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Developing Effective Framework for Managing Ballast Water Contaminants from Ships on Ballast Voyages from Europe to Nigerian Seaports

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Abstract

The study investigated the invasive qualities of ballast water samples from ships on ballast voyages from European sea regions into Nigeria seaport with a view to developing a sustainable framework for ballast water management in Nigeria seaports in line with the standards of the International Maritime Organization. The objectives of the study was among other things to compare the ballast water samples from ships on ballast voyages from European sea regions to Nigeria, with samples taken from local waters in Nigeria seaports. The study used experimental research design in which ballast water samples from ships on ballast voyages from European sea region as well as samples from local waters in Nigeria seaports were collected subjected to laboratory test/experiment to determine the level of invasive species, metallic ions, PH, conductivity, hardness, acidity, among many other qualities. Primary data was collected from the experiment. The difference of means statistical method implemented with the use of SSPS statistical software was used to analyze the data obtained. It was found that the ballast water samples from local Nigeria waters have significantly higher phytoplankton content than the ballast water samples from ships on ballast voyages from European region; the ballast water sample from the European sea region have significantly higher content of algae, amoeba triphobiotes and other non-chlorophyll rich invasive species than the local ballast water sample from Nigeria. Phytoplankton has a t-score of 48.568 of and of p-value 0.000, which indicates that there exists significant difference in concentration of phytoplankton between ballast waters samples collected from the two regions. Triphyboites of amoeba has t-score of 10.333 and p-value of 0.002; indicating the existence of significant difference between the concentration of triphyboites of amoeba in waters of European and Nigeria sea regions. The test indicates that the turbidity, conductivity, hardness and total dissolved solids (TDS) of ballast waters samples from European sea region are significantly higher than that of the local sample from the Nigerian waters. Moreover, the study shows that the there is significant difference between the acidity and alkalinity (chemical properties) of the European region and local ballast water samples used in the study. A framework for effective ballast water management in Nigeria seaports was developed based on the findings of the study.

Keywords: *ballast, water, management, framework, seaports, Nigeria.*

1.0 Introduction

The daily movement of ballast water based dangerous pathogens and invasive microorganisms are a major hazard for marine biodiversity and coastal environment. About 2,000 aquatic non-indigenous species are known to have been introduced world – wide, of which in minimum 850 are through to have been introduced by ships through ballast water operations. This has negative impacts on Impact on Biodiversity: predation on native communities, alternation of habitat structure and re-organization of the trophic web, importation of diseases and disease agents, alternation of the genome. It equally has economic consequences as it negatively impacts on aquaculture production, fisheries resources, fouling of abstraction piping on ships with deleterious effects on recreational resources. The discharge of ballast water into the local waters without treatment and proper management also carries the danger of contamination of the local water with harmful pollutants altering the physical and chemical properties of water bodies which could lead to food shortages, infections and diseases, and influx of invasive species. The identified dangers motivated the development of

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the ballast water management system in seaports, yet the approach to the implementation of the provisions of the Ballast Water Management (BWM) regulations in Nigeria seem inadequate and totally unacceptable as foreign vessels visiting Nigeria ports on ballast voyage have being accused of unregulated dumping of ballast water within the port environs and territorial waters following the dilapidation and/or total lack of ballast water treatment and infrastructure in most ports in Nigeria. This suggest that the port authorities and maritime safety administration agencies tend to imply that there is no need and/or evidence to enforce in totally the ballast water management regulations on foreign ships visiting Nigeria ports, thus the adaptation to the seeming unregulated discharge of ballast water from foreign ships into the local marine ecosystem without consequences. This is evident in the ship arrest records maintained in the data base of the Abuja Memorandum of Understanding for Port States Control (Abuja MOU) which for the past five years (2016-2020), has 53 vessels arrested for contravening the provisions of safety of life at sea (SOLAS), Regulations for the prevention of Marine pollution from Ships (MARPOL 73/78), the Load-lines (LL) conventions, etc., but non detailed for the fragrant discharges of ballast water into the marine ecosystem in without treatment in violation of the provisions of BWM convention 2004 as amended.

In line with the provision of the BWM conventions, the chemical, physical, biological properties of ballast water samples and the concentration of major identified contaminants/sediments in ballast water samples from foreign ships on voyages from European waters to Nigerian seaports need to be determined and samples property treated before it can be safely discharged into the local waters. The lack of capacity and inadequate infrastructure is believed to have made the port authorities complacent in the drive to wholly and effectively implement the provisions of the BWM convention. Moreover, whereas many regional ports of the World have developed empirical evidences to support the implementation of ballast management strategies in their local ports by comparing the selected physical, chemical and biological properties of ballast water samples from various regions and their local samples as well as the concentration of various contaminants in ballast water samples compared to that of the waters of their regions as basis for determining most safe methods of management and discharge of ship-based ballast water in the port.

There is currently no empirical evidence available in literature to suggest that the Nigeria ports have compared the concentrations of identified contaminants/pollutants, chemical properties, physical and biological features of ballast water samples from Nigeria and foreign vessels on ballast voyages from European waters to Nigerian waters as basis for the development of empirical evidences and support for the decision on the choice of most safe and appropriate ballast water treatment and management strategies in Nigerian seaports, in line with the provisions of the IMO's BWM system. This gap is knowledge identified above is the problem which the current study aims to address.

The use of mechanical, physical, chemical and biological processes, either singularly or in combination, to remove, render harmless, or avoid the uptake or discharge of harmful aquatic organisms and pathogen is called ballast water management. Ballast water management prevent minimize and ultimately eliminate risks to the environment, human health property and resources which arise from the transfer of harmful aquatic organisms an pathogens via ships ballast waters and related sediments. The assessment study on ballast water management and the consequences in Nigerian ports is therefore important and significant because it will inform maritime officers on the need to protect the marine body from harmful effect environment pollution.

Considering the unprecedented changes that have affected the socio-cultural and economy of Nigerian, the findings of the study will assist the government on the need to protect the region from collapse caused by ballast water particularly invasive species as preserve the regions cultural occupation of fishing and farming for a healthy environment. This will help the Nigeria Maritime administration and Safety Agency (NIMASA) and the Nigeria Ports Authority (NPA) in developing policies for effective and sustainable management of ballast water discharges from ships on ballast voyages from European sea regions to Nigeria.

2.0 Empirical Review

Adesola, Ohimain and Inyang (2016) did a preliminary review on ballast water and legal framework for ballast water processes in Nigeria. The study was aimed at establishing a standard for ballast water regulation on Nigeria seaports in line with the provision of the Internal Maritime Organization's ballast water management regulations (Adesola, Ohimain and Inyang, 2016). The study use exploratory survey method to determine the existence of invasive species, sediments, biofilms, and traces of heavy metals in ship ballast waters. It recommends the development of ballast water management policy in Nigeria seaports in line with the IMO regulations (Adesola, Ohimain and Inyang, 2016).

Inah and Abua (2019) carried out a study on the Implementation of Ballast Water Management Control in Calabar River, Nigerian Port Authority, Cross River State – Nigeria. The aim of the study was to examine the implementation of ballast water treatment control policies in Calabar Port, Cross River State, Nigeria (Inah and Abua (2019). The study used primary data sourced through survey in which questionnaire was used as the survey instrument. Descriptive and inferential statistics were used to analyze the data and the results revealed that among the 10 strategies provided for ballast water treatment and management in the seaport; only six strategies were being fully implemented by the Nigeria Ports Authority. The findings of the study thus indicate that the authorities in Calabar port are not adhering fully to the IMO provisions and standards for ballast water treatment and management in the seaport(Inah and Abua (2019). The study recommended that effective measures be deployed to enhance effective implementation of all the 10

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strategies for ballast water treatment and management in line with international standards(Inah and Abua (2019).

In a similar but different study, Nwigwe and Kiyokazu (2022) did a study on the Challenges hindering the ballast water management compliance in Nigeria. The study established that the problem of invasive species transfer through ship's ballast water has resulted in the mandatory International Maritime Organization (IMO D-2 standards for existing vessel to installation ballast water treatment system (BWTS) onboard for compliance with the schedule deadline of 8 September 2024 (Nwigwe and Kiyokazu, 2022). It however observed that, many ship owners are still not able to comply with the regulation due to the presence of several challenges. Hence, the aim of the study was to evaluate the challenges hindering the Ballast Water Management System (BWMS) compliance of shipping operators in Nigeria from installation of BWTSs. It used the expert interview and industry review methods to determine that, technical challenges (TCs), environmental challenges (ENCs), economic challenges (ECCs), and other challenges (OCs) were identified as the major challenges responsible for the non-compliance among the Nigerian shipping companies(Nwigwe and Kiyokazu, 2022). The study used Analytical Hierarchy Process for evaluating and ranking the various challenges, and the results obtained indicate that OCs, which include external and internal influences on ship operators, ship type, age, and trading route, obtained the highest rank (0.3666), followed by ECCs (0.3648) and TCs obtaining the third rank (0.1456). ENCs were regarded as the least concern (0.1223) for shipping operators in the region in their decision to comply with the BWMS by installing BWTS onboard their ship (Nwigwe and Kiyokazu, 2022).

Bailey, (2015) carried out a study in title 'An overview of thirty years of research on ballast water as a vector for aquatic invasive species to freshwater and marine environments'. The study investigated the propensity of ballast water from ships on ballast voyages from varied sea regions in the World. The aim of the study was to determine major invasive species and concentration of determinant invasive species types (Bailey, 2015). The findings of the study reveal that there are disproportionate concentrations of various invasive species types in different sea regions of the World such that each sea region is unique in the type of invasive species types it breeds. This implies that ballasting and de-ballasting operations could lead to the transfer of dangerous invasive species from one sea region to another (Bailey, 2015).

Lastly, Endresen, Behrens, Brynestad, Andersen, & Skjong (2004) did a study on the Challenges in global ballast water management. The aim of the study was to identify among other things, what constitute the major challenges to ballast water treatment and management in line with IMO regulations and standards (Enderson et al, 2004).. The study used secondary data obtained from survey. The findings of the study indicates that the lack and/or inadequacy of port infrastructural facilities for ballast water management and treatment among other factors constitute a major challenge to effective data water treatment and management in seaports (Enderson et al, 2004).

3.0 Data and methods

3.1 Description of the Study Area

The study is aimed at determining how ballast water discharges into the Nigeria coastal waters and marine ecosystem influence the introduction of an increase in invasive species into the Nigeria marine ecosystem by comparing ballast waters samples drawn from European sea regions and the waters of Nigeria. It also seeks to develop a framework for developing a ballast waters management policy for vessels on ballast voyages from sea regions in European waters to Nigeria seaports. Therefore, the while the Nigeria maritime environment, constitute the key study area, ballast water samples were collected from vessels on ballast voyages into Nigeria seaports from North America; for experimental purposes. Samples of foreign ballast water were taking from various foreign ships on ballast voyages from Europe. The foreign ballast water was taken from ships on ballast voyages from European sea region, particularly from the Spain. The local ballast water samples were taking from the Lagos Apapa seaport environment and Onne seaport which are the ports that berth significant portion of vessels on ballast voyages from European sea region. Therefore the study area of the research is the Nigeria marine ecosystem but in comparison ballast water samples taken from foreign waters/ships (European waters) that call to seaports in Nigeria.

3.2 Research Design

The study adopted experimental research design approach in which samples of ballast water from both the waters of Onne seaport and Apapa port Lagos (local Nigeria waters) which constitute the major seaports that handle significant number of the ships on ballast voyages that calls to Nigeria. All sample of ballast water taken from both Nigeria and European sea regions were taken to the laboratory to determine the content and concentration of various contaminants and ions as well as the characteristic properties which influence the optimum performance of marine life and biodiversity in the Nigeria marine ecosystem. Also the concentration of aquatic species in the collected local and foreign ballast water samples as well as the physical and chemical properties of the ballast water samples were determined and compared.

3.3 Sources of Data

This research relied entirely upon primary sources of data for the study. Primary data constitute of data generated from primary means experiments, survey, interviews, etc. Since the study adopted an experimental design method, primary data were generated from the results of the various experiments conducted at Springboard Research Laboratories, Awka, Anambra state, Nigeria, using samples of ballast water drawn from vessels on ballast voyages from Europen sea region, as earlier identified, and the local waters as aforementioned. Electrical conductivity test, turbidity test, Atomic Analysis Spectrophotometer (AAS) water analysis test, PH test, Harness test, and test of the concentration of various ions and contaminants that affect optimum living of various aquatic

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lives in the Nigeria marine ecosystem were carried out while the results were recorded as primary data sourced for the research. For the local samples, ballast water samples were collected from both Onne seaport environment and Apapa seaport and analyzed for significant difference. It was determined that no significant difference in properties exist between the two local ballast waters samples. The study thus proceeded to use the sample collected from Onne as representative from Nigeria waters. To limit the effects of error, each experiment and/or test was carried out four times and an average value determined for each parameter tested in each ballast water sample. The procedures and methods adopted for test are further discussed below:

3.3.1 Water Analysis Using Agilent Atomic Absorption Spectroscope (AAS)

The purpose of the water analysis using the AAS technology is to identify and determine the various concentrations of elements and ions in the samples of local ballast water from Nigeria seaports and foreign ballast water samples collected from vessels on ballast voyages from European sea regions. Since continuous uncontrolled discharge of ballast water with the presence and concentrations of these contaminants, invasive species and ions may affect and/or alter the environmental and living conditions, as well as the optimum performance of local marine organisms in Nigerian marine ecosystem; thus the need for the treatment, control and management of ballast water discharge into the Nigeria marine ecosystem by foreign vessels on ballast voyage to Nigerian ports. Atomic absorption spectrophotometer was put on and the flare lot up on the burner with acetylene as fuel and compressed air as oxidant at the appropriate rates of flow. Standard solutions of each of the ballast water samples containing the contaminants/elements under investigation were aspirated into the nebulizer- burner assembly via a capillary tube and the absorbance readings were taken from the direct readout of the atomic absorption spectrophotometer. This was immediately followed by aspirating the sample solutions into the nebulizer – burner assembly via a capillary tube and the absorbance readings also obtained from the digital readout of the instrument. The hollow – cathode lamp of the analytic elements (i.e. contaminants contained in each sample of ballast water in the solution under investigation) was used at the wavelength of the element. This was repeated for each element in turn using its hollow cathode lamp and at the wavelength of the element. Each test was conducted four times as aforementioned to limit the occurrence of error.

The concentrations of each of the identified contaminant elements in the local sample from Nigeria waters and foreign ballast water samples from Europe under investigation were obtained by extrapolation from the standard curve. The units of measurement are the milligram per liter (mg/l).

3.3.2 LABTECH PH Meter Experiment to Determine the PH: Acidity and Alkalinity level of the Foreign and Local ballast Water Samples

The determination of the level of acidity and alkalinity of the two ballast water samples became necessary as a result of the fact that the optimum growth, performance and ability of some species of marine biodiversity to survive in their environment may be affected by the level of acidity and/or alkalinity of the water bodies. Thus species that may thrive optimally in low acidic waters may not survive high alkaline water of even high acidic water regions. The acidity and alkalinity (PH level) of each sample of ballast water was determined using LABTECH PH meter. The PH meter was calibrated using standard buffers of PH4, PH 7 and PH 10. The electrode of the PH meter was dipped into each of the standard buffers in turn and rinsed with distilled water, cleared with a soft tissue before dipping into the next one. The temperature compensator was set at the appropriate temperature before the calibration. After the calibration, the electrode was rinsed and cleaned with a soft tissue.

The PH of the samples were measured by dipping the electrode into each of the samples in turn and rising the electrode with distilled water before dipping it into the next sample. The temperature knob was set at the temperature of each of the samples and the PH reading was obtained from the digital readout.

3.3.3 Experiment to Determine the Conductivity of the Water Samples

The electrical conductivity of a water sample is a measure of it capacity to conduct electricity. This property also provides evidence of the quantum of dissolved salts/ions present in the water sample as pollutants. Thus, a water sample with higher conductivity properties indicates the presence of higher concentrations of dissolved salts, ions and or pollutants which when introduced in higher concentrations into a less polluted or ions reach water sample, could alter the environmental, living conditions, performance and survival of marine species in the host water body/region. In this study, the conductivity measurement was carried out using HANNA EC 215 conductivity meter. The conductivity meter was calibrated with a standard 0.01m KCL solution having a conductivity of 1413 μS/cm. The conductivity cell was rinsed with deionized water and cleansed with a soft tissue. The conductivity of the samples was determined by dipping the cell into each of the samples in turn and rinsing the cell with deionized water. The conductivity readings were obtained from the digital readout.

3.3.4 Experimental Determination of Total Hardness of the Ballast Water Samples

25ml of each of the water samples was pipetted into a 100ml conical flask. 1ml of the ammonium chloride buffer of PH 10 was added to the water sample. Three (3) drops of Eriochrome black – T indicator was added to the conical flask, the colour of the solution turned wine red. The water solution was titrated with 0.01m EDTA solution using a micro burette. The colour of the solution changed from wine red to blue at the end point. Total hardness, mg $CaCO_3/l$ $[mg/l(as\ CaCO_3)]$

$$= \frac{\text{Vol. EDTA}\ (titre) \times M_{EDTA} \times 100 \times 1000}{Vol. of\ smaple}$$

3.3.5 Experimental Determination of the Turbidity of the Ballast Water Samples

Turbidity is the amount of cloudiness of the water samples. High turbidity indicates the presence of dissolved silt, mud, salt, bacteria, algae, germs, contaminants and other forms of precipitate and invasive species which makes water samples appear cloudy and non-transparent. Thus the measurement of turbidity indicates the presence of higher concentration of dissolved pollutants and possibly invasive species. Turbidity was determined using WGZ-1B Turbidity by Xinrui instruments and meters Co. Ltd. Shanghai China. 15ml of deionized sample of each of the ballast water types was poured into the sample cell as blank. The blank was used to zero the turbidimeter. The turbidimeter was calibrated with a formazine standard turbidity solution of 10 Normal Turbidity Units (NTU) diluted from a stock standard solution of 400 NTU.

15ml of the standard turbidity solution was poured into another cell of the same thickness until a reading of 10NTU was obtained on the digital readout. 15ml of the sample was poured into another cell after being shaken vigorously. The sample cell containing the sample was put into the light shield and closed after the blank was removed and the read button was pressed. The value was then digitally displayed in NTU.

3.3.6 Experimental Determination of the Concentration of CHLORIDE ions (CL^-) in the Ballast Water Samples

25ml of each of the ballast water samples was pipetted into a 100ml conical flask. 1ml of potassium chromated indicator was added to the water sample. The solution in the conical flask was titrated with 0.02m silver nitrate to a reddish brown end point using a micro burette. A blank titration was done as above using deionized water. The experiment was conduct four times as aforementioned to obtain an averagely accurate reading. The Chloride ion content Chloride was determined in milligrams per liter as (mg/l) using Cl^- (mg/l) =

$$= \frac{(Sample\ titre - Blank\ titre) \times 0.02m \times 35.5 \times 1000}{Vol.of\ sample}$$

3.3.7 Experimental Determination of the Concentration of NITRATE ions (NO_3^-) of the Ballast Water Samples

To each of 10ml of ballast water samples containing standard nitrate solution of different concentrations were added 10ml of (13m) H_2SO_4 and swirled. The beakers containing the solutions were allowed to reach thermal equilibrium inside a cold water bath prior to heating. To each of the beakers was added 0.5ml of brucine-sulphahilic acid reagent, swirled properly to mix and placed in 100^oC water bath for 25 minutes. After heating, the beakers were removed from the hot water bath, immersed in a cold water bath and allowed to reach thermal equilibrium and hence analyzed with spectrophotometer and the absorbance read at 410mm wavelength. The samples and blank were treated in the same manner.

3.3.8 Experimental Procedure for the Determination of the Content/Concentration of Algae, phytoplankton and other invasive species in the Water samples Collected.

Empirical literatures provide evidences that Algal blooms can produce toxic effects on the ecosystem and cause significant environmental damage to marine organisms. Providing knowledge and understanding on the existence and concentrations of Algae, phytoplankton, and other invasive marine species in water ballast water samples from different regions and quantifying algal blooms is necessary in differentiating ballast waters management strategies in the regions and how unsafe management of ballast water from regions with high concentration of invasive species can affect the local marine ecosystem and biodiversity. The study used CCM-200 Chlorophyll Meter method developed by the USA Environmental Protection Agency (EPA) to determine the concentrations of Algae, phytoplankton and other invasive species to determine the concentrations of each of the identified marine species in the ballast water samples collected from local and foreign sea regions as explained. The collected ballast water samples containing, Algal, phytoplankton and other invasive species are measured on filter paper with the CCM-200 Plus Chlorophyll-a (Chl-a) Meter. The Chl-a is a photosynthetic pigment and by measuring it, knowledge and understanding is provided on the dynamics and concentrations of algal and phytoplankton blooms in each sample. The water samples were then sieved through filter paper on which the chlorophyll measurements were made. The concentration of other non-chlorophyll reach species representing forms of invasive species was also determined by adapting the same method. Each water samples was tested four times for each parameter to generate a more accurate measurement and limit the occurrence of error.

3.5 Method of Data Analysis

The data collected was analyzed using the different of means test to estimate the existence of significant differences between foreign ballast water sample collected from European sea regions and local ballast water sample collected from Nigeria, with regards to each parameter tested as described above. For example, different readings of the concentrations of contaminants, invasive species, Algae and phytoplankton in each of the local and foreign ballast water samples were compared using the different of means statistical tool.

Similarly, different readings collected from each ballast water samples on the various tests and parameters of interest such as: Turbidity test, the hardness test, the conductivity test, the water analysis test using AAS, and the acidity test were analyzed using the difference of means statistical tool to compare and determine the existence of significant difference between the water samples.

For objective one (1), the results of the experimental test for the foreign ballast water samples and the local sample from Nigeria waters will be compared using the difference of means model. The corresponding hypotheses will be tested using the T-Test. The T-test assesses whether the means of the two groups are statistically, significantly different from each other.

The formula is given below:

Difference of mean $X_{diff} = \sqrt{\frac{\bar{x}_f - \bar{x}_l}{\frac{s_f^2}{n_f} + \frac{s_l^2}{n_l}}}$

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Where t= t-statistics results for the difference of means

$\bar{x}_f$ = mean of foreign ballast water sample from Europereading for each test parameter

$\bar{x}_l$ = Mean of local ballast water sample from Nigeria waters reading for each test parameter

S_f^2 = Variance of individual parameter readings for foreign ballast water samples

S_l^2 = Variance of parameter estimates for local ballast water samples collected operators.

n_f = n_l = = N = Samples sizes

An independent sample T-test may equally be used to estimate the significances of the differences in the readings from the foreign ballast water samples from European sea regions, and the local ballast water sample from Nigeria. The formula for the T-Test is shown below:

$$T=\frac{XT-XC}{\sqrt{\frac{VarT}{NT}+\frac{Varc}{Nc}}}$$

4.0 Results and Discussion of Findings

Table1 Difference in the Means of the Concentration of Algae, phytoplankton and other invasive species in the Ballast Water Samples from European Sea Region and Nigeria Waters

	Mean	N	Std. Deviation	Std. Error Mean
PHYFOREIGN	10.0000	4	.81650	.40825
PHYLOCAL	48.0000	4	1.41421	.70711
ALGAEFOREIG	49.7500	4	1.25831	.62915
ALGAELOCAL	46.500	4	.57735	28868
AMEBAFOREIG	14.7500	4	.50000	.25000
AMOEBALOCAL	10.2500	4	.95743	.4781
OTHERINVASIVESFOREIG	20.0000	4	1.41421	.70711
OTHERINVASIVESLOCAL	7.7500	4	1.25831	.62915

	Mean Differences			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower
PHYFOREIGN - PHYLOCAL	-38.00000	.81650	.40825	-39.29923
ALGAEFOREIGN - ALGAELOCA	3.25000	1.70783	.85391	.53247
AMEBAFOREIGN - AMEBALOCA	4.50000	.57735	.28868	3.58131
OTHERSFOREIGN - OTHERSLOCAL	12.25000	.50000	.25000	11.45439

Source: Authors Calculation

The result of the analysis on table-1 indicates that the mean algae content of in the ballast water sample from the Europe sea region is 49.7500/ml with a standard deviation of 1.2531 while the mean content of algae in the local ballast water sample from Nigerian waters is 46.50/milliliter with standard deviation of 0.577. The difference of means between the algae content in the ballast water sample from ships on ballast voyages from European waters and local (Nigeria) ballast water types is 3.2500/milliliter with standard deviation of 1.70783 and standard error of 0.85391. The implication is that the ballast water sample from ships on ballast voyages from European waters has about 3.2500/milliliter higher than the algae content of the local ballast water sample collected from Nigeria waters.

This implies that the ballast water samples collected from ships on ballast voyages from European sea region has the propensity to introduce into the local waters, more variants of algae species; when introduced into the Nigeria local waters without treatment, thus providing evidential support for the development and implementation ballast water treatment and management policies in Nigeria seaport, in line with the IMO's ballast water management regulations.

The mean phytoplankton content per milliliter of ballast water sample from European sea region collected from ships on ballast voyages from that region is 10.0000/ml with standard deviation of 0.81650 while the mean phytoplankton content of the local ballast water sample collected from Nigeria is 48.0000/ml with standard deviation of 1.41421. The difference in the means of the two ballast water samples is 38.00000 per milliliter with a standard deviation of 0.81650 in favour of the local ballast water sample from the Nigerian waters. It therefore implies that the local ballast water samples from the Nigerian waters has higher phytoplankton content than the ballast water samples collected from European sea region, thus informing further on the needs for serious implementation of the ballast water management and treatment strategies for all the ships seeking to de-ballast in the Nigeria maritime environment.

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The result of the analysis further reveal that the ballast water samples from ships on ballast voyages from Europe has a mean content of 14.7500/ml triphyboites of amoeba with standard deviation of 0.50000 while the local ballast water sample from Nigeria waters has a mean content of 10.2500/ml triphyboites of amoeba with standard deviation of 0.95743. The mean difference between the amoeba specie content of the ballast water samples from the European sea region and Nigerian waters is 4.50000/ml with standard deviation of 0.57735. The result shows that the ballast water samples from the European sea region collected from ships on ballast voyages from Europe has higher content of amoeba invasive species than the local sample of ballast water from the Nigerian waters. The significance of the difference with is determined in section 4.3 under the test of hypotheses.

Similarly, while the content of other non-chlorophyll rich invasive species in the ballast water samples from European waters shows a mean of 20.0000/ml with standard deviation of 1.41421, the mean content of other invasive species/types in the local ballast water sample is 7.7500/ml with standard deviation of 1.25831. The difference of means between the content of other invasive species types in the European and local samples of ballast water used in the study is 12.2500/ml with standard deviation of 0.5000. This indicates that the ballast water sample collected from the ships on ballast voyages from European waters has far higher content of other non-chlorophyll rich invasive species types than the local ballast water sample. The indication is that the ballast water samples from European waters form a major source of invasive species into the Nigeria coastal waters and environment. This underscores the need for proactive development and implementation of ballast water treatment and management policies and strategies in Nigeria seaports

Table.2: Differences in the Turbidity, Conductivity, Hardness, PH, and Total Dissolved Solids (TDS) in the Ballast Water Samples from European and Nigeria Waters

Variable		Mean	N	Std. Deviation	Std. Error Mean
Turbidity	TURBIDITYLOCAL	10.4275	4	.01893	.00946
	TURBIDITYFOREIGN	12.1900	4	.00000	.00000
CONDUCTIVITY	CONDUCTIVITYFOR	72801.2500	4	1.89297	.94648
	CONDUCTIVITYLOCAL	35400.7500	4	1.50000	.75000
HARDNESS	HARDNESSFOR	6401.5000	4	.00000	.00000
	HARDNESSLOCAL	3140.0000	4		
ALKALINITY	ALKANLINITYLOCAL	1000.0750	4	.09574	.04787
	ALKALINITYFPREIGN	600.1000	4	.14142	.07071
PH	PHFOREIGN	6.9400	4	.02828	.01414
	PHLOCAL	6.7225	4	.00957	.00479
TDS	TDSFOREIGN	33488.0000	4	.00000	.00000
	TDSLOCA	16284.5000	4	1.00000	.50000

		Mean Differences			
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference
					Lower
TURBIDITY	TURBIDITYFOR - TURBIDITYLOCAL	1.76250	.01893	.00946	1.79262
CONDUCTIVITY	CONDUCTIVITYFOR - CONDUCTIVITYLOCAL	37400.50000	.57735	.28868	37399.58131
HARDNESS	HARDNESSFOR - HARDNESSLOCAL	3261.50000	1.00000	.50000	3259.90878
ALKALINITY	ALKANLINITYFOREIGN - ALKALINITYLOCAL	-399.97500	.12583	.06292	399.77478

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PH	PHFOREIGN - PHLOCAL	.21750	.03202	.01601	.16656
TDS	TDSFOREIGN - TDSLOCAL	17203.50000	1.00000	.50000	17201.90878

Source: Authors Calculation.

The result of the analysis on table2 indicates that the respective mean turbidity of the of the ballast water samples collected from Nigeria and European sea regions used in the study is 10.4275 NTU and 12.1900NTU with standard deviations of 0.01893 and 0.000 respectively. The difference in the turbidity in the two ballast water samples is 1.76250 with standard deviation of 0.01893, indicating that the ballast water sample from vessels on ballast voyages from European waters has an average of 1.76250 higher turbidity than the local ballast water sample from Nigeria waters. This implies that the ballast water sample from European sea region has higher concentration and contents of dissolved contaminants and invasive species.

Similarly, the conductivity of the test carried out indicates a mean conductivity of 72801.2500 microsiemens per centimeter (µS/cm) with standard deviation of 1.89297 for the ballast water sample from European waters, while the mean conductivity of the local ballast water sample from Nigeria is 35400.7500µS/cm with standard deviation of 1.5000. The difference of means result shows a mean difference of 37400.50000µS/cm with standard deviation of 0.57735. This provides evidence that the ballast water samples collected from ships on ballast voyages from European waters has higher conductivity than that of the local ballast water sample. Since conductivity has relationship with the salt content and/or quantum of ions in solution of the water samples, this result further supports the fact provided above that the ballast sample from European waters has higher content of contaminants and invasive species, and thus higher conductivity. Thus implies than the ballast water sample from European sea region form a source of contaminants and invasive species for the local waters of Nigeria.

The ballast water sample from European waters has a mean hardness of 6401.5000miligrams per liter (mg/l) with standard deviation of 0.00 while the local ballast water sample has a mean hardness of 3140.0000. The difference in hardness between the ballast water sample from European waters and local Nigeria waters shows a mean difference of 3261.50000mg/l with standard deviation of 1.0000. This implies that the hardness of the ballast water sample from European sea region is higher than that of the local ballast water sample from Nigeria by an average of 3261.500mg/l. The implication is that the ballast water sample from the European sea region contains higher amounts of carbonate contaminants than the local ballast water samples from Nigeria waters.

In a similar manner, the respective mean alkalinity of the ballast water samples from European waters and local Nigeria waters is 1000.0750mg/l and 600.100mg/l with respective standard deviations of 0.09574 and 0.14142. The average difference in the alkalinity in the two ballast water samples is 399.97500mg/l with standard deviation of 12583, implying that the local ballast water sample from Nigeria has a high alkalinity than the foreign ballast water sample used in the study.

The mean acidity (PH) of the ballast water samples is 6.9400 and 6.7225 respectively for the European and local Nigeria sea regions with respective standard deviations of 0.02828 and 0.009828. The average difference in the acidity (PH) between the ballast water samples from European waters and Nigeria is 0.21750 with standard deviation of 0.03202. This indicates that the ballast water sample from European sea region has average acidity of 0.21750 higher than the acidity level of the local ballast water from the Nigeria waters. This underscores the need for management, treatment and control of the discharge of ballast waters from vessels on ballast voyages from European waters into Nigeria territorial waters.

The mean total dissolved solids (TDS) is the ballast waters samples from Europe and local Nigeria waters is 33488.0000mg/l and 16284.5000mg/l respectively with respective standard deviations of 0.00 and 1.00000. The average difference in the TDS of the ballast water sample types is 17203.50000mg/l with standard deviation of 1.000. The indication is that the ballast water sample from European sea region also has higher content of TDS than the local ballast water sample from Nigeria. The European ballast water sample has an average of 17203.500mg/l TDS higher than the local ballast water sample form the Nigeria waters.

Table3: Differences in the Concentration of Identified Contaminants in Ballast Water Samples Collected from European and Nigeria Sea Regions

Variable		Mean	N	Std. Deviation	Std. Error Mean
Nitrate ion	NITRATEFOREIGN	.5925	4	.00500	.00250
	NITRATELOCAL	1.1250	4	.05000	.02500
Chloride ion	CHLORIDEFOR	21229.5000	4	.57735	.28868
	CHLORIDELOCAL	9656.0000	4	.81650	.40825

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Mercury	MERCURYFOREIN MERCURYLOCAL	.0570 .0408	4 4	.00082 .00096	.00041 .00048
Aluminum	ALUMINIUMFOREIGN ALUMINIUMLOCAL	.0238 0.0040	4 4	.02488 .00183	.01244 .00091
Copper	COPPERFOREIGN - COPPERLOCAL	.0350 .0450	2 2	.00707 .00707	.00500 .00500
Calcium	CALCIUMFOREIGN - CALCIUMLOCAL	17.8925 16.4825	4 4	.00500 .00500	.00250 .00250
Iron	IRONFOREIGN - IRONLOCAL	.1060 .1040	4 4	.00577 .00082	.00289 .00041
Magnesium	MAGNESIUMFOR MAGNESIUMLOC	7.0345 7.9325	4 4	.00640 .00500	.00320 .00250
Manganese	MANGANESEFOR MANGANESELOC	.9800 .9850	4 4	.00816 .00577	.00408 .00289
Selenium	SELENIUMFOR SELENIUMLOCAL	.0370 .0290	4 4	.00082 .00082	.00041 .00041
Zinc	ZINCFOREIGN - ZINCLOCAL	.1290 .2500	4 4	.00082 .05774	.02887
Chromium	CHROMIUMFOR CHROMIUMLOC	.0125 .0875	4 4	.00500 .00500	.00250 .00250

Mean differences

		Mean Differences			
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference
					Lower
Nitrate ion	NITRATEFOREIGN - NITRATELOCAL	-.53250	.04500	.02250	-.60411
Chloride	CHLORIDEFOR - CHLORIDELOCAL	11573.50000	1.29099	.64550	11571.44574
Mercury	MERCURYFOREING - MERCURYLOCAL	.01625	.00171	.00085	.01353
Aluminum	ALUMINIUMFOREIGN - ALUMINIUMLOCAL	.01975	.02654	.01327	-.02248
Copper	COPPERFOREIGN - COPPERLOCAL	-.01000	.01414	.01000	-.13706
Calcium	CALCIUMFOREIGN - CALCIUMLOCAL	1.41000	.00816	.00408	1.39701
Iron	IRONFOREIGN - IRONLOCAL	.00200	.00523	.00261	-.00632
Magnesium	MAGNESIUMFOR - MAGNESIUMLOC	-.89800	.00542	.00271	-.90662

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Manganese	MANGANESEFOR - MANGANESELOC	-.00500	.01000	.00500	-.02091
Selenium	SELENIUMFOR - SELENIUMLOCAL	.00800	.00082	.00041	.00670
Zinc	ZINCFOREIGN - ZINCLOCAL	-.12100	.05832	.02916	-.21379
Chromium	CHROMIUMFOR - CHROMIUMLOC	-.07500	.00577	.00289	-.08419

Source: Authors Calculation

The result of the analysis as shown in table3 indicates that nitrate ions, chloride ions and mercury contaminants in the ballast water sample collected from ships on ballast voyages from European sea region has mean values of 0.5925mg/l, 21229.5000mg/l and 0.0570mg/l respectively with respective standard deviations of 0.00500, 0.57735 and 0.00082 while the local ballast water sample from Nigeria has respective mean contaminants of nitrate, chloride, and mercury of 1.1250mg/l, 9656.0000mg/l and .0408mg/l with respective standard deviations of 0.05000, 0.81650 and 0.00096. The differences between the average parts per million of nitrate, chloride and mercury contaminants of the ballast water samples from Europe and Nigeria waters are -0.53250mg/l, 11573.50000mg/l and 0.01625mg/l with respective standard deviations of 0.04500, 1.29099 and 0.00171. This indicates that while the ballast water sample from the European waters has higher parts per million contaminants of chloride and mercury, the local ballast water sample has an average of 0.53250 parts per million higher nitrate contaminants than the foreign ballast water sample used.

Similarly, the average parts per million contaminants of aluminum, copper and calcium in the ballast water sample from the European waters is 0.0238mg/l, 0.0350mg/l and 17.8925mg/l respectively with respective standard deviations of 0.02488, 0.00707 and 0.00500 while the average parts per million of aluminum, copper and calcium contaminants in the local ballast water sample from the Nigerian waters is 0.0040mg/l, 0.0450mg/l and 16.4825mg/l respectively with standard deviations of 0.00183, 0.00707 and 0.00500. The mean differences between the parts per million of each of aluminum, copper and calcium contaminants in the ballast water samples from European and local Nigeria waters are 0.01975mg/l, -0.01000mg/l and 1.41000mg/l respectively with respective standard deviations of 0.02654, 0.01414 and 0.00816. This also indicates that while the ballast water sample from ships on ballast voyages from Europe has higher parts per million contaminants of aluminum and calcium, the local ballast water sample from Nigerian waters has higher parts per million copper contaminants.

The ballast water sample from ships on ballast voyages from European waters has mean parts per million iron, magnesium and manganese contaminants of 0.1060mg/l, 7.0345mg/l and 0.9800mg/l respectively with respective standard deviations of 0.00577, 0.00640 and 0.00816 while the local ballast water sample has mean parts per million contaminants of 0.1040mg/l iron, 7.9325mg/l of magnesium and 0.9850mg/l of manganese with standard deviations of 0.00082, .00500 and 0.00577. The mean differences in the parts per million contaminants of iron, magnesium and manganese contaminants between the European and local ballast water samples are 0.00200mg/l, -0.89800mg/l and -0.00500mg/l with respective standard deviations of 0.00523, 0.00542 and 0.01000. The results shows that while the ballast water sample from ships on ballast voyages from European waters has an average of 0.00200mg/l contaminants of iron higher than the contaminants of iron in the local ballast water sample, the local ballast water sample has higher magnesium and manganese contaminants than the ballast water sample from European waters.

Lastly, the ballast water sample from ships on ballast voyages from European waters has mean parts per million of selenium, zinc and chromium contaminants of 0.370mg/l, 0.1290mg/l and 00125mg/l respectively with respective standard deviations of .00082, 0.00082, and 0.00500 while the local ballast water sample has mean parts per million contaminants of 0.0290mg/l selenium, 0.2500mg/l of zinc and 0.0875mg/l of chromium with standard deviations of 0.00082, .05774 and 0.00500. The mean differences in the parts per million contaminants of selenium, zinc and chromium contaminants between the ballast water samples from Europe and Nigeria waters are 0.00800mg/l, -0.12100mg/l and -0.07500mg/l with respective standard deviations of 0.00082, 0.05832 and 0.00577. The results indicates that while the ballast water sample from European waters has an average of 0.00800mg/l contaminants of selenium higher than the contaminants of selenium in the local ballast water sample, the local ballast water sample has higher parts per million contaminants of zinc and chromium than the ballast water sample from European waters. The significances of the differences in parts per million of each of the identified contaminants are determined in table4 below.

Table**4: Significances of the Difference in the Properties cum Concentrations of Invasive Species between Ballast Water Samples from European and Nigeria Sea Regions**

Aquatic species types	t	df	p-value

phytoplankton	PHYFOREIGN - PHYLOCAL	-93.081	3	.000
Algae	ALGAEFOREIGN - ALGAELOCA	3.806	3	.032
Amoeba triphobiotes	AMEBAFOREIGN - AMEBALOCA	15.588	3	.001
Other invasive species	OTHERSFOREIGN - OTHERSLOCAL	49.000	3	.000

Source: Authors calculation. Note; if p-value >0.05, accept $\mathbf{H_{0a}}$, otherwise, reject $\mathbf{H_{0a}}$

The hypothesis states that there is no significant difference between the concentration of invasive aquatic species in the ballast water samples from European and local Nigeria waters. The result of the test as shown in table4 indicates that for the respective of aquatic species of phytoplankton, algae, amoeba triphobiotes and other non-chlorophyll rich aquatic species identified in the water samples have respective t-statistics of 93.081, 3.806, 15.588 and 49.00 with respective p-values of 0.000, 0.032, 0.001 and 0.000. Since the respective p-values of each aquatic species type is less than 0.05 (p-value <0.05) at 3 degrees of freedom, we reject null hypothesis H_{0a} and conclude that there is significant difference between the concentration of invasive aquatic species in the ballast water samples from local and European waters. The directions of the differences indicates that while the local ballast water sample has significantly higher phytoplankton content than the ballast water sample from European waters, the ballast water sample from European waters has significantly higher content of algae, amoeba triphobiotes and other non-chlorophyll rich invasive species than the local ballast water sample from Nigeria.

Table5: Examining the Existence of Significant Difference between each of the Selected Physical Properties of the Ballast Water samples from European waters and Nigeria

		t	df	Sig. (p-value)
Parameter	Turbidityfor - Turbiditylocal	186.215	3	.000
Conductivity	Conductivityfor - Conductivitylocal	129559.132	3	.000
Hardness	Hardnessfor - Hardnesslocal	6523.000	3	.000
TDS	TDSforeign - TDSlocaL	34407.000	3	.000

Source: Authors Calculation

The test on table5 examines the existence of significant difference between each of selected physical properties of the ballast water samples from European waters and Nigeria used in the study. The selected physical properties of the ballast water samples as shown above include: turbidity, conductivity, hardness and total dissolved solids (TDS) in solution. The result of the analysis shows that the respective t-statistic for each of turbidity, conductivity, hardness and TDS is 186.215, 129559.132, 6523.00 and 34407.00 with respective p-values of 0.000, 0.000, 0.000 and 0.000. Since the p-values are each less than the alpha value (0.000<0.05), accept the alternate hypothesis that there is significant difference between the selected physical properties (turbidity, conductivity, hardness and TDS) of the ballast water samples from Europe and Nigeria waters. The test shows that the turbidity, conductivity, hardness and TDS of ballast water sample from Europe are significantly higher than that of the local sample from the Nigerian waters.

Table6: Examining the Existence of Significant Difference between the Selected Chemical Properties (acidity and Alkalinity) of the Foreign and Local Ballast Water samples

		t	df	Sig. (p-value)
Alkalinity	Alkanlinityfor - Alkalinitylocal	-6357.358	3	.000
PH	PHforeign - PHlocal	13.587	3	.001

Source: Authors Calculation

Table6 above examines the existence of significant difference between the selected chemical properties (acidity and Alkalinity) of the foreign and local ballast water samples used in the study. The result of the test of hypothesis on the difference between the acidity and alkalinity of the ballast water samples shows respective t-statistic of -6357.358 and 13.587 for alkalinity and acidity with respective p-values of 0,000 and 0,001. Since the p-values are each less than the alpha value (i.e. 0.000<0.05; and 0.001<0.05), we accept the alternate hypothesis that there is significant difference between the chemical properties of the foreign and local ballast water samples used in the study. However, the negative coefficient -6357.358 of the t-statistic for the alkalinity test indicates that the local ballast water sample has significantly higher alkalinity than the ballast water sample from ships on ballast voyages from European waters which shows significantly higher acidic properties.

Table7: Examines the Existence of Significant Difference between the Parts Per Million of the Identified Chemical Contaminants in the Ballast Water Samples from European and Nigeria waters.

Contaminants		t	df	Sig.
Nitrate ion	NITRATEFOREIGN - NITRATELOCAL	-23.667	3	.000
Chloride	CHLORIDEFOR - CHLORIDELOCAL	17929.589	3	.000
Mercury	MERCURYFOREING - MERCURYLOCAL	19.030	3	.000

Aluminum	ALUMINIUMFOREIGN - ALUMINIUMLOCAL	1.488	3	.233
Copper	COPPERFOREIGN - COPPERLOCAL	-1.000	1	.500
Calcium	CALCIUMFOREIGN - CALCIUMLOCAL	345.378	3	.000
Iron	IRONFOREIGN - IRONLOCAL	.765	3	.500
Magnesium	MAGNESIUMFOR - MAGNESIUMLOC	-331.608	3	.000
Manganese	MANGANESEFOR - MANGANESELOC	-1.000	3	.391
Selenium	SELENIUMFOR - SELENIUMLOCAL	19.596	3	.000
Zinc	ZINCFOREIGN - ZINCLOCAL	-4.150	3	.025
Chromium	CHROMIUMFOR - CHROMIUMLOC	-25.981	3	.000

Source: Authors Calculation

Tbale7 examines the existence of significant difference between the parts per million of the identified chemical contaminants in the ballast water samples from European and Nigeria waters. The result of the test as shown in table4.3.4 indicates that for each of nitrate ions, chloride ion, mercury, aluminum, calcium, magnesium, manganese, selenium, zinc and chromium chemical contaminants, there is a significant difference in the parts per million between the ballast water samples from European and Nigeria waters. However, while the ballast water sample from European waters shows a significantly higher parts per million of chloride ion, mercury, aluminum, calcium, and selenium; the local ballast water sample shows a significantly higher parts per million of nitrate ions, magnesium, manganese, zinc and chromium.

Furthermore, the result of the test reveal that there is no significant difference between the parts per million of copper and iron contaminants in the ballast waters samples from European and Nigeria waters since the p-value for each of copper and iron contaminants are greater than 0.05 (i.e. 0.500>0.05).

4.1 Framework for Treatment and Management of Ballast Water from Ship on Ballast Voyages from European Waters to Nigeria Seaports

The figure2 below shows the framework for the treatment and management of ballast water from vessels on ballast voyage from European waters to Nigeria seaport.

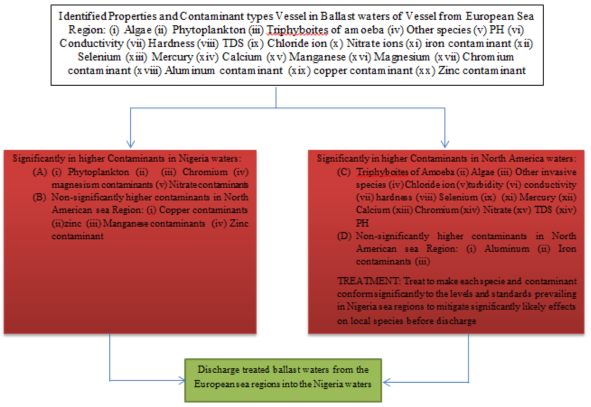

Figure-2: Framework for treatment and management of ballast water from ships from European waters in Nigeria seaports. Source: Prepared by the Author.

Following the above frameworks, ballast water treatment and management policies in Nigeria seaports should factor in most, the significantly varied contaminant types and properties of ballast waters samples from the European sea regions to ensure that the Nigeria coastal waters, aquatic species and overall marine environment is protected from effects of ballast water induced marine pollution in Nigeria.

4.2 Discussion of Results and Policy Implications

The findings of the study have implications for the development of policies for the treatment and management of ballast waters in Nigeria seaports, in line with International Maritime Conventions for the management of ballast water from ships. This is because the inappropriate treatment and management of ballast waters ships involved in international voyages from various sea regions into Nigeria seaports could led to the alteration of the properties of local waters, introduction of invasive species and depletion of local species.

The findings of the study indicate that the foreign ballast water samples from the Europe has significantly less acidity (PH) than the local ballast water sample from Nigeria. The local ballast water management policy must as a result factor this into the policy development and implementation such discharging ballast from European sea region without treatment in consideration of the disparity in PH levels may affect negatively the optimum breeding, performance and survival of local species, thus corroborating the findings of Inah and Abua (2019). This situation also hold true for all significantly different contaminant types identified in the study for both the ballast water samples from the Europe Union region.

5.0 Conclusion

In line with the objectives of the study, the study has established that there is significant difference between the content of invasive aquatic species between the ballast waters samples from ships on ballast voyages from European sea region and ballast water samples from Nigeria waters. The result of the study revealed that the ballast water samples from local Nigeria waters have significantly higher phytoplankton content than the ballast water samples from ships on ballast voyages from European region; the ballast water sample from the European sea region have significantly higher content of algae, amoeba triphobiotes and other non-chlorophyll rich invasive species than the local ballast water sample from Nigeria.

Other invasive species have t-score of 14.813 and p-value of 0.001 which also shows the existence of significant difference in the concentration of marine invasive species between ballast water samples from European waters and Nigeria waters.

The result also reveals that there is significant difference between the selected physical properties (turbidity, conductivity, hardness and TDS) of the ballast water samples from European sea region and Nigeria waters used in the study. The test indicates that the turbidity, conductivity, hardness and total dissolved solids (TDS) of ballast waters samples from European sea region are significantly higher than that of the local sample from the Nigerian waters.

Moreover, the study shows that the there is significant difference between the acidity and alkalinity (chemical properties) of the European region and local ballast water samples used in the study. While the alkalinity of the local Nigeria ballast water sample is significantly higher than that of the European region ballast water sample, the acidity of the European region ballast water sample is significantly higher than that of the local water sample.

The respective t-scores of 1.148, 58.674, 23.00, 1.000 and 4.899 for iron, mercury, calcium and manganese with corresponding p-values of 0.33, 0.00, 0.391 and 0.016 indicates that while magnesium, chromium, and aluminum contaminants are significantly higher in Nigeria waters than North American waters; zinc and copper contaminants are not significantly higher.

Lastly, the result of the of the study indicates that for each of nitrate ions, chloride ion, mercury, aluminum, calcium, magnesium, manganese, selenium, zinc and chromium chemical contaminants, there is a significant difference in the parts per million between the ballast water samples from the European sea region and local Nigeria waters. However, while the European region ballast water sample shows a significantly higher parts per million of chloride ion, mercury, aluminum, calcium, and selenium; the local ballast water sample shows a significantly higher parts per million of nitrate ions, magnesium, manganese, zinc and chromium.

The study has succeeded in providing evidences towards developing a sustainable policy for ballast water treatment and management in Nigeria seaports to ensure that inappropriate management strategies and discharge of ballast water into the Nigeria territorial waters does not lead to the introduction of harmful invasive species and harmful chemical contaminants in quantities that may at the long run endanger the optimum performance of the local marine ecosystem and biodiversity. We thus conclude that given the existence of significant differences between the concentrations of various invasive species, contaminants and properties of ballast water samples from European and Nigeria waters on one hand; and Nigeria waters on the other hand provides empirical evidences for sustained implementation of IMO regulations and standards from ballast water management in Nigeria seaport.

6.0 Recommendations

In view of the findings of the study as shown in the above tables, the study recommend as follows:

(a) That the Nigeria ports authority (NPA) should develop facilities and serious implement ballast water treatment and management strategies aimed at curtailing the influx of invasive species into Nigerian waters from ships calling to the seaports from the European regions sea regions which has a significantly higher invasive species than the territorial waters of Nigeria.

(b) That given that the foreign ballast water sample shows a significantly higher turbidity, conductivity, hardness, and TDS evidencing the presence of higher dissolved ions, solids and invasive species, the NPA should adopt and implement the International maritime Organization's instruments for ballast water management and provide shore infrastructure for management of ballast from ships calling to ports from the European sea regions which constitute significant regions from which most vessels in Nigeria seaports call from.

References

1. Adesola S. O., Ohimain E.I., and Inyang I, R. (2016) Preliminary Review of Ballast Water Legal Framework and Processes in Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) Volume 10, Issue 2 Ver. I (Feb. 2016), PP 46-51 www.iosrjournals.org.*
2. Ajibo, C. C., M. C. Anozie, E. Onyeabor, T. O. Umahi, J. J. Odinkonigbo, & H. Agu. (2019). An overview of thirty years of research on ballast water as a vector for aquatic invasive species to freshwater and marine environments. *Aquatic Ecosystem Health & Management*, 18(3), 261–268. https://doi.org/10.1080/14634988.2015.1027129 [Taylor & Francis Online], [Web of Science ®], [Google Scholar]
3. Bailey, S. A. (2015). An overview of thirty years of research on ballast water as a vector for aquatic invasive species to freshwater and marine environments. *Aquatic Ecosystem Health & Management*, 18(3), 261–268. https://doi.org/10.1080/14634988.2015.1027129
4. Crew, M. A. (1999). Regulation under Increasing Competition. Boston, MA: Kluwer Academic Publishers
5. Endresen, Ø., H. L. Behrens, S. Brynestad, A. B. Andersen, & R. Skjong. (2004). Challenges in global ballast water management. *Marine Pollution Bulletin*, 48(7–8), 615–623.

https://doi.org/10.1016/j.marpolbul.2004.01.016 [Crossref], [Web of Science ®], [Google Scholar]

6. Gollasch S (2010). Global expert workshop on harmonization of methodologies for test facilities of ballast water management systems. Global Ballast Water Management Programme (GloBallast). World Maritime University, Malmo, 24 – 25 January 2010.
7. IMO (2006c). Basic approval of active substances used by Special Pipe Ballast Water Management System (combined with Ozone treatment). Submitted by Japan. International Maritime Organization, Marine Environment Protection Committee, MEPC 55/2. 12 April 2006. IMO, London.
8. IMO (2008a). Procedure for approval of ballast water management systems that make use of active substances (G9). MEPC 57/21. Annex 1. Resolution MEPC.169 (57). Adopted on 4 April 2008. IMO, London.
9. IMO (2013b). List of ballast water management guidelines, guidance documents and approved ballast water management systems. Note by the Secretariat. International Maritime Organization. Marine Environment Protection Committee, MEPC 66/INF2. 03 October 2013. IMO, London
10. Inah. E. O. and Abua M. A (2019) Implementation of Ballast Water Management Control in Calabar River, Nigerian Port Authority, Cross River State – Nigeria. *International Journal of Scientific & Engineering Research Volume 10 (8), Pp. 699- 706*
11. Jang, P.-G., B. Hyun, & K. Shin. (2020). Ballast water treatment performance evaluation under real changing conditions. *Journal of Marine Science and Engineering*, 8(10), 0817. https://doi.org/10.3390/jmse8100817 [Crossref], [Web of Science ®], [Google Scholar]
12. Liebich V Stehouwer PP, Veldhuis M (2012). Re-growth of potential invasive phytoplankton following UV-based ballast water treatment. Aquat Invasions 7:29-36
13. Lloyd's Register (2011a). Ballast water treatment technology, Current status. June 2011. Lloyds Register Group
14. Lyon T.P. and Haitao Y. (2010) Why Do States Adopt Renewable Portfolio Standards?: An Empirical Investigation. The Energy Journal, Vol. 31, No. 3. Copyright ©2010 by the IAEE.
15. Lloyd's Register (2011b). Ballast water treatment technology, Update. September 2011. Lloyds Register Group
16. Martinez LF, Mahamud MM, Lavfn AG, Bue JL (2012). Evolution of phytoplankton cultures after ultraviolet light treatment. Mar Pollut Bull 64:556 - 562
17. NSF International (2010). Generic protocol for the verification of ballast water treatment technology. For U.S. Environmental Protection Agency Environmental Technology Verification Program. In cooperation with U.S. Coast Guard Environmental Standards Division, Washington, DC and U.S. Naval Research Laboratory, Center for Corrosion Science and Engineering Washington, DC Programme. http//www.bawapla.com/.Accessed 05 June 2012.
18. Nwigwe T. I. & Minami K. (2022) Challenges hindering the ballast water management compliance in Nigeria. *Journal of International Maritime Safety, Environmental Affairs, and Shipping, Vol. 6(2), 141-147*, DOI: 10.1080/25725084.2022.2126128
19. Newbery, D. M. (2000). Privatization, Restructuring and Regulation of Network Utilities. Cambridge, MA: The MIT Press.
20. Olivieri VP, Snead MC, Kruse CW Kawata K (1986). Stability and effectiveness of chlorine disinfectants in water distribution systems. Environ Health Perspect 69:15-29
21. Shiferaw M (2012). EcoSeaSafe 7th Framework Programme, http://ecoseasafeproject.com/. Accessed 5 June 2012
22. STEP (2010). U.S. Coast Guard Shipboard Technology Evaluation Program. Ship Enrolment Application for Ballast Water Management System. Version 2.3.
23. Tsolaki, E., & E. Diamadopoulos. (2010). Technologies for ballast water treatment: A review. *Journal of Chemical Technology & Biotechnology*, 85(1), 19–32. https://doi.org/10.1002/jctb.2276 [Crossref], [Web of Science ®], [Google Scholar]
24. Top, C., E. G. E. Kara, M. Yildiz, G. Kara, & E. Kacmaz. (2021). Determination of the appropriate ballast water treatment systems based on the voyage regions for turkish shipowners' companies. *Marine Technology Society Journal*, 6(18), 156–173. https://doi.org/10.4031/MTSJ.55.6.12 [Crossref], [Google Scholar]
25. Ukwe, C., & C. A. Ibe. (2010). A regional collaborative approach in transboundary pollution management in the guinea current region of Western Africa. *Ocean & Coastal Management*, 53(9), 493–506. https://doi.org/10.1016/j.ocecoaman.2010.06.021 [Crossref], [Web of Science ®], [Google Scholar]
26. Wright, D. A. (2018). Compliance assessment for the ballast water convention: Time for a re-think? A U.K. case study. *Journal of Marine Engineering & Technology*. https://doi.org/10.1080/20464177.2018.1513686 [Google Scholar]
27. Wang, Z., D. Nong, A. M. Countryman, J. J. Corbett, & T. Warziniack. (2020). Potential impacts of ballast water regulations on international trade, shipping patterns, and the global economy: An integrated transportation and economic modeling

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assessment. *Journal of Environmental Management*, 275, 110892. https://doi.org/10.1061/(ASCE)0733-9364(1992)118:3(577) [Crossref], [Web of Science ®], [Google Scholar]

28. Wan, Z., J. Chen, & D. Sperling. (2018). Institutional barriers to the development of a comprehensive ballast-water management scheme in China: Perspective from a multi-stream policy model. *Marine Policy*, 91, 142–149. https://doi.org/10.1139/a2012-002 [Crossref], [Web of Science ®], [Google Scholar]
29. sZhang, X., M. Bai, Y. Tian, H. Du, & Z. Zhang. (2017). The estimation for ballast water discharged to China from 2007 to 2014. *Marine Pollution Bulletin*, 124(1), 89–93. https://doi.org/10.1002/jctb.2276 [Crossref], [Web of Science ®], [Google Scholar]

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