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Research Article

Effective Management of Ballast Water Contaminants from Ships on Ballast Voyages from North America to Nigerian Seaports

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ABSTRACT

The study, Effective Management of Ballast Water Contaminants from Ships on Ballast Voyages from North America to Nigerian Seaports, investigates the environmental risks associated with ballast water discharge and proposes a framework for sustainable ballast water treatment and management in Nigeria. Using experimental research design, ballast water samples from ships arriving from North America and Nigerian coastal waters were analyzed for physicochemical properties, ion concentrations, and invasive species content. Tests conducted using Atomic Absorption Spectrophotometer (AAS), pH meters, conductivity, turbidity, and hardness meters revealed significant differences between both regions. Ballast waters from North America exhibited higher concentrations of algae, amoeba, chloride, mercury, iron, calcium, and selenium, while Nigerian samples contained higher levels of phytoplankton, magnesium, and chromium. The findings confirm that untreated ballast discharge from foreign vessels can alter the chemical and biological balance of Nigerian marine ecosystems, posing risks to local biodiversity and fisheries. Based on these results, a ballast water management framework was developed to ensure compliance with International Maritime Organization (IMO) Ballast Water Management (BWM) standards. The study recommends that Nigerian ports establish ballast water inspection and treatment infrastructure to mitigate the transfer of invasive species and contaminants, thus safeguarding marine biodiversity and supporting sustainable blue economy development.

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1. Introduction

The ocean has been characterized by the introduction of ship-based harmful hazardous materials like particles, agricultural wastes and residential waste, chemical contaminants and the invasion of different forms of micro-organisms which alter the optimum performance of marine biodiversity. Ballast water is a liquid used for adding weight to and/or stabilizing a vessel as vessels fundamentally rely on ballast water for safe operation while ballast water management is the prevention, minimization and ultimately elimination of risks to of invasion of the marine environment by alien species, contaminants and pathogen hosts within the environment, which arise from the transfer of harmful aquatic organisms and pathogens via ships ballast waters and related contaminants/sediments.

The challenges of ship-based marine pollution is one of the major environmental problems facing Nigerian ports since independence especially in the wake of the boom in oil and gas operations and transportation via the major seaports in Nigeria. This constitutes the reason for the degradation of the marine ecosystem and biodiversity importantly within the Niger Delta region of Nigeria [1].

For example, reference [1] and the International maritime Organization [2] identified that since the 1970s, more than 1000 forms of invasive species and pathogens were identified from ship ballast water tanks, and transferred from various maritime territories of origin to other foreign territories where they constitute danger to the optimum breeding and survival of local aquatic species, Recent studies by Craig [3] however estimated that estimated over 3000 – 7000 different species are being moved daily around the world through ship-based ballast water operations. Consequently, dangerous pathogens, invasive species and harmful contaminants are being moved daily through shipping operations across global territorial waters where they constitute danger to the survival of local species by altering the biological, physical and chemical properties of water bodies thus constituting harmful pollutants responsible for the destruction of breeding places of local aquatic species and poor performance of the ocean economy of affected territories. This suggests that every vessel-based ballast water operations is a potential risky activities necessitating the need for a careful approach to ballast water management and treatment in seaports to limit the impacts of foreign invasive species and contaminants on local waters that does not originally support the growth of such invasive species and contaminants [3-5].

Following the ugly trend and harmful impacts of unregulated discharge of ship-based ballast water operations, the International Maritime Organization (IMO) introduced a regulatory framework and mechanism referred to as ballast water management (BWM) in 1973, aimed at ensuring that port authorities and maritime safety agencies take proactive steps to curtail the unregulated discharge of ballast water within the seaports and territorial waters by foreign ships visiting the ports. Subsequently in 2004, there was an adoption of the international convention for the control and management of ship's ballast water and sediment (BWM) in London by many maritime powers [5-7]. The implication of this is that port authorities as implementation agencies will need to make adequate investment in ballast water infrastructure management and ship inspection equipment in order to ensure that the aims of the ballast water management instrument and convention is actualized for their various territorial waters. Nigerian seaports following the high ship traffic to the ports from various industrial Countries hosting most of the invasive species and contaminants should be positioned to remain in the forefront of ensuring a safe non polluted marine ecosystem in Nigeria and West Africa [2,8].

The need for the treatment of the content of the ballast waters tanks in line with the provisions of the Ballast Water Management (BWM) convention in major seaports in Nigeria therefore becomes important in ensuring that harmful contaminants and invasive bio species from foreign ship trading in Nigeria seaport do not mar the desire of the Government to develop all aspects of the local blue economy variables including fisheries resources and biodiversity to contribute to the overall development of Nigeria. Main attention should be given to in the following tank types which remain the most easily routes of ballast water discharge from ships into the marine environment:

- Double Bottom Tank (DBT)
- Side Tanks (ST),
- Forepeak Tanks (FPT),
- After Peak Tanks (APT),
- Top Size Tanks (TST) and
- Central Tanks (CT) gave rise to the introduction of water management systems.

The IMO [2,5] ballast water management (BWM) instrument suggests the existence and/or dominance of four major ballast water management characteristic features and test that it must be subjected to before a decision can be made on the safety and/or otherwise of its discharge and the mode and proffered method of discharge. These include the determination of the physical, chemical, and biological features of the water samples before discharge in the ocean. Other provision of the BWM convention require the provision of Port reception facilities considered by the BWM convention as an option, the treatment on board ship before ballast water is discharge as well as standards for ballast water management provided for in the BWM convention in regulations D1 and D2. Ballast water management requirement introduced two different protective regimes as;

(i) Ballast water exchange standard (Regulation D–1 standard) requiring ships to exchange a minimum of 95% ballast water volume;

(ii) Ballast water performance standard (Regulation D-2 standard) requires that the discharge of ballast water have the number of viable organism below the specified limits.

Contaminants/Sediment management on ballast water management requires every ship to remove and dispose ballast water related contaminants/sediments in accordance with the vessels ballast water management plan, vessels constructed after 2009 should, without compromising safety or operational efficiency, be designed and constructed to minimize the sediment uptake and entrapment to facilitate removal of sediments, and to provide safe access for contaminant/sediment removal and sampling [9;10. Contamination of coastal areas with high amenity value is a common feature of ballast water. In addition to costs incurred by shipping lines, serious economic losses can be experienced by industries and individuals dependent on coastal areas particularly; the tourism and fisheries sectors are where the greatest impacts are felt. However, there are also many other business activities and sectors that can potentially suffer disruptions and loss of earning. However, tt is not adequate to expect that ship owners must comply with the provisions of the BWM conventions, thus port authorities in Nigeria need to employ regulatory mechanisms and enforcement framework in line with the provision of the BWM convention in managing ship-based ballast water operations in Nigeria seaports [2,11,12]. The approach by port authorities in Nigeria in implementing BWM convention seems to suggest that most vessels visiting the ports on ballast voyage carry treated ballast water types safe for discharge into the local waters as the ports currently lack infrastructure for ballast water treatment and experimental testing, depending only on the ship-based equipment which does not give room for unbiased assessment [5,13]. There is need that port authorities provide infrastructure for ballast water inspection and dully carry-out experimental test on all such water samples aimed at determining the biological, physical and chemical features of the samples well as the levels of the identified contaminants as basis for decision on most appropriate and safe disposal strategy for ship-based ballast water types from various trading regions [14,15].

The current study is aimed at providing empirical evidences on the need for the local port authorities and maritime safety administration to ensure proactive enforcement of the BWM instrument in Nigeria, which they seem to have neglected over the years and to support the numerous evidences provided by the International maritime Organization (IMO) at the global level as reason for the decision that port employ ballast water management instruments to curtail the introduction of harmful species and contaminants into local waters [16-18]. With specific reference to ballast water management in Nigeria seaports, available empirical studies have not been able to determine the existence or otherwise of significant difference in the properties, concentrations of various contaminant types and invasive species between ballast water samples collected from North American sea regions and Nigerian marine environment. This is because ships on ballast from North America constitute the significant part of the regions from which ships call to Nigeria ports. No available empirical literature has been able to determine the basis for developing a framework for ballast water management in Nigeria seaports for vessels on ballast voyages from Northern American sea regions.

In line with the above, the study identified the following objectives which it seeks to address:

1.1. Objectives of the Study

1) To determine gaps in the concentration of contaminants in ballast waters samples from ships on ballast voyages from North America sea region to Nigeria seaports.
2) To develop effective framework for the treatment and management of ballast waters from ships on ballast voyages from North America sea region to Nigeria sea ports based on gaps in concentration of contaminants in ballast water samples from the two regions.

1.2. Research Questions

In order to achieve the above stated objectives of this research the following questions must be answered:

1) Are there significant differences in the concentrations of contaminants in ballast samples drawn from ships from North America sea regions and local ballast water sample from Nigeria seaports?
2) What effective ballast water management framework can be developed for the management of ballast water from ships on ballast voyages from North American sea region to Nigeria seaports?

1.3. Research Hypotheses

H_{01}: There is no significant difference between contaminant levels in the ballast waters samples from North America and Nigeria sea regions.

H_{02}:H_{03}: A framework for sustainable treatment and management of ballast water from ships on ballast voyage from North America sea region to Nigeria cannot be developed.

2. Empirical Review

Reference [19] 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 [19]. 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 [19].

Reference [20] 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 [20]. 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 [20,21]. The study recommended that effective measures be deployed to enhance effective implementation of all the 10 strategies for ballast water treatment and management in line with international standards [20,21].

In a similar but different study, reference [22] 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 [22]. 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 [22]. 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 [22].

Reference [23] 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 [23]. 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 [23,24].

Lastly, References [26] and did a studies on the Challenges in global ballast water management were aimed to identify among other things, what constitute the major challenges to ballast water treatment and management in line with IMO regulations and standards [25,26]. The studies used primary data obtained from survey. The findings of the studies imply 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 [26-28].

2.1. Literature Gap

From the aforementioned empirical studies, it is obvious that there exist research gaps which available empirical studies have failed to address over the years. With specific reference to ballast water management in Nigeria seaports, available empirical studies have not been able to determine to what extent differences exist between the properties, concentrations of various contaminant types and invasive species between ballast water samples from North American sea region and Nigerian waters. There is also no developed effective framework based on empirical findings, for the sustainable treatment and management of ballast water samples from ships on ballast voyages from North American region to Nigerian waters. These are the knowledge gaps which this study seeks to address.

3. Data and Methods

This section explains the methods and procedures that were used in dealing with the research questions and realizing the objectives of the study. It explained the process used in conducting the research inclusive of the experiments carried out to determine the concentrations of invasive species and various ions which affect the optimum living of aquatic organism/marine-biodiversity in the marine ecosystem.

The research employed experimental approaches in determining the concentrations of the organism, contaminants and ions in the various ballast water samples collected from Nigerian local waters, North American sea region and European waters. This chapter also examined in details the methods and sources of data, research design, methods of data analysis and test of hypotheses, among others.

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 other 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 North America 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 North America. The foreign ballast water was taken from ships on ballast voyages from North American sea region, particularly from the U.S.A. and Canada. These regions form the most places from which ships on ballast voyages call to Nigeria seaports. 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 North American 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 (North American 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 North American 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 North American 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 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 North America 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 North American waters 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) =

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

3.3.7. Experimental Determination of the Concentration of NITRATE ions (NO3-) 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°C 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 North American 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 $X_{diff} = \sqrt{\frac{\bar{x}_f - \bar{x}_l}{\frac{S_f^2}{n_f} + \frac{S_l^2}{n_l}}}$

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

$\bar{x}_f$ = mean of foreign ballast water sample from North America reading 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 North America 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. Results and Discussion

Table 1. Comparing the Concentrations of Algae, Phytoplankton and other Invasive Species in the North American and Nigeria local ballast water samples

ALGAE/milliliter	Mean	Mean difference	N	Std. Deviation	Std. Error Mean
foreignAmeica	51.5000		4	1.29099	.64550
LocalNigeria	46.5000	5.00000	4	.57735	.28868
PHYTOPLANKTON					
foreignAmeica	24.7500		4	.95743	.47871
LocalNigeria	48.0000	-23.25000	4	1.41421	.70711
triphyboites of amoeba					
foreignAmeica	18.0000		4	.81650	.40825
LocalNigeria	10.2500	7.75000	4	.95743	.47871
OTHER INVASIVE SPECIES					
foreignAmeica	23.7500		4	.95743	.47871
LocalNigeria	7.7500	16.00000	4	1.25831	.62915

Source: Authors calculation

The result of the study on Table1 indicates that the mean concentrations of Algae, phytoplankton, triphyboites of amoeba and other invasive species per milliliter of ballast water samples collected from the North American waters is 51.5, 24.75, 18.00 and 23.75 with respective standard deviations of 1.29, 0.96, 0.82 and 0.96. The result also indicates that the average concentration of Algae, phytoplankton, triphyboites of amoeba and other invasive species per milliliter of ballast water samples collected from the local Nigeria waters is 46.500, 48.00, 10.25 and 7.75 respectively with respective standard deviations of 0.57, 1.40, 0.95 and 1.25.

The mean difference between the concentration of Algae in the ballast water samples from the North American waters and Nigeria waters is 5.00/ml of ballast water samples used. This indicates the presence of higher concentrations of Algae specie in the North America water than waters in the Nigeria coastal zones. Similarly, the difference of means in the concentrations of phytoplankton, triphyboites of amoeba and other invasive species between the samples of ballast water collected in North American waters and Nigeria waters is 23.25/ml, 7.75/ml, and 16.00/ml respectively. By implications, waters of the North American sea routes have higher concentrations of phytoplankton, triphyboites of amoeba and other invasive species than the coastal waters in Nigeria. The investigation of the significances of the differences in means indicates that a t-score of 7.07 and p-value of 0.006 for Algae. This shows that a significance difference exist between the concentrations of algae between ballast water samples in North American and Nigerian waters. For Phytoplankton, a t-score of 48.568 of and of p-value 0.000 also indicates that there exists significant difference between both ballast waters samples collected from the two regions. Similarly, triphyboites of amoeba has t-score of10.333 and p-value of 0.002; indicating the existence of significant difference between the concentration in the waters of the North American and Nigeria. Other invasive species have t-score of 14.813 and p-value of 0.001 which also shows the existence of significant difference.

The implications of the findings is that ships on ballast voyage from the North American sea routes to Nigeria seaports have higher propensity of introducing invasive species into the Nigeria coastal waters if allowed to discharge her ballast contents in Nigeria without proper treatment as provided in the ballast water regulations. The treatment should thus aim at ensuring that the ballast waters samples from ships on ballast voyage from North American waters conform to the concentrations of the identified invasive species in Nigeria coastal waters. The figure below summarizes the comparison of the various identified species in Nigeria and North American waters.

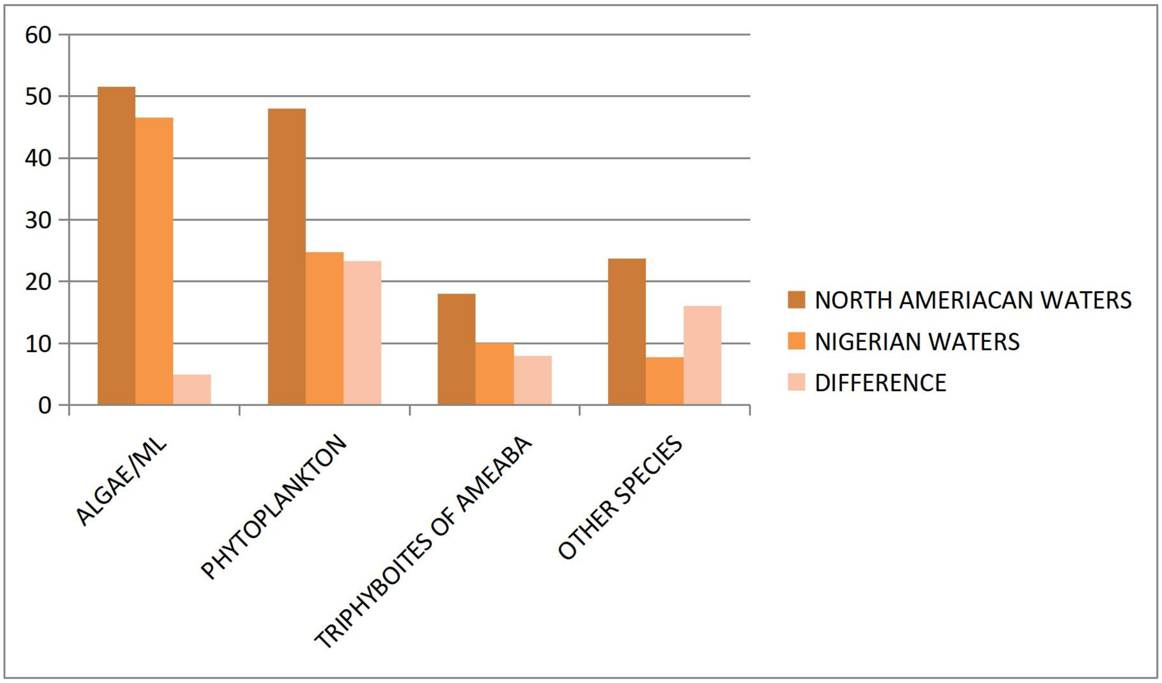


Figure 1. Comparison of the various identified species in Nigeria and North American waters. Source: Prepared by author.

Table 2. Differences in the Turbidity, Conductivity, Hardness, and Total Dissolved Solids (TDS) in the North American and Nigeria local ballast water samples

TURBIDITY (NTU)	Mean	Mean difference	N	Std. Deviation	Std. Error Mean
localNigeria	10.4275		4	.01893	.00946
foreignAmeica	14.0000	3.57250	4	.33665	.16833
CONDUCTIVITY(μS/cm)					
foreignAmeica	82727.5000		4	48.36321	24.18160
LocalNigeria	35400.7500	47326.75000	4	1.50000	.75000
HARDNESS(mg/L)					
foreignAmeica	6540.7500		4	40.83605	20.41803
LocalNigeria	3140.0000	3400.75000	4	.00000	.00000
TDS (mg/L)					
foreignAmeica	141968.0000		4	196561.33334	98280.66667
LocalNigeria	16284.5000	125683.50000	4	1.00000	.50000

Source: Author's calculation.

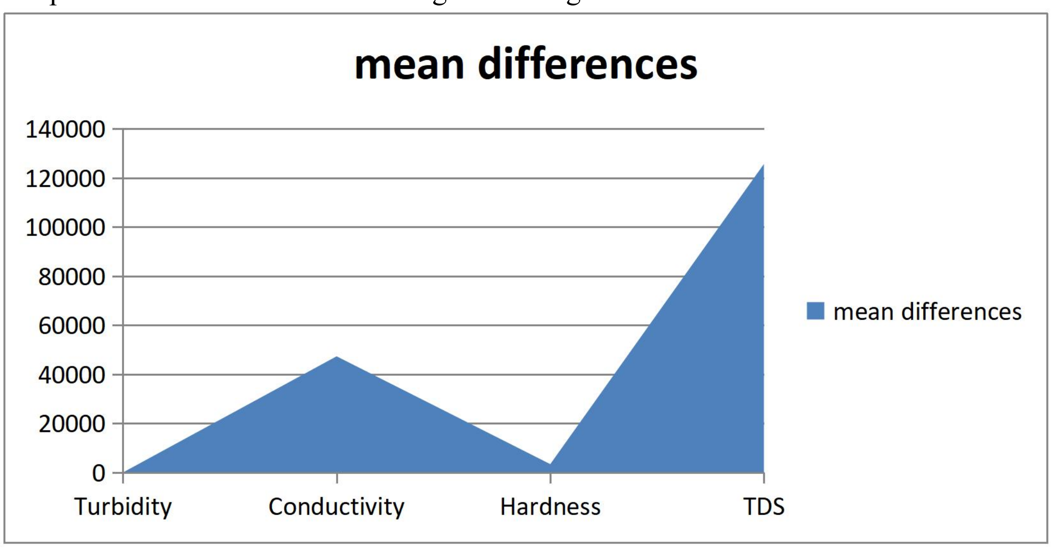
The result on Table2 indicates that the respective mean turbidity of the of the North American and local Nigeria waters ballast water samples used in the study is 14.0000 NTU and 10.4275NTU with standard deviations of.33665 and 0.00 respectively. The difference of means in the turbidity of the two ballast water samples is 3.57250 with standard deviation of .33619, indicating that the foreign ballast water samples from the North America has higher turbidity than the local ballast water sample from Nigeria. The t-score is -21.253 with a p-value of 0.00, indicating that there is a significant difference between the turbidity of the ballast water samples from North America and Nigeria coastal waters. This means that the ballast water sample from the North America has higher concentration and content of dissolved contaminants and invasive species.

Similarly, the conductivity test carried out indicates a mean conductivity of 82727.5000 microsiemens per centimeter (µS/cm) with standard deviation of 48.36321for the foreign ballast water sample from North America while the mean conductivity of the local ballast water sample from Nigeria is35400.7500 µS/cm with standard deviation of 1.5000. The difference of means result shows a mean difference of 47326.75000µS/cm with standard deviation of48.86972. The t-score is 1936.854 with a p-value of 0.000. This indicates that there is significant difference in conductivity properties between ballast water samples from the North American and local Nigeria sea regions.

The result also shows that the mean hardness of the North American and Nigeria ballast waters samples is 6540.75005000miligrams per liter (mg/l) and 3140.00005000miligrams per liter (mg/l) respectively with respective standard deviations of 40.83605 and 0.000. The difference in hardness between both samples of the ballast water is 3400.750005000miligrams per liter (mg/l); indicating that the ballast water sample from North America sea region has higher hardness. The t-score of 166.556and p-value of 0.000 indicates that significant differences exist between ballast water samples from North American sea region and Nigeria waters.

The mean Total Dissolved Solids (TDS) in the North American and local samples is 141968.0000mg/l and 16284.5000mg/l respectively. The difference in TDS between the two ballast water samples from North America and Nigeria sea regions is 125683.5mg/l with respective standard deviations of 196561.6. The t-score is 1.279with p-value of .291, indicating that there is no significant difference between the mean TDS of the ballast water samples from both sea regions.

Sea figure below for a summary of the differences in mean of turbidity, conductivity, hardness and TDS of ballast water samples from North America and Nigeria sea regions.



Source: Prepared by Author

Table 3. Differences in the PH, Chloride Iron Concentration, and Nitrate ion Concentration in the North American and Nigeria local ballast water samples.

PH at 26°C	Mean	Mean difference	N	Std. Deviation	Std. Error Mean
foreignAmeica	5.5750		4	.08660	.04330
LocalNigeria	6.7225	-1.1475	4	.00957	.00479
Concentration of Chloride, Cl^- (mg/l)					
foreignAmeica	31516.2500		4	4.78714	2.39357
LocalNigeria	9656.0000	21860.25000	4	.81650	.40825
Concentration of Nitrate, NO_3^- (mg/l)					
foreignAmeica	.7075		4	.00957	.00479
LocalNigeria	1.1250	-.41750	4	.05000	.02500

Source: Authors calculation

The result on Table3 above indicates that the respective mean PH of the of the North American and local Nigeria waters ballast water samples used in the study is 5.5750 and 6.722 with standard deviations of .3.08660 and .00957respectively. The difference of means in the PH of the two ballast water samples is -1.1475 with standard deviation of 0.08421, indicating that the foreign ballast water samples from the North America has less acidity (PH) than the local ballast water sample from Nigeria. The t-score is -43.996 with a p-value of 0.000, indicating that the local ballast water sample from Nigeria has significantly higher PH (acidity) than the ballast water samples from North America waters..

Similarly, the concentration of chloride ion in the ballast water samples indicates a mean chloride –ion content of 31516.2500mg/l and 9656.0000mg/l respectively for samples from North American and Nigeria sea regions with respective standard deviations of 4.78714 and 0.81650. The difference of means result shows a mean difference of 21860.25mg/l with standard deviation of 4.50. The t-score is 9715.667 with a p-value of 0.000. This indicates that there is significant difference in chloride –in concentration in between ballast water samples from the North American and local Nigeria sea regions, with the North American samples having the higher chloride –ion concentration.

Furthermore, the concentration of Nitrate –ion in the ballast water samples indicates a mean Nitrate –ion content of 0.7075mg/l and 1.1250mg/l respectively for samples from North American and Nigeria sea regions with respective standard deviations of 0.009574 and 1.1250. The difference of means result shows a mean difference of -0.41750mg/l with standard deviation of 0.0492. The t-score is -16.956 with a p-value of 0.000. This indicates that there is significant difference in chloride –in concentration in between ballast water samples from the North American and local Nigeria sea regions, with the Nigeria samples having the higher Nitrate –ion concentration.

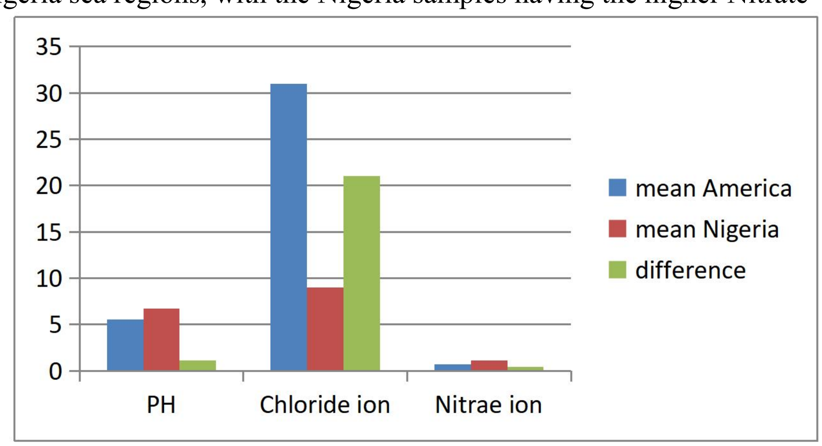


Figure 3. PH, Chloride –ion and Nitrate Ion content of the waters samples.

Source: Authors calculation

Table 4. Differences in the Content of Other Identified Contaminants Present in the Ballast Water Samples from North America and Nigeria Sea Regions.

SELENIUM (mg/l)	Mean	Mean difference	N	Std. Deviation	Std. Error Mean
foreignAmeica	.0670		4	.00476	.00238
LocalNigeria	.0290	.03800	4	.00082	.00041
IRON (mg/l)					
foreignAmeica	.3100		4	.00816	.00408
LocalNigeria	.1040	.20600	4	.00082	.00041
ZINC (mg/l)					
foreignAmeica	.2200		4	.00816	.00408
LocalNigeria	.2500	-.03000	4	.05774	.02887
MERCURY (mg/l)					
foreignAmeica	.0708		4	.00096	.00048
LocalNigeria	.0408	.03000	4	.00096	.00048
CALCIUM (mg/l)					
foreignAmeica	19.0500		4	.05774	.02887
LocalNigeria	16.4825	2.56750	4	.00500	.00250
MAGNESIUM (mg/l)					
foreignAmeica	6.1500		4	.05774	.02887
LocalNigeria	7.9325	-1.78250	4	.00500	.00250
CHROMIUM (mg/l)					
foreignAmeica	.0300		4	.00000	.00000
LocalNigeria	.0875	-.05750	4	.00500	.00250
MANGANESE (mg/l)					
foreignAmeica	1.1575		4	.05058	.02529
LocalNigeria	.9850	.17250	4	.00577	.00289
Copper PPm (mg/l)					
foreignAmeica	.0425		4	.00500	.00250
LocalNigeria	.0450	-.00250	4	.00577	.00289
Aluminum ppm (mg/l)					
foreignAmeica	.0035		4	.00058	.00029
LocalNigeria	.0055	-.00200	4	.00058	.00029

Source: Author's calculation

The result of the study as shown in table4 above indicates that the difference between the concentration of Selenium contaminants in the ballast water samples from North America and Nigeria sea regions is 0.03800mg/l with standard deviation of 0.00424, t-score of 17.913 and p-value of 0.000. This implies that Selenium contaminant in the ballast water samples from North America region is significantly higher than samples from Nigeria sea regions.

Similarly, each of Iron, Mercury, calcium, and manganese contaminants in the ballast water sample from North American sea region, have mean averages of 0.20600mg/l, 0.03000mg/l, 2.56750mg/l and 0.17250mg/l higher than that of the ballast water samples from Nigeria waters. The respective t-scores of 50.209, 32.863, 84.514 and 6.912 for iron, mercury, calcium and manganese with corresponding p-values of 0.00, 0.00, 0.00 and 0.06 indicates that the ballast water samples from North America sea region has significantly higher iron, calcium, manganese, and mercury contaminants than samples from Nigeria sea regions.

Furthermore, Zinc, magnesium, chromium, copper and aluminum contaminants in ballast water samples from Nigeria sea region, have respective averages of 0.03000mg/l, 1.78250mg/l, 0.0575, 0.0025mg/l and 0.0020mg/l higher than that of the samples from the North American sea region. 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, 0.00, 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. These have implications for developing policies for ballast water management in Nigeria seaports.

In the subsequent sections, we discussed the policy implications of the findings of the study for the treatment and management of ballast waters from vessels arriving Nigeria seaports on ballast voyages from European and North American seaport.

Table 5. Test of hypothesis H_{01}: There is no Significant Difference in Concentrations of Marine Species Types cum Contaminants between Ballast Waters Samples from North American and Nigeria Sea Regions.

Marine Species/Contaminants		t	df	Sig.
Phytoplankton	Phyforeign - phylocal	48.568	3	.000
Algae	Algaeforeign - Algaeloca	7.071	3	.006
Amoeba	Amebaforeign - Amebaloca	10.333	3	.002
Others	Othersforeign - Otherslocal	14.813	3	.001
Turbidity	Turbidityfor - Turbiditylocal	21.253	3	.000
Conductivity	Conductivityfor - Conductivitylocal	1936.854	3	.000
Hardness	Hardnessfor - Hardnesslocal	166.556	3	.000
PH	TDSforeign - TDSlocaL	1.279	3	.291
PH	PHforeign - PHlocal	-43.996	3	.000
Nitrate ion	Nitrateforeign - Nitratelocal	-16.956	3	.000
Chloride	Chloridefor - Chloridelocal	9715.667	3	.000
Mercury	Mercuryforeing - Mercurylocal	58.674	3	.000
Aluminum	Aluminiumforeign - Aluminiumlocal	-4.899	3	.016
Copper	Copperforeign - Copperlocal	-1.000	1	.391
Calcium	Calciumforeign - Calciumlocal	23.00	3	0.391
Iron	Ironforeign - Ironlocal	1.148	3	0.33
Magnesium	Magnesiumfor - Magnesiumloc	-58.674	3	.000
Manganese	Manganesefor - Manganeseloc	1.00	3	0.016
Selenium	Seleniumfor - Seleniumlocal	17.913	3	.000
Zinc	Zincforeign - Zinclocal	-1.148	3	.334
Chromium	Chromiumfor - Chromiumloc	-23.000	3	.000

Source: Authors Calculation

The test of hypothesis H_{01} on Table5 reveals that significant differences exist in the various properties and invasive species types between the ballast water samples from ships on ballast voyages from North American sea region and Nigeria waters. For example, 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. Similarly, 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 North American and Nigeria sea regions. 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 North American waters and Nigeria waters.

For PH level, the t-score is -43.996 with a p-value of 0.000, indicating that the local ballast water sample from Nigeria has significantly higher PH (acidity) than the ballast water samples from North America waters. The concentration of total dissolved solids (TDS) has t-score of 1.279 with p-value of .291, indicating that there is no significant difference between the mean TDS of the ballast water samples from both sea regions.

The t-score of 166.556 and p-value of 0.000 indicates that significant differences exist in hardness between ballast water samples from North American sea region and Nigeria waters while the t-score is 1936.854 with a p-value of 0.000 indicates that there is significant difference in conductivity properties between ballast water samples from the North American and local Nigeria sea regions.

The difference of means in the turbidity of the two ballast water samples is 3.57250 with standard deviation of .33619, indicating that the foreign ballast water samples from the North America has higher turbidity than the local ballast water sample from Nigeria. The t-score is -21.253 with a p-value of 0.00, indicating that there is a significant difference between the turbidity of the ballast water samples from North America and Nigeria coastal waters.

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.

The respective t-scores of 50.209, 32.863, 84.514 and 6.912 for iron, mercury, calcium and manganese with corresponding p-values of 0.00, 0.00, 0.00 and 0.06 indicates that the ballast water samples from North America sea region has significantly higher iron, calcium, manganese, and mercury contaminants than samples from Nigeria sea regions.

The difference between the concentration of Selenium contaminants in the ballast water samples from North America and Nigeria sea regions is 0.03800mg/l with standard deviation of 0.00424, t-score of 17.913 and p-value of 0.000. This implies that Selenium contaminant in the ballast water samples from North America region is significantly higher than samples from Nigeria sea regions.

The t-score is 9715.667with a p-value of 0.000. This indicates that there is significant difference in chloride –in concentration in between ballast water samples from the North American and local Nigeria sea regions while t-score of -16.956 with p-value of 0.000 indicate that the Nigeria ballast water sample have significantly higher Nitrate –ion concentration than ballast water sample from ships on ballast voyages from North America.

4.1. Framework for Ballast Water Treatment and Management in Nigeria Seaports

The figure below shows the framework for the treatment and management of ballast water from vessels on ballast voyage from North American sea region to Nigeria seaport.

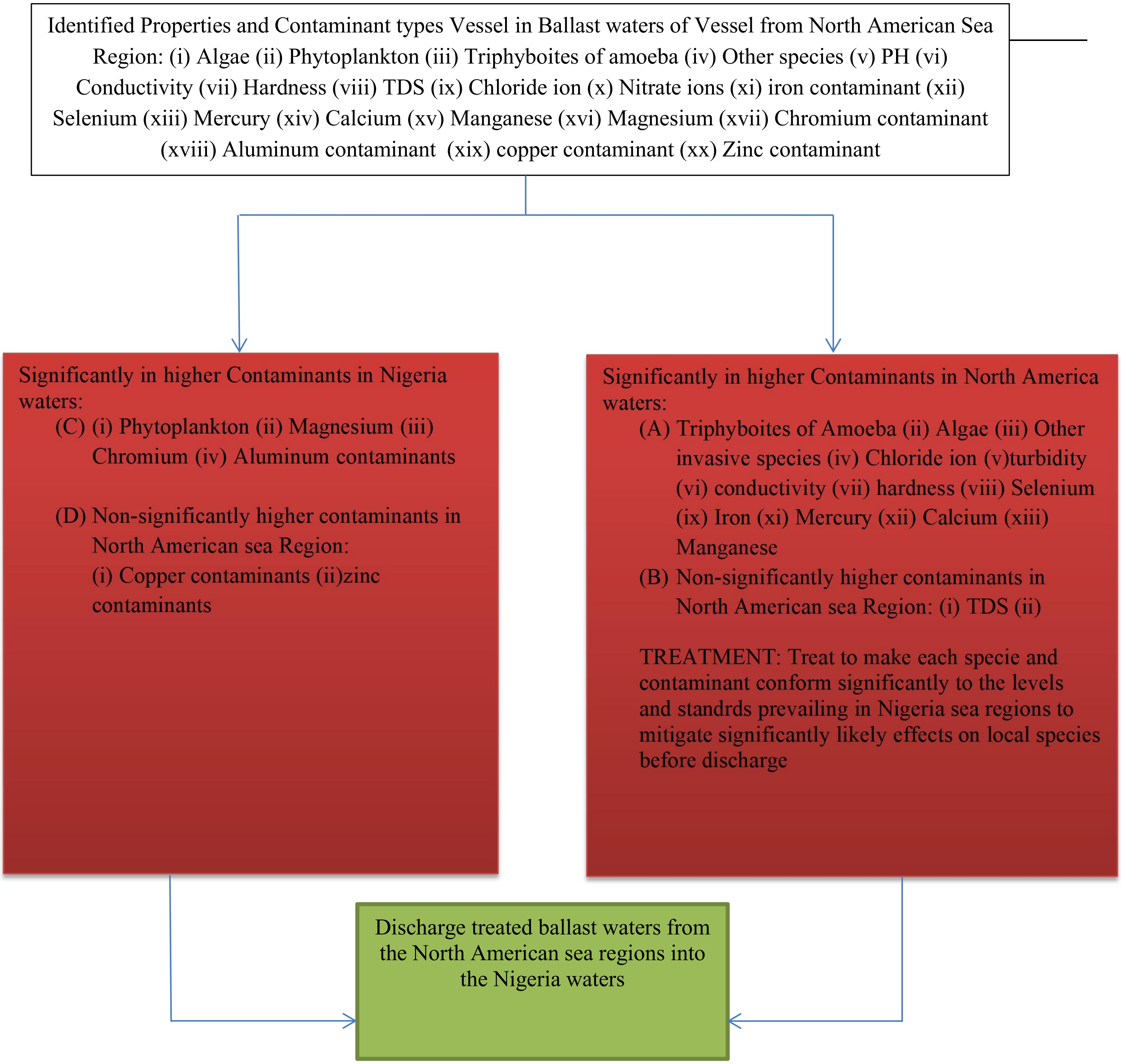


Figure 3. Framework for treatment and management of ballast water from ships from North America in Nigeria seaports.

Source: Prepared by the Author

Following the above framework, 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 North American 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.

Thus the result of the study indicates that significant difference exist between the concentrations of algae between ballast water samples in North American and Nigerian waters while a significant difference also exist in the concentrations of triphyboites of amoeba, Phytoplankton, and other invasive species between North America waters and Nigeria waters with North American waters having higher concentrations of these contaminants. This corroborates the findings of references [9] and [8]. The policy implication of this in the development of ballast water management policy is that ballast from vessels on ballast voyages from North America sea regions to Nigeria must treated to normalize the concentrations of particularly triphyboites of amoeba and other invasive species, before they are allowed to be discharged into the Nigeria waters. Failure to address this will lead to gradual dominance of invasive species of the Nigerian waters by foreign species from the North American sea region to the detriment of Nigeria local species which may no longer thrive in the likely emerging new conditions. This also supports the findings of references [13,18,29]. Thus, local ballast water management policy in Nigeria seaport must recognized all significant species and contaminant found in ballast of foreign ships in our ports, and significantly eliminate or at least, mitigate the likely effects before such ballast waters are allowed to be discharged into the Nigeria coastal waters. The implications of the findings is that ships on ballast voyage from the North American sea routes to Nigeria seaports have higher propensity of introducing invasive species into the Nigeria coastal waters if allowed to discharge her ballast contents in Nigeria without proper treatment as provided in the ballast water regulations. The treatment should thus aim at ensuring that the ballast waters samples from ships on ballast voyage from North American waters conform to the concentrations of the identified invasive species in Nigeria coastal waters.

Similarly, the findings of the study indicate that the foreign ballast water samples from the North America 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 North American 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 reference [11].

5. Conclusion

The study has succeeded in providing evidences towards developing a sustainable policy for ballast water treatment and management in Nigeria seaports for vessels on ballast voyages from North American sea region to Nigeria, 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. The study thus conclude that given the existence of significant differences between the concentrations of various invasive species, contaminants and properties of ballast water samples from North American and Nigeria waters provides empirical evidences for sustained implementation of IMO regulations and standards from ballast water management in Nigeria seaport.

5.1. 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 North American 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 North American sea regions which constitute significant regions from which most vessels in Nigeria seaports call from.

(c) More attention should be paid to the treatment and management of ballast water samples that show the containment of significantly higher parts per million of the chemical contaminants identified in the study as these if introduced significantly into the Nigerian territorial waters without control, treatment and proper management, may alter the performance of the local marine biodiversity and ecosystem.

Author's Contributions

Concept design: Ihiechi Darlington C.; Onwuegbuchunam Donatus E., Data Collection or Processing: Ihiechi Darlington C. Nwokedi Theophilus C., Analysis or Interpretation: Nwokedi Theophilus C., Literature Review: Ihiechi Darlington C. Writing, Reviewing and Editing: Onwuegbuchunam Donatus E., Ihiechi Darlington C.

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Conflict of Interest

There is no conflicting interest known to the researchers non are they envisaging any conflicting interest in the future. There is no conflict of interest in this study.

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