Sustainable Wastewater Management in Nigeria: A Case Study of Port Harcourt

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ABSTRACT

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| Wastewater management is a critical challenge facing rapidly urbanizing cities in developing countries, with significant implications for public health, environmental sustainability, and socio-economic development. This study investigates the complex challenges and opportunities for sustainable wastewater management in Port Harcourt, Nigeria, through a quantitative survey of government officials, experts, and community residents. The research addresses four central questions related to current practices and challenges, the effectiveness of existing systems, key sustainability issues and concerns, and potential improvements to integrate sustainability principles. The study employs a correlational design and an online questionnaire to collect data from 80 participants, comprising 66 government officials, experts, and 14 community residents. The findings reveal significant associations between various aspects of wastewater management and sustainability, highlighting the multi-dimensional nature of the problems facing Port Harcourt's wastewater systems. The results suggest that improving the sufficiency of collection methods, adequacy of treatment, and enforcement of regulations could enhance the effectiveness of wastewater management and mitigate public health risks. The study also underscores the importance of addressing infrastructure gaps, social and cultural barriers, and policy gaps to enable transitions towards more sustainable wastewater practices. The discussion of the findings links the results to the existing literature and theoretical frameworks on sustainable wastewater management in developing urban contexts. The study contributes to the body of knowledge by providing empirical evidence, applying a sustainability lens, employing quantitative methods, and emphasizing stakeholder engagement in the specific context of Port Harcourt. The study highlighted the urgent need for a comprehensive, sustainability-oriented approach that addresses wastewater systems' interrelated technical, environmental, social, economic, and governance dimensions. |

***Keywords:*** *Wastewater management, sustainability, water management, public health, waste disposal, waste treatment*

1. INTRODUCTION

Wastewater management has emerged as a critical issue for cities worldwide, particularly in the developing world, where rapid urbanization and industrialization have outpaced investments in water infrastructure (Varma et al., 2024). The improper collection, treatment, and disposal of domestic, commercial, and industrial effluents pose significant risks to public health, environmental integrity, and sustainable development (Obaideen et al., 2022). Globally, it is estimated that over 80% of wastewater is discharged into the environment without adequate treatment, leading to pollution of water bodies, soil contamination, and the spread of waterborne diseases (Tariq and Mushtaq, 2023).

Nigeria exemplifies the significant wastewater challenges facing rapidly growing cities in the Global South. With a population exceeding 200 million and an urbanization rate of over 50%, the country's major metropolitan areas, like Lagos and Kano, generate massive volumes of domestic and industrial wastewater that essentially go untreated (Kodiya et al., 2025; Ache, 2019). Weak regulations, limited infrastructure, inadequate funding, and lack of technical capacity constrain efforts to establish comprehensive wastewater management systems. It is estimated that only 10% of urban households in Nigeria have access to adequate wastewater disposal facilities, with the remainder discharging wastewater and untreated effluents into rivers, lagoons, and the ocean, resulting in severe water pollution, environmental degradation, and risks to public health (Ilyas et al., 2019; Sharma et al., 2024; Jadeja and Jain, 2022).

Port Harcourt, the capital of Rivers State, encapsulates Nigeria's wastewater crisis. As the centre of the country's oil industry, Port Harcourt generates significant volumes of domestic sewage and industrial effluents, which overwhelm the city's limited and dysfunctional wastewater treatment infrastructure (Omoyajowo et al., 2024; Nwinyi et al., 2020). With a population exceeding 1.5 million, it is estimated that most of Port Harcourt's wastewater flows untreated into local waterways, creeks, and the Bonny River estuary (Wizor and Nwankwoala , 2019). This not only pollutes crucial freshwater sources but also harms coastal and marine ecosystems in the Niger Delta region (Numbere et al., 2023; Onyena and Sam, 2020; Bodo and Gimah, 2020).

This study aims to address the research gap by providing an in-depth sustainability-focused assessment of wastewater management in Port Harcourt. By examining current practices, challenges, and sustainability concerns through the perspectives of government, industry, and community stakeholders, the study offers important insights to inform integrated policy and planning solutions.

**2.0 Methodology**

This study employs a quantitative research design, utilizing an online survey as the primary data collection tool to investigate wastewater management practices and sustainability integration in Port Harcourt, Nigeria. The survey was designed to gather data on current practices, challenges, effectiveness, sustainability concerns, and potential improvements in wastewater management. The target population for the study includes government officials, experts, and community residents involved in or affected by wastewater management in Port Harcourt. A purposive sampling technique was used to select 80 participants, with 66 government officials and experts and 14 community residents, ensuring a balanced representation of key stakeholder groups.

**2.1 Survey Questionnaire**

The survey questionnaire was developed based on a review of relevant literature and existing instruments related to wastewater management and sustainability. It included a mix of closed-ended questions (Likert scales, multiple-choice) and open-ended questions to gather quantitative data on participants' attitudes, behaviors, and perceptions. The questionnaire was piloted with a small sample of participants to assess its clarity, comprehensiveness, and face validity, and feedback from the pilot was used to refine the instrument before the main data collection.

**2.2 Data Collection**

Data collection was conducted using the Google Form platform, which allowed for efficient data collection from a geographically dispersed sample. Participants were invited to complete the survey through email invitations and online advertisements. Informed consent was obtained from all participants before their involvement in the study, and their responses were kept anonymous and confidential. The survey was designed to be concise and straightforward, with participants free to skip any questions they did not wish to answer.

**2.3 Data Analysis**

Data analysis involved a combination of descriptive and inferential statistics to examine patterns, relationships, and differences in participants' responses. Descriptive statistics, such as frequencies and percentages, were used to summarize and visualize the data for each variable and stakeholder group. Inferential statistics, including correlation analysis, were employed to explore the relationships between variables and answer the research questions. All statistical analyses were conducted using SPSS software, and the results were interpreted in the context of the existing literature and theoretical frameworks on sustainable wastewater management.

**ETHICAL Consideration:**

The study adhered to strict ethical principles to protect participants' rights, well-being, and confidentiality. The research design and procedures were reviewed and approved by the relevant institutional ethics committees before data collection commenced. Measures were taken to ensure the privacy and confidentiality of participants, including the anonymous collection of survey responses and secure storage of data in password-protected files. The study also aimed to minimize any potential risks or burdens to participants, and the findings were disseminated ethically and responsibly to promote positive social and environmental change in Port Harcourt.

**3.0 RESULTS:**

The following are the research questions to the respondents:

Research Questions:

1: What are the current practices and challenges for wastewater management in Port Harcourt?

2: How effective are the current wastewater management systems and infrastructure in Port Harcourt?

3: What are the key sustainability issues and concerns related to wastewater management in Port Harcourt?

4: How can wastewater management systems and practices be improved to integrate sustainability principles in Port Harcourt?

**Table 1:** Demographic Data of Respondents

|  |  |  |
| --- | --- | --- |
| Variables | Frequency | Percentages |
| What stakeholder group do you belong to? |  |  |
| Government officials and experts | 66 | 82.5 |
| Community residents | 14 | 17.5 |
| Total | 80 | 100 |
| What is your age group? |  |  |
| 18-30 | 59 | 73.7 |
| 31-50 | 19 | 23.7 |
| 51-65 | 1 | 1.3 |
| Over 65 | 1 | 1.3 |
| Total | 80 | 100 |
| What gender do you identify as? |  |  |
| Male | 55 | 68.7 |
| Female | 23 | 28.8 |
| Non-binary / Other | 0 | 0 |
| I prefer not to say | 2 | 2.5 |
| Total | 80 | 100 |
| What is the highest education level you have attained? |  |  |
| Primary school | 0 | 0 |
| Secondary school | 9 | 11.2 |
| University degree | 59 | 73.8 |
| Postgraduate degree | 10 | 12.5 |
| No formal education | 0 | 0 |
| Other (please specify) | 2 | 2.5 |
| Total | 80 | 100 |
| Years of experience in wastewater management |  |  |
| 1-5 years | 59 | 73.8 |
| 6- 10 years | 12 | 15.0 |
| 10 years and above | 9 | 11.2 |
| Total | 80 | 100 |

Researcher Survey, (2024)

**Table 2:** Correlation Analysis for Research Question 1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | Collection Methods | Treatment | Funding Infrastructure | Health Issues | Expanded Infrastructure |
| Collection Methods | 1.000 | 0.712\*\* | -0.231\* | -0.298\*\* | -0.199 |
| Treatment | 0.712\*\* | 1.000 | -0.218 | -0.316\*\* | -0.201 |
| Funding Infrastructure | -0.231\* | -0.218 | 1.000 | 0.273\* | 0.341\*\* |
| Health Issues | -0.298\*\* | -0.316\*\* | 0.273\* | 1.000 | 0.314\*\* |
| Expanded Infrastructure | -0.199 | -0.201 | 0.341\*\* | 0.314\*\* | 1.000 |

Researcher Survey, (2024)

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

**Table 3:** Correlation Analysis for Research Question 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | Effectiveness | Infrastructure Gap | Enforcement | Monitoring Need | Upgrading Priority |
| Effectiveness | 1.000 | -0.256\* | 0.312\*\* | -0.287\* | -0.100 |
| Infrastructure Gap | -0.256\* | 1.000 | -0.176 | 0.194 | 0.092 |
| Enforcement | 0.312\*\* | -0.176 | 1.000 | -0.222\* | -0.082 |
| Monitoring Need | -0.287\* | 0.194 | -0.222\* | 1.000 | 0.096 |
| Upgrading Priority | -0.100 | 0.092 | -0.082 | 0.096 | 1.000 |

Researcher Survey, (2024)

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

**Table 4:** Correlation Analysis for Research Question 3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | Sustainability Issues | Sustainability Assessment | Sustainability Principles | Social & Cultural Barriers | Government Responsibility |
| Sustainability Issues | 1.000 | -0.278\* | -0.201 | 0.189 | 0.087 |
| Sustainability Assessment | -0.278\* | 1.000 | 0.311\*\* | -0.225\* | 0.194 |
| Sustainability Principles | -0.201 | 0.311\*\* | 1.000 | -0.267\* | 0.209 |
| Social & Cultural Barriers | 0.189 | -0.225\* | -0.267\* | 1.000 | -0.072 |
| Government Responsibility | 0.087 | 0.194 | 0.209 | -0.072 | 1.000 |

Researcher Survey, (2024)

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

**Table 5:** Correlation Analysis for Research Question 4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | Sustainability Integration | Innovative Solutions | Decentralized Methods | Policy Gaps | Multi-stakeholder collaboration |
| Sustainability Integration | 1.000 | 0.521\*\* | 0.458\*\* | 0.372\*\* | 0.396\*\* |
| Innovative Solutions | 0.521\*\* | 1.000 | 0.493\*\* | 0.404\*\* | 0.395\*\* |
| Decentralized Methods | 0.458\*\* | 0.493\*\* | 1.000 | 0.342\*\* | 0.343\*\* |
| Policy Gaps | 0.372\*\* | 0.404\*\* | 0.342\*\* | 1.000 | 0.281\* |
| Multi-stakeholder collaboration | 0.396\*\* | 0.395\*\* | 0.343\*\* | 0.281\* | 1.000 |

Researcher Survey, (2024)

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

Table 1 revealed that according to the stakeholder group, the majority of the participants (82.5%, n=66) belong to the "Government officials and experts" stakeholder group. The remaining 17.5% (n=14) of the participants are "Community residents." In terms of age group, nearly three-quarters of the participants (73.7%, n=59) are in the 18-30 age group. Almost a quarter (23.7%, n=19) of the participants are in the 31-50 age group. Only 1.3% (n=1) of the participants are in the 51-65 and Over 65 age groups.

Also, more than two-thirds of the participants (68.7%, n=55) identify as male, just over a quarter (28.8%, n=23) of the participants identify as female, no participants identify as non-binary or other gender and a small percentage (2.5%, n=2) prefer not to disclose their gender. In education level, the majority of the participants (73.8%, n=59) have attained a university degree as their highest level of education. 12.5% (n=10) of the participants have a postgraduate degree. 11.2% (n=9) of the participants have completed secondary school. None of the participants had only primary school education or no formal education, and a small percentage (2.5%, n=2) selected "Other" for their education level. Furthermore, nearly three-quarters of the participants (73.8%, n=59) have 1-5 years of experience in wastewater management. 15% (n=12) of the participants have 6-10 years of experience. 11.2% (n=9) of the participants have 10 years or more of experience in wastewater management.

Table 2 reveals a strong positive correlation between "Collection Methods" and "Treatment" (r = 0.712, p < 0.01). This suggests that respondents who agree that their household/community's current wastewater collection and disposal methods are sufficient and appropriate also agree that adequate wastewater treatment occurs before final disposal in their area. There is a moderate negative correlation between "Collection Methods" and "Health Issues" (r = -0.298, p < 0.01). This indicates that respondents who agree that their household/community's current wastewater collection and disposal methods are sufficient and appropriate tend to disagree that improper wastewater disposal causes public and environmental health issues in their community. There is a moderate negative correlation between "Treatment" and "Health Issues" (r = -0.316, p < 0.01). This suggests that respondents who agree that adequate wastewater treatment occurs before final disposal in their area tend to disagree that improper wastewater disposal causes public and environmental health issues in their community.

There is a weak positive correlation between "Funding Infrastructure" and "Health Issues" (r = 0.273, p < 0.05). This indicates that respondents who agree that lack of funding, infrastructure, and capabilities pose significant challenges for wastewater management tend to agree that improper wastewater disposal causes public and environmental health issues in their community. There is a moderate positive correlation between "Funding Infrastructure" and "Expanded Infrastructure" (r = 0.341, p < 0.01). This suggests that respondents who agree that lack of funding, infrastructure, and capabilities pose significant challenges for wastewater management also tend to agree that expanded infrastructure and facilities are urgently required for appropriate wastewater management. There is a moderate positive correlation between "Health Issues" and "Expanded Infrastructure" (r = 0.314, p < 0.01). This indicates that respondents who agree that improper wastewater disposal causes public and environmental health issues in their community also tend to agree that expanded infrastructure and facilities are urgently required for appropriate wastewater management.

Table 3 reveals a weak negative correlation between "Effectiveness" and "Infrastructure Gap" (r = -0.256, p < 0.05). This suggests that as the perception of the effectiveness of Port Harcourt's current wastewater management systems and practices increases, the agreement that major infrastructure and technology gaps undermine Port Harcourt's wastewater treatment capabilities tends to decrease slightly. There is a moderate positive correlation between "Effectiveness" and "Enforcement" (r = 0.312, p < 0.01). This indicates that as the perception of the effectiveness of Port Harcourt's current wastewater management systems and practices increases, the agreement that strong enforcement and oversight occur for wastewater standards and facility compliance also tends to increase.

There is a weak negative correlation between "Effectiveness" and "Monitoring Need" (r = -0.287, p < 0.05). This suggests that as the perception of the effectiveness of Port Harcourt's current wastewater management systems and practices increases, the perceived need to improve monitoring and enforcement for wastewater compliance tends to decrease slightly. There is a weak negative correlation between "Enforcement" and "Monitoring Need" (r = -0.222, p < 0.05). This indicates that as the agreement that strong enforcement and oversight occur for wastewater standards and facility compliance increases, the perceived need to improve monitoring and enforcement for wastewater compliance tends to decrease slightly. There are no significant correlations between "Upgrading Priority" and any other variables at the 0.05 level (2-tailed). There are also no significant correlations between "Infrastructure Gap" and "Enforcement" or "Monitoring Need" at the 0.05 level (2-tailed).

Table 4 shows a weak negative correlation between "Sustainability Issues" and "Sustainability Assessment" (r = -0.278, p < 0.05). This suggests that as the agreement that current wastewater handling causes severe sustainability issues in Port Harcourt increases, the assessment of the sustainability of existing wastewater systems and practices tends to decrease slightly. There is a moderate positive correlation between "Sustainability Assessment" and "Sustainability Principles" (r = 0.311, p < 0.01). This indicates that as the assessment of the sustainability of existing wastewater systems and practices increases, the agreement that sustainability principles are adequately incorporated into wastewater planning and operations also tends to increase.

There is a weak negative correlation between "Sustainability Assessment" and "Social and cultural Barriers" (r = -0.225, p < 0.05). This suggests that as the assessment of the sustainability of existing wastewater systems and practices increases, the agreement that social and cultural barriers inhibit transitions to sustainable wastewater management tends to decrease slightly. There is a weak negative correlation between "Sustainability Principles" and "Social & Cultural Barriers" (r = -0.267, p < 0.05). This indicates that as the agreement that sustainability principles are adequately incorporated into wastewater planning and operations increases, the agreement that social and cultural barriers inhibit transitions to sustainable wastewater management tends to decrease slightly. No significant correlations exist between "Government Responsibility" and any other variables at the 0.05 level (2-tailed). There are also no significant correlations between "Sustainability Issues" and "Sustainability Principles," "Social and cultural Barriers," or "Government Responsibility" at the 0.05 level (2-tailed).

There is a strong positive correlation between "Sustainability Integration" and "Innovative Solutions" (r = 0.521, p < 0.01). This suggests that as the agreement that sustainability principles need to be integrated into all aspects of wastewater management increases, the agreement that innovative and sustainable wastewater treatment solutions should be prioritized over conventional approaches also tends to increase. There is a moderate positive correlation between "Sustainability Integration" and "Decentralized Methods" (r = 0.458, p < 0.01). This indicates that as the agreement that sustainability principles need to be integrated into all aspects of wastewater management increases, the support for implementing decentralized, ecological wastewater treatment methods also tends to increase.

There is a moderate positive correlation between "Sustainability Integration" and "Policy Gaps" (r = 0.372, p < 0.01). This suggests that as the agreement that sustainability principles need to be integrated into all aspects of wastewater management increases, the recognition of the need for policies and planning for sustainability as a critical gap in wastewater management also tends to increase. There is a moderate positive correlation between "Sustainability Integration" and "Multi-stakeholder Collaboration" (r = 0.396, p < 0.01). This indicates that as the agreement that sustainability principles need to be integrated into all aspects of wastewater management increases, the recognition of the importance of multi-stakeholder collaboration for transitions to sustainable wastewater systems also tends to increase. There are significant positive correlations between all other pairs of variables at the 0.01 level (2-tailed), except for the correlation between "Policy Gaps" and "Multi-stakeholder Collaboration," which is significant at the 0.05 level (2-tailed). The correlations range from weak to moderate in strength, suggesting interrelationships between the various aspects of improving wastewater management systems and practices to integrate sustainability principles in Port Harcourt.

# 3.2 Discussion

The findings of this study provide valuable insights into the current practices, challenges, effectiveness, sustainability concerns, and potential improvements related to wastewater management in Port Harcourt, Nigeria. The study respondents are predominantly government officials and expe0072ts, with a smaller representation of community residents. Most participants are male young adults (18-30 years old) and have attained a university degree. Most participants have 1-5 years of experience in wastewater management.

Research Question 1 focused on the current practices and challenges for wastewater management in Port Harcourt. The correlation analysis revealed significant associations between the sufficiency of collection methods, adequacy of treatment, infrastructure challenges, health issues, and the need for expanded infrastructure. These findings align with previous studies highlighting wastewater infrastructure inadequacies and the resulting environmental and public health impacts in Port Harcourt (Omoyajowo et al., 2024; Nwinyi; Omenihu et al., 2020). The strong positive correlation between collection methods and treatment suggests that improving the coverage and efficiency of wastewater collection systems could have cascading benefits for treatment processes. The negative correlations between collection methods/treatment and health issues underscore the critical role of effective wastewater management in mitigating public health risks, as emphasized in the literature (Haidri et al., 2024; Cossu et al., 2024).

Research Question 2 examined the effectiveness of current wastewater management systems and infrastructure in Port Harcourt. The correlation analysis indicated significant associations between the perceived effectiveness, infrastructure gaps, enforcement, and monitoring needs. The negative correlation between effectiveness and infrastructure gaps aligns with previous studies that have identified the lack of adequate treatment facilities and technology as a significant constraint to effective wastewater management in Port Harcourt (Ikiriko et al., 2024; Ewim et al., 2023; Akpan et al., 2020). The positive correlation between effectiveness and enforcement suggests that strengthening regulatory oversight and compliance mechanisms could enhance the performance of wastewater systems, as noted in the literature (Mokhtar et al., 2024; Maskun et al., 2024; Navarro and Burlani, 2021). The negative correlation between effectiveness and monitoring needs highlights the importance of robust monitoring and evaluation frameworks for ensuring the sustained functionality of wastewater infrastructure.

Research Question 3 investigated the critical sustainability issues and concerns related to wastewater management in Port Harcourt. The correlation analysis revealed significant associations between sustainability issues, assessments, principles, and barriers. The negative correlation between sustainability issues and sustainability assessment suggests that the severe sustainability challenges posed by current wastewater handling practices are recognized by stakeholders, aligning with the environmental, social, and economic concerns highlighted in the literature (Cossio et al., 2020; Omoyajowo et al., 2024). The positive correlation between sustainability assessment and sustainability principles indicates that stakeholders who perceive existing wastewater systems as more sustainable also tend to agree that sustainability principles are adequately incorporated into planning and operations. This finding underscores the importance of mainstreaming sustainability considerations into wastewater management, as the literature emphasizes (Shanmugam et al., 2022; Pan et al., 2018). As noted in previous studies, the negative correlations between sustainability assessment/principles and social and cultural barriers suggest that addressing these contextual factors is crucial for enabling transitions to more sustainable wastewater practices (Bhatnagar et al., 2024; Tarpani and Azapagic, 2023).

Research Question 4 explored how wastewater management systems and practices can be improved to integrate sustainability principles in Port Harcourt. The correlation analysis revealed significant positive associations between the recognition of the need for sustainability integration, the prioritization of innovative solutions, the support for decentralized methods, the identification of policy gaps, and the importance of multi-stakeholder collaboration. These findings align with the growing body of literature that advocates for a paradigm shift towards more integrated, ecologically sound, and participatory approaches to wastewater management (Katre and Tozzi, 2018; Huang et al., 2023). The strong correlations between sustainability integration and innovative solutions/decentralized methods suggest that stakeholders recognize the potential of alternative technologies and approaches to address the limitations of conventional, centralized wastewater systems. The moderate correlations between sustainability integration and policy gaps/multi-stakeholder collaboration highlight the critical role of enabling institutional frameworks and collaborative governance in driving sustainable wastewater transitions, as These correlations provide insights into the relationships between strategies and approaches for improving wastewater management and integrating sustainability principles in Port Harcourt. The results suggest significant positive associations exist between the recognition of the need for sustainability integration, the prioritization of innovative solutions, the support for decentralized methods, the identification of policy gaps, and the importance of multi-stakeholder collaboration.ile the findings of this study provide valuable insights into the current state and potential improvements of wastewater management in Port Harcourt, it is essential to examine the challenges and limitations associated with the research critically. One key challenge is the study participants' limited sample size and representativeness. Although the total sample of 80 respondents included government officials/experts and community residents, the majority (82.5%) belonged to the former group. This imbalance may have skewed the results towards the perspectives and experiences of stakeholders with more technical knowledge and decision-making power, potentially overlooking the diverse viewpoints and concerns of ordinary citizens affected by wastewater issues. Future studies could aim to recruit a more balanced and inclusive sample with a more excellent representation of marginalised communities and vulnerable populations (Collins et al., 2018).

Another limitation is the reliance on self-reported data through the online survey questionnaire. While this method allowed for efficient data collection, it may have introduced biases and inaccuracies due to participants' subjective perceptions, social desirability, or lack of detailed knowledge about certain aspects of wastewater management (Snelling et al., 2024). The closed-ended Likert scale questions also constrained the depth of responses, potentially oversimplifying complex issues and relationships. Future research could employ mixed methods, combining surveys with qualitative interviews, focus groups, and observational data to triangulate findings and gain richer insights into stakeholders' experiences and perspectives (Gibson, 2017).

The correlational design of the study also limits the ability to infer causal relationships between the variables examined. While the results revealed significant associations between various aspects of wastewater management and sustainability, the direction and mechanisms of influence cannot be conclusively determined (Nnadozie et al., 2017). For example, the negative correlation between sustainability issues and sustainability assessment could suggest that recognizing severe sustainability challenges leads to lower assessments of existing wastewater systems or, conversely, that stakeholders who perceive current systems as less sustainable are more likely to identify sustainability issues. Future studies could employ longitudinal or experimental designs to establish better sustainable wastewater transitions' causal linkages and temporal dynamics (Schuwirth et al., 2019).

The study's focus on Port Harcourt as a single case study also raises questions about the generalizability of the findings to other contexts. While the challenges and opportunities identified in Port Harcourt may resonate with the experiences of other rapidly urbanizing cities in Nigeria and the Global South, the specific socio-cultural, political, economic, and environmental factors shaping wastewater management may vary significantly across different localities (Katre and Tozzi, 2018; Huang et al., 2023). Comparative studies examining sustainable wastewater transitions in multiple cities or regions could help to identify common patterns and context-specific variations, enabling more robust and transferable findings (Ache, 2019).

Finally, while necessary for understanding sustainable wastewater management's social and institutional dimensions, the study's emphasis on stakeholder perceptions and attitudes may have overlooked the technical complexities and material constraints involved in implementing sustainability principles in practice (Larsen et al., 2016). Future research could delve deeper into the specific technological, infrastructural, and operational challenges and innovations associated with decentralized, ecological, and resource-oriented wastewater systems in the Port Harcourt context (Paes et al., 2024).

Despite these challenges and limitations, this study contributes to the growing research on sustainable wastewater management in developing urban contexts. By providing empirical evidence on the current practices, challenges, effectiveness, sustainability concerns, and potential improvements in Port Harcourt, the study highlights the urgent need for more integrated, participatory, and sustainability-oriented approaches to wastewater governance and infrastructure development. The findings can inform policy discussions, stakeholder collaborations, and future research efforts to advance sustainable wastewater transitions in Port Harcourt and beyond.

**CONCLUSION**

This study investigated the challenges and opportunities for sustainable wastewater management in Port Harcourt, Nigeria, through a quantitative survey of government officials, experts, and community residents. Findings revealed significant associations between wastewater management practices and sustainability, highlighting multi-dimensional issues such as inadequate collection methods, treatment, and infrastructure gaps. The results emphasize the need for improved enforcement, stakeholder collaboration, and the integration of sustainability principles to address public health risks and environmental concerns. By applying a sustainability lens and employing quantitative methods, this research contributes to the understanding of sustainable wastewater management in rapidly urbanizing cities in the Global South. The study underscores the importance of a comprehensive, participatory approach to address the technical, environmental, social, economic, and governance dimensions of wastewater systems.

**Ethical Approval:**

The research design and procedures were reviewed and approved by the relevant institutional ethics committees before data collection commenced.

**Consent:**

Written informed consent was obtained from all participants before their involvement in the study

**Disclaimer (Artificial intelligence)**

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript**.**

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