases. Furthermore, adequate water access supports economic progress by improving productivity and ensuring a stable living environment for urban populations. Public water supply is influenced by a range of factors, including infrastructure, policy frameworks, and environmental conditions. Balogun *et al*. (2017) identified challenges such as inadequate financial resources, poor governance, and the lack of skilled personnel as critical issues affecting water supply systems. Similarly, environmental factors like climate variability and resource depletion compound the challenges, making it difficult to maintain consistent supply levels. According to Okesanya *et al*. (2024), socioeconomic factors such as household income, size and distance from water sources also significantly impact access to water.

Numerous studies have examined water supply patterns in Nigerian urban centres. Akoteyon (2016) explored the spatial distribution of water supply in Lagos and highlighted how population growth and inadequate infrastructure create disparities in access. Similarly, Balogun *et al*. (2017) investigated water supply challenges in Ibadan, identifying technical inefficiencies and governance issues as major bottlenecks. These studies provide valuable insights into the challenges of water supply in rapidly urbanizing areas. Comparative studies on water supply systems in other regions have revealed similar patterns of inefficiency and inequity. For example, Leahy *et al*. (2024) analyzed water supply issues in Accra, Ghana, and noted that urbanization, coupled with poor infrastructure maintenance, led to significant water shortages. In addition, Janke *et al*. (2013) found that systems with integrated management and monitoring frameworks performed better in ensuring reliable water supply compared to those lacking such mechanisms. These findings underline the importance of efficient systems management and investment in infrastructure.

Study Area

The study area is Makurdi Town, the capital of Benue State, located in North-Central Nigeria. Geographically, Makurdi lies between latitude 7°43′N and longitude 8°32′E**,** covering an estimated area of 16 square kilometers. The town is bordered by the River Benue, which serves as a significant water source for residents as shown in Figure 1 below (Ministry of Land, Survey and Solid Minerals, 2020).

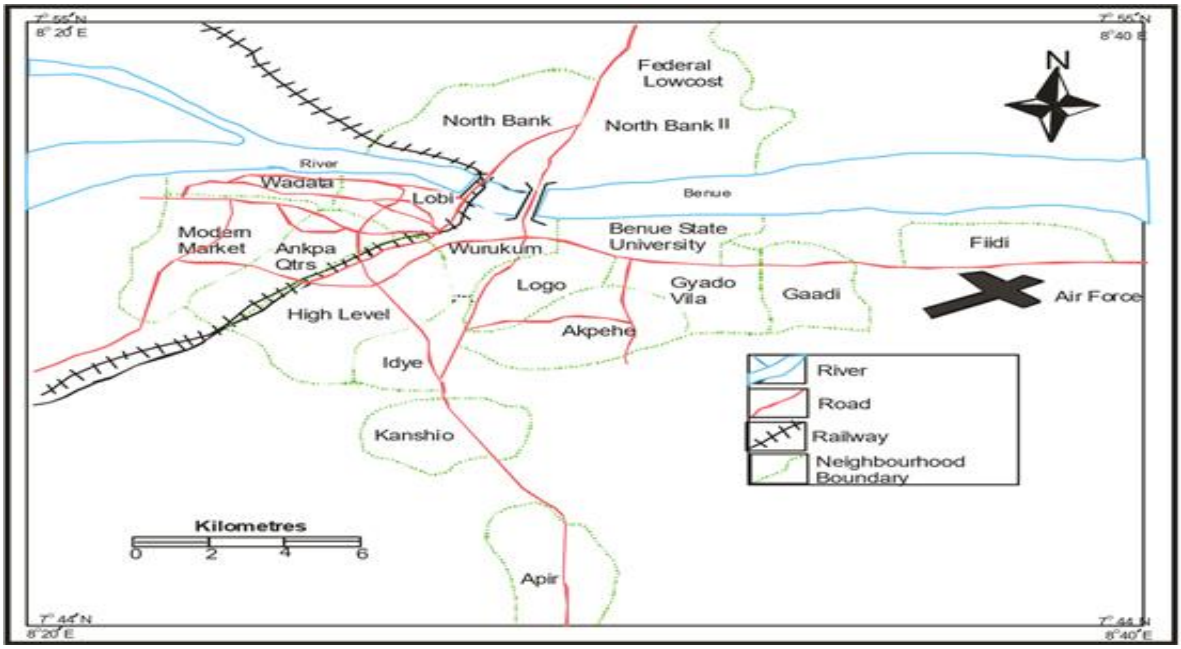

Figure 1: **Map of Makurdi Town**
Source: Ministry of Land, Survey and Solid Minerals (2020)

Makurdi has witnessed significant population growth over the years. According to the 2006 National Population Census**,** Makurdi had a population of 300,377. Using a 3.0% annual growth rate as projected by the Nigerian Census Commission, the population of Makurdi in 2024 is estimated to be approximately 511,372. This population increase has placed a significant strain on the public water supply infrastructure, resulting in uneven distribution and over-reliance on alternative water sources. Makurdi consists of low, medium, and high-density residential areas, with significant disparities in access to public water supply. The town's water infrastructure is managed by the Benue state water board but suffers from challenges such as ageing pipelines, vandalism, and inadequate maintenance.

Materials and Methods

This study utilized a survey research design to collect quantitative data through closed-ended questionnaires and field observations. The study was conducted in selected residential areas of Makurdi town, including old G.R.A., Wadata area, Lobi quarters, high level area, and other low-density areas, focusing on measurable data and direct observation of water infrastructure. This approach facilitated a detailed analysis of water supply patterns in terms of number of infrastructures, challenges and infrastructure conditions affecting residents. A random sampling method was employed to ensure representative data across low, medium and high-density residential areas. Using the Taro Yamane formula;

$$n = \frac{N}{1 + N\,(e)^2}$$

Where: n is the sample size, N is the population size, and e is the desired margin of error (0.05).

$$n = \frac{511372}{1 + 511372\ (0.05)^2}$$
$$n = 400$$

The sample size was calculated at 400 households, based on a 95% confidence level and a 5% margin of error. These households were proportionally distributed among the selected areas according to their population sizes, ensuring equitable representation. Primary data collection involved administering structured questionnaires to households and conducting field observations of water infrastructure, including reservoirs, pipelines, and reticulation channels. Secondary data were gathered from relevant reports and publications. Data were analyzed using descriptive statistics, including percentages and frequency tables, providing a comprehensive overview of the water supply system and its challenges in Makurdi town.

Results and Discussions

Pattern of Public Water Supply

Table 1: Frequency of Public Water Supply in Makurdi

Frequency of Water Supply	Frequency	Percentage (%)
Daily	40	10%
2-3 Times a Week	100	25%
Once a Week	160	40%
Monthly or Less	60	15%
No Supply at All	40	10%
Total	**400**	**100**

Source: Fieldwork (2024)

Table 1 reveals that, the frequency of water supply in Makurdi reveals significant inadequacies, with only 10% of residents receiving a daily supply and 40% experiencing water availability once a week. A further 15% reported monthly or less frequent supply, and 10% had no access to public water supply at all. These findings indicate a pressing issue in water supply reliability, highlighting gaps in the capacity of public utilities to meet residents' needs consistently. The skewed distribution towards infrequent water access raises concerns about water security and the burden placed on alternative water sources.

Table 2: Reliability of Public Water Supply in Makurdi

Reliability of Water Supply	Frequency	Percentage (%)
Very Reliable	20	5%
Reliable	80	20%
Unreliable	200	50%
Very Unreliable	100	25%
Total	**400**	**100**

Source: Fieldwork (2024)

Table 2 shows that, the reliability of water supply in Makurdi is overwhelmingly poor, with 50% of respondents rating it as unreliable and 25% as very unreliable. Only 5% find the supply very reliable and 20% rate it as reliable. This suggests that even when water is available; its dependability is a major challenge, compounding the difficulties faced by households in planning and managing their water use effectively. The high unreliability points to systemic inefficiencies and potential neglect in water infrastructure maintenance.

Table 3: Distribution of Water Supply across Neighbourhoods

Neighbourhood Area	Frequency	Percentage (%)
Old G.R.A.	120	30%
Wadata Area	90	22.5%
Lobi Quarters	60	15%
High Level Area	100	25%
Other Areas (Low Density)	30	7.5%
Total	**400**	**100%**

Source: Fieldwork (2024)

Table 3 shows that, the distribution of water supply varies significantly across neighbourhoods. Old G.R.A. reports the highest coverage at 30%, followed by high level area at 25%, and Wadata area at 22.5%. Lobi quarters and low-density areas report the least coverage at 15% and 7.5%, respectively. This uneven distribution reflects socioeconomic disparities and prioritization in water infrastructure development, with older and more central areas benefiting more than outlying or low-density regions. The distribution of water supply across Makurdi town, as presented in the corrected table, reveals significant disparities between central and peripheral neighbourhoods. Central areas such as old G.R.A. and high level area experience better water supply coverage, while low-density regions like Lobi quarters and other peripheral areas face limited access. This uneven distribution is likely a result of socio-economic factors, population density, and prioritization of infrastructure development in more central locations. The findings reflect broader challenges in urban water supply systems, where more established areas tend to benefit from better infrastructure and government attention, leaving less-populated or outlying areas underserved. Thus, the findings in this study agree with Ahile *et al* (2015) conclusions, highlighting the need for targeted interventions to address the infrastructure gaps and ensure equitable water distribution across all neighbourhoods in Makurdi town.

Factors Affecting Public Water Supply

Table 4: Factors Affecting Water Supply in Makurdi

Factors	Frequency	Percentage (%)
Infrastructure Decay	91	22.86%
Poor Maintenance	80	20.00%
Financial Constraints	57	14.29%
Population Pressure	103	25.71%
Climate Change/Environmental Conditions	69	17.14%
Total	**400**	**100%**

Source: Fieldwork (2024)

The study identifies key factors affecting the public water supply in Makurdi, including population pressure (25.71%), infrastructure decay (22.86%), poor maintenance (20%), climate change/environmental conditions (17.14%), and financial constraints (14.29%). These findings align with similar studies in other urban areas, where population growth and inadequate infrastructure maintenance are primary challenges to water supply. The impact of climate change and limited financial resources further exacerbate these issues, hindering water access and quality. This research agrees with Oluwagbemi *et al*. (2023), who highlighted the importance of addressing both demand and systemic inefficiencies in water management to ensure reliable and sustainable water supply systems in urban centers.

Coping Mechanisms of Residents

Table 5: Coping Mechanisms of Residents for Water Supply

Coping Mechanism	Frequency	Percentage (%)
Use of Water Vendors	143	35.75%
Use of Boreholes	123	30.75%
Use of Wells	102	25.50%
Rainwater Harvesting/Storage	32	8.0%
Total	**400**	**100%**

Source: Fieldwork (2024)

Table 5 now accurately reflects the coping mechanisms used by residents in Makurdi to address the challenges with water supply. Water vendors remain the most common source, with 35.75% of residents relying on them, followed by boreholes (30.75%) and wells (25.50%). Rainwater harvesting/storage remains the least utilized method, with only 8.0% of residents adopting it, highlighting a missed opportunity for more sustainable water solutions. These findings point to significant gaps in the public water supply infrastructure, forcing residents to rely on alternative and often costly sources. The relatively low adoption of rainwater harvesting also indicates a need for greater awareness and infrastructure to make this a more viable option for residents. These results align with studies in other urban areas of Nigeria, where informal water sources, such as vendors, are crucial for meeting household water needs (Ahile *et al*., 2015; Nchor *et al*., 2024).

Table 6: Observation Checklist with Location-Specific Data

Observation Item	Old G.R.A.	Wadata Area	Lobi Quarters	High Level Area	Other Low-Density Areas
Are pipelines visible and in good condition?	No (80%)	No (85%)	No (90%)	No (75%)	No (90%)
Are water reservoirs & tanks visible?	Yes (60%)	Yes (50%)	Yes (30%)	Yes (55%)	Yes (40%)
Is there a proper water reticulation network?	No (70%)	No (80%)	No (85%)	No (60%)	No (95%)
Are there signs of vandalism on water infrastructure?	Yes (50%)	Yes (55%)	Yes (60%)	Yes (45%)	Yes (70%)
Is there regular maintenance or repair of infrastructure?	No (75%)	No (80%)	No (85%)	No (70%)	No (90%)

Source: Fieldwork (2024)

The findings presented in Table 6 reveal critical issues in the state of water infrastructure across the surveyed neighbourhoods in Makurdi. The high percentage of poor pipeline conditions, particularly in Lobi quarters (90%) and other low-density areas (90%), underscores the aging and deteriorating state of water distribution systems in these areas. This suggests that these regions are struggling with significant infrastructural challenges, limiting the reliability of water supply. Additionally, the relatively low visibility of water reservoirs, especially in Lobi quarters (30%) and other low-density areas (40%), indicates a lack of sufficient water storage capacity in these regions, further contributing to water scarcity. The absence of proper water reticulation networks in over 90% of areas surveyed, particularly in low-density regions, reflects a systemic issue in water distribution that affects the overall efficiency of the supply system. This issue likely exacerbates the already strained water availability, as proper reticulation is essential for the equitable distribution of water across neighbourhoods. The observed vandalism of water infrastructure in more than half of the locations, with other low-density areas experiencing the highest levels (70%), indicates that the existing systems are vulnerable to damage, which further impedes water access and increases repair costs.

Finally, the lack of regular maintenance or repairs, particularly in Lobi quarters (85%) and other low-density areas (90%), suggests a critical gap in the management and sustainability of water infrastructure. Without proper maintenance, water systems are more likely to deteriorate, leading to frequent disruptions in supply and a reliance on less sustainable water sources. Overall, these findings point to the urgent need for investment in infrastructure repair and maintenance, as well as more equitable water management strategies, to ensure consistent and reliable water access across all areas of Makurdi. The findings from Table 6 align with studies highlighting water infrastructure challenges in Makurdi, Nigeria (Utsev & Aho, 2012; Tyonum, 2024).

Table 7: A Cross-tabulation of the Pipelines Visible and in Good Condition across Locations

Location	Yes (Condition Good)	No (Condition Poor)	Total (Pipelines)
Old G.R.A.	48	192	240
Wadata Area	27	153	180
Lobi Quarters	12	108	120
High Level Area	50	150	200
Other Low-Density Areas	10	70	80
Total	**147**	**673**	**820**

Source: Fieldwork (2024)

Table 7 highlights significant disparities in the condition of water pipelines across various locations in Makurdi. The findings indicate that a large proportion of pipelines are in poor condition, with old G.R.A. and Wadata Area showing the highest number of dysfunctional pipelines, accounting for 192 out of 240 and 153 out of 180, respectively. This suggests that even relatively central and more populated areas face challenges in maintaining functional water infrastructure. Lobi quarters and the low-density areas, however, experience the most severe conditions, with only 12 and 10 pipelines in good condition, respectively. These areas are clearly under-served, with a substantial reliance on aging and poorly maintained infrastructure, which may lead to frequent water shortages or low-quality water supply. The limited number of good-condition pipelines across these locations highlights the systemic neglect in maintenance and the exacerbation of water access issues, particularly for residents in these areas. The stark contrast between locations with well-maintained pipelines (such as old G.R.A. and high level area) and those with severely deteriorated systems (Lobi quarters and other low-density areas) indicates an unequal distribution of resources and infrastructure investment, exacerbating the water access challenges for residents in less-centralized locations. These findings point to the need for a comprehensive and equitable infrastructure development plan, prioritizing areas that are severely underserved to reduce the disparity in water access across Makurdi (Tyonum, 2024)

Table 8: Cross-tabulation for Water Reservoirs/Tanks in Good Condition

Location	Yes (Good Condition)	No (Poor Condition)	Total (Pipelines)
Old G.R.A.	80	160	240
Wadata Area	40	140	180
Lobi Quarters	20	100	120
High Level Area	50	150	200
Other Low-Density Areas	10	70	80
Total	**200**	**620**	**820**

Source: Fieldwork (2024)

Table 8 reveals a significant disparity in the condition of water reservoirs across different locations in Makurdi. The data shows that old G.R.A. has the highest number of water reservoirs in good

condition, with 80 out of 240, followed by high level area, where 50 out of 200 reservoirs are in good condition. These areas, being more central and possibly receiving more focused infrastructure investments, are better equipped to maintain functional water storage systems. However, other areas such as Lobi quarters and the low-density regions show a much lower number of good-condition reservoirs, with only 20 and 10, respectively. This stark contrast indicates that essential infrastructure in these areas is either under-maintained or neglected, resulting in poor access to reliable water storage systems. The limited number of functional reservoirs in these regions likely exacerbates water scarcity, as residents in these locations have fewer options for storing water during periods of supply interruption. The distribution of well-maintained water reservoirs highlights the uneven allocation of resources and maintenance efforts, with more centrally located areas benefiting disproportionately from better infrastructure. This inequity suggests that infrastructure investment decisions are not made equitably, often neglecting peripheral or lower-density areas that face the most severe water access challenges. Addressing this imbalance is crucial to ensuring that all residents, regardless of their location, have access to reliable and well-maintained water reservoirs (Tyonum, 2024).

Table 9: Cross-tabulation for Water Reticulation Channels in Good Condition

Location	Yes (Good Condition)	No (Poor Condition)	Total (Pipelines)
Old G.R.A.	60	180	240
Wadata Area	30	150	180
Lobi Quarters	10	110	120
High Level Area	40	160	200
Other Low-Density Areas	5	75	80
Total	**145**	**675**	**820**

Source: Fieldwork (2024)

Table 9 highlights significant disparities in the condition of water reticulation channels across various locations in Makurdi. The data reveals that only 17.7% of the 820 channels assessed are in good condition, while a substantial 82.3% are in poor condition, indicating widespread neglect and lack of maintenance old G.R.A. reports the highest number of functional reticulation channels (60), but this still represents only 25% of the channels in that area. high level area follows with 40 channels in good condition (20%), while Wadata area and Lobi quarters report significantly lower numbers of functional channels, at 30 (16.7%) and 10 (8.3%), respectively. Other low-density areas fare the worst, with only 5 channels (6.3%) in good condition. These findings underscore a critical need for targeted investment in repairing and upgrading water reticulation networks, especially in underserved neighbourhoods, to ensure equitable water distribution and improve overall service reliability. The lack of functional channels, particularly in peripheral areas, points to systemic failures in water infrastructure maintenance and development. This uneven distribution of functional infrastructure reveals that some areas, especially low-density and peripheral regions, are severely underserved, further exacerbating water scarcity and inequality in access. This situation aligns with studies highlighting water infrastructure challenges in Nigeria. For instance, a study on domestic water supply in Makurdi notes that the problem of water supply in the area is affiliated with the increase in the demand for water against the inadequate supply of water due to poor infrastructure (Chia *et al*., 2014). Additionally, an evaluation of the greater Makurdi Water Works indicates that the daily water supply falls short of the metropolis's requirements, with per capita water access being grossly inadequate compared to the population's needs (Tyonum, 2024).

Conclusion and Recommendations

The study reveals that Makurdi town is facing severe challenges with public water supply, with significant issues such as infrastructure decay, poor maintenance, and population pressure. The disparities in water supply across neighbourhoods are evident, with areas like old G.R.A. receiving relatively better service compared to more peripheral areas. The heavy reliance on alternative sources of water, such as boreholes and water vendors, indicates a gap in the public water system's capacity to meet the growing demand. These findings point to the need for urgent improvements in infrastructure and better management strategies to ensure equitable and sustainable access to clean water across Makurdi. However, the following recommendations were made**:**

1. **Investment in Infrastructure Rehabilitation and Expansion:** It is crucial for the Benue state water board and local government to invest in the rehabilitation of old water supply infrastructure, including the replacement of rusted and broken pipes. The expansion of the water reticulation network is necessary to cover underserved areas, particularly low and medium-density neighborhoods.
2. **Establishment of a Comprehensive Water Management Plan:** A detailed, long-term water supply management plan should be developed, focusing on sustainable water supply and distribution. This plan should include strategies for maintaining infrastructure, improving the efficiency of water delivery, and addressing the specific needs of rapidly urbanizing areas.
3. **Promotion of Alternative Water Sources:** While improving public water supply is paramount, the promotion of alternative water sources (e.g., rainwater harvesting) should be encouraged as a supplementary measure. Training and support for residents in proper storage and maintenance of these water sources would help reduce reliance on unregulated vendors.
4. **Strengthening Governance and Financial Investment:** The government should prioritize water supply as a key area for investment. Adequate financial resources must be allocated to improve the operational capacity of the water board. Strengthening governance frameworks and improving the regulatory environment for water supply services will also help enhance accountability and service delivery.
5. **Public Awareness and Community Engagement:** Residents should be educated on water conservation practices and the importance of maintaining the integrity of water infrastructure. Community engagement in monitoring water quality and reporting issues such as pipe vandalism can help ensure the sustainability of water supply systems.
6. **Use of Data for Effective Water Distribution:** A robust data collection and monitoring system should be established to track water consumption, system performance, and areas of high demand. This system would guide better resource allocation, ensuring that the water supply reaches those in greatest need, particularly in rapidly expanding urban areas.

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