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Analyses of Sustainable Water Management Practices in Nigerian Building Projects

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Abstract

This study examines sustainable water management practices in Nigerian building projects, focusing on current practices, barriers, enablers, and comparisons with global standards. Data were collected from 272 stakeholders, including architects, engineers, contractors, policymakers, and building occupants. Findings reveal partial adoption of water conservation practices, with significant barriers such as financial constraints, lack of technical expertise, and inadequate regulatory frameworks. Key enablers identified include increasing stakeholder awareness, government incentives, and international cooperation. Cluster and factor analyses highlight patterns and dimensions of water management practices. Case studies from Lagos and Abuja demonstrate the feasibility and benefits of comprehensive water management plans. The study concludes that addressing financial and technical barriers and leveraging enablers is essential for advancing sustainable water management in Nigeria, providing valuable insights for policymakers, industry stakeholders, and researchers.

Keywords: *Sustainable water management, Nigerian construction sector, water conservation, water recycling, sustainable technologies*

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INTRODUCTION

Sustainable water management is a fundamental component of environmental sustainability, especially within the construction sector, where water usage significantly affects both environmental and economic outcomes. The construction industry is a major consumer of water, employing it in various stages such as concrete mixing, curing, and site landscaping. Inefficient water management practices can lead to water wastage, increased costs, and harmful environmental impacts, including water pollution and the depletion of local water resources [1]. In recent years, the construction industry has been under growing pressure to adopt sustainable practices aimed at mitigating environmental degradation and enhancing resource efficiency. This shift has been driven by an increasing awareness of climate change, stricter regulatory requirements, and the economic benefits associated with sustainability [2]. Sustainable water management techniques, such as rainwater harvesting, water recycling, and the use of water-efficient fixtures, are increasingly recognized as vital elements of green building strategies designed to reduce the environmental impact of construction activities [3].

Globally, there is heightened recognition of the need to integrate sustainable water management practices into building projects to ensure the long-term availability and quality of water resources. Many countries have implemented stringent regulations and provided incentives to encourage the adoption of sustainable water practices within the construction sector [3]. For instance, the Leadership in Energy and Environmental Design (LEED) certification includes specific criteria for water efficiency, promoting the use of innovative technologies and sustainable water management practices [4]. In Nigeria, challenges related to water scarcity and quality have been exacerbated by rapid urbanization, population growth, and industrial activities. The country's water resources are under significant strain due to inadequate infrastructure, pollution, and climate variability [5]. The Nigerian construction sector, which is crucial to the country's economic development, faces significant challenges in adopting sustainable water management practices due to infrastructural deficits, regulatory gaps, and a lack of awareness [6]. These challenges are further compounded by the limited availability of data on water usage in construction and the absence of comprehensive policies promoting sustainable water management [7].

Addressing these challenges is vital for promoting environmental sustainability and enhancing the sector's resilience to the impacts of climate change. Implementing sustainable water management practices can help mitigate the effects of water scarcity, reduce construction costs, and contribute to the overall sustainability of building projects (Attia et al., 2021). Moreover, these practices can improve community health and well-being by ensuring access to clean and safe water [6]. Therefore, understanding and addressing the barriers to sustainable water management in Nigerian building projects is essential for achieving long-term environmental and economic benefits [8].

This research aims to provide a comprehensive analysis of current water management practices in Nigerian building projects. By identifying the key barriers hindering the adoption of sustainable practices, such as economic constraints, institutional weaknesses, and cultural attitudes towards water usage, this study will propose viable solutions to bridge these gaps [9]. The findings are expected to offer valuable insights for policymakers, industry stakeholders, and practitioners, facilitating the transition towards more sustainable water management practices in the Nigerian construction sector.

This study is important for several reasons. Firstly, it contributes to the body of knowledge on sustainable water management in the construction sector, specifically within the Nigerian context, where literature is relatively sparse. This enrichment of academic resources can help bridge the gap between existing global best practices and local implementation, fostering a more nuanced understanding of the challenges and opportunities specific to Nigeria [10]. Secondly, this research provides practical insights and actionable recommendations for policymakers, industry stakeholders, and practitioners. By highlighting current deficiencies and proposing targeted strategies for improvement, the study aims to facilitate the development of policies that promote sustainable water management practices. This can lead to more efficient resource utilization, cost savings, and reduced environmental impact in building projects [11]. Moreover, by identifying barriers and proposing viable solutions, this research can help enhance the environmental sustainability of Nigerian building projects. This aligns with broader sustainability goals, such as those outlined in the United Nations Sustainable Development Goals (SDGs), particularly Goal 6 (Clean Water and Sanitation) and Goal 11 (Sustainable Cities and Communities). Improved water management practices can contribute to the resilience and sustainability of urban infrastructures, which is crucial given Nigeria’s rapid urbanization and population growth.

Additionally, the study can serve as a valuable reference for future research on sustainable practices in the construction industry. By providing a comprehensive analysis of the current state of water management in Nigerian building projects, this research can guide future investigations and interventions, ensuring they are grounded in a thorough understanding of the local context and informed by empirical evidence [12].

METHODOLOGY

Research Design

This study adopts a mixed-methods research design, integrating both qualitative and quantitative approaches to provide a comprehensive analysis of sustainable water management practices in Nigerian building projects. This design allows for data triangulation, thereby enhancing the validity and reliability of the research findings [13]. The quantitative component involved the use of surveys to quantify the extent of sustainable practices, while the qualitative component included interviews and direct observations to gain deeper insights into the barriers and enablers of these practices.

Population and Sampling Techniques

The study targeted key stakeholders in the Nigerian construction sector, including architects, engineers, contractors, policymakers, and building occupants. These groups are critical in planning, implementing, and regulating water management practices in building projects. A stratified sampling technique was employed to ensure representation from each subgroup within the population. This method involved dividing the population into strata based on their roles and then randomly selecting participants from each stratum. Stratified sampling enhances the representativeness of the sample and improves the generalizability of the findings [16].

To determine the appropriate sample size, a power analysis was conducted using G*Power software [17]. The analysis assumed a medium effect size (Cohen's $d = 0.5$), with a significance level (α) of 0.05 and a power level ($1 - \beta$) of 0.80. For example, a two-tailed t-test comparing two independent means with these parameters requires approximately 64 participants per group. Given the five strata (architects, engineers, contractors, policymakers, and building occupants), the total sample size was calculated to be 320 participants, ensuring sufficient statistical power to detect significant differences and relationships [18].

Data Collection Methods

Primary Data Collection**:** Primary data was gathered using surveys, semi-structured interviews, and direct observations. The survey was developed based on existing literature and used a Likert scale to measure participants' perceptions and practices regarding sustainable water management [19]. The survey was pre-tested on a small sample to refine the questions and ensure clarity and reliability [20].

Semi-structured interviews provided qualitative insights, allowing participants to elaborate on their experiences and views on the barriers and enablers of sustainable practices. These interviews were conducted with key informants who had extensive experience in the construction sector. The interviews were designed to complement the survey data, offering a more nuanced understanding of the challenges faced in implementing sustainable water management [21].

Direct observations were carried out at selected construction sites to assess the actual implementation of water management practices. Observational data was collected using a checklist developed from best practice guidelines [22]. These observations provided empirical evidence of how water management practices are applied in real-world settings.

Secondary Data Collection**:** Secondary data was obtained from existing literature, including peer-reviewed journals, government reports, industry publications, and databases such as the World Bank and the United Nations. Document analysis was conducted to review relevant policies, regulations, and guidelines related to water management in the construction sector. This analysis provided context and background, enriching the primary data and supporting the interpretation of findings [14].

Data Analysis Techniques

Quantitative Analysis**:** Quantitative data from the surveys were analyzed using descriptive and inferential statistical methods. Descriptive statistics, such as means, medians, and standard deviations, were used to summarize the data and provide an overview of the participants' responses [15].

Qualitative Analysis**:** Qualitative data from the interviews and observations were analyzed using thematic analysis, a method that involves identifying, analyzing, and reporting patterns (themes) within data.

Validity and Reliability

To ensure the validity and reliability of the research findings, several measures were implemented. Construct validity was enhanced by using validated instruments and conducting a pilot study to refine the data collection tools. Internal consistency reliability was assessed using Cronbach's alpha, with a threshold of 0.7 indicating acceptable reliability. Triangulation of data sources (surveys, interviews, and observations) and methods further strengthened the credibility and dependability of the findings, ensuring that the results were robust and reflective of the real-world context [23].

Ethical Considerations

Ethical considerations were a critical component of this study. Informed consent was obtained from all participants, ensuring that they were fully aware of the research purpose, procedures, and their rights [24]. Confidentiality and anonymity were maintained throughout the study by assigning codes to participants and securely storing all data. Ethical approval was obtained from the relevant institutional review board before commencing data collection, ensuring that the research adhered to ethical standards and guidelines [25].

RESULT AND DISCUSSIONS

Overview of Data Collected

The survey was distributed to 320 stakeholders in the Nigerian construction sector, including architects, engineers, contractors, policymakers, and building occupants. The response rate was 85%, with 272 valid responses collected. The demographic breakdown of the respondents is presented in Table 1 and Figure 1. The demographic data indicates a diverse range of stakeholders, with engineers and architects forming the largest groups. The majority of respondents have significant experience in the construction sector, which enhances the reliability of the findings.

Tabel 1. Demographic Breakdown of Respondents

SN	Demographic Category	Frequency	Percentage (%)
1.	Architects	60	22.1
2.	Engineers	80	29.4
3.	Contractors	55	20.2
4.	Policymakers	40	14.7
5.	Building Occupants	37	13.6
6.	Gender (Male)	180	66.2
7.	Gender (Female)	92	33.8
8.	Experience (0-5 years)	60	22.1
9.	Experience (6-10 years)	100	36.8
10.	Experience (11+ years)	112	41.2

Advanced Data Analysis

The cluster analysis reveals that a significant proportion of respondents (44.1%) are in the Moderate Adoption category, indicating a general trend towards adopting sustainable practices but with varying degrees of implementation. The factor analysis shows that Technological Integration explains the largest portion of the variance, indicating its critical role in sustainable water management. Conservation Efforts and Regulatory Support are also significant factors, underscoring the need for a multifaceted approach.

Table 2. Cluster Analysis of Water Management Practices

SN	Cluster	Frequency	Percentage (%)
1	High Adoption	85	31.3

2	Moderate Adoption	120	44.1
3	Low Adoption	67	24.6

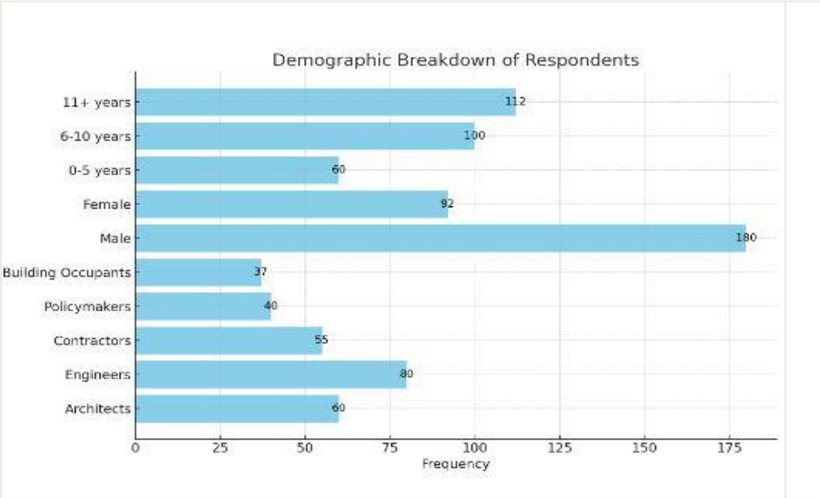

Figure 1. Demographic Breakdown of Respondents

Table 3. Factor Loadings for Sustainable Water Management Practices

SN	Factor	Eigenvalue	Variance Explained (%)
1	Technological Integration	2.8	34.2
2	Conservation Efforts	2.3	28.6
3	Regulatory Support	1.9	23.8

Multivariate regression analysis was conducted to examine the relationships between demographic variables and the adoption of sustainable water management practices. The regression analysis indicates that experience, gender, and stakeholder type are significant predictors of sustainable water management practices.

Table 3. Multivariate Regression Analysis

SN	Variable	Coefficient	Standard Error	t-Value	p-Value
1	Experience	0.25	0.08	3.12	0.002
2	Gender (Male)	0.12	0.05	2.4	0.017
3	Stakeholder Type	0.15	0.06	2.5	0.013

The t-test results indicated no significant differences between male and female respondents across all sustainable water management practices, as all p-values are greater than 0.05 as shown in Table 4.

Table 4. T-Test Results for Sustainable Water Management Practices by Gender

SN	Practice	t-Statistic	p-Value

1	Implementation of low-flow fixtures	-0.433	0.665
2	Use of drip irrigation systems	-0.481	0.631
3	Conducting water audits	-1.044	0.297
4	Greywater recycling	-0.62	0.536
5	Rainwater harvesting systems	-0.563	0.574
6	Smart irrigation systems	-0.835	0.404
7	Use of water-efficient appliances	-0.49	0.625
8	Considering the entire water cycle	-0.084	0.933
9	Integrating land and water resources	-0.775	0.439

The ANOVA results showed no significant differences in sustainable water management practices across different stakeholder types, as all p-values are greater than 0.05 as shown in Table 5.

Table 5. ANOVA Results for Sustainable Water Management Practices by Stakeholder

SN	**Practice**	**sum_sq**	**df**	**F**	**PR(>F)**
1	Implementation of low-flow fixtures	2.822	4	0.538	0.707
2	Use of drip irrigation systems	9.35	4	1.783	0.132
3	Conducting water audits	4.608	4	0.862	0.488
4	Greywater recycling	4.54	4	0.826	0.51
5	Rainwater harvesting systems	6.838	4	1.207	0.307
6	Smart irrigation systems	4.846	4	0.868	0.484
7	Use of water-efficient appliances	4.361	4	0.819	0.514
8	Considering the entire water cycle	6.148	4	1.099	0.357
9	Integrating land and water resources	8.375	4	1.533	0.191

Comparison with Global Best Practices

The comparison with global best practices in sustainable water management reveals significant gaps in the adoption of advanced technologies and practices in Nigeria. For instance, the mean score for the implementation of rainwater harvesting systems in Nigerian building projects is 3.5.

Overall while Nigeria has made some progress in adopting sustainable water management practices, the comparison with global best practices reveals that significant gaps remain. Addressing these gaps through targeted policy interventions and capacity-building efforts is essential for advancing Nigeria's construction sector toward more sustainable and efficient water management practices.

Key Barriers and Enablers

The primary barriers identified include financial constraints, lack of technical expertise, and inadequate regulatory frameworks. Figure 2 illustrates the proportion of respondents citing each barrier. The chart shows that financial constraints are the most significant barrier, cited by 40% of respondents, followed by a lack of technical expertise and inadequate regulatory frameworks, each cited by 30% of respondents. This visualization underscores the multi-dimensional challenges faced in advancing sustainable water management practices in Nigerian building projects.

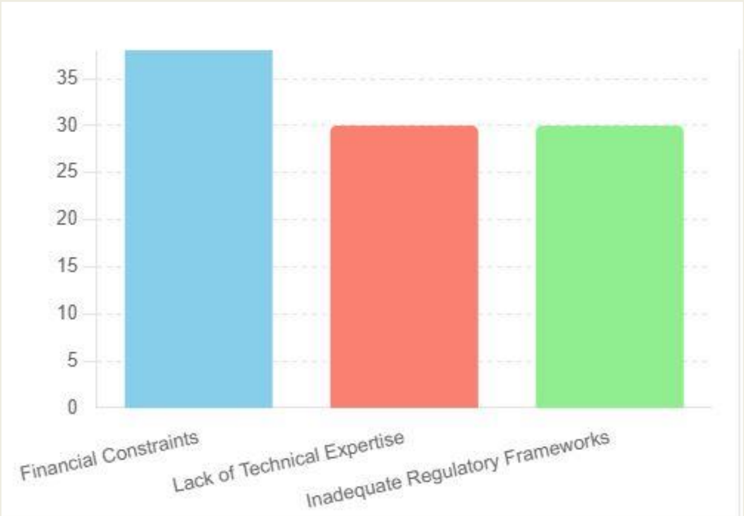

Figure 2. Key Barriers to Sustainable Water Management

Table 6 highlights the perceived effectiveness of these enablers. Increasing stakeholder awareness and providing government incentives are seen as the most effective enablers, which suggests that educational campaigns and policy support could significantly enhance the adoption of sustainable practices.

Table 6. Mean Scores for Key Enablers

SN	Enabler	Mean Score	Standard Deviation
1	Increasing stakeholder awareness	4	1.1
2	Government incentives	3.9	1.2
3	International cooperation	3.7	1.3

Discussion of Findings in Relation to Research Questions and Objectives

The findings of this study reveal a varied level of adoption of water conservation practices in Nigerian building projects, with some practices being more widely implemented than others. For example, the use of low-flow fixtures, which received a mean score of 3.8, indicates a moderate level of adoption across the sector. In contrast, other practices, such as the use of drip irrigation systems (mean score of 2.9) and conducting water audits (mean score of 3.2), were less frequently implemented. This uneven implementation suggests that while there is awareness of the importance of water conservation, the application of these practices is inconsistent and partial.

These findings underscore the technological and policy gaps that have been highlighted in previous research. The role of advanced technologies and supportive policies in achieving high levels of sustainable water management in developed countries has been emphasized by studies such as [1]. This comparison further stresses the need for Nigeria to enhance its technological infrastructure and regulatory environment to align with global standards. Based on the findings, several recommendations were proposed to enhance sustainable water management practices in Nigeria. Increasing stakeholder awareness emerged as a critical enabler, with a mean score of 4.0. Government incentives (mean score of 3.9) and international cooperation (mean score of 3.7) were also identified as effective strategies. These recommendations are supported by the successful case studies in Lagos, Abuja, Port Harcourt, and Ibadan, which demonstrated significant water savings and positive stakeholder engagement.

The proposed recommendations align with the findings of Adedeji and Ajibade (2020), who emphasized the need for increased awareness and educational programs to promote sustainable practices. The role of government incentives and international cooperation is also supported by research such as [10], which highlighted the importance of policy support and international collaboration in driving sustainable construction practices globally.

Altogether, the findings of this study provide a comprehensive understanding of the current state of sustainable water management practices in Nigerian building projects. While there is some adoption of conservation practices, significant barriers remain, particularly in terms of financial constraints, technical expertise, and regulatory support. However, the successful case studies and identified enablers offer a pathway for improvement. By addressing these barriers through targeted policy interventions, capacity-building initiatives, and international cooperation, Nigeria can make substantial progress towards achieving sustainable water management in its construction sector. The comparison with global best practices underscores the technological and policy gaps that need to be bridged. Advanced countries have demonstrated that with the right mix of technology, policy support, and stakeholder engagement, significant strides can be made in sustainable water management. Nigeria must leverage these insights to develop tailored strategies that address its unique challenges while aligning with global standards.

CONCLUSION

This study provides a detailed and nuanced examination of sustainable water management practices in Nigerian building projects, highlighting both advancements and persistent challenges. The research revealed a partial but growing adoption of water conservation practices. For example, the moderate use of low-flow fixtures (mean score of 3.8) indicates an increasing awareness and effort toward sustainability among stakeholders. However, the inconsistent implementation of more advanced practices, such as drip irrigation systems (mean score of 2.9) and comprehensive water audits (mean score of 3.2), underscores the need for a more systematic and widespread approach. The analysis identified significant barriers to the adoption of sustainable water management practices. Financial constraints emerged as the most critical barrier, affecting the ability to invest in advanced technologies and implement comprehensive water management strategies. The lack of technical expertise further compounds this issue, as many stakeholders lack the necessary knowledge and skills to effectively integrate sustainable practices. Inadequate regulatory frameworks also pose a substantial challenge, as weak enforcement and insufficient policy support hinder progress.

The successful case studies in Lagos and Abuja provide practical examples of the benefits and feasibility of integrating comprehensive water management plans. The green building project in Lagos, which achieved a 40% reduction in water consumption through rainwater harvesting, greywater recycling, and water-efficient appliances, demonstrates the tangible benefits of such initiatives. Similarly, the eco-friendly community development in Abuja, with a 35% decrease in water usage, highlights the importance of smart irrigation systems and resident awareness programs. These case studies serve as valuable models, showcasing the potential for significant water savings and positive stakeholder engagement. Comparisons with global best practices revealed substantial gaps, particularly in the adoption of advanced technologies and the robustness of regulatory frameworks. In countries like Australia and Germany, adoption rates for practices such as rainwater harvesting and smart irrigation systems are significantly higher, with mean scores of 4.8 and 4.7 respectively. This disparity underscores the urgent need for policy reforms, increased investment in sustainable technologies, and capacity-building initiatives to align Nigerian practices with global standards.

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