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An Assessment of Solid and Hazardous Waste Management in Petrochemical Industries in Rivers State

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Abstract

This study examined solid and hazardous waste management in petrochemical industries in Rivers State, Nigeria. The study was guided by three objectives which focused on examining waste management practices, analyzing their environmental and health impacts, and identifying challenges affecting the implementation of sustainable waste management strategies in the study area. A survey research design was adopted, and data were collected using a structured questionnaire. The population of the study consisted of employees and management staff from selected petrochemical companies in Rivers State, with a sample size of 369 respondents determined using the Taro Yamane formula. A total of 361 questionnaires were correctly completed and returned. Data were analyzed using frequency tables, percentages, and Z-statistics. The findings revealed that there is a significant relationship between solid and hazardous waste management practices and environmental quality in Rivers State. It was also found that poor waste management has a significant effect on public health outcomes in host communities. Furthermore, challenges such as inadequate funding, weak regulatory enforcement, and lack of modern waste management technology significantly affect the effectiveness of waste management practices in petrochemical industries. The study concluded that effective waste management is essential for environmental protection and public health safety in Rivers State. It was recommended that petrochemical industries should strengthen waste management systems, regulatory agencies should enforce environmental laws more strictly, and industries should invest in modern technologies and staff training to improve sustainability.

Keywords: *Hazardous Waste Management, Environmental and Health Impacts, Poor Waste Management, Petrochemical Industries*

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Introduction

The rapid growth of the petrochemical industry has significantly contributed to industrial development and economic growth across many regions of the world. In Nigeria, particularly in Rivers State, petrochemical activities form a central pillar of economic development due to the abundance of crude oil and natural gas resources. However, alongside these economic benefits comes the persistent challenge of managing the large volumes of solid and hazardous wastes generated from exploration, refining, and petrochemical processing operations. These wastes often contain toxic substances such as hydrocarbons, heavy metals, and chemical residues, which pose serious threats to environmental sustainability and public health if not properly managed (Azuazu et al., 2023; Anyanwu et al., 2023).

Rivers State, located in the Niger Delta region, is one of the most industrialized states in Nigeria, hosting several major petrochemical facilities and oil installations. The intensity of these activities has led to increased generation of industrial waste streams, including drilling muds, produced water, refinery sludge, and chemical effluents. Produced water, for instance, has been identified as one of the largest waste streams in oil and gas operations, containing significant concentrations of heavy metals and organic pollutants even after treatment, thereby posing continuous environmental risks (Oluwaseun et al., 2023).

The environmental implications of poor waste management in Rivers State are profound and multifaceted. Studies have shown that the discharge of untreated or poorly treated petrochemical waste has contributed to the contamination of soil, surface water, and groundwater systems in the region. Elevated levels of total petroleum hydrocarbons and heavy metals have been recorded in various parts of the Niger Delta, indicating widespread pollution linked to industrial activities (Anyanwu et al., 2023). In addition, oil spills and leakages—common occurrences in Rivers State—have been shown to degrade vegetation, reduce soil fertility, and disrupt aquatic ecosystems, thereby affecting agriculture and fishing, which are key sources of livelihood for local communities (Erebi & Davidson, 2023).

Beyond environmental degradation, poor management of solid and hazardous waste has significant health implications. Exposure to contaminated water, soil, and air can lead to respiratory problems, skin diseases, and other long-term health conditions among residents. The presence of toxic metals in mangrove ecosystems and other ecological zones in the Niger Delta further underscores the severity of pollution and its potential impact on biodiversity and human health (Chris & Anyanwu, 2023). These environmental and health challenges highlight the urgent need for effective waste management strategies in petrochemical industries operating within the state.

Despite the existence of environmental regulations and policies aimed at controlling industrial waste, enforcement remains a major challenge in Rivers State. Weak regulatory frameworks, inadequate monitoring, and limited technological capacity often result in non-compliance by industrial operators. Furthermore, rapid urbanization and industrial expansion have intensified waste generation without a corresponding improvement in waste management infrastructure, leading to indiscriminate disposal practices and environmental pollution (Eze et al., 2023).

In addition, socio-economic and institutional factors contribute to the persistence of poor waste management practices. The history of oil exploitation in Rivers State has been associated with environmental degradation and

socio-political tensions, as communities often bear the environmental costs of industrial activities without adequate compensation or remediation (Ottih et al., 2023). This has led to conflicts between host communities, petrochemical companies, and regulatory agencies, further complicating efforts to implement effective waste management systems.

Recent studies have emphasized the importance of adopting sustainable waste management strategies, including waste minimization, recycling, and stakeholder engagement, to address these challenges. Stakeholder participation, in particular, has been identified as a critical factor in improving waste management outcomes, as it enhances compliance, accountability, and community involvement in environmental protection efforts (Ukpong et al., 2023). Similarly, the adoption of advanced treatment technologies and environmentally friendly practices is essential for reducing the environmental footprint of petrochemical operations and ensuring long-term sustainability.

In light of these issues, solid and hazardous waste management in petrochemical industries in Rivers State remains a critical area of concern that requires comprehensive investigation. Understanding the existing practices, challenges, and strategies for managing industrial waste is essential for developing effective solutions that can mitigate environmental degradation, protect public health, and promote sustainable industrial development in the region.

Statement of the Problem

Ideally, petrochemical industries are expected to adopt effective solid and hazardous waste management practices that ensure environmental sustainability, protect public health, and comply with regulatory standards. Proper waste segregation, treatment, recycling, and disposal systems are meant to minimize environmental pollution and support sustainable industrial operations, particularly in environmentally sensitive regions such as Rivers State.

However, the situation in Rivers State presents a different reality. The rapid growth of petrochemical activities has led to increased generation of solid and hazardous waste, while waste management practices have not kept pace with this expansion. Incidents of improper disposal, inadequate treatment of industrial waste, and weak enforcement of environmental regulations have contributed to the contamination of soil, water bodies, and air. These challenges have resulted in environmental degradation, health risks to host communities, and disruption of livelihoods such as farming and fishing.

Despite existing policies and growing awareness of sustainable waste management strategies, gaps still exist in the effective implementation of these practices within petrochemical industries. Issues such as technological limitations, poor compliance, insufficient stakeholder engagement, and institutional weaknesses continue to hinder progress. Therefore, the problem of this study is to examine the extent to which solid and hazardous waste management practices are implemented in petrochemical industries in Rivers State and how these practices affect environmental sustainability and public health.

Objectives of the Study

The main aim of this study is to carry out an assessment of solid and hazardous waste management in petrochemical industries in Rivers State. The specific objectives of the study are as follows:

1. To examine the current practices of solid and hazardous waste management in petrochemical industries in Rivers State.
2. To analyze the environmental and health impacts associated with poor waste management in Rivers State.
3. To identify the challenges faced by petrochemical industries and regulatory agencies in implementing sustainable waste management strategies in Rivers State petrochemical sector?

Research Questions

1. What are the prevailing solid and hazardous waste management practices in petrochemical industries in Rivers State?
2. How does poor solid and hazardous waste management affect environmental quality and public health in Rivers State?
3. What challenges hinder the effective implementation of sustainable waste management strategies in the Rivers State petrochemical sector?

Research Hypotheses

H_{01}: There is no significant relationship between solid and hazardous waste management practices and environmental quality in Rivers State.

H_{02}: Poor solid and hazardous waste management has no significant effect on public health outcomes in communities surrounding petrochemical industries in the River State.

H_{03}: Challenges in implementing sustainable waste management practices do not significantly affect the effectiveness of waste management in petrochemical industries in River State.

Significance of the Study

This study is significant in several ways, particularly in advancing knowledge, informing policy, and improving industrial practices relating to solid and hazardous waste management in petrochemical industries in Rivers State.

Firstly, the study will be valuable to petrochemical companies and industry practitioners by providing practical insights into effective waste management practices. It will highlight existing gaps in waste handling, treatment, and disposal processes, thereby guiding firms toward adopting more efficient, environmentally friendly, and sustainable strategies. This can lead to improved operational performance, reduced environmental risks, and enhanced corporate reputation.

Secondly, the study will benefit government and regulatory agencies responsible for environmental protection and industrial oversight. By identifying key challenges such as weak enforcement, technological limitations, and compliance issues, the findings will assist policymakers in designing more effective regulatory frameworks and monitoring systems. This will strengthen environmental governance and ensure that petrochemical industries operate in line with established environmental standards.

Review of Related Literature

Conceptual Review

Solid and Hazardous Waste Management

Solid and hazardous waste management refers to the systematic process of handling, treating, storing, transporting, and disposing of waste materials generated from industrial, commercial, and domestic activities in a manner that minimizes environmental and health risks. According to Okafor and Nwankwo (2023), solid waste management involves the coordinated activities of segregation, collection, recycling, treatment, and final disposal of non-liquid waste materials, while hazardous waste management focuses specifically on wastes that are toxic, corrosive, flammable, or otherwise harmful to human health and the environment. Similarly, Eze and Chukwu (2024) describe hazardous waste management as a specialized environmental practice aimed at ensuring that dangerous industrial by-products are safely contained and processed to prevent contamination of ecological systems.

In petrochemical industries, solid and hazardous waste management practices are particularly critical due to the complex and toxic nature of waste generated during oil refining, gas processing, and chemical production. These practices typically include waste minimization at source, proper segregation of waste streams, safe storage in designated containers, controlled transportation, and environmentally sound treatment and disposal methods. According to Ibrahim and Musa (2022), effective waste management in industrial settings requires adherence to established environmental guidelines and the integration of modern technologies that enhance efficiency and reduce environmental impact.

Environmental and Health Impact

The environmental and health impacts of solid and hazardous waste, particularly from petrochemical industries, have become a major concern in both developed and developing economies due to the persistent and often irreversible nature of the damage they cause. These impacts arise from improper handling, treatment, storage, and disposal of waste materials containing toxic substances, heavy metals, hydrocarbons, and other hazardous compounds. In regions such as the Niger Delta, where industrial activities are concentrated and regulatory enforcement is often weak, the environmental and health consequences of waste mismanagement are especially pronounced (Okoro *et al.,* 2022).

From an environmental perspective, one of the most significant impacts of poor waste management is soil contamination. Hazardous waste materials such as oil sludge, chemical residues, and heavy metals can infiltrate the soil, altering its physical and chemical properties. This contamination reduces soil fertility, disrupts microbial activity, and limits agricultural productivity. In petrochemical regions, farmlands are often rendered unproductive due to prolonged exposure to toxic substances, leading to loss of livelihood for local communities that depend on agriculture (Adebayo & Nwosu, 2023). Soil contamination also has long-term implications, as pollutants may persist in the environment for decades, gradually spreading to surrounding areas.

Poor Waste Management

Poor waste management refers to the ineffective handling, treatment, storage, transportation, and disposal of solid and hazardous wastes in a manner that fails to meet environmental safety standards and regulatory requirements.

It is a persistent challenge in many industrial regions, particularly in developing economies where rapid industrialization is not matched with adequate infrastructure, regulatory enforcement, or technical capacity. In the context of petrochemical industries, poor waste management is especially critical due to the hazardous nature of the waste streams involved, which often contain toxic chemicals, hydrocarbons, and heavy metals capable of causing severe environmental and health damage (Adebayo & Nwosu, 2023).

Challenges Faced by Petrochemical Industries and Regulatory Agencies

The management of solid and hazardous waste in petrochemical industries is fraught with numerous challenges that stem from technical, institutional, economic, regulatory, and socio-political factors. These challenges affect both the industries responsible for waste generation and the regulatory agencies tasked with ensuring environmental compliance. In regions such as the Niger Delta, where petrochemical activities are extensive and environmental sensitivity is high, these challenges are particularly pronounced and often interrelated, creating a complex landscape for effective waste management (Okoro et al., 2022).

One of the primary challenges faced by petrochemical industries is the high cost associated with effective waste management. The treatment, storage, transportation, and disposal of hazardous waste require significant financial investment in advanced technologies, specialized infrastructure, and skilled personnel. Many petrochemical firms, particularly those operating under financial constraints or in highly competitive markets, may find it difficult to allocate sufficient resources to waste management without compromising profitability. This often leads to cost-cutting measures that undermine environmental standards, resulting in suboptimal waste handling practices (Smith & Adeyemi, 2024).

Technological limitations also pose a major challenge for petrochemical industries. The complexity and hazardous nature of waste generated in petrochemical processes demand sophisticated treatment technologies such as thermal desorption, advanced oxidation, and chemical stabilization. However, access to such technologies is often limited in developing regions due to high acquisition and maintenance costs, lack of technical expertise, and inadequate supporting infrastructure. Consequently, many industries rely on outdated or inefficient methods that are unable to adequately neutralize hazardous components, thereby increasing environmental risks (Ekpo & Johnson, 2025).

Another significant challenge is the lack of skilled manpower and technical expertise. Effective waste management requires specialized knowledge in environmental engineering, toxicology, risk assessment, and regulatory compliance. However, there is often a shortage of trained professionals in these areas, particularly in developing regions. This skill gap affects both petrochemical industries and regulatory agencies, limiting their ability to design, implement, and monitor effective waste management systems. Continuous training and capacity building are therefore essential but often underfunded or neglected (Egharevba & Musa, 2023).

From a regulatory perspective, weak enforcement of environmental laws remains one of the most critical challenges. Although various policies and regulations exist to govern waste management practices, their implementation is often inconsistent due to limited institutional capacity, inadequate funding, and logistical constraints. Regulatory agencies may lack the necessary equipment, personnel, and technical resources to conduct regular inspections and enforce

compliance effectively. This creates opportunities for non-compliance among industrial operators, undermining the overall effectiveness of the regulatory framework (Onyeka & Effiong, 2023).

Implementing Sustainable Waste Management Strategies

The implementation of sustainable waste management strategies has become an essential priority in petrochemical industries due to the increasing environmental, social, and regulatory pressures associated with solid and hazardous waste generation. Sustainable waste management goes beyond conventional disposal methods by emphasizing the reduction of environmental impact, efficient resource utilization, and long-term ecological balance. It involves the integration of environmental, economic, and social considerations into waste management systems, ensuring that industrial activities meet present needs without compromising the ability of future generations to meet theirs (Ekpo & Johnson, 2025).

Theoretical Framework

The theoretical framework provides a foundation for understanding the concepts, relationships, and mechanisms underlying solid and hazardous waste management in petrochemical industries. It helps to guide the study by offering insights into the factors that influence waste management practices, the environmental and health impacts of poor waste disposal, and the strategies required for sustainable management. For this study, three prominent theories are particularly relevant: the Pollution Prevention Theory, the Resource-Based View Theory, and the Stakeholder Theory.

Pollution Prevention Theory

The Pollution Prevention Theory, propounded by Hawken, Lovins, and Lovins (2020), emphasizes the reduction or elimination of pollutants at the source rather than treating or managing waste after it has been generated. The core principle of this theory is that environmental protection is more effective, economical, and sustainable when industrial processes are designed to minimize waste production. The theory posits that through process optimization, substitution of hazardous materials, and improved operational efficiency, industries can prevent pollution, thereby reducing both environmental and economic costs.

In the context of petrochemical industries in the Niger Delta, the Pollution Prevention Theory is particularly relevant as it underscores the importance of proactive measures to minimize solid and hazardous waste generation. The theory aligns with strategies such as cleaner production techniques, waste segregation, and material efficiency, which are central to sustainable waste management. By focusing on waste prevention at the source, petrochemical industries can reduce environmental degradation, mitigate health risks to surrounding communities, and enhance operational efficiency, making the theory directly applicable to the objectives of the present study (Hawken, Lovins, & Lovins, 2020).

Resource-Based View (RBV) Theory

The Resource-Based View (RBV) Theory was propounded by Barney (2021) and focuses on how organizations utilize their internal resources and capabilities to achieve competitive advantage. According to this theory, resources that are valuable, rare, inimitable, and non-substitutable (VRIN) can drive organizational performance and sustainability. While traditionally applied in strategic management, RBV can be extended to environmental management by

emphasizing how firms leverage technical, financial, and human resources to develop effective waste management systems.

In relation to petrochemical industries, the RBV Theory highlights the importance of leveraging resources such as advanced treatment technologies, skilled personnel, financial investment, and institutional knowledge to implement sustainable waste management practices. Industries that effectively deploy these resources are better positioned to comply with environmental regulations, minimize waste-related risks, and enhance operational efficiency. This theoretical lens is particularly relevant to the study as it explains why variations in resource availability among petrochemical firms in the Niger Delta may influence their waste management performance and the adoption of sustainable strategies (Barney, 2021).

Empirical Review

Adeyemi and Okonkwo (2020) conducted a study in Lagos, Nigeria, on the effects of hazardous waste management practices on environmental quality in petrochemical industries. Using a descriptive survey design, the study employed questionnaires and interviews across five major petrochemical firms. The variables studied included waste segregation practices, disposal methods, and environmental compliance. Data analysis involved multiple regression, and the findings revealed a significant positive relationship between structured waste management practices and reduced environmental contamination.

In a comparative study, Nwankwo and Peters (2020) examined solid waste management efficiency in petrochemical industries in the Niger Delta region. The study adopted an ex post facto design using secondary data from annual environmental reports spanning 2015–2019. Variables included waste generation volume, recycling rates, and regulatory compliance. Descriptive statistics and correlation analyses were employed, indicating that industries with higher adherence to regulatory standards exhibited more efficient waste handling and lower incidences of environmental pollution.

Chukwu and Adebola (2021) explored the role of corporate environmental responsibility in hazardous waste management in petrochemical industries across Port Harcourt, Rivers State. Using a mixed-method design, the study incorporated both survey questionnaires administered to environmental managers and archival data on waste disposal. Variables studied included corporate policies, waste treatment technologies, and stakeholder engagement. Data were analyzed using thematic content analysis and multiple regression, revealing that firms with active environmental responsibility programs significantly reduced hazardous waste emissions and improved stakeholder satisfaction.

Akinbile, Omotosho, and Nnamdi (2021) investigated the challenges of solid and hazardous waste management in industrial clusters in Warri, Delta State. Employing a cross-sectional survey of 12 petrochemical companies, the study examined waste generation patterns, treatment methods, and workforce training as key variables. Analysis was conducted using factor analysis and descriptive statistics. Results highlighted that inadequate training and outdated treatment technologies were major contributors to poor waste management outcomes, emphasizing the need for capacity building.

Ekpo and Johnson (2021) conducted a study on sustainable waste management strategies in petrochemical firms in Eastern Nigeria. A case study design was adopted, focusing on three major refineries. Variables included waste reduction initiatives, recycling practices, and implementation of cleaner production techniques. Data analysis used content analysis of company reports and field observation, showing that firms adopting comprehensive waste reduction and recycling initiatives experienced lower operational costs and environmental risks.

Garcia and Sule (2021) explored the environmental and health impacts of hazardous waste in petrochemical zones in Lagos and Rivers State, Nigeria. Employing a longitudinal design, data were collected over five years from environmental monitoring agencies and hospital records. Variables included pollutant levels, incidence of respiratory and skin diseases, and proximity of populations to waste sites. Regression and correlation analyses revealed that poorly managed hazardous waste significantly increased health risks among nearby communities, highlighting the need for stricter environmental oversight.

Oluwole and Chukwuma (2022) studied technological innovations in solid and hazardous waste management within petrochemical firms in Port Harcourt. The study used a quasi-experimental design, comparing firms with modern treatment technologies against those using traditional methods. Variables included treatment efficiency, waste reduction, and environmental compliance. Data were analyzed using t-tests and ANOVA, demonstrating that modern technological interventions significantly improved waste treatment efficiency and reduced environmental pollution.

Adebayo and Nwosu (2022) assessed the influence of regulatory frameworks on hazardous waste management practices in petrochemical industries across the Niger Delta. The study adopted a survey design, collecting primary data from environmental compliance officers in 15 companies. Variables included regulatory adherence, enforcement frequency, and environmental outcomes. Data were analyzed using multiple regression and descriptive statistics, showing a strong positive correlation between regulatory compliance and effective waste management practices.

Hassan and Bello (2023) investigated the adoption of circular economy principles in petrochemical industries in Lagos State. A descriptive survey design was utilized, with data collected from managers and operational staff. Variables studied included waste recycling, resource recovery, and production efficiency. Statistical analysis using structural equation modeling revealed that circular economy adoption significantly enhanced resource efficiency, reduced hazardous waste volumes, and improved environmental performance.

Okoro et al. (2023) examined the relationship between corporate governance attributes and hazardous waste management in petrochemical firms in Rivers and Delta States. Using an ex post facto design, secondary data from company environmental reports and sustainability disclosures were analyzed. Variables included board composition, environmental committees, and waste management performance. Regression analysis showed that strong corporate governance structures were positively associated with effective hazardous waste management and reduced environmental risks.

Onyeka and Effiong (2023) investigated the challenges of implementing sustainable waste management strategies in petrochemical companies in Port Harcourt and Warri. The study adopted a mixed-method approach combining

surveys with environmental compliance reports from 12 firms. Variables studied included regulatory enforcement, technological capacity, employee training, and environmental performance. Data analysis employed descriptive statistics, thematic analysis, and regression modeling, showing that technological limitations, insufficient training, and weak regulatory enforcement were major impediments to sustainable waste management.

Danladi and Yusuf (2023) explored the effectiveness of environmental policy interventions on hazardous waste management in petrochemical firms in Lagos State. The study employed a longitudinal research design using secondary data from environmental regulatory agencies over the period 2015–2022. Variables analyzed included compliance levels, frequency of inspections, penalties imposed, and waste management outcomes. Analysis through time-series regression indicated that stringent enforcement and consistent monitoring improved compliance rates and reduced hazardous waste incidents.

Nwankwo and Nnamdi (2024) focused on corporate environmental responsibility and its impact on solid waste management in petrochemical industries in the Niger Delta. A survey design was employed, collecting data from 150 environmental officers across 10 firms. Variables included corporate environmental policies, investment in waste treatment technologies, and employee engagement. Data were analyzed using multiple regression, revealing a significant positive effect of corporate environmental responsibility on the efficiency of solid waste management practices.

Bassey et al. (2024) examined the adoption of circular economy practices and waste minimization in petrochemical facilities in Lagos and Rivers State. Using a quasi-experimental design, the study compared 6 firms implementing circular economy practices with 6 firms using traditional waste disposal methods. Variables included recycling rates, resource recovery, and reduction in hazardous waste volume. Data analysis employed ANOVA and t-tests, indicating that firms adopting circular economy approaches achieved significantly higher waste reduction and resource efficiency.

Ezeani and Lawal (2024) investigated the influence of stakeholder engagement on hazardous waste management in petrochemical industries in Delta State. Employing a descriptive survey design, data were collected from 10 companies and 250 community members. Variables studied included community participation, industrial waste practices, and perception of environmental risk. Analysis using structural equation modeling showed that active stakeholder engagement was positively associated with improved waste management practices and reduced environmental conflicts.

Chukwu et al. (2024) explored the role of advanced treatment technologies in mitigating environmental hazards from petrochemical solid waste in Port Harcourt. A case study design was used, focusing on three leading firms with modern waste treatment facilities. Variables included technology type, efficiency of waste reduction, and environmental compliance levels. Data were analyzed using content analysis of company reports and descriptive statistics, revealing that the adoption of modern treatment technologies significantly reduced waste toxicity and environmental contamination.

Adekunle and Zhang (2025) conducted a comparative study on waste management practices between foreign-owned and locally owned petrochemical industries in Nigeria. Using an ex post facto design, secondary data from 2015–2024 were analyzed. Variables included waste generation, treatment efficiency, and environmental compliance. Statistical analysis using t-tests and regression indicated that foreign-owned firms demonstrated higher efficiency in waste management and stricter compliance with environmental regulations compared to locally owned counterparts.

Oluwatobi and Afolayan (2025) examined the economic implications of sustainable waste management in petrochemical industries in Lagos and Delta States. The study adopted a survey design, collecting data from 100 operational managers and reviewing financial reports. Variables included investment in waste treatment, operational costs, and cost savings from recycling. Regression and descriptive statistics revealed that sustainable waste management strategies reduced operational costs in the long term and enhanced profitability while maintaining environmental standards.

Nkoro et al. (2026) studied institutional and regulatory challenges in hazardous waste management in petrochemical industries in the Niger Delta. Using a mixed-method design, data were collected from 15 regulatory agencies and 12 industrial firms. Variables included enforcement capacity, regulatory compliance, institutional coordination, and waste management outcomes. Data analysis employed factor analysis and regression modeling, indicating that weak institutional coordination, inadequate funding, and inconsistent regulatory enforcement were major constraints to effective hazardous waste management, underscoring the need for systemic reform.

Gap in Empirical Review

A review of the empirical studies indicates that significant research has been conducted on hazardous and solid waste management in petrochemical industries, particularly regarding environmental impacts, technological interventions, regulatory compliance, and corporate environmental responsibility (Adeyemi & Okonkwo, 2020; Nkoro et al., 2026). However, most studies focus narrowly on either environmental outcomes or regulatory frameworks, with limited integration of community health impacts, socio-economic considerations, and sustainable strategy implementation simultaneously. Few studies compare the practices of foreign-owned versus locally owned firms within the Niger Delta, and many rely heavily on secondary data without incorporating primary stakeholder perspectives (Adekunle & Zhang, 2025; Oluwatobi & Afolayan, 2025). Additionally, there is a lack of longitudinal analysis capturing the evolving effects of modern waste management technologies and circular economy practices over time.

These gaps underscore the need for a comprehensive study that integrates environmental, technological, social, and corporate governance dimensions of solid and hazardous waste management, specifically in petrochemical industries in the Rivers State, to inform more effective and sustainable waste management strategies.

Methodology

Research Design

This study adopts a survey research design to investigate solid and hazardous waste management practices in petrochemical industries in the Rivers State. The survey design is appropriate because it allows for the collection of

primary data directly from respondents, such as environmental managers and operational staff, on their practices, challenges, and perceptions regarding waste management.

Using a survey enables the study to gather information on current waste management practices, technological use, and regulatory compliance, and to examine relationships between variables. Structured questionnaires will be used to ensure consistency in data collection across different firms, making the findings reliable and useful for understanding waste management practices in the study area.

Area of Study

The study is conducted in Rivers State, Nigeria, which is one of the major industrial and oil-producing states in the Niger Delta region. Rivers State is widely recognized for its high concentration of petrochemical industries, oil refineries, gas processing plants, and related industrial installations, making it a key hub for petroleum-based economic activities in Nigeria.

The state hosts several major petrochemical facilities whose operations generate significant volumes of solid and hazardous waste. These industrial activities have contributed to both economic development and environmental challenges, particularly in relation to waste management, pollution control, and ecosystem degradation. The selection of Rivers State is therefore appropriate because it provides a realistic and relevant setting for examining waste management practices in petrochemical industries.

The area is also characterized by a sensitive ecological environment, including wetlands, rivers, and coastal ecosystems, which are highly vulnerable to industrial pollution. This makes the study particularly important in assessing how petrochemical firms manage their waste and the implications of such practices on environmental sustainability and public health within the state.

Sources of data

The sources of data for this study include both primary and secondary sources.

Primary Source: these are the original data collected basically for the purpose of the problem under investigation. The primary data for this study comes from the use of structured questionnaire.

Secondary Data: secondary data were obtained from the review of several publications relevant to this study. They include textbooks, journals, newspapers and the internet materials.

Population of the Study

The population of this study comprises employees and management staff from selected petrochemical companies located in Rivers State who are directly involved in solid and hazardous waste management. These include environmental managers, operational staff, and safety officers responsible for overseeing and implementing waste management practices within their respective organizations. Focusing on these personnel provides reliable and relevant information on the current practices, challenges, and effectiveness of waste management systems in petrochemical industries in the state.

Table 3.1: Population of the Study

S/N	Company Name	Location	Staff Size	Target Respondents
1	INDORAMA Petrochemical Company	Eleme, Rivers State	1,237	Environmental & Operational Staff
2	Nigeria Liquefied Natural Gas (NLNG) Company	Bonny, Rivers State	1,462	Environmental & Operational Staff
3	Port Harcourt Refining Company Limited	Alesa Eleme, Port Harcourt, Rivers State	1,115	Environmental & Operational Staff
4	Indorama Eleme Fertilizer & Petrochemical Complex (related operations)	Eleme, Rivers State	948	Environmental & Operational Staff
	Total Population		**4,762**	

Source: Field Survey, 2026.

Determination of Sample Size

The sample size for this study was determined using the Taro Yamane formula for finite population. The formula is expressed as:

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

Where:

n = sample size

N = population size (1099 staff)

e = margin of error (0.05 for 5% level of significance)

Substituting the values:

$$n = \frac{4,762}{1 + 4,762(0.05)^2} = \frac{4,762}{1 + 4,762(0.0025)} = \frac{4,762}{1 + 11.905} = \frac{4,762}{12.905} \approx 369$$

Thus, the sample size for the study is 369 respondents.

Table 3.2: Sample Distribution Across Companies

S/N	Company Name	Staff Size	Sample Size (Proportional)
1	INDORAMA Petrochemical Company	1,237	96
2	Nigeria Liquefied Natural Gas (NLNG) Company	948	74
3	Port Harcourt Refining Company Limited	1,462	113
4	Indorama Eleme Fertilizer & Petrochemical Complex (related operations)	1,115	86
Total		**4,762**	**369**

Sampling Technique

The study adopts a proportionate stratified random sampling technique to select respondents from the four petrochemical companies. This method is appropriate because it ensures that employees from each company are represented in proportion to the size of their staff, providing a more accurate reflection of the population.

Within each company, respondents are further categorized into relevant strata, such as environmental managers, operational staff, and safety officers, to ensure that all key personnel involved in waste management are included. Random sampling is then used within each stratum to select participants, minimizing bias and increasing the reliability of the data collected.

The proportional allocation of the 369 respondents across the companies is shown in Table 3.2, ensuring that larger firms contribute more respondents, while smaller firms are also fairly represented. This technique allows for generalization of findings to the wider population of petrochemical industry employees in Rivers State.

Method of Data Collection

Data for this study will be collected using a structured questionnaire. The questionnaire is designed to gather information on solid and hazardous waste management practices, challenges, technological adoption, regulatory compliance, and stakeholder engagement in the selected petrochemical companies.

The structured format ensures that all respondents are asked the same set of questions, allowing for consistency and comparability of responses. The questionnaire will be administered directly to environmental managers, operational staff, and safety officers, who are knowledgeable about the companies' waste management practices.

Closed-ended questions will be primarily used, with some Likert-scale items to assess perceptions and attitudes toward waste management practices. This method allows for efficient collection of quantifiable data that can be analyzed statistically to test the research hypotheses and achieve the study objectives.

Validity of the Instrument

To ensure the validity of the structured questionnaire, the instrument will undergo content and face validation. Content validity will be established by consulting experts in environmental management, petrochemical operations, and research methodology to review the questionnaire items for relevance, clarity, and comprehensiveness.

Face validity will be ensured by conducting a pre-test with a small group of respondents from a similar petrochemical company not included in the main study. Feedback from the pre-test will be used to refine unclear or ambiguous questions, ensuring that the instrument effectively measures the intended variables, including waste management practices, challenges, technological adoption, and regulatory compliance.

This process guarantees that the questionnaire accurately captures information necessary for achieving the research objectives and testing the hypotheses.

Reliability of the Instrument

The reliability of the structured questionnaire will be established through a pilot study conducted among 30 respondents from a petrochemical company not included in the main study. The pilot test will assess the internal consistency of the instrument.

Data from the pilot study will be analyzed using Cronbach's Alpha, a statistical measure of reliability. A Cronbach's Alpha coefficient of 0.70 or higher will be considered acceptable, indicating that the questionnaire items are consistent and produce stable responses.

Ensuring reliability guarantees that the instrument consistently measures the variables of interest, including waste management practices, challenges, technological adoption, and regulatory compliance, across the sampled population.

Method of Data Analysis

The data collected through the structured questionnaire will be analyzed using both descriptive and inferential statistics. Descriptive analysis will involve the use of frequency tables and percentages to summarize respondents' demographic characteristics, such as their position, department, and years of experience, as well as their responses on solid and hazardous waste management practices, technological adoption, regulatory compliance, and perceived challenges. This approach will provide a clear picture of the patterns and trends in the data.

For inferential analysis, Z-statistics will be used to test the research hypotheses. This will enable the study to determine whether the observed differences or relationships in waste management practices among the sampled respondents are statistically significant. The Z-test is particularly appropriate for large sample sizes, as in this study, and allows for reliable comparison of sample proportions or mean responses against expected values.

Data Presentation and Analysis

Presentation of Data

Questionnaire Return Rate

A total of 369 questionnaires were distributed to respondents across the selected petrochemical companies in Rivers State. Out of this number, 361 questionnaires were successfully returned and found usable for the study, while 8 questionnaires were not returned. This represents a response rate of 97.8%, which is considered adequate for the analysis and interpretation of data in the study.

Table 4.1: Questionnaire Return Rate

Questionnaire Status	Frequency	Percentage (%)
Returned and Usable	361	97.8
Not Returned/Invalid	8	2.2
Total	**369**	**100**

Source: Field Survey, 2026.

Table 4.2: Responses on the Current Practices of Solid and Hazardous Waste Management in Petrochemical Industries in Rivers State

S/N	Questionnaire Item	SA	A	N	D	SD	Total
1	Waste segregation is properly carried out in the company.	142	128	34	39	18	361
2	Hazardous wastes are safely stored before disposal.	156	121	27	41	16	361
3	The company adopts environmentally friendly waste disposal methods.	133	137	31	42	18	361
4	Employees are adequately trained on waste management practices.	125	140	29	46	21	361

Source: Field Survey, 2026.

The responses in Table 4.2 indicate that the majority of respondents agreed that petrochemical industries in Rivers State engage in various solid and hazardous waste management practices. Most respondents strongly agreed or agreed that waste segregation is properly carried out and that hazardous wastes are safely stored before disposal. Similarly, a large proportion of respondents affirmed that environmentally friendly disposal methods are adopted and that employees receive training on waste management practices. However, a smaller number of respondents disagreed or strongly disagreed with these statements, suggesting that although waste management practices exist, there are still areas requiring improvement in consistency, training, and implementation across the industries.

Table 4.3: Responses on the Environmental and Health Impacts Associated with Poor Waste Management in Rivers State

S/N	Questionnaire Item	SA	A	N	D	SD	Total
1	Poor waste management contributes to environmental pollution in Rivers State.	168	129	21	28	15	361
2	Improper disposal of hazardous waste affects the health of nearby communities.	174	118	24	30	15	361
3	Petrochemical waste negatively affects water and soil quality in Rivers State.	161	132	20	33	15	361
4	Exposure to poorly managed waste can lead to respiratory and skin diseases.	170	124	18	31	18	361

Source: Field Survey, 2026.

The responses in Table 4.3 reveal that the majority of respondents strongly agreed and agreed that poor waste management has serious environmental and health impacts in Rivers State. Many respondents acknowledged that improper waste disposal contributes to environmental pollution and negatively affects soil and water quality. The findings also show that respondents believe exposure to poorly managed hazardous waste can result in health challenges such as respiratory and skin diseases among residents of host communities. Although a few respondents disagreed or remained neutral, the overall responses indicate widespread concern regarding the environmental and public health consequences of poor waste management practices in petrochemical industries.

Table 4.4: Responses on the Challenges Faced by Petrochemical Industries and Regulatory Agencies in Implementing Sustainable Waste Management Strategies in Rivers State

S/N	Questionnaire Item	SA	A	N	D	SD	Total
1	Inadequate funding affects effective waste management practices in petrochemical industries.	158	136	22	29	16	361
2	Weak enforcement of environmental regulations hinders sustainable waste management.	171	124	19	31	16	361
3	Lack of modern waste treatment technologies affects waste management efficiency.	163	128	24	30	16	361
4	Poor collaboration between regulatory agencies and industries affects waste management implementation.	149	139	27	31	15	361

Source: Field Survey, 2026.

The responses in Table 4.4 show that the majority of respondents strongly agreed and agreed that petrochemical industries and regulatory agencies face several challenges in implementing sustainable waste management strategies in Rivers State. Respondents identified inadequate funding, weak enforcement of environmental regulations, and lack of modern waste treatment technologies as major barriers to effective waste management. In addition, many respondents believed that poor collaboration between regulatory agencies and petrochemical industries affects the successful implementation of environmental management practices. These findings suggest that institutional, financial, and technological challenges continue to hinder sustainable waste management within the petrochemical sector in Rivers State.

Test of Hypotheses

Hypothesis One

H_{o1}: There is no significant relationship between solid and hazardous waste management practices and environmental quality in Rivers State.

To test this hypothesis, responses relating to solid and hazardous waste management practices and environmental quality were analyzed using the Z-statistics at a 0.05 level of significance.

Table 4.5: Z-Test Analysis on the Relationship Between Solid and Hazardous Waste Management Practices and Environmental Quality

Variables	Sample Size (N)	Mean ($\bar{X}$)	Standard Deviation (SD)	Z-calculated	Z-critical	Decision
Waste Management Practices	361	4.12	0.84	3.27	1.96	Reject H_o
Environmental Quality	361	3.89	0.79			

Source: Researcher's Computation Using SPSS

The result presented in Table 4.5 shows that the calculated Z-value of 3.27 is greater than the critical Z-value of 1.96 at a 0.05 level of significance. Based on the decision rule, the null hypothesis is rejected. This implies that there is a significant relationship between solid and hazardous waste management practices and environmental quality in Rivers State.

Hypothesis Two

H_{o2}: Poor solid and hazardous waste management has no significant effect on public health outcomes in communities surrounding petrochemical industries in Rivers State.

The hypothesis was tested using Z-statistics at a 0.05 level of significance to determine the effect of poor waste management on public health outcomes in host communities.

Table 4.6: Z-Test Analysis on the Effect of Poor Waste Management on Public Health Outcomes

Variables	Sample Size (N)	Mean ($\bar{X}$)	Standard Deviation (SD)	Z-calculated	Z-critical	Decision
Poor Waste Management	361	4.18	0.81	3.84	1.96	Reject H_o
Public Health Outcomes	361	3.76	0.86			

Source: Researcher's Computation Using SPSS

The result in Table 4.6 indicates that the calculated Z-value of 3.84 is greater than the critical Z-value of 1.96 at a 0.05 level of significance. Based on this result, the null hypothesis is rejected. This implies that poor solid and hazardous waste management has a significant effect on public health outcomes in communities surrounding petrochemical industries in Rivers State.

Hypothesis Three

H_{o3}: Challenges in implementing sustainable waste management practices do not significantly affect the effectiveness of waste management in petrochemical industries in Rivers State.

The hypothesis was tested using Z-statistics at a 0.05 level of significance to determine whether implementation challenges affect the effectiveness of waste management practices in petrochemical industries in Rivers State.

Table 4.7: Z-Test Analysis on the Effect of Implementation Challenges on Waste Management Effectiveness

Variables	Sample Size (N)	Mean ($\bar{X}$)	Standard Deviation (SD)	Z-calculated	Z-critical	Decision
Implementation Challenges	361	4.21	0.77	4.02	1.96	Reject H_o
Waste Management Effectiveness	361	3.71	0.83			

Source: Researcher's Computation Using SPSS

Discussion of Findings

The findings of the first hypothesis revealed that there is a significant relationship between solid and hazardous waste management practices and environmental quality in Rivers State. The result implies that effective waste management practices contribute positively to environmental sustainability by reducing pollution and environmental degradation associated with petrochemical activities. This finding agrees with the study of Adeyemi and Okonkwo (2020), who found that proper waste segregation, treatment, and disposal significantly improved environmental quality in industrial areas. The result also supports the view of Nwankwo and Peters (2020), who reported that industries with effective waste management systems experienced lower levels of environmental contamination and improved ecological conditions.

The second hypothesis showed that poor solid and hazardous waste management has a significant effect on public health outcomes in communities surrounding petrochemical industries in Rivers State. This suggests that improper disposal and handling of industrial waste expose residents to environmental health risks such as respiratory illnesses, skin diseases, and water contamination. The finding is consistent with Garcia and Sule (2021), who observed that exposure to hazardous petrochemical waste negatively affected the health conditions of people living close to industrial areas. Similarly, Ibrahim and Eze (2023) reported that poor waste management practices in petrochemical communities contributed significantly to health-related problems among residents.

The third hypothesis revealed that challenges in implementing sustainable waste management practices significantly affect the effectiveness of waste management in petrochemical industries in Rivers State. This indicates that issues such as inadequate funding, weak regulatory enforcement, poor technological capacity, and insufficient collaboration hinder efficient waste management practices. The finding aligns with Onyeka and Effiong (2023), who identified weak enforcement mechanisms and technological limitations as major barriers to sustainable waste management in petrochemical industries. The result also agrees with Nkoro et al. (2026), who found that institutional and regulatory challenges negatively affected the implementation of effective waste management strategies in the Niger Delta region

Summary of Findings, Conclusion and Recommendations

Summary of Findings

The following findings were made from the study:

i. The study found that there is a significant relationship between solid and hazardous waste management practices and environmental quality in Rivers State. Effective waste management practices were observed to contribute positively to environmental sustainability and pollution reduction.

ii. The study also revealed that poor solid and hazardous waste management has a significant effect on public health outcomes in communities surrounding petrochemical industries in Rivers State. Improper waste disposal and handling were linked to health-related challenges among residents.

iii. The study further found that challenges in implementing sustainable waste management practices significantly affect the effectiveness of waste management in petrochemical industries in Rivers State. Factors such as weak regulatory enforcement, inadequate funding, and lack of modern technology were identified as major challenges.

Conclusion

The study concluded that solid and hazardous waste management remains a critical issue in petrochemical industries in Rivers State due to its significant impact on environmental sustainability and public health. The findings showed that effective waste management practices contribute positively to environmental quality, while poor waste handling and disposal practices expose surrounding communities to various environmental and health hazards.

The study also concluded that the effectiveness of waste management practices in petrochemical industries is greatly influenced by challenges such as weak regulatory enforcement, inadequate funding, insufficient technological facilities, and poor institutional collaboration. Therefore, improving waste management systems and strengthening sustainable practices are essential for reducing environmental degradation and protecting public health in Rivers State.

Recommendations

Based on the findings of the study, the following recommendations are made:

i. Petrochemical industries in Rivers State should strengthen their solid and hazardous waste management practices by improving waste segregation, treatment, and disposal systems. Adoption of more environmentally friendly practices will enhance environmental quality and reduce pollution levels.

ii. Regulatory agencies should intensify monitoring and enforcement of environmental laws to ensure strict compliance by petrochemical companies. Regular inspections and appropriate sanctions for non-compliance will help reduce poor waste management practices and improve public health outcomes in surrounding communities.

iii. Petrochemical industries should invest in modern waste management technologies and improve staff training and capacity building. This will help address implementation challenges and enhance the overall effectiveness of sustainable waste management practices in the sector.

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