
IMPACT OF AGEING WATER INFRASTRUCTURE ON WATER SUPPLY IN NIGER STATE: CASE STUDY OF SULEJA AND MINNA

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ABSTRACT

Ageing water infrastructure has become a major challenge to sustainable urban water supply in many developing countries, resulting in declining service reliability, increasing household dependence on alternative water sources and growing socio-economic burdens. This study assessed the impact of ageing water infrastructure on water supply reliability in Minna and Suleja, Niger State, Nigeria. Data were collected from 805 households (405 in Minna and 400 in Suleja), Niger State Water Board personnel, field observations, infrastructure inspections and secondary sources. Correlation and regression analyses were employed to evaluate the relationship between infrastructure condition and water supply reliability. The findings revealed that boreholes constitute the dominant household water source, while dependence on public piped water has declined because of deteriorating infrastructure. Minna consistently recorded better infrastructure condition, higher reliability, shorter water collection distance and lower household water expenditure than Suleja. Statistical analyses established a significant positive relationship between infrastructure condition and water supply reliability, indicating that deteriorated pipelines substantially reduce service continuity and increase household dependence on expensive alternative water sources. The study concludes that ageing infrastructure is the principal factor limiting sustainable urban water supply in Niger State with the correlation of 0.80 and 0.75 for Minna and Suleja respectively. It recommends systematic infrastructure rehabilitation, preventive asset management, expansion of distribution networks, continuous water quality monitoring and greater investment in modern water infrastructure to improve service reliability and achieve sustainable urban water management.

Keywords: ageing; infrastructure; water supply; reliability

1. INTRODUCTION

Reliable access to safe, sufficient, and affordable water remains one of the fundamental requirements for human health, economic development, environmental sustainability, and social well-being (United Nations, 2015). Water is indispensable for domestic consumption, food production, industrial activities, energy generation, ecosystem conservation, and urban development. Consequently, the availability of reliable water infrastructure has become a major determinant of sustainable development and human welfare. Despite substantial investments in water infrastructure worldwide, ensuring continuous and equitable access to safe drinking water remains a persistent challenge, particularly in low- and middle-income countries. Rapid urbanization, population growth, climate change, ageing infrastructure, inadequate maintenance, weak institutional capacity, and insufficient financial investment continue to undermine the reliability of water supply systems across many regions of the world (United Nations, 2023; Ferdowsi *et al.*, 2024).

The challenges associated with ageing water infrastructure are considerably more severe across developing countries, where financial constraints, weak institutional capacity, rapid urbanization, population growth, inadequate maintenance culture, and limited technical expertise have accelerated infrastructure deterioration. Across Sub-Saharan Africa, many urban water utilities operate with obsolete treatment facilities, deteriorated distribution networks, ageing pumping equipment, and inadequate monitoring systems, resulting in high levels of non-revenue water, poor operational efficiency, intermittent water supply, and declining water quality.

Niger State occupies a strategic position within Nigeria's hydrological landscape. As the largest state in the country by land area, it is traversed by the Rivers Niger and Kaduna and contains numerous dams, reservoirs, streams, and groundwater resources that provide considerable water supply potential.

Although considerable research has been conducted on water supply, water quality, governance, and sanitation in Nigeria, relatively few studies have comprehensively investigated the condition of ageing water infrastructure and its direct influence on water supply reliability in Niger State. Existing studies have largely focused on national assessments, selected metropolitan areas, or isolated aspects such as water quality, financing, governance, or access, with limited integration of technical infrastructure condition, household service reliability, environmental vulnerabilities, and socio-economic impacts within a single analytical framework. Recent reviews have likewise concluded that empirical evidence linking infrastructure condition, governance, operational performance, and service reliability remains fragmented in Nigeria, particularly at the state level, thereby limiting evidence-based infrastructure planning and policy development (Adeniran, 2022; Ojo & Sohail, 2024). Consequently, there remains insufficient empirical evidence to guide infrastructure rehabilitation, maintenance prioritization, investment planning, and policy formulation specifically for Niger State. This knowledge gap limits evidence-based decision-making by government agencies, water utilities, and development partners seeking to improve the performance and resilience of public water supply systems.

Against this background, this study evaluates the impact of ageing water infrastructure on water supply reliability in Minna and Suleja, Niger State, Nigeria. The study provides empirical evidence to support infrastructure rehabilitation, improve water utility performance, strengthen climate resilience, enhance public health protection, towards achieving Sustainable Development Goal 6 on clean water and sanitation. The findings are also expected to provide practical guidance for policymakers, engineers, water utility managers, and development agencies responsible for planning sustainable water infrastructure development in Niger State and Nigeria as a whole.

2. METHODOLOGY

2.1 Description of the Study Area

Niger State is the largest state in Nigeria by land area, occupying approximately 76,363 km² in the North-Central region. It lies between latitudes 8°20'N and 11°30'N and longitudes 3°30'E and 7°20'E. The state experiences a tropical continental climate with annual rainfall ranging from 1,100 to 1,600 mm and average temperatures between 25°C and 35°C. The Rivers Niger and Kaduna traverse the state, together with numerous streams, reservoirs, and groundwater resources. Despite these abundant water resources, increasing population growth, ageing infrastructure, inadequate maintenance, and urban expansion continue to constrain reliable public water supply (National Population Commission, 2023; Federal Ministry of Water Resources and Sanitation, 2024).



Fig 2.1

2.1.1 Minna

Minna is the capital city of Niger State and serves as the state's administrative, educational, and commercial centre. The city experiences rapid urbanization, increasing population growth, and expanding residential development that have significantly increased demand for potable water. Water supply is primarily provided by the Niger State Water Board through treatment plants, pumping stations, storage reservoirs, and distribution networks, although many households supplement public supply with private boreholes and water vendors due to intermittent service.

2.1.2 Suleja

Suleja is one of the fastest-growing urban centres in Niger State because of its proximity to the Federal Capital Territory, Abuja. Rapid population growth and urban expansion have considerably increased pressure on existing water infrastructure. Although the town possesses public water supply facilities, many households continue to depend on private boreholes, wells, and commercial water vendors because of inadequate service continuity and ageing infrastructure.

2.2 Sources of Data

Data for this study were obtained from both primary and secondary sources to ensure comprehensive assessment of ageing water infrastructure and water supply reliability.

2.2.1 Primary Data

Primary data were obtained through field investigations comprising infrastructure inspection, structured questionnaire administration, interviews with technical personnel of the Niger State Water Board, direct field observation and water quality testing where applicable.

2.2.2 Secondary Data

Secondary information was obtained from the Niger State Water Board, National Population Commission (NPC), National Bureau of Statistics (NBS), WHO/UNICEF Joint Monitoring Programme (JMP), World Health Organization (WHO), Federal Ministry of Water Resources and Sanitation, published journal articles, textbooks, government reports, and relevant policy documents. These sources provided demographic information, infrastructure records, policy guidelines, and background information supporting the primary data.

2.3 Evaluation Index

The relationship between infrastructure condition and water supply reliability was evaluated using the Pearson Product–Moment Correlation Coefficient (PPMCC) and Multiple Linear Regression. Pearson's correlation coefficient was computed using Equation 2.1.

$$r = \frac{n \sum_{i=1}^n X_i Y_i - (\sum_{i=1}^n X_i)(\sum_{i=1}^n Y_i)}{\sqrt{[n \sum_{i=1}^n X_i^2 - (\sum_{i=1}^n X_i)^2][n \sum_{i=1}^n Y_i^2 - (\sum_{i=1}^n Y_i)^2]}} \quad (2.1)$$

Where r is the Pearson Product–Moment Correlation Coefficient, X_i is the infrastructure condition score for the i^{th} observation, Y_i is the water supply reliability score for the i^{th} observation, n is the Number of observations (sample size), $\sum$ is the summation operator and i is the observation index ($i=1,2,\dots,n$).

The value of the correlation coefficient ranges from -1 to $+1$, where positive values indicate a direct relationship between infrastructure condition and water supply reliability, negative values indicate an inverse relationship, and values close to zero indicate little or no linear relationship.

The regression model adopted using Equation 2.2

$$Y = \beta_0 + \beta_1 X_1 + \varepsilon \quad (2.2)$$

Where Y is the water supply reliability, β_0 is the constant, β_1 are the regression coefficients, X_1 ...is the independent variables and ε is the error term.

Statistical significance was evaluated using $p < 0.05$ where p represents the probability value. Where comparisons between Minna and Suleja were required, an independent-samples t-test was applied. Because the stated formula does not assume equal population variances, it represents Welch's independent-samples t-test.

3. RESULTS AND DISCUSSION

3.1 Assessment of Ageing Water Infrastructure (Piping)

The primary data provided first-hand information regarding infrastructure condition, operational performance, and household experiences. The table 3.1 shows that piped water ranks lowest in the sources of water.

Water Source Distribution (Minna vs Suleja)

Table 3.1: Water Source Distribution

Water Source	Minna (%)	Suleja (%)
Borehole	47.4	35.5
Well	21.7	24
Vendor	18.3	29.5
Piped	12.6	11

The objective is to determine the extent to which ageing infrastructure contributes to declining water service performance. A total of 612.4 KM length of pipeline was assessed in Minna while 587.3 KM was assessed for Suleja.

The condition assessment of transmission and distribution pipelines presented in table 3.2 indicates that most pipeline networks in both Minna and Suleja fall within the fair and poor condition categories. Although Minna recorded a moderately higher proportion of pipelines in good and excellent condition, Suleja exhibited relatively larger percentages of pipelines classified as poor and very poor. This pattern demonstrates that a considerable proportion of the distribution network has exceeded its intended design life and now operates with reduced hydraulic efficiency.

Table 3.2: Pipeline Condition Rating

PIPELINE CONDITION RATING SCALE			
Minna Pipeline (%)	Suleja Pipeline (%)	Ratings	Description
13.6	11.2	80-100	Excellent
26.1	24.3	60-79	Good
30.7	28.9	40-59	Fair
18.9	21.4	20-39	Poor
10.7	14.2	0-19	Very Poor

The deterioration of pipeline infrastructure can largely be attributed to prolonged service life, inadequate preventive maintenance, corrosion, repeated leakages, pipe bursts and delayed replacement of obsolete distribution networks. As pipelines age, structural failures become increasingly frequent, resulting in substantial water losses before treated water reaches consumers. Leakage also contributes to pressure reduction within the network, allowing contaminants to infiltrate damaged pipelines whenever negative pressure conditions occur.

3.2 Relationship between Ageing Infrastructure and Water Supply Reliability

The condition of ageing water infrastructure and the reliability of public water supply in Minna and Suleja. Correlation and regression analyses were conducted to determine the magnitude and significance of the relationships between infrastructure condition and selected reliability indicators. In addition, graphical analyses were used to illustrate the nature of these relationships and identify the infrastructure variables exerting the greatest influence on service reliability.

The scatter plots presented in Figure 3.2 reveal a clear positive relationship between the Infrastructure Condition Index (ICI) and the Water Supply Reliability Index (WSRI) of 0.8 and 0.75 for Minna and Suleja respectively, while the R^2 values of 0.64 for Minna metropolis and 0.56 for Suleja town. In both cities neighbourhoods with better infrastructure conditions consistently recorded higher levels of water supply reliability, while areas characterised by deteriorated infrastructure experienced lower reliability scores. The pattern of the scatter plots demonstrates that improvements in infrastructure condition are associated with corresponding improvements in service reliability.

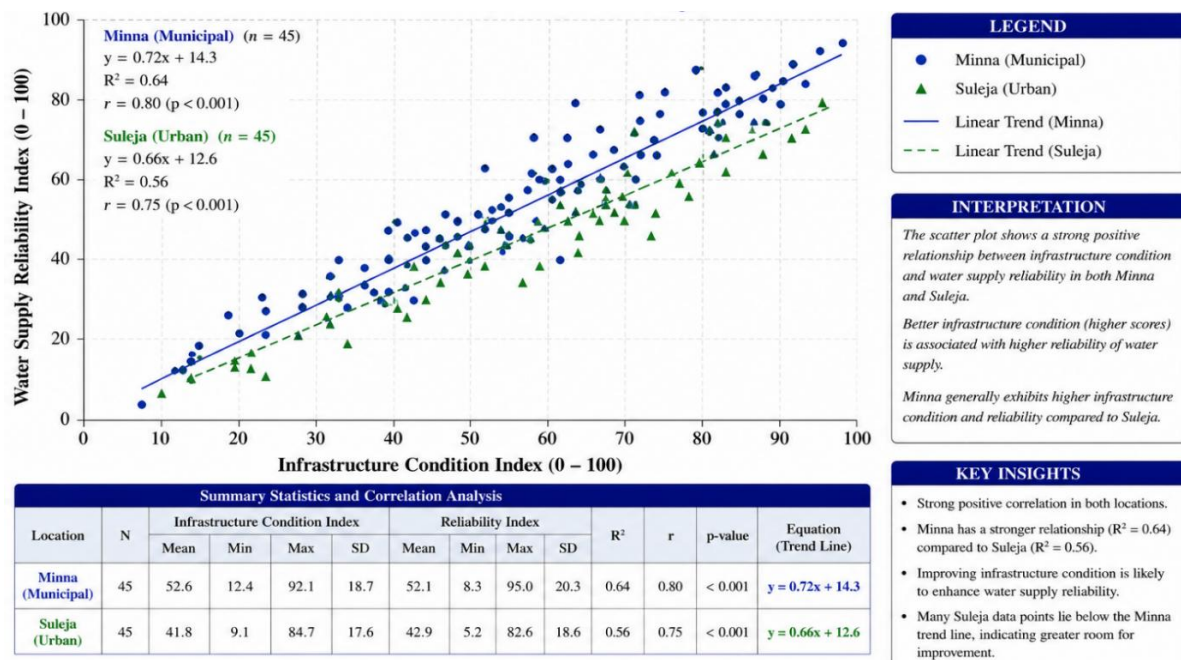


Figure 3.2: Infrastructure Condition versus Reliability

This relationship is expected because the various components of the water supply system operate as an integrated engineering network. Well-maintained pipelines minimise leakage and pressure losses, efficient pumping stations ensure continuous water conveyance, functional treatment plants sustain production capacity, and adequate storage facilities maintain service continuity during periods

of peak demand. Conversely, deterioration within any of these components interrupts system performance and reduces the reliability experienced by consumers.

The observed relationship agrees with previous investigations conducted by Copeland and Tiemann (2019), and World Bank (2024), all of which identified infrastructure condition as one of the strongest determinants of urban water supply reliability. This finding directly addresses the principal objective of the study by establishing empirical evidence linking ageing infrastructure with water supply performance in Niger State.

The linear regression models presented in Figure 3.2 further confirm that infrastructure condition significantly predicts water supply reliability in both Minna and Suleja. The regression lines exhibit positive slopes, indicating that improvements in infrastructure condition are associated with proportional increases in reliability. The relatively stronger regression observed in Minna suggests that infrastructure improvements produce more immediate gains in service reliability because the existing system remains comparatively functional. Although the relationship remains statistically significant in Suleja, the lower gradient reflects the cumulative influence of additional constraints such as rapid urban expansion, increasing water demand and operational limitations.

The GIS analyses established a strong positive relationship between infrastructure condition and water supply reliability at 5% significance level, confirming that improvements in infrastructure condition would directly enhance service reliability.

The analyses therefore fulfil the central objective of the study by quantitatively establishing the relationship between infrastructure condition and water supply reliability while providing an evidence-based foundation for subsequent policy recommendations.

3.3 Distance to Water Source

Figure 3.3 presents the average distance travelled by households to obtain water. The results indicate that respondents in Minna travelled an average distance of approximately 72.5 m to their primary water source, whereas households in Suleja travelled substantially farther, averaging approximately 185.4 m. Although both values remain below the international threshold commonly used to define basic water accessibility, the considerable disparity between the two cities reflects significant differences in infrastructure distribution and service availability.

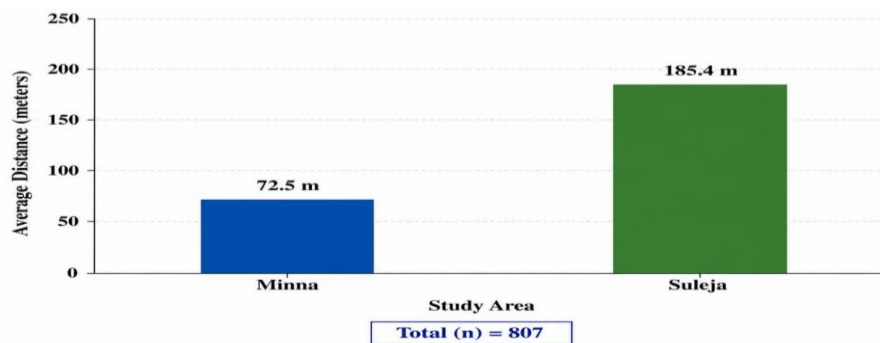


Figure 3.3: Average Distance to Water Source

3.4 Treatment Plant Condition

The assessment of treatment plant condition shown in Figure 3.4 indicates that most facilities operate within the fair condition category, while only a limited proportion can be considered good or excellent. Minna generally recorded moderately better treatment plant conditions than Suleja, although neither city possesses treatment infrastructure that could be considered fully modern or highly efficient.

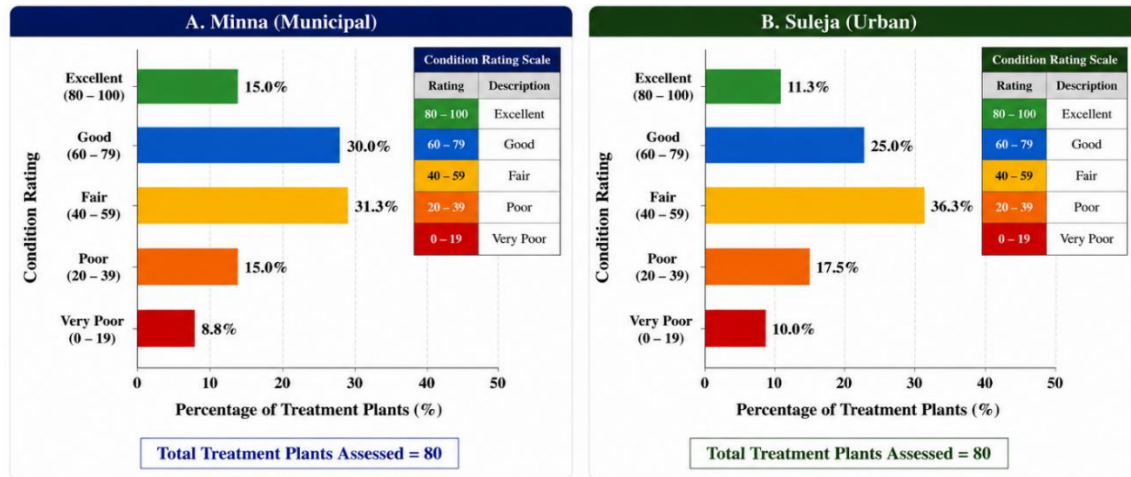


Figure 3.4: Treatment Plant Condition

3.5 Pumping Station Condition

Figure 3.5 presents the condition of pumping stations responsible for conveying treated water throughout the distribution system. The results reveal that pumping stations in Minna generally, perform better than those in Suleja, although both cities exhibit considerable proportions of facilities classified as fair or poor. Only a relatively small number of pumping stations achieved excellent condition ratings.

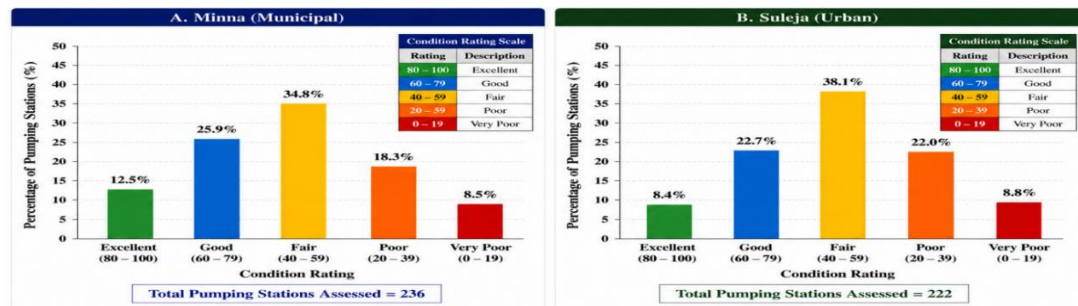


Figure 3.5: Pumping Station Condition

3.6: Storage Facility Condition

Storage facility condition, illustrated in Figure 3.6, reveals similar deterioration patterns. Most storage reservoirs were classified within the fair category, while smaller proportions were rated as excellent or good. Minna again demonstrated slightly better performance than Suleja, although substantial rehabilitation remains necessary in both cities.

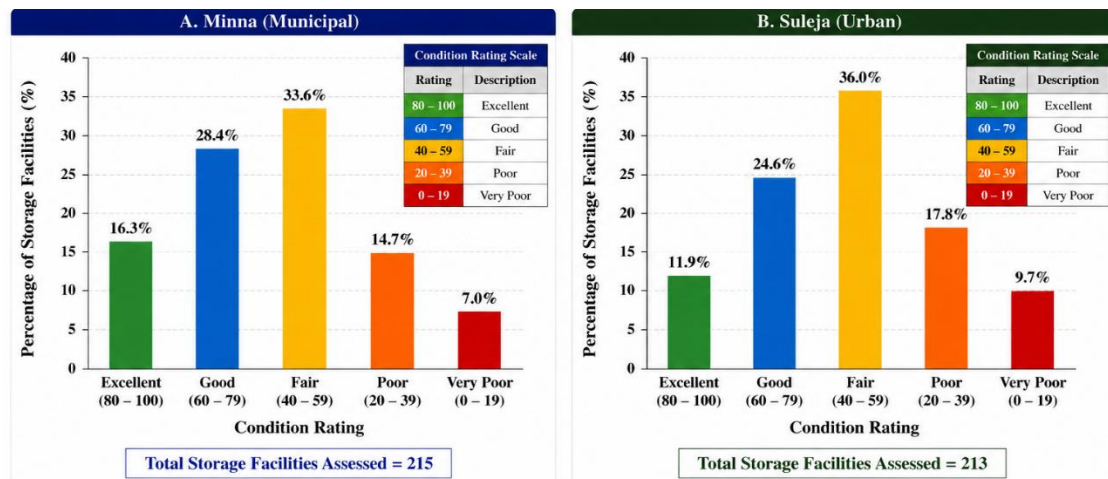


Figure 3.6: Storage Facility Condition

3.7: Comparative of Monthly Water Expenditure

The comparison of monthly household water expenditure presented in Figure 3.7 demonstrates that households in Suleja spend considerably more on domestic water than households in Minna. Although household income levels in both cities remain broadly comparable, the higher dependence on commercial water vendors and alternative water sources substantially increases water-related expenditure among Suleja households.

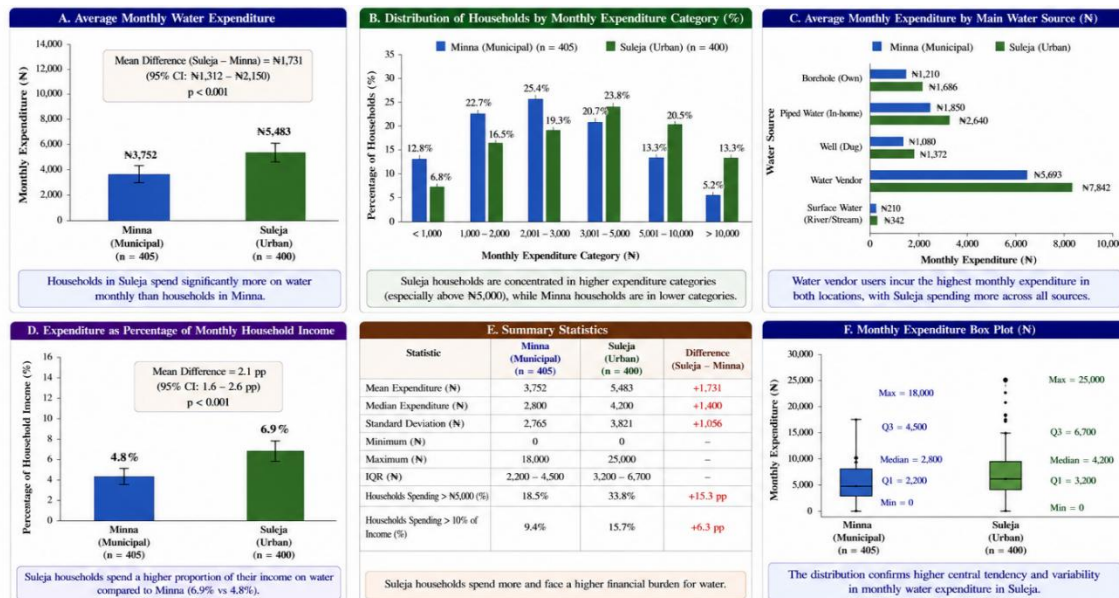


Figure 3.7: Comparative of Monthly Water Expenditure

4. CONCLUSION

The findings demonstrate that ageing infrastructure has significantly reduced the efficiency, reliability and sustainability of urban water supply systems in both cities.

The study concludes that ageing infrastructure is the principal factor limiting sustainable urban water supply in Niger State with correlation of 0.80 and 0.75 for Minna and Suleja respectively.

Pipeline ratings shows that 29.6% of 612.4 km of pipeline in Minna have failed, while 35.6% of 587.3 km pipeline in Suleja have failed.

From a policy perspective, the results highlight the urgent need for systematic rehabilitation of ageing water infrastructure in Niger State. Investment should shift from reactive maintenance towards preventive asset management, strategic infrastructure renewal and expansion of water distribution networks to underserved communities. The study was limited by its focus on two urban centres and by the use of cross-sectional survey data, which provide a snapshot of existing conditions without capturing long-term temporal changes in infrastructure performance. Future research should extend similar assessments to other urban centres within Nigeria, incorporate longitudinal monitoring, evaluate climate change impacts on water infrastructure resilience and develop predictive asset deterioration models using advanced machine learning and artificial intelligence techniques.

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