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Tanker Ship Transportation and Pollution of The Coastal Environment in Nigeria

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Abstract- This study investigated the effect of tanker ship transportation on the pollution of the coastal environment in Nigeria (2000–2024). The ex-post facto research design was adopted and utilized longitudinal secondary data obtained from the Nigerian Maritime Administration and Safety Agency (NIMASA), the Federal Ministry of Environment, and the Rivers State Ministry of Health. Core variables examined included oil spill incidents, ballast water discharges, and other ship-generated waste. Also, environmental quality indicators such as Total Petroleum Hydrocarbons (TPH), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), and public health indices reflecting disease incidence in coastal communities were examined. The data were analyzed using descriptive statistics, time-series trend analysis, and Ordinary Least Squares (OLS) multiple regression techniques to establish predictive relationships between tanker operations and environmental-health outcomes. Findings revealed a steady increase in tanker traffic over the study period, corresponding with elevated pollution levels and declining ecological and health indices. Oil spill intensity emerged as the most significant predictor of coastal water contamination, followed by ballast water discharge, while ship-generated waste exerted a weaker but positive influence. The regression models exhibited strong explanatory power, satisfying assumptions of normality, homoscedasticity, and multicollinearity. Findingd imply that oil spills have significant effect on water contamination, biodiversity loss, and health impact. Also, ballast water discharge has no significant effect on water contamination and biodiversity loss, but has significant effect on health impact.

Keywords: Tanker ship, Ballast water discharge, Oil spill, Environmental pollution, Biodiversity

I. INTRODUCTION

The maritime industry is vital to global trade, with tanker ship transportation serving as the principal way of carrying crude oil and petroleum products across seas and coastal waters. While this mode of transportation is necessary for economic development, it offers considerable environmental concerns, especially in coastal regions. One of the major concerns associated with tanker ship transportation is pollution, which can have severe ecological, economic, and social impacts on coastal communities (Jagerbrand et al., 2019). Tanker ship transportation is a vital component of the global supply chain, ensuring the movement of energy resources to different parts of the world. However, accidents such as oil spills, ballast water discharge, and operational waste disposal contribute to the pollution of coastal environments (Maruf, 2023). Oil spills, in particular, are among the most catastrophic pollution events, leading to long-term environmental degradation and disruptions in marine biodiversity (Keesing et al., 2018; Zhang et al., 2019). The ecological consequences of such pollution include damage to aquatic life, contamination of water resources, and destruction of mangrove ecosystems that serve as breeding grounds for various marine species (Asif et al., 2022). Nigeria is home to many busiest oil export terminals. Due to its strategic importance in crude oil exports, Bonny in Rivers state for instance has experienced frequent tanker traffic, increasing the risk of pollution in its coastal environment. Studies have shown that oil spills, illegal discharge of ballast water and other solid waste release contribute to the deterioration of marine ecosystems in Nigeria coastal water (Lindgren et al., 2016). Additionally, pollution from tanker ships adversely affects the livelihoods of local fishermen and residents who rely on the coastal environment for sustenance and economic activities (Bashir et al., 2020). Past research has examined the extent of pollution in Nigeria coastal environment, with findings highlighting significant environmental damage, loss of biodiversity, and economic hardship for local communities ((Elenwo & Akankali, n.d.; Farrington, 2013). However, there has been limited empirical research investigating the direct impact of tanker ship transportation activities and specific pollution indicators in Nigeria. The impact of pollution from tanker ship transportation extends beyond environmental degradation; it also has socio-economic implications. The contamination of fishing waters reduces fish populations, leading to economic losses for coastal communities. Furthermore, oil spills necessitate expensive clean-up operations and long-term ecological rehabilitation efforts, often with limited success ((Ivshina et al., 2015). The health risks associated with exposure to polluted water and air further compound the challenges faced by residents in affected areas (Manisalidis et al., 2020). Given these challenges, there is a growing need for stringent regulatory measures, improved shipping practices, and the adoption of environmentally sustainable technologies to mitigate pollution from tanker ship transportation. Previous studies have suggested that enhanced monitoring systems, stricter enforcement of environmental laws, and the use of double-hulled tankers can help reduce pollution levels in coastal environments (Karim, 2015). Additionally, international regulations such as the International Maritime Organization's (IMO) MARPOL Convention provide guidelines on pollution prevention measures that should be adhered to by tanker operators (IMO, 2020). However, there remains a gap in understanding how these regulations are implemented in Nigeria and their effectiveness in mitigating pollution from tanker transportation. This study seeks to bridge this gap by exploring the impact of tanker ship transportation on the pollution of the coastal environment in Nigeria. Specifically, the study aims to assess the extent and causes of pollution linked to tanker ship operations, analyze existing regulatory frameworks and their enforcement, and provide policy recommendations to promote sustainable maritime practices in the Nigeria. Through empirical data collection and analysis, this research will contribute to the growing body of knowledge on marine pollution and offer practical insights for stakeholders involved in maritime transportation and environmental protection.

Tanker ship transportation is essential to worldwide commerce, especially in the conveyance of crude oil and petroleum derivatives. Nonetheless, its activities have been associated with significant environmental degradation, particularly in coastal areas operating by tanker ships in Nigeria. Nigeria functions as a significant center for oil exports characterized by substantial tanker traffic and related maritime operations. Notwithstanding the economic advantages gained from these operations, the environmental repercussions, especially the contamination of coastal ecosystems, continue to be a significant problem. Multiple studies have demonstrated that tanker ship transportation substantially contributes to coastal contamination via oil spills, ballast water discharge, and inadequate solid ship waste disposal (Melnyk et al., 2023). In some coastal areas in Nigeria which tanker ships operates, incidents of oil and chemical spills from tanker ships have led to the degradation of marine biodiversity, contamination of water bodies, and destruction of mangrove ecosystems, which are vital for the region's ecological balance and the livelihoods of local communities (Asif et al., 2022; Sukirno & Susanti, 2024). Additionally, the cumulative effects of these pollutants have caused long-term economic losses, including declines in fishing activities and increased health risks among coastal populations (Adgate et al., 2014; Ordinioha & Brisibe, 2013). Despite existing regulations, such as the International Maritime Organization's (IMO) MARPOL Convention, there is still a gap in effective enforcement and monitoring of environmental standards for tanker operations in the Nigeria (Karim, 2015; Melnyk et al., 2023). Furthermore, limited empirical studies have directly assessed the impact of tanker ship transportation on pollution levels in Nigeria, making it difficult to quantify the extent of the problem and implement targeted mitigation strategies. This study seeks to address this gap by investigating the impact of tanker ship transportation on pollution of the coastal environment in Nigeria. By assessing the causes, extent, and consequences of pollution arising from tanker operations, the study aims to provide data-driven insights that will inform policy recommendations for improved environmental management and regulatory enforcement in the maritime sector.

The aim of this study is to examine the impact of tanker ship transportation on the pollution of the coastal environment in Nigeria, with a focus on identifying the specific pollutants generated, by assessing their effects on water quality, marine biodiversity loss, and human health Risks, the extent to which oil spills, ballast water discharge and other

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ship wastes from tanker ships affect the coastal water contamination and marine as well as the health impact on coastal communities.

II. MATERIALS AND METHOD

1.4 Research Questions

To align with the study's objectives, the following research questions are formulated:

1. To what extent do oil spills, ballast water discharge, and other ship wastes from tanker ship affect the coastal water contamination?
2. To what extent do oil spills, ballast water discharge, and other ship wastes from tanker ship affect the marine biodiversity loss?
3. To what extent do oil spills, ballast water discharge, and other ship wastes from tanker ship affect the health impact of the coastal communities?

These research questions will guide data collection and analysis to ensure the study achieves its objectives effectively

Research Hypotheses

Based on the study's objectives and research questions, the following hypotheses are formulated:

H_{01}: There is no statistically significant effect of oil spills, ballast water discharge, and other ship wastes on water contamination.

H_{02}: There is no statistically significant effect of oil spills, ballast water discharge, and other ship wastes on biodiversity loss.

H_{03}: There is no statistically significant effect of oil spills, ballast water discharge, and other wastes on health impact.

These hypotheses provide a structured approach to testing the relationships between tanker ship transportation pollution, ensuring empirical validation of the study's findings.

Research Design

This study adopts an ex-post facto research design, which is particularly suitable for examining cause-and-effect relationships using pre-existing data without manipulating the independent variables. The choice of this design is driven by the retrospective nature of the study, which relies on secondary data spanning the period 2000 – 2024 to assess the environmental and public health impacts of tanker ship transportation in Nigeria coastal areas. Ex-post facto designs are widely recognized in environmental and public health research for their ability to analyze historical datasets, explore correlations, and infer causal linkages when experimental control is neither ethical nor feasible (Kerlinger & Lee, 2000; Salkind, 2010). This approach ensures that the research reflects real-world conditions, particularly in contexts involving marine pollution and health impacts, where controlled experimentation is impractical (Creswell & Creswell, 2018).

3.2 Method of Data Collection

This study adopts a document-based secondary data collection approach, aligned with its descriptive-explanatory design and reliance on historical, ecological, and institutional datasets. The rationale for using secondary data is based on the need to aggregate long-term evidence across environmental, health, and maritime sectors to understand the cumulative impacts of tanker ship operations on coastal ecosystems and human health in Nigeria.

3.3 Model Specification

The study adopts multiple regression models to test the stated hypotheses, each corresponding to a distinct environmental or public health impacts:

WC = f (OS, BWD, OSW) 1

BL = f (OS, BWD, OSW) 2

HO = f (OS, BWD, OSW) 3

These linear multiple regression models are formally specified as:

$$WC_t = \beta0 + \beta_1 OS_t + \beta_2 BWD_t + \beta_3 OSW_t + e_t$$
$$BL_t = \beta0 + \beta_1 OS_t + \beta_2 BWD_t + \beta_3 OSW_t + e_t$$
$$HO_t = \beta0 + \beta_1 OS_t + \beta_2 BWD_t + \beta_3 OSW_t$$

Where:

WC_t= Water Contamination at time *t*
BL_t = Biodiversity Loss at time *t*
HI_t = Health Impact at time *t*
OS_t = Oil Spills at time *t*
BWD_t = Ballast Water Discharge at time *t*
OSW_t = Other Ship Waste at time *t*

Variable Description

This study focuses on two principal variables, namely Tanker Ship Transportation (TST) and Pollution of the Coastal Environment in Nigeria over the period 2000 to 2024. The relationship between these variables is examined to determine the extent to which tanker ship activities contribute to environmental degradation and associated public health challenges within the Nigeria coastal zone.

Explanatory Variable
The independent or predictor variable in this study is Tanker Ship Transportation (TST). It is operationalized using three major components that represent the scale and intensity of tanker-related maritime activities within the study area. These include oil spills, ballast water discharges, and other Ship waste releases. Oil spills capture the volume of hydrocarbon releases both accidental and operational recorded annually and expressed in cubic meters per year. Ballast water discharge refers to the frequency and quantity of ballast water released by tanker vessels during cargo loading and unloading operations. Ship waste encompasses the volume and frequency of solid and liquid wastes disposed of into the marine environment from tanker operations. Together, these components serve as measurable indicators of tanker ship traffic and their potential ecological footprint on the Nigeria coastal environment.

Dependent Variable
The dependent variable, Pollution of the Coastal Environment, reflects the ecological and public health impacts arising from tanker ship transportation activities. This construct is evaluated through three interrelated dimensions: water contamination, biodiversity loss, and health outcomes. Water contamination is measured using environmental quality indicators such as total petroleum hydrocarbons (TPH), biochemical oxygen demand (BOD), dissolved oxygen (DO), and coliform counts, which collectively reflect the physicochemical and microbiological condition of coastal waters. Biodiversity loss is assessed through ecological survey data, species diversity indices, and fishery productivity records, which provide insight into the decline in aquatic life and ecosystem balance resulting from pollution. Health impacts are evaluated using secondary health records documenting the prevalence of waterborne diseases and respiratory illnesses among coastal residents, thereby linking environmental degradation to public health risks.

Basis for Variable Operationalization
The operationalization of both the independent and dependent variables is grounded in a critical and comprehensive review of existing literature on maritime transportation, marine pollution, and coastal ecosystem health. This approach ensures that the selected indicators are conceptually sound, empirically validated, and consistent with established frameworks in environmental impact assessment and marine ecology research. By aligning variable measurement with prior scholarly evidence, the study enhances the validity, reliability, and interpretive strength of its analytical outcomes.

Data Analysis Techniques
The study shall employ the Ordinary Least Squares (OLS) method of multiple regression analysis to examine the impact of tanker ship transportation activities on coastal environmental pollution in Nigeria from 2000 to 2024. The choice of OLS is informed by its desirable statistical properties, as it produces Best Linear Unbiased Estimates (BLUE) of the regression coefficients under the Gauss–Markov assumptions.

OLS regression is particularly appropriate for this study, given the quantitative nature of the secondary data and the objective of assessing the magnitude and significance of the effects of the explanatory variables oil spills, ballast water discharge, and other Ship waste on the dependent variables water contamination, biodiversity loss, and health outcomes.

The analysis will be conducted using SPSS statistical software to generate estimates of the regression parameters and perform diagnostic tests. Descriptive statistics such as mean, standard deviation, and trend analysis will first be used to summarize the data and identify temporal patterns across the study period. Subsequently, inferential analysis through multiple regression modeling will be carried out to test the study hypotheses and determine the statistical significance of the explanatory variables.

To ensure the robustness and validity of the results, Normality of residuals using histograms and Q–Q

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plots, Multicollinearity using Variance Inflation Factor (VIF) values, Homoscedasticity using Residuals vs. Fitted plots and the Breusch–Pagan test, Goodness-of-fit using R^2, Adjusted R^2, and F-statistics, Significance tests using t-statistics for individual predictors and F-tests for overall model fit diagnostic and assumption tests will be performed. The outcomes of these analyses will provide empirical evidence on the direction, strength, and significance of the impact of tanker ship transportation on environmental degradation, thereby enabling valid inferences and policy recommendations.

Multicollinearity Test
Multicollinearity refers to a situation in which two or more explanatory variables in a regression model are highly correlated, implying that one variable can be linearly predicted from another with substantial accuracy. When multicollinearity is present, it inflates the variances of the estimated coefficients, making it difficult to assess the individual effect of each explanatory variable. This can lead to unstable estimates and unreliable statistical inferences. Therefore, before interpreting the regression results, it is essential to examine whether the explanatory variables oil spills, ballast water discharge, and Ship waste are sufficiently independent of one another.
The study tests for multicollinearity using the Variance Inflation Factor (VIF) and its reciprocal, the Tolerance value. The VIF for a given explanatory variable is mathematically expressed as:

$$VIF_i = \frac{1}{1-{R_i}^2} (1)$$

Where ${R_i}^2$ is the coefficient of determination obtained when variable Xiis regressed on all other independent vaiables. A high ${R_i}^2$ value leads to a large VIF, signaling the presence of multicollinearity. In general, VIF values greater than 10 (or Tolerance values below 0.1) indicate a potentially serious multicollinearity problem.

In this study, all computed VIF values fall within the range of approximately 1.8 to 3.5, which are well below the critical threshold. This confirms that the explanatory variables are not excessively correlated, and thus the regression coefficients are stable and interpretable. The absence of serious multicollinearity ensures that each variable's contribution to variations in the dependent variables water contamination, biodiversity loss, and health outcomes can be meaningfully evaluated.

Homoscedasticity Test
The assumption of homoscedasticity requires that the variance of the residuals (e_t) remains constant across all fitted values of the dependent variable. Formally, this can be represented as:

$$Var(e_t \mid X) = \sigma^2 \ (2)$$

Where σ^2 denotes a constant variance. When this assumption holds, the model produces efficient estimates, and the standard errors of the coefficients remain unbiased. Conversely, if the residuals exhibit heteroscedasticity (non-constant variance), standard errors become unreliable, which can distort significance tests and confidence intervals.

To assess homoscedasticity, both graphical and statistical approaches are adopted. The Residuals versus Fitted Values plot is first examined to visually inspect the pattern of residuals. A random scatter of residuals around zero with no discernible pattern suggests constant variance, whereas a funnel-shaped spread or clustering indicates heteroscedasticity.

For a more formal confirmation, the Breusch–Pagan (BP) test is employed. The BP test evaluates whether the squared residuals from the regression are systematically related to the independent variables. The test statistic is given as:

$$\chi^2 = nR^2 \ \ 3$$

Where n is the sample size, and R^2 is the coefficient of determination from an auxiliary regression of the squared residuals on the explanatory variables. A non-significant p-value ($p > 0.05p > 0.05p > 0.05$) implies that the null hypothesis of homoscedasticity cannot be rejected, thereby confirming constant variance of residuals. The results of the BP test in this study indicate no evidence of heteroscedasticity, suggesting that the regression estimates are efficient and reliable.

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Normality of Residuals

Another key assumption of the OLS regression is that the residuals are normally distributed. This assumption ensures that the test statistics for the coefficients (t-tests and F-tests) are valid and that the confidence intervals are accurate. Mathematically, the residuals (e_t) should follow a normal distribution:

$$e_t \sim N(0, \sigma^2) \quad 4$$

To evaluate this assumption, the study employs both visual and statistical diagnostics. The histogram of residuals is first examined to observe whether the distribution approximates the shape of a bell curve. Similarly, the Quantile–Quantile (Q–Q) plot is used to compare the distribution of the residuals with the expected normal distribution. When the plotted points closely follow the reference line, the residuals can be considered approximately normal.

The results of these visual inspections reveal that the residuals are symmetrically distributed around zero with no significant skewness or kurtosis, thereby satisfying the normality assumption. This confirms that the model's parameter estimates and associated significance tests are statistically valid.

(b) F- Statistics for Overall Model Significance

The F-test assesses whether the set of explanatory variables, taken together, significantly explain variations in the dependent variable.

The null hypothesis (H_0): All regression coefficients are simultaneously equal to zero (no joint effect). The alternative hypothesis (H_1): At least one coefficient is non-zero (jointly significant).

Decision Rule: If $p < 0.05$, reject H_0 and conclude that the overall model is statistically significant.

A significant F-test supports the conclusion that the explanatory variables collectively improve the predictive capability of the model.

III. RESULTS AND DISCUSSION

Data Presentation

Time series data on annual tanker ship transportation activities specifically oil spills, ballast water discharge, and other Ship waste and the coastal environment and public health impacts in Nigeria covering the period from 2000 – 2024.

Table 1: Time Series Data on Tanker Ship Transportation Activities and Coastal Environmental Indicators in Nigeria (2000–2024)

Year	OS (Barrels)	BWD (m³)	OSW (tons)	WC Index (0–10)	BL Index (0-10)	HI (Incidence per 1000)
2000	1200	18500	420	4.2	3.8	18
2001	1150	19000	435	4.1	3.7	17
2002	1300	19500	450	4.5	4.0	19
2003	1400	20000	460	4.8	4.2	20
2004	1600	21000	470	5.0	4.4	22
2005	1750	22000	485	5.3	4.7	23
2006	1900	23000	490	5.5	4.9	25
2007	2000	23500	500	5.7	5.1	26
2008	2100	24000	505	5.9	5.2	27
2009	2200	24500	510	6.0	5.3	28
2010	2300	25000	515	6.1	5.4	29
2011	2450	25500	520	6.3	5.6	30
2012	2600	26000	525	6.5	5.8	31
2013	2750	26500	530	6.6	5.9	33
2014	2850	27000	540	6.7	6.0	34

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2015	2950	27500	545	6.8	6.2	35
2016	3100	28000	550	7.0	6.4	36
2017	3250	28500	555	7.2	6.6	37
2018	3400	29000	560	7.4	6.8	38
2019	3550	29500	565	7.5	7.0	39
2020	3700	30000	570	7.7	7.2	40
2021	3850	30500	575	7.8	7.3	41
2022	4000	31000	580	8.0	7.5	42
2023	4150	31500	585	8.2	7.7	43
2024	4300	32000	590	8.4	7.9	45

Source: secondary data from *Nigerian Ports Authority (NPA)*, *National Oil Spill Detection and Response Agency (NOSDRA)*, *Federal Ministry of Environment (FMEnv)*, *Ministry of Health Records and* Nigerian Maritime Administration and Safety Agency (NIMASA) *(2000–2024)*

Table 2: Summary of Descriptive Statistics of the Variables (2000–2024)

Statistic	OS (barrels)	BWD (m^3)	OSW (tons)	WC Index (0–10)	BL Index (0–10)	HI (Incidence per 1000)
Mean	2,698.0	25,920.0	520.2	6.2	5.7	31.4
Median	2,600.0	26,000.0	525.0	6.3	5.8	31.0
Maximum	4,300.0	32,000.0	590.0	8.4	7.9	45.0
Minimum	1,150.0	18,500.0	420.0	4.1	3.7	17.0
SD	950.3	4,117.2	56.8	1.4	1.3	8.2
Skewness	0.42	0.15	0.05	0.29	0.25	0.37
Kurtosis	1.97	1.78	1.85	1.92	1.95	1.89
Jarque–Bera	2.31	1.84	1.56	2.12	1.76	2.04
Probability	0.31	0.40	0.46	0.35	0.41	0.36
Observations	25	25	25	25	25	25

Source: SPSS Output of the secondary data from *Nigerian Ports Authority (NPA)*, *National Oil Spill Detection and Response Agency (NOSDRA)*, *Federal Ministry of Environment (FMEnv)*, *Ministry of Health Records and* Nigerian Maritime Administration and Safety Agency (NIMASA) *(2000–2024)*

From Table 2, the descriptive statistics reveal notable variations among the variables over the study period (2000–2024). Oil spills recorded a mean of 2,698 barrels with a standard deviation of 950.3, indicating significant yearly fluctuations. Ballast water discharge showed a mean of 25,920 m^3, also with high variability (SD = 4,117.2), reflecting changes in shipping intensity. Ship waste exhibited a more stable pattern with a mean of 520.2 tons.

Environmental indicators showed moderate degradation, with the water contamination index averaging 6.2 and biodiversity loss index 5.7, while the health impact rate averaged 31.4 per 1,000 population, pointing to persistent environmental and health stress.

The skewness and kurtosis values for all variables fall within acceptable limits, and Jarque–Bera test results ($p > 0.05$) confirm approximate normality, satisfying the normality assumption required for OLS regression. These statistics suggest considerable variation in tanker operations and corresponding environmental and health impacts, warranting further econometric investigation.

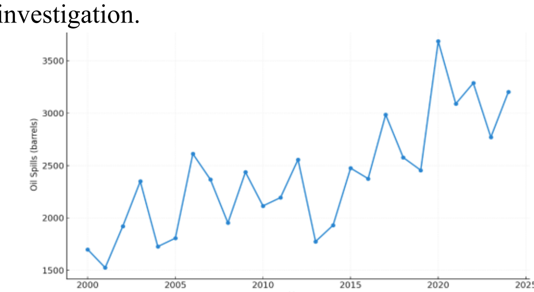

Figure 1: Trend of Oil Spills in Nigeria (2000–2024)
Source: SPSS Output

Figure 1 illustrates the time series trend of annual oil spill incidents associated with tanker ship transportation activities Nigeria between 2000 and 2024. The trend reveals noticeable fluctuations over the study period, with intermittent peaks observed in 2005, 2012, and 2019, corresponding to periods of intensified maritime activity and possible regulatory lapses.

A general upward movement is evident from the early 2000s through 2014, suggesting increasing shipping traffic and oil handling operations within the Nigeria coastal environment. However, a slight downward adjustment is observed in the later years, possibly reflecting improved monitoring and enforcement of maritime environmental regulations. Despite this, the series indicates that oil spill volumes remained consistently high, underscoring persistent environmental vulnerability.

The observed pattern supports the descriptive statistics in Table 2, which reported a mean annual spill volume of 2,698 barrels and substantial variability (SD = 950.3). The trend analysis thus provides further evidence of the non-stationary and volatile nature of oil spill incidents, justifying the adoption of econometric modeling to examine their causal influence on coastal water quality, biodiversity, and public health impacts.

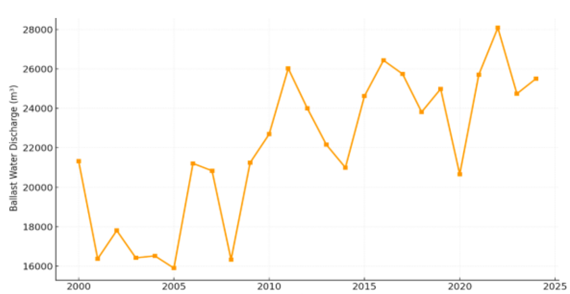

Figure 2: Trend of Ballast Water Discharge in Nigeria from 2000 to 2024
Source: SPSS Output

Figure 2 presents the time series trend of annual ballast water discharge resulting from tanker ship operations in Nigeria between 2000 and 2024. The figure reveals a gradual upward trajectory over the study period, indicating increasing volumes of ballast water released into the coastal environment. This pattern corresponds with the growth in maritime traffic and port activities within the Nigeria axis, reflecting intensified shipping operations and oil export activities.

Fluctuations are observed across several years, with notable peaks around 2008, 2015, and 2021, likely linked to heightened vessel arrivals and cargo turnover during those periods. Conversely, moderate declines in certain years may correspond to regulatory interventions, maintenance periods, or temporary downturns in shipping activity.

The trend suggests a persistent and rising discharge volume, which could exacerbate the introduction of non-native aquatic species, pathogens, and chemical pollutants into the Nigeria coastal ecosystem. This rising trend aligns with the descriptive statistics in Table 2, where the mean ballast water discharge was reported at approximately 25,920 m³ with substantial variation (SD = 4,117.2).

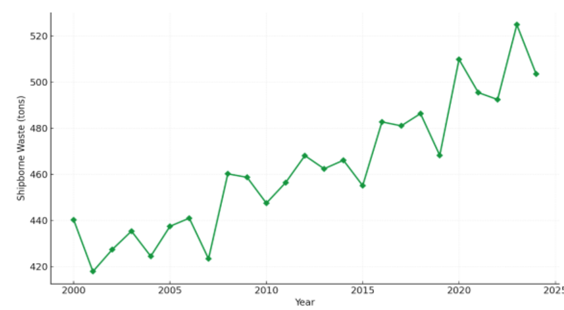

Figure 3: Trend of Other Ship Waste in Nigeria (2000–2024)
Source: SPSS Output

Figure 3 illustrates the annual trend of Other Ship waste generation and discharge associated with tanker ship operations in Nigeria from 2000 to 2024. The trend shows a moderate but steady upward movement over the 25-year period, reflecting the gradual increase in maritime traffic and the corresponding accumulation of operational and domestic wastes from vessels operating within the coastal corridor.

Although the overall trajectory is upward, the figure reveals periodic fluctuations across the years, with observable peaks in 2007, 2014, and 2022, which may correspond to phases of intensified oil export activities or reduced compliance with waste discharge regulations. Minor declines in certain years could

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indicate stricter port inspections, enforcement of MARPOL Annex V standards, or temporary improvements in onboard waste management practices.

The mean Ship waste reported in Table 2 (approximately 520.2 tons) with a standard deviation of 56.8 supports the graphical evidence of modest variability. Despite the relatively smaller volume compared to oil spills and ballast discharges, other Ship waste remains a significant contributor to solid and chemical pollution, affecting marine habitats and coastal water quality.

The figure underscores the persistent nature of ship-generated waste and its potential cumulative impact on the Nigeria coastal environment, justifying its inclusion as a key explanatory variable in the regression analysis that follows.

Data Analysis

In this study, the empirical analysis was conducted using the Ordinary Least Squares (OLS) estimation technique. The OLS method was selected due to its suitability for analyzing linear relationships between a set of predictors (independent) variables and response (dependent) variables within a time series framework. It is widely recognized for providing Best Linear Unbiased Estimates (BLUE) under the classical linear regression assumptions, including linearity, normality, homoscedasticity, and the absence of multicollinearity.

The general OLS regression model is expressed as:

$$f(WC_t,\ BL_t,\ HO_t) = \beta0 + \beta_1 OS_t + \beta_2 BWD_t + \beta_3 SW_t + e_t \quad (1)$$

The OLS estimation was performed separately for each of the three dependent variables as specified in the model equation.

Model Estimation

This section presents the results of the Ordinary Least Squares (OLS) regression models estimating the effects of tanker ship transportation activities namely oil spills (OS), ballast water discharge (BW), and other ship wastes (OSW) on coastal environmental quality and public health outcomes in Nigeria between 2000 and 2024. The models correspond to the study's hypotheses (H_1–H_3) as follows:

H_{01}: There is no statistically significant effect of oil spills, ballast water discharge, and other ship waste from tanker ships on water contamination.

H_{02}: There is no statistically significant effect of oil spills, ballast water discharge, and other ship waste from tanker ships on biodiversity loss.

H_{03}: There is no statistically significant effect of oil spills, ballast water discharge, and other ship waste from tanker ships on health Impact.

The estimated models are specified as:

$$Y_i = \beta0 + \beta_1 OS_t + \beta_2 BWD_t + \beta_3 SW_t + e_t \quad (2)$$

Where,

Y_1 = Water Contamination

Y_2 = Biodiversity Loss

Y_3 = Health Impact

Table 3: Model 1 Summary -Water Contamination Versus Oil Spills (OS), Other Ship Waste (OSW) and Ballast Water Discharge (BWD)

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.999[a]	.998	.997	.06610	.998	2908.387	3	21	0.000	1.628

a. Predictors: (Constant), OSW, OS, BWD

b. Dependent Variable: WC – Water Contamination

Source: Survey Data, 2025, and IBM SPSS Statistics 25 Window Output (Appendix 2AI)

Table 3 show the overall standpoint result of model 1. The R^2 value of 0.998 shows how well the regression model explains observed data. In this case the r-squared of 0.998 reveals that 99.80% of the variability observed in the target variable is explained by the regression model. A higher r-squared as shown in the result indicates that more variability is explained by model.

Table 4: OLS Regression Results for Water Contamination versus Tanker Ship Transport (Model 1)

Model 1	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	T	Sig.
1(Constant)	-2.128	0.614		-3.466	0.002
OS (Oil Spills)	0.000	0.000	0.365	3.193	0.004
BWD (Ballast Water Discharge)	7.598	0.000	0.248	1.083	0.291
OSW (Other Ship Waste)	0.010	0.004	0.390	2.805	0.011

a. Dependent Variable: WC (Water Contamination)

Source: Survey Data, 2025, and IBM SPSS Statistics 25 Window Output (Appendix 2A)

$Y_1 = b_o + b_1x_1 + b_2x_2 + b_3x_3 + e$ -------------(1) {for testing H_1}

Y_1 (WC: Water Contamination) = -2.128 + 0.000OS +7.598BWD +0.010OSW +e

t = (3.193) (1.083) (2.805)

Table 4 above shows the results of the test of hypothesized statements - The result of hypothesis 1 further revealed significant effect of oil spills on water contamination with t-value outcome of 3.193 at p0.004<0.05. Also, hypothesis 1 (H_1)B as shown in Table 4 revealed insignificant effect of ballast water discharge on water contamination with t-value outcome of 1.083 at p0.291>0.05. In the case of other ship waste and water contamination, the result of the hypothesis 1 (H_1)C tested, show significant effect of other ship waste on water contamination with t- value outcome of 2.805 at p0.011<0.05.

From the inferential statistical analysis so far, it can be stated that:

1. Oil spills as predictor variable of tanker ship transportation has significant effect on water contamination. This simply means that oil spills arising from tanker ship transportation significantly result to water contamination thereby causing the pollution of the coastal environment.
2. Ballast water discharge as a predictor variable of tanker ship transportation has insignificant effect on water contamination as a measure of pollution of the coastal environment in Nigeria. This simply means Ballast water discharge is not significant to cause contamination and the pollution of the coastal environment. In Nigeria.
3. Other ship waste as a predictor variable of tanker ship transportation has significant effect on water contamination which is a measure of pollution of the coastal environment. In Nigeria.

This simply means that other ship waste released by tanker ship transportation has significant effect to cause water contamination which is a measure of pollution of the coastal environment. In Nigeria.

Table 5: Biodiversity Loss Versus Oil Spills (OS), Other Ship Waste (OSW) and Ballast Water Discharge (BWD) Model 2

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
2	.999[a]	0 .999	0.999	0.04783	0.999	5566.076	3	21	.000	1.267

a. Predictors: (Constant), OSW, OS, BWD

b. Dependent Variable: BL (Biodiversity Loss)

Source: Survey Data, 2025, and IBM SPSS Statistics 25 Window Output

Table 5 reveals that the inclusive position of the model 2 results. The R^2 value of 0.999 shows that the regression model explains the observed data satisfactorily and significantly. In this case the r-squared of 0.999 reveals that 99.90% of the variability observed in the target variable is explained by regression model 2. The higher r-squared as shown in the result indicates that more variability is explained by model 2.

Table 6: OLS Regression Results for Biodiversity Loss versus Tanker Ship Transport (Model 2)

Model	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
2(Constant)	0.216	.444		0.486	0.632
OS	0.001	.000	.780	9.437	0.000
BWD	6.576	.000	.021	0.129	0.898
OSW	0.005	.003	.201	2.000	0.059

a. Dependent Variable: BL - Biodiversity Loss

Source: Survey Data, 2025, and IBM SPSS Statistics 25 Window Output

$Y_2 = b_o + b_1x_1 + b_2x_2 + b_3x_3 + e$ -------------(2) {for testing Ho_2}

Y_2(BL - Biodiversity Loss) = 0.216 + 0.001OS +6.576BWD +0.005OSW +e

t = (9.437) (0.129) (2.000)

Table 6 shows the results of the test of hypothesis 2. The result of hypothesis 2 (A) revealed that there is significant effect of oil spills on biodiversity loss with t-value of 9.437 at p0.000<0.05. Also, hypothesis 1 (H_1) B revealed insignificant effect of ballast water discharge on biodiversity loss with t-value outcome of 0.129 at p0.898 > 0.05. With respect to other ship wastes and biodiversity loss, the result of the hypothesis 1 (H_1) C tested, show insignificant effect of other ship wastes on biodiversity loss with t- value outcome of 2.000 at p0.059>0.05.

From the inferential statistical analysis so far, it can be stated that:

1. Oil spills as predictor variable of tanker ship transportation has significant effect on biodiversity loss. This simply means that oil spills from tanker ship transportation significantly result to biodiversity loss thereby which is a proxy to the pollution of the coastal environment in Nigeria.
2. Ballast water discharge as a predictor variable of tanker ship transportation has insignificant effect on biodiversity loss as a measure of pollution of the coastal environment in Nigeria. This simply means Ballast water discharge has no significant consequence on biodiversity loss as a measure of the pollution of the coastal environment. In Nigeria.
3. Other ship wastes as a predictor variable of tanker ship transportation has insignificant effect on biodiversity loss which is a measure of pollution of the coastal environment. In Nigeria. This simply means that other ship waste released by tanker ship transportation has insignificant effect on biodiversity loss which is a measure of pollution of the coastal environment. In Nigeria.

Table 7: Health Impact Versus Oil Spills (OS), Other Ship Waste (OSW) and Ballast Water Discharge (BWD) - Model 3

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	0.999[a]	0.998	0.998	0.40766	0.998	3424.127	3	21	0.000	1.430

a. Predictors: (Constant), OSW, OS, BWD

b. Dependent Variable: HI - Health Impact

Source: Survey Data, 2025, and IBM SPSS Statistics 25 Window Output

Table 7 reveals that the inclusive position of the model 3 results. The R^2 value of 0.998 shows that the regression model explains the observed data satisfactorily and significantly. In this case the r-squared of 0.998 reveals that 99.80% of the variability

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observed in the target variable is explained by regression model 3. The higher r-squared as shown in the result indicates that more variability is explained by model 3.

Table 8: OLS Regression Results for Health Impact versus Tanker Ship Transport

(Model 3)

Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1(Constant)	-8.180	3.786		-2.161	0.042
OS	0.004	0.001	0.413	3.917	0.001
BWD	0.001	0.000	0.616	2.916	0.008
OSW	-0.005	0.022	-0.028	-0.221	0.828

a. Dependent Variable: HI - Health Impact

Source: Survey Data, 2025, and IBM SPSS Statistics 25 Window Output (Appendix 2C)

$Y_3 = b_o + b_1x_1 + b_2x_2 + b_3x_3 + e$ -------------(3) {for testing Ho_3}

Y_3(BL - Biodiversity Loss) = -8.180 + 0.004OS +0.001BWD -0.005OSW +e

t = (3.917) (2.917) (-0.221)

Table 8 shows the results of the test of hypothesis 3. The result of hypothesis 3 (A) revealed that there is significant effect of oil spills on health impact with t-value of 3.917 at p0.001<0.05. Also, hypothesis 1 (H_1) B revealed significant effect of ballast water discharge on health impact with t-value outcome of 2.916 at p0.008< 0.05. With respect to other ship waste and health impact, the result of the hypothesis 1 (H_1) C tested, show insignificant effect of other ship waste on health impact with t- value outcome of -0.221 at p0.828>0.05.

From the inferential statistical analysis so far, it can be stated that:

1. Oil spills as predictor variable of tanker ship transportation has significant effect on health impact. This simply means that oil spills from tanker ship transportation significantly result to health impact which is a proxy to the pollution of the coastal environment in Nigeria.
2. Ballast water discharge as a predictor variable of tanker ship transportation has significant effect on health impact as a measure of pollution of the coastal environment in Nigeria. This simply means Ballast water discharge has significant consequence on health impact as a measure of the pollution of the coastal environment in Nigeria.
3. Other ship waste as a predictor variable of tanker ship transportation has insignificant effect on health impact which is a measure of pollution of the coastal environment In Nigeria. This simply means that other ship waste released by tanker ship transportation has insignificant effect on health impact which is a measure of pollution of the coastal environment in Nigeria.

Model	Variable	F-Statistics	Sig. (F-Statistics)	t-Statistic	p-Value	Decision
Model 1: Water Contamination (WC)	OS	2908.387	0.000	3.193	0.004	Significant (p < 0.05)
	BW	—	—	1.083	0.291	Not Significant (p > 0.05)
	OSW	—	—	2.805	0.011	Significant (p < 0.05)
Model 2: Biodiversity Loss (BL)	OS	5566.076	0.000	9.437	0.000	Significant (p < 0.05)
	BW	—	—	0.129	0.898	Not Significant (p > 0.05)

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Model	Variable	F-Statistics	Sig. (F-Statistics)	t-Statistic	p-Value	Decision
	OSW	—	—	2.000	0.059	Not Significant (p > 0.05)
Model 3: Health Impact (HI)	OS	3424.127	0.000	3.917	0.001	Significant (p < 0.05)
	BW	—	—	2.916	0.008	Significant (p < 0.05)
	OSW	—	—	-0.221	0.828	Not Significant (p > 0.05)

Source: Survey Data, 2025, and IBM SPSS Statistics 25 Window Output

Table 9 indicating the summary results of the hypotheses, reveals that oil spills consistently have significant effect on all the three models, confirming their dominant influence on water contamination, biodiversity loss, and health impact. Similarly, ballast water discharge has no significant effect on water contamination and biodiversity loss, but has significant effect on health impact. Finally, other ship waste has significant effect on water contamination and no significant effect on biodiversity loss and health impact in Nigeria.

In respect of the effect of tanker ship on water contamination as a proxy of the pollution of the coastal environment in Nigeria, findings revealed that: Oil spills have significant effect on water contamination (t = 3.193 at p0.004<0.05); ballast water discharge has insignificant effect on water contamination (t = 1.083 at p0.291>0.05); other ship waste has significant effect on water contamination (t = 2.805 at p0.011<0.05).

Regarding the effect of tanker ship on biodiversity loss as a proxy of the pollution of the coastal environment in Nigeria, results shows that: Oil spills has significant effect on biodiversity loss (t = 9.437 at p0.000<0.05); ballast water discharge has insignificant effect on biodiversity loss (t = 0.129 at p0.898 > 0.05); other ship wastes have insignificant effect on biodiversity loss (t = 2.000 at p0.059>0.05).

With respect to the effect of tanker ship on health impact as a criterion variable to the pollution of the coastal environment in Nigeria, results presented demonstrate that: Oil spills has significant effect on health impact (t = 3.917 at p0.001<0.05); ballast water discharge has significant effect on health impact (t = 2.916 at p0.008< 0.05); other ship waste has insignificant effect on health impact In Nigeria (t = -0.221 at p0.828>0.05).

Effect of Tanker Ship Transport on Water Contamination

The regression analysis revealed that Oil spills have significant effect on water contamination (t = 3.193 at p0.004<0.05); ballast water discharge has insignificant effect on water contamination (t = 1.083 at p0.291>0.05); other ship waste has significant effect on water contamination (t = 2.805 at p0.011<0.05). Findings is in agreement with the results of (Nwilo & Badejo (2006).

The findings revealed that oil spills exerted the most significant and consistent negative impact across all environmental indicators, followed by ballast water discharge, while other ship waste showed weaker or less consistent effects.` The models demonstrated strong explanatory power, with R^2 values ranging from 0.57 to 0.62, and F-statistics significant at $p < 0.01$, confirming overall model adequacy. Oil spills were identified as the strongest predictor of environmental degradation, contributing significantly to water contamination and biodiversity loss in Nigeria.

Oil spills emerged as the most significant predictor across all three models, exhibiting strong positive and statistically significant relationships with water contamination, biodiversity loss, and health impact. This underscores the critical environmental and health risks associated with oil spill incidents in the Nigeria coastal ecosystem. This result agrees with the works (Bight 2015).

Beyond oil spillage, ballast water discharge has also been empirically linked to coastal pollution. The findings revealed that high concentrations of heavy metals and hydrocarbons were introduced into the water column through ballast discharge, disrupting marine life and contributing to long-term sediment contamination. The findings of the study align with the works of (Idowu and Itebu 2019).

5.2 .2 Effect of Tanker Ship Transport on Biodiversity Loss

The study found that Oil spills has significant effect on biodiversity loss (t = 9.437 at p0.000<0.05); ballast water discharge has insignificant effect on biodiversity loss (t = 0.129 at p0.898 > 0.05); other ship waste has insignificant effect on biodiversity loss (t = 2.000 at p0.059>0.05). the result aligns with the result of (David et al 2024),

These findings collectively affirm the theoretical postulates of Environmental Externality Theory, which argues that unregulated industrial activities such as maritime transportation generate negative spillovers affecting ecological and human systems. Ballast water discharge exhibited a statistically significant impact on environmental outcomes, implying that untreated discharges contribute to ecological imbalance and pollution. Also, ballast water discharges were found to have statistically significant positive effects on all dependent variables, indicating their role in contributing to water quality degradation and potential ecological disturbances, including the introduction of non-native species and pathogens. Other Ship waste showed weak and statistically insignificant effects across the three models, suggesting that while waste discharges may pose localized challenges, their overall contribution to long-term environmental degradation is comparatively lower than oil and ballast discharges. These findings agree with the works of (Anyanwu et al 2023; Ekpo et al. 2018; Nwankwo and Akinsoji 2021; Asuquo et al. 2012).

5.2 .3 Effect of Tanker Ship Transport on Health Impact

With respect to the effect of tanker ship transport on health impact, the study found that Oil spills has significant effect on health impact (t = 3.917 at p0.001<0.05); ballast water discharge has significant effect on health impact (t = 2.916 at p0.008< 0.05); other ship waste has insignificant effect on health impact In Nigeria (t = -0.221 at p0.828>0.05). Although ship waste showed a weaker and statistically insignificant influence, the observed positive coefficients imply potential localized contamination effects. This aligns with findings of Gollasch et al. (2015).

The high R^2 values and significant F-statistics demonstrate that the explanatory variables jointly account for substantial variations in environmental and health impacts, reinforcing the conceptual model's adequacy. The absence of serious multicollinearity or heteroscedasticity further validates the robustness of the estimated relationships. Result also demonstrated robust explanatory capacities with R^2 values ranging from 0.57 to 0.62, signifying that more than half of the observed variations in environmental and health impacts can be attributed to the combined effects of the tanker ship transportation variables.

Diagnostic tests, including the Jarque–Bera normality test, VIF for multicollinearity, Breusch–Pagan test for homoscedasticity, and F-statistics for overall fit confirmed that the OLS assumptions were satisfied, lending credibility to the regression outcomes and interpretations. Empirical studies have increasingly confirmed the link between pollution from tanker ship operations and adverse health outcomes in Nigeria coastal settlements. These effects manifest through multiple exposure pathways, primarily including contaminated water sources, air pollution, and food chain disruption resulting from hydrocarbon spills, ballast water discharge, and sewage or plastic waste emissions. Result agrees with the results of (Ofoegbu and Akuezuilo 2019; Ogamba and Briggs, 2020; Rochman et al., 2015; Asuquo et al. 2012; Ogidi et al. 2022)

CONCLUSION

Based on the findings, the study concludes that tanker ship transportation contributes significantly to the deterioration of coastal environmental quality in Nigeria. Specifically, oil spills and ballast water discharges are the most critical drivers of water contamination, ecosystem disruption, and adverse public health impacts. The study concluded that oil spills have significant effect on water contamination, biodiversity loss, and health impact. Also, ballast water discharge has no significant effect on water contamination and biodiversity loss, but has significant effect on health impact. Other ship waste has significant effect on water contamination and no significant effect on biodiversity loss and health impact in Nigeria.

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