Vol. 5(2), pp. 43-48, June 2024
https://doi.org/10.14662/arjhim2024350

ISSN: 2734-2190
https://www.academicresearchjournals.org/ARJHIM/Index.htm

Academic Research Journal on Health Information Management

Research paper

Investigating the impact of Ballast water discharges into the Koko, Oghara and Warri Waterways by Commercial Ships: Implication of invasive vegetation impacts on the indigenes' and other aquatic lives' health in the environment

Ohwoudue Eriyonja Roland[1] and [2]Eshagberi Godwin

([1 and 2]Dept of Science Laboratory Technology, Delta state Polytechnic, Otefe-Oghara, Delta state, Nigeria)

Accepted 12 June 2024

This study investigates the impact of ballast water discharges on the Koko, Oghara, and Warri ports in Delta State, Nigeria, focusing on invasive species, heavy metal contamination, and their effects on local aquatic ecosystems and communities. The primary objectives include assessment of phytoplankton viability and diversity, evaluation of heavy metal concentrations in ballast water, and analysis of the socioeconomic impacts on fishing activities of locals. Methods employed include flow cytometry for phytoplankton analysis, for heavy metals assays and physicochemical screening forballast water quality. Results showed varying phytoplankton viability across the sites, with Oghara Port having the highest at 70%, followed by Warri Port at 65%, and Koko Port at 55%. The control site had a significantly higher viability rate of 90%. Flow cytometry revealed a decline in phytoplankton diversity, particularly in Koko Port, which was dominated by invasive species. Heavy metal analysis indicated that all ports exceeded International Maritime Organization (IMO) standards for lead (Pb) and cadmium (Cd). Warri Port had lead concentrations of 0.45 ppm and cadmium at 0.10 ppm, while the control site showed much lower levels, emphasizing the pollution risks from ballast water discharges. The socioeconomic impact on fishing was significant, with 49% of respondents reporting reduced fish catches due to invasive species and pollution. Additionally, 28% noted increased invasive vegetation that obstructed navigation and fishing. Various ballast water treatment methods were assessed; electrolysis treatment reduced bacterial counts by 85% but resulted in only 25% phytoplankton viability. UV irradiation treatment reduced bacterial counts by 70% but also adversely affected phytoplankton health. The study highlights the urgent need for effective ballast water management practices to mitigate ecological and socioeconomic impacts. Recommendations include comprehensive monitoring to ensure compliance with IMO standards for heavy metals and biological contaminants and investment in advanced ballast water treatment technologies to enhance effectiveness while minimizing adverse effects on native species. Community engagement initiatives should be developed to raise awareness about invasive species and pollution risks. Continued research is needed to understand the long-term ecological impacts on marine biodiversity and fisheries. The findings offer a foundation for future research aimed at developing policies and practices to safeguard marine ecosystems from the challenges posed by invasive species and pollution related to ballast water discharges.

Keywords: Ballast Water Management, Invasive Species, Phytoplankton Viability, Heavy Metal Contamination, Socioeconomic Impact, Aquatic Ecosystems, Fishing Activities, Delta state

Cite this article as: Roland, O.E., Godwin, E. (2024). Investigating the impact of Ballast water discharges into the Koko, Oghara and Warri Waterways by Commercial Ships: Implication of invasive vegetation impacts on the indigenes' and other aquatic lives' health in the environment. Acad. Res. J. Health. Inform. Manage. 5(2):43-48

INTRODUCTION

Ballast water, which is used for the stability of ships, is the main vector for the introduction of marine invasive species. Invasive species can pose a risk to marine ecosystem services. They can negatively affect biodiversity, increase the probability of disease transmission and be infectious for humans, animals, and plants. The economic and ecologic impacts of marine invasive species can be enormous (Keller et al., 2011).

Annual costs linked to aquatic invasive species are in the order of hundreds of billions of USD. To mitigate the spread, the United Nations' International Maritime Organization (IMO) adopted the Ballast Water Convention that entered into force in 2017. The convention requires all ships with ballast water to apply a type approved Ballast Water Treatment System (BWTS) to eliminate organisms (Adelino et al., 2021).

Industrialization and commercialization activities are crucial for the development of any economy. There is usually marked growth in income and livelihoods and household income of the populations directly living in the trade routes or industrial hubs connected with marine trade, commerce or transportations. There are other direct and indirect impacts on communities in the coastal areas such as rapid urbanization, infrastructural developments and blending of cultures and potential boost in tourism and hospitality earnings and revenues(Uysal & Turan, 2020).

Statement of the Problem

Warri, Koko and Oghara are three major towns in Delta State where Shipping activities do occur. The presence of ships and other marine vessels in these towns is due to the commercial activities such as cargo transportation as well as crude oil and refined petroleum products transportation. Consequently, these ships and large vessels always have ballast water as part of them. It is needed by these vessels for balance and safe navigation mechanisms.

Ballast waters are usually collected at ports of sail. This means that the ships are bring along with these waters potential foreign aquatic life (both plants and animals). This had led in many cases to incidences of invasive species as the discharged ballast waters contain species which thrive to survive and later dominate their new habitat or environments. Invasive phytoplankton, especially diatoms as primary producers providing the base of the marine food web, can cause changes with cascading effects up to higher trophic levels. Diatoms are able to survive ship journeys in ballast water and may be transported to new habitats (Lavoie et al., 1999).

Due to the potential damage caused by invasive species the International Maritime Organization (IMO) adopted the Ballast Water Management Convention. The Convention Regulations specify the D-2 standard, which specifies the amount of organisms allowed to be present in ballast water upon discharge (David et al., 2015).

Objectives of the Study

- Investigate the constituents of ballast water discharged by ships in the Warri, Koko and Oghara ports.
- Investigate the impact of invasive species in the ballast water discharged in these ports
- Investigate potential heavy metals presence in the ballast water discharged in these ports
- Investigate the impact of the invasive species on other marine life and livelihood of the local population

Significance of this study

The significance of this study lies in its critical examination of ballast water management practices and their ecological implications in Delta State, Nigeria. As shipping activities continue to expand, the potential for invasive species introduction through ballast water becomes increasingly concerning. This research aims to assess the constituents of ballast water discharged at the Warri, Koko, and Oghara ports, providing essential data on the types and extent of invasive species present. By investigating the relationships between ballast water conditions and zooplankton density, the study seeks to understand how these factors contribute to the proliferation of invasive species, which could disrupt local marine ecosystems and threaten biodiversity. The findings will not only enhance our understanding of the ecological risks associated with ballast water discharges but also inform policymakers and stakeholders about necessary interventions to mitigate these risks.

METHODOLOGY

The study adopted land-based testing where samples of ballast water, as well as water samples from identified discharge sites, were collected and transported to the laboratory at Delta State Polytechnic Science Laboratory. Water from the ports at Warri, Koko, and Oghara ports was pumped and stored in designated and labeled water sample jars. Control water was pumped directly into separate holding jars. Ballast water samples were collected from vessels on an opportunistic basis. Sampling efforts focused on bulk carriers and general cargo carriers since they are responsible for discharging the largest percentage of ballast water internationally.

Flow cytometry was employed in the analysis of marine and ship's ballast water. It is a comparatively fast and accurate method. Three samples of 2 mL from each incubation bottle were used for the analysis. Flow cytometric measurements were performed with a Beckman Coulter Epics XL MCL (488 nm laser) (Beckman Coulter, CA, USA).

Phytoplankton cell numbers were measured by triggering the FL4 parameter (red fluorescence, 675 nm, chlorophyll 'a'), which allowed distinction from particles other than phytoplankton (Veldhuis and Kraay, 2000). The flow cytometer data were presented in two-dimensional graphs where particles with analogous properties appeared as clusters. An indication of diversity was obtained by visually determining the number of clusters of different sizes and fluorescence signals.

As recommended in the IMO G2 Guidelines for Sampling of Ballast Water, the samples were taken from the discharge line, as close to the point of discharge as practicable, during the actual discharge of ballast water.

Incubation samples were taken during land-based testing. Samples were collected in 10 L Nalgene bottles at both uptake (T0) and discharge (T5). The samples were transported to a climate-controlled room at Delta State Polytechnic Science Laboratory, Otefe-Oghara. This room was maintained at a stable temperature of 15 °C (±2 °C) with a 16:8 hour light/dark period. Bottles were placed on magnetic stirrers that maintained water movement (130 rotations/min), replicating the conditions marine plankton are accustomed to. Nutrients were added at concentrations typical of the local waters under natural conditions, without effluent discharges or pollution.

Treatment of the ballast water samples was carried out using electrolysis and UV irradiation methods. After treatment, organism concentration was determined using two quantification approaches: the Vital Stain (VS) method and the Most Probable Number (MPN) method.

The data collected were analyzed using the Statistical Package for Social Sciences (SPSS) software package.

RESULTS AND DISCUSSIONS

Table 1: Phytoplankton Viability across Sampling Sites

Sampling Site	Viability ≥ 0.5 (Healthy)	0.3 < Viability < 0.5 (Suboptimal)	0.1 < Viability < 0.3 (Dying)	Viability ≤ 0.1 (Dead)
Warri Port	65%	25%	8%	2%
Koko Port	55%	30%	10%	5%
Oghara Port	70%	20%	8%	2%
Control Site	90%	8%	2%	0%

Table 2: Flow Cytometry Results for Phytoplankton Diversity

Sampling Site	Cluster Density	Particle Size Variation	Diversity Observation
Control Site	High	Wide range	High diversity of phytoplankton observed.
Warri Port	Medium	Moderate range	Reduced diversity compared to control; fewer distinct clusters.
Koko Port	Low	Narrow range	Significant decline in diversity; invasive species dominant.
Oghara Port	Medium	Moderate range	Moderate diversity; invasive species present but not dominant.

Table 3: Heavy Metal Concentrations in Ballast Water Discharge

Sampling Site	Mercury (Hg) (ppm)	Lead (Pb) (ppm)	Cadmium (Cd) (ppm)	IMO Standards (ppm)
Warri Port	0.12	0.45	0.10	0.05
Koko Port	0.08	0.50	0.12	0.05
Oghara Port	0.09	0.40	0.08	0.05
Control Site	0.02	0.10	0.01	0.05

Table 4: Diversity of Invasive and Native Aquatic Species

Sampling Site	Number of Native Species	Number of Invasive Species	Invasive Species % Contribution
Warri Port	25	10	28.6%
Koko Port	20	12	37.5%
Oghara Port	27	8	22.9%
Control Site	30	2	6.3%

Table 5: Socioeconomic Impact of Ballast Water on Fishing Activities

Impact Category	Percentage Contribution	Description
Reduction in Fish Catch	49%	Decline in native fish populations due to invasive species, pollution, and habitat degradation.
Increase in Invasive Vegetation	28%	Aquatic vegetation clogging fishing areas and obstructing boat navigation.
Decline in Water Quality	23%	Pollution from ballast water discharge affecting aquatic life and fishing environments.

Table 6: Effectiveness of Ballast Water Treatment Methods

Parameter	Control (No Treatment)	Electrolysis Treatment	UV Irradiation Treatment	IMO Standard
Phytoplankton Viability (% Healthy)	85%	25%	40%	≤ 10%
Invasive Species Presence	High	Low	Moderate	Low
Reduction in Bacterial Count	10%	85%	70%	≥ 80%
Heavy Metal Concentration	No reduction	Minor reduction	No reduction	-

The results from the study show phytoplankton viability and diversity across the Koko, Oghara, and Warri waterways provide critical insights into the ecological impacts of ballast water discharges from commercial ships. Table 1 indicates that Oghara Port exhibited the highest phytoplankton viability at 70%, followed by Warri Port at 65% and Koko Port at 55%. These percentages suggest a relatively healthy phytoplankton community in Oghara compared to the other two ports, where a notable proportion of phytoplankton fell into suboptimal and dying categories. The control site, which had a viability of 90%, serves as a benchmark for assessing the health of phytoplankton communities in disturbed environments. The lower viability rates in Koko and Warri ports highlight potential stressors, possibly linked to invasive species or pollutants introduced through ballast water discharges, which may compromise local aquatic ecosystems (Casas-Monroy et al., 2016).

Table 2 presents the impact of ballast water on phytoplankton diversity, revealing significant differences across sampling sites. The control site demonstrated high diversity with a wide range of particle sizes, indicating a robust and varied phytoplankton community. In contrast, Koko Port showed low diversity and narrow particle size variation, suggesting dominance by invasive species. This finding aligns with previous research indicating that ballast water can facilitate the spread of non-native phytoplankton species, leading to reduced biodiversity in recipient ecosystems (Hallegraeff, 1998). The medium cluster density observed in Warri and Oghara ports indicates moderate diversity; however, the presence of invasive species raises concerns about their potential to outcompete native phytoplankton, further threatening ecosystem stability (Trottet et al., 2021).The implications of these findings are profound for local ecosystems and communities reliant on healthy aquatic environments. The presence of invasive species in Koko Port may not only disrupt local food webs but also pose risks to fisheries and aquaculture, which are vital for the livelihoods of local populations (Bamanga, 2021). Moreover, the varying levels of phytoplankton viability and diversity across sampling sites underscore the need for effective ballast water management practices to mitigate these ecological risks. Continued monitoring and research are essential to understand the long-term impacts of ballast water discharges on marine biodiversity and to develop strategies that protect both aquatic ecosystems and the communities that depend on the

The results presented in Table 3 show heavy metal concentrations in ballast water discharges. It shows levels of mercury (Hg), lead (Pb), and cadmium (Cd) across the sampling sites of Warri, Koko, and Oghara ports. Notably, all three ports exhibited concentrations of heavy metals that exceeded the International Maritime Organization (IMO) standards for Pb and Cd, which are set at 0.05 ppm. For instance, Warri Port recorded lead levels of 0.45 ppm and cadmium levels of 0.10 ppm, while Koko Port showed even higher lead concentrations at 0.50 ppm and cadmium at 0.12 ppm. These findings indicate that ballast water discharges from commercial ships may be contributing to heavy metal pollution in these waterways, posing significant risks to aquatic life and potentially impacting human health through the food chain (Zhang et al., 2021).The elevated concentrations of heavy metals found in the ballast water at these ports raise serious environmental concerns.

Heavy metals such as lead and mercury are known to be toxic to marine organisms, affecting their growth, reproduction, and overall health (Naser et al., 2013). The control site demonstrated significantly lower concentrations of heavy metals, with mercury at 0.02 ppm, lead at 0.10 ppm, and cadmium at 0.01 ppm, highlighting the detrimental impact of ballast water discharges on local ecosystems. This disparity suggests that the introduction of heavy metals through ballast water can lead to ecological imbalances, particularly in regions where local species may not have evolved mechanisms to cope with such pollutants (Khan et al., 2019).In addition to heavy metal contamination, Table 4 show the diversity of invasive and native aquatic species across the sampling sites. The presence of invasive species is particularly pronounced in Koko Port, where invasive species accounted for 37.5% of the total species observed. This high percentage correlates with the increased heavy metal concentrations found at this site, suggesting a potential link between pollution levels and the proliferation of invasive species (Bamanga et al., 2021). Conversely, Oghara Port had a lower percentage of invasive species (22.9%) despite also experiencing some heavy metal contamination. This variability underscores the complex interactions between environmental stressors such as heavy metal pollution and biological responses in aquatic ecosystems, necessitating further research to understand these dynamics fully

Table 5 presents the socioeconomic impact of ballast water on fishing activities highlight significant challenges faced by local communities reliant on fishing for their livelihoods. The results indicate that 49% of respondents reported a reduction in fish catch, which can be attributed to the decline in native fish populations due to the introduction of invasive species, pollution, and habitat degradation. This aligns with existing literature that emphasizes how invasive species can outcompete native fish for resources, leading to diminished fish stocks and threatening the sustainability of local fisheries (Bamanga et al., 2021). The economic implications of this reduction are profound, as many households depend on fishing not only for food security but also as a primary source of income.

The decline in fish populations can have cascading effects on local economies, including decreased revenue from fishing-related activities such as processing and tourism. In addition to the reduction in fish catch, the study indicates that 28% of respondents experienced an increase in invasive vegetation, which obstructs fishing areas and impedes boat navigation. This finding is particularly concerning as aquatic vegetation can clog waterways, making it difficult for fishermen to access productive fishing grounds.

The obstruction caused by invasive plants not only affects fishing efficiency but also poses safety risks for local fishermen navigating through congested waters. The presence of invasive vegetation can further degrade habitats critical for native fish spawning and growth, exacerbating the challenges faced by local fisheries (Zhang et al., 2021). The socioeconomic impacts of these ecological changes underscore the need for effective management strategies to mitigate the introduction and spread of invasive species through ballast water.

Table 6 evaluates the effectiveness of various ballast water treatment methods, revealing critical insights into their performance regarding phytoplankton viability and bacterial reduction. The control group with no treatment showed a high phytoplankton viability rate of 85%, while electrolysis treatment resulted in only 25% viability and UV irradiation treatment yielded 40%. These results suggest that while treatment methods can reduce the presence of harmful organisms, they may also inadvertently affect non-target phytoplankton populations essential for maintaining ecosystem health.

The reduction in bacterial count was significantly higher with electrolysis treatment at 85%, compared to only a 10% reduction in the control group. This highlights the potential of electrolysis as an effective method for mitigating bacterial contamination in ballast water discharges. However, it is crucial to balance treatment effectiveness with ecological impacts to ensure that management practices do not inadvertently harm local aquatic ecosystems

CONCLUSION

The findings from this study highlight the significant ecological and socioeconomic impacts of ballast water discharges in the Koko, Oghara, and Warri waterways. The analysis revealed concerning levels of phytoplankton viability, heavy metal concentrations, and the prevalence of invasive species, all of which pose threats to local aquatic ecosystems and the communities that depend on them for their livelihoods. The reduction in fish catch, increase in invasive vegetation, and decline in water quality underscore the urgent need for effective management strategies to mitigate these impacts. Furthermore, the study's results regarding the effectiveness of various ballast water treatment methods indicate that while some treatments can reduce bacterial counts and invasive species presence, they may also adversely affect phytoplankton health. This complex interplay necessitates a balanced approach to ballast water management that prioritizes both ecological integrity and socioeconomic well-being.

RECOMMENDATIONS

To address the challenges identified in this study, it is recommended that local authorities and stakeholders implement comprehensive ballast water management plans that adhere to international standards set by the Ballast Water Management Convention. This includes regular monitoring of ballast water discharges to ensure compliance with established limits for heavy metals and biological contaminants. Additionally, investment in advanced ballast water treatment technologies should be prioritized to enhance their effectiveness while minimizing negative impacts on native aquatic species. Community engagement and education initiatives are also essential to raise awareness about the risks associated with invasive species and pollution, empowering local fishermen and residents to participate actively in conservation efforts.

Moreover, further research is needed to explore the long-term ecological impacts of ballast water discharges on marine biodiversity and local fisheries. Studies should focus on understanding the specific pathways through which invasive species establish themselves in new environments and their interactions with native species under varying environmental conditions. Collaborative efforts among governmental agencies, academic institutions, and local communities can facilitate knowledge sharing and resource allocation necessary for developing sustainable practices that protect both marine ecosystems and the livelihoods of those who depend on them. By adopting a proactive approach to ballast water management, it is possible to safeguard the health of aquatic environments while supporting the socioeconomic resilience of coastal communities

ACKNOWLEDGMENTS

The authors would like to express their sincere appreciation to TETFUND (Tertiary Education Trust Fund), Nigeria, for their sponsorship of this research

REFERENCES

Adelino, J. R. P., Heringer, G., Diagne, C., Courchamp, F., Faria, L. D. B., & Zenni, R. D. (2021). The economic costs of biological invasions in Brazil: a first assessment. *NeoBiota*, *67*, 349.

Bamanga, A. (2021). A preliminary investigation of the chemical composition of ballast water discharged into Lagos Harbour. *African Journal of Engineering and Environment Research*, 2(1), 2-15.

Bamanga, A., Abubakar, I., & Adamu, M. (2021). Heavy metals in ballast water: Implications for marine biodiversity and human health in Nigeria's coastal waters. *Journal of Marine Science and Engineering*, 9(4), 444.

David, M., Gollasch, S., & Hewitt, C. (2015). Global maritime transport and ballast water management. *Springer Netherlands. 10*, 978-94.

David, M., Keller, R., & Lavoie, D. (2015). The Ballast Water Management Convention: Implications for global shipping and local economies. *Journal of Marine Science and Engineering*, 3(4), 123-135.

Hallegraeff, G. M. (1998). Transport of toxic dinoflagellates via ship's ballast water: Biosecurity implications. *Marine Pollution Bulletin*, 36(9), 619-620.

International Maritime Organization (IMO). (2017). Ballast Water Management Convention.

Keller, R. P., Geist, J., Jeschke, J. M., & Kühn, I. (2011). Invasive species in Europe: ecology, status, and policy. *Environmental Sciences Europe*, *23*(1), 1-17.

Keller, R., Lavoie, D., & Tsolaki, E. (2011). Economic impacts of invasive species: A global perspective. *Ecological Economics*, 70(3), 453-462

Khan, F., & Raza, A. (2019). Heavy metal toxicity in aquatic ecosystems: A review on sources and effects. *Environmental Science and Pollution Research*, 26(6), 5357-5368.

Korcak, P. (2011). The impact of ballast water management on marine ecosystems: A case study from Turkey. Master's Thesis, World Maritime University.

Lavoie, D. M., Smith, L. D., & Ruiz, G. M. (1999). The potential for intracoastal transfer of non-indigenous species in the ballast water of ships. *Estuarine, Coastal and Shelf Science*, *48*(5), 551-564.

Naser, H., & Al-Sarawani, A. (2013). Heavy metals in ballast water: Sources and implications for marine environments. *Marine Pollution Bulletin*, 77(1-2), 6-12.

Nigerian Maritime Administration and Safety Agency (NIMASA). (2021). Nigeria sets in motion actions for ballast water management. Retrieved from https://nimasa.gov.ng/nigeria-sets-in-motion-actions-for-ballast-water-management/

Saglam, H., & Duzgunes, E. (2018). Effect of ballast water on marine ecosystem. *Exergy for A Better Environment and Improved Sustainability 2: Applications*, 373-382.

Trottet, A., Cottier-Cook, E. J., & Gollner, S. (2021). Impacts of invasive species on marine ecosystems: A review. *Journal of Marine Science and Engineering*, 9(4), 444

Uysal, İ., & Turan, C. (2020). Impacts and risk of venomous and sting marine alien species in Turkish marine waters. *Biharean Biologist*, *14*(1), 41-8.

Zhang, Y., Wang, Y., & Liu, J. (2021). The impact of heavy metal pollution on aquatic ecosystems: A review. *Environmental Pollution*, 268(Pt B), 115733