TECHNOLOGICAL INNOVATIONS IN COMBATING SHIP-SOURCE MARINE POLLUTION IN NIGERIA

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ABSTRACT

Shipping constitutes the backbone of global commerce, facilitating the movement of approximately 90% of the world's goods, yet it remains a significant contributor to marine pollution through oil spills, ballast water discharge, and harmful emissions. This paper examines the role of technological innovations such as emission control systems, oil spill monitoring and response technologies, and ballast water treatment systems in addressing ship-source marine pollution. It argues that while these technologies are vital for environmental protection, their effectiveness depends largely on robust regulatory enforcement and institutional capacity. The study analyses the regulatory role of the International Maritime Organization and evaluates the domestic implementation of international standards in Nigeria through agencies such as the Nigerian Maritime Administration and Safety Agency (NIMASA) and the National Oil Spill Detection and Response Agency (NOSDRA). Adopting a doctrinal research methodology, the paper relies on primary legal sources, including international conventions particularly the MARPOL Convention relevant national legislation, and institutional frameworks, alongside secondary materials subjected to content analysis. The findings reveal that despite comprehensive legal and regulatory regimes, weak enforcement, inadequate technical expertise, and limited infrastructure significantly undermine compliance. These shortcomings reflect broader challenges of environmental governance and regulatory accountability in developing jurisdictions. The paper recommends strengthening institutional capacity, improving technological integration, and enhancing enforcement mechanisms to ensure more effective control of ship-source marine pollution in Nigeria and beyond.

Keywords: *Environment, Marine pollution, ship-source, technological innovation*

1.0 Introduction

Marine pollution remains a significant global concern, with far-reaching impacts on marine ecosystems, human health, and key economic sectors such as fisheries and tourism. Although a substantial proportion of marine pollution originates from land-based sources, ship-source pollution poses a serious threat, particularly in coastal nations engaged in extensive maritime commerce.[50] This form of pollution arises from both operational and accidental discharges from vessels, including oil and oily mixtures, noxious liquid substances, sewage, garbage, and harmful anti-fouling coatings. Ship-source pollution not only degrades marine environments but also contributes to the introduction of invasive aquatic species through ballast water discharge and undermines the economic sustainability of fishing industries. For instance, fisheries in the West African region generate over €500 million annually and support more than 600,000 livelihoods, underscoring the economic significance of preserving marine ecosystems. In Nigeria, the impact of marine pollution is particularly evident in the Niger Delta region, where intensive oil exploration and maritime activities have contributed to environmental degradation.[51] In response to these challenges, technological innovations have increasingly assumed a central role in efforts to prevent, detect, and mitigate pollution from ships. Technologies such as ballast water treatment systems, oil spill detection and response mechanisms, are transforming environmental management within the maritime sector. However, the effectiveness of these technologies is largely dependent on the strength of the regulatory frameworks governing their adoption and implementation.[52]

At the international level, the International Maritime Organization has established a comprehensive legal regime through instruments such as the MARPOL Convention[53], which sets out detailed rules for preventing pollution from ships. Its various annexes regulate pollutants including oil, chemicals, sewage, garbage, and air emissions, while also mandating the use of pollution-control technologies and requiring port authorities to provide adequate waste reception facilities. Compliance is enforced through flag State, coastal State, and port State control mechanisms, thereby promoting international uniformity. Notwithstanding these

[50] Umezurike Ezugwu, 'Marine Environmental Pollution In Nigeria and its Possible Implication' https://www.researchgate.net/publication/397446993_MARINE_ENVIRONMENTAL_POLLUTION_IN_NIGERIA_AND_ITS_POSSIBLE_IMPLICATION_AND_SOLUTION accesssed March 13, 2026
[51] Ibid
[52] Ibid
[53] International Convention for the Prevention of Pollution from Ships (adopted 2 November 1973, as modified by the protocol of 1978, entered into force 2 October 1983)

regulatory efforts, the effectiveness of such frameworks in developing maritime states like Nigeria, remains limited. Challenges such as weak enforcement, inadequate port reception facilities, limited technological capacity, and insufficient monitoring systems continue to undermine compliance. As a result, pollution from operational discharges persists, raising concerns about the long-term sustainability of marine environments in key port areas such as Lagos, Onne, and Calabar.[54]

The principal aim of this study is to examine the role of technological innovations in mitigating ship-source marine pollution within Nigeria's maritime environment while the specific objectives include:

1. To examine the major sources of ship-source marine pollution within Nigeria's maritime environment
2. To analyse the existing international and legal frameworks governing ship-source marine pollution in Nigeria
3. To identify the challenges and gaps in the adoption and implementation of technological innovations for mitigating ship-source marine pollution in Nigeria

2.0 Overview of Ship-source Marine Pollution in Nigeria

The international maritime community has become increasingly aware of the persistence of ship-generated marine pollution, particularly regarding the challenges posed by ineffective port waste management systems. Within Nigerian ports and terminals, infractions frequently occur due to the inadequate supply and management of waste reception facilities intended for the disposal of oil residues, refuse, and hazardous materials generated on ships.[55] Between 2008 and 2011, Tin Can Island Port recorded increases of approximately 32% in garbage and 18% in oily waste, indicating growing pressure on already insufficient facilities.[56] The absence of modern, technology-driven waste processing systems further intensifies this issue, limiting the efficiency and ecological safety of waste management operations.

The Nigerian Ports Authority (NPA), tasked with the responsibility for the administration of Nigeria's ports, does not operate a waste disposal and reception facility; rather, it delegates these services to private pollution control firms. While this approach aims to improve service

[54] A.Essien, 'An Analysis of Ship-Source Marine Pollution in Nigeria' (2017) 5(3) Journal of Marine Science and Engineering' < https://www.researchgate.net/publication/355087293_An_Analysis_of_Ship-Source_Marine_Pollution_in_Nigeria_Seaports>

[55] Ibid

[56] Ibid

delivery, it raises concerns regarding accountability and transparency.[57] The lack of independent oversight and technological auditing systems creates opportunities for regulatory lapses and cost-cutting practices that may compromise environmental standards.

Consequently, the inadequacy of waste reception facilities, along with ineffective monitoring systems, encourages vessels to unlawfully discharge waste at sea before arriving at the port.[58] These practices exacerbate marine pollution and adversely affect coastal communities dependent on fishing and marine resources. This highlights a significant gap in infrastructure as well as in the implementation of modern technologies for waste tracking, monitoring, and enforcement.

3.0 Types and Causes of Ship-source Marine Pollution in Nigeria

The MARPOL Convention classifies ship-source pollution into distinct categories through its annexes, each addressing a specific type of pollutant. They include:

3.1 Oil Pollution: This occurs when oil or oily mixtures are released into the marine environment, either through operational discharges or accidental spills.[59] Operational sources include bilge water from engine rooms, lubricants, and cleaning agents. Bilge water accumulates in the lowest section of the ship from various sources, including main and auxiliary engines, boilers, and evaporators. Despite filtration systems, minute concentrations of oil often remain, endangering marine life. Some shipping companies bypass regulations by releasing untreated bilge water and thereby causing environmental damage.

3.2 Pollution by Noxious Liquid Substances: This refers to the discharge of hazardous chemicals transported in bulk. These substances are extremely toxic, posing long-term risks to both human health and marine ecosystems.[60]

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[57] **Onder Canbulat, 'Ship-Generated Waste Management in İstanbul Ports: An Analytical Methodology to Evaluate Waste Reception Performance (WRP)' (2023) 11(4) Journal of ETA marine Science 259-269<** https://www.researchgate.net/publication/375116841_Ship-Generated_Waste_Management_in_Istanbul_Ports_An_Analytical_Methodology_to_Evaluate_Waste_Reception_Performance_WRP**> accessed 20 March 2026**

[58] Abhijit Arvind, 'Ship Generated Waste Management Practices, challenges and innovations on board and at Ports: A Systematic Review < https://www.academia.edu/145419800/Ship_generated_waste_management_practices_challenges_and_innovations_onboard_and_at_ports_a_systematic_review> accessed 20 March 2026

[59] MARPOL 73/78, Annex I

[60] MARPOL 73/78, Annex II.

3.3 Pollution by Harmful Substances in Packaged Form: Pollution can also arise from dangerous goods carried in containers, drums, or other packaged forms.[61] Leakage or accidental loss overboard can introduce hazardous materials into the marine environment.

3.4 Sewage Pollution (Blackwater and Greywater): Sewage from ships includes wastewater from toilets, medical facilities, and sinks. Cruise ships, carrying thousands of passengers, generate substantial amounts of sewage. MARPOL Annex IV[62] regulates sewage discharge standards, equipment, and port reception facilities. Greywater, though not explicitly regulated, often contains harmful bacteria, detergents, and oils.

3.5 Garbage Pollution: Ship-generated solid waste includes plastics, food waste, and cargo residues.[63] Plastic pollution is particularly concerning because it persists in the marine environment and harms marine species.[64]

4.0 **Legal and Regulatory Framework for Combatting Ship-Source Marine Pollution**

The existence of well-developed legal instruments and institutional mechanisms that regulate maritime activities is essential for a successful response to ship-source marine pollution.

4.1 International Framework

4.1.1 The International Maritime Organization

The United Nations specialised agency responsible for regulating international shipping and promoting maritime security, safety, and environmental preservation is the International Maritime Organization. Nigeria is a member of the International Maritime Organization (IMO) and has adopted key conventions such as the International Convention for the Prevention of Pollution from Ships and the International Convention for the Control and Management of Ships' Ballast Water and Sediments. These are implemented domestically through the Nigerian Maritime Administration and Safety Agency (NIMASA). The IMO in relation to technological innovations for combatting ship-source marine pollution, provides the legal and technical

[61] MARPOL 73/78, Annex III.
[62] International Convention for the Prevention of Pollution from Ships (adopted 2 November 1973, as modified by the protocol of 1978, entered into force 2 October 1983).
[63] MARPOL 73/78, Annex V
[64] J.A Akanli, E.I Elelenwo, 'Sources of Marine Pollution on Nigerian Coastal Resources: An Overview' (2015) 5(2) Open Journal of Marine Science https://www.scirp.org/journal/paperinformation?paperid=55413 accessed 23 March 2026.

framework for developing, implementing, and standardizing anti-pollution technologies.[65] The use of technologies such as ballast water treatment systems, bilge water treatment systems, oil spill containment and recovery equipment, and green shipping technologies is mandated by key conventions under the IMO.

4.1.2 The International Convention for the Prevention of Pollution from Ships (MARPOL)

MARPOL is the primary international convention established to mitigate pollution from ships. It was ratified by the International Maritime Organization (IMO) in 1973.[66] MARPOL establishes extensive regulations aimed at mitigating marine pollution from ships, arising mainly from operational and unintentional sources. MARPOL is comprised of six Annexes, each addressing a distinct category of pollution: oil (Annex I), noxious liquid substances (Annex II), harmful substances in packaged form (Annex III), sewage (Annex IV), garbage (Annex V) and air pollution (Annex VI). Although these provisions are regulatory, they are heavily dependent on technical innovations. For example, MARPOL mandates the implementation of technologies such as double hulls in oil tankers to mitigate the risk of oil spillage during collisions under Annex I.[67] Similarly, MARPOL Annex IV and Annex V encourage the implementation of sophisticated onboard treatment systems, such as sewage treatment facilities and waste management technologies, to guarantee that discharges comply with the established environmental standards.[68]

4.2 National Framework

4.2.1 National Oil Spill Detection and Response Agency

The National Oil Spill Detection and Response organization (NOSDRA) is Nigeria's principal organization responsible for monitoring, detecting, and responding to oil spills, especially in its territorial waters and offshore oil operations. Established pursuant to the NOSDRA Act of

[65] Bruce G, Eyres J, 'International Maritime Organization' (2012)< https://www.researchgate.net/publication/301075900_International_Maritime_Organization> accessed 23 March 2026

[66] International Convention for the Prevention of Pollution from Ships (adopted 2 November 1973, as modified by the protocol of 1978, entered into force 2 October 1983)

[67] Ibid

[68] Amran Al-Kamzari, 'The problem of small-scale marine oil spills discharged by unattributable vessels: A review' (2025) https://www.ea.gov.om/media/fivawfud/the-problem-of-small-scale-marine-oil-spills-discharged-by-unattributable-vessels.pdf accessed 23 March 2026

2006,[69] the body plays a crucial role in enforcing environmental regulations and advocating for the adoption of technology solutions to mitigate marine pollution. NOSDRA utilizes modern technologies, including satellite and drone surveillance for early spill detection, Geographic Information Systems (GIS) for tracking and mapping affected regions, and oil spill modelling software for predicting spill movements and consequences. It also promotes the deployment of advanced response apparatus, including automated oil skimmers and containment booms, to guarantee early containment and cleanup. NOSDRA enforces adherence to national legislation and aligns its operations with international standards, thereby promoting the implementation of preventive technologies such as double-hull vessel designs and onboard containment systems.[70] Additionally, NOSDRA promotes the effectiveness and timeliness of oil spill response through technology-driven and regulatory measures.[71]

4.2.2 Nigerian Maritime Administration and Safety Agency (NIMASA)

The Nigerian Maritime Administration and Safety Agency (NIMASA) is the primary regulatory body responsible for ensuring environmental compliance, maritime safety, and security. The agency was established under the NIMASA Act of 2007[72] and is responsible for the implementation and enforcement of international maritime conventions. It serves as Nigeria's flag state administration. NIMASA is instrumental in the promotion and enforcement of technological innovations that are consistent with the Ballast Water Management Convention and the MARPOL Convention. These include onboard pollution control technologies, such as oil filtering equipment, sewage treatment systems, ballast water treatment systems to prevent the introduction of invasive species, and double-hull vessel designs to reduce the risk of oil accidents. In addition to conducting ship inspections, certification, and compliance monitoring, the agency also ensures that environmental standards are met.[73]

5.0 Technological Innovations in Combating Ship-source marine Pollution

[69] National Oil Spill Detection and Response Agency (Establishment) Act 2006.

[70] **Matilda A, Femi A, 'Role of the National Oil Spill Detection and Response Agency (NOSDRA) in Resolving Oil Spill Disputes in Nigeria Introduction and Problem Statement' (2025)** https://www.researchgate.net/publication/396310577_Role_of_the_National_Oil_Spill_Detection_and_Response_Agency_NOSDRA_in_Resolving_Oil_Spill_Disputes_in_Nigeria_Introduction_and_Problem_Statement **accessed 23 March 2026.**

[71] Ibid

[72] Nigerian Maritime Administration and Safety Agency Act 2007.

[73] Elezuo k, Bello M, Aladetohun NF, 'Harnessing the fisheries sector of the blue economy for sustainable economic growth and development in Nigeria: Opportunities, challenges, and strategies' (2024) 12(5) International Journal of Fisheries and Aquatic Studies 15-23 < https://www.fisheriesjournal.com/archives/2024/vol12issue5/PartA/12-4-12-922.pdf> accessed 22 March 2026

Through instruments like MARPOL, modern technologies have been developed to minimise operational discharges, enhance monitoring systems, and advocate for ecologically sustainable shipping operations.[74] They include:

5.1 Monitoring and surveillance technologies

Monitoring and surveillance technologies are crucial in mitigating ship-source pollution because they allow for early identification, accurate tracking, and timely reaction to maritime contamination.[75]

5.1.1 Satellite remote sensing: is one of the most effective methods for monitoring ship-source pollution. Satellites provide continuous, wide-area coverage of oceans, making it possible to detect oil spills even in remote offshore regions.[76] Technologies such as the Synthetic Aperture Radar (SAR) identify oil slicks by detecting changes in sea surface roughness, while optical and infrared sensors detect variations in colour and temperature caused by oil layers. Ships can benefit from satellite systems by subscribing to maritime monitoring services that provide real-time alerts about nearby spills or suspicious discharges. Shipping companies can also integrate satellite data into their navigation and environmental management systems, allowing crews to avoid contaminated areas and report incidents promptly.

5.1.2 Aerial surveillance: complements satellite monitoring by offering real-time observation of pollution incidents.[77] Aircraft equipped with advanced tools such as ultraviolet and infrared cameras, laser fluoro sensors, and multi-spectral scanners can confirm the presence of oil, map its extent, and estimate its thickness. Ships can collaborate with aerial surveillance operations by maintaining open communication channels with maritime authorities and response teams. For instance, when a ship reports a suspected spill, aerial units can be deployed to verify and assess the situation. Ships involved in offshore operations can also contract aerial monitoring services as part of their environmental protection plans.

[74] Micromarin, 'The Future of Ship Management: How Digital Platforms Are Transforming the Maritime Industry' (2026) <https://micromarin.com/blog/how-digital-platforms-are-transforming-the-maritime-industry> accessed 13 March 2026

[75] Chiemezie A, Chinonso L, Ebi F, 'Economic Impacts of Marine Pollution in Nigeria and the Need for Sustainable Policy Interventions' (2024) 3(4) International Journal of Social Science Humanity & Management Research 441-449 https://ijsshmr.com/v3i4/Doc/5.pdf accessed 22 March 2026

[76] **Carl E, Kim P, 'Aerial Surveillance, Monitoring, and Remote Sensing of Maritime Oil Spills: A Global Survey of Current Capabilities' (2026) <** https://www.researchgate.net/publication/400442703_Aerial_Surveillance_Monitoring_and_Remote_Sensing_of_Maritime_Oil_Spills_A_Global_Survey_of_Current_Capabilities**> accessed 24 March 2026**

[77] Ibid

5.1.3 Surface and subsurface sensors: provide localised, real-time monitoring of water conditions and are particularly effective for detecting pollution that cannot be seen from the surface. These sensors can be mounted on buoys, autonomous underwater vehicles (AUVs), or directly on ships.[78] They help measure oil concentration continuously and sound an alarm when pollution levels exceed safe thresholds. Ships can also facilitate the implementation of sensor networks in ports and along important shipping lanes by sharing data with authorities.[79] This proactive monitoring assists ships in the early detection of leaks, the prevention of accidental discharges, and the demonstration of compliance with environmental standards.

6.1.4 Artificial intelligence and data integration enhance the effectiveness of all other monitoring technologies by enabling faster analysis and smarter decision-making. AI systems can automatically process satellite imagery to detect oil spills, predict their movement based on environmental conditions such as wind and currents, and recommend optimal response strategies.[80] For example, AI-powered software can analyse sensor data to identify abnormal discharge patterns, predict equipment failures that could lead to leaks, and optimize waste management processes.

6.2 Oil Pollution Prevention and Response Technologies

These technologies are particularly important in combating ship-source pollution, which arises from tanker accidents, illegal discharges, bunkering operations, and routine vessel activities.

6.2.1 Oil Containment Boom: One of the most frequently used methods in oil spill response is the oil containment boom. These are floating barriers used to confine and concentrate oil on the water's surface, preventing it from spreading to vulnerable areas including shorelines, ports, and mangrove habitats.[81] In Nigeria, oil containment booms are frequently employed in spill response operations, notably in coastal regions and major ports such as Port Harcourt Port and Lagos Port Complex.[82]

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[78] **Giovanni B, Vincenzo C, 'Review on Sensors for Sustainable and Safe Maritime Mobility'(2024)<** https://www.researchgate.net/publication/378331300_Review_on_Sensors_for_Sustainable_and_Safe_Maritime_Mobility**> accessed 24 March 2026**

[79] Ibid

[80] Ibid

[81] Virginia O, Ekunke G, 'A Review of Modern Technologies and Best Practices for Oil Spill Containment and Response' (2025) < https://www.researchgate.net/publication/390419131_A_review_of_modern_technologies_and_best_practices_for_oil_spill_containment_and_response> accessed 24 March 2026

[82] Ibid

6.2.2 Skimmers: Skimmers are mechanical devices that remove oil from the water's surface. Skimmers use various mechanisms, such as revolving drums, discs, or suction systems. They play an important role in preventing ship-source pollution because they allow for the recovery of spilt oil, particularly in port regions where spills are frequently localised.

6.2.3 Chemical Dispersants: In addition to mechanical methods, chemical dispersants are commonly utilised to control oil spills. Dispersants are chemical agents that split up oil into smaller droplets, allowing marine microbes to naturally degrade it. This approach helps reduce the visibility and spread of oil slicks on the water's surface, thereby minimising the risk of shoreline pollution.[83]

6.2.4 Oil Spill Modelling and Forecasting System: Oil spill modelling and forecasting system is a more sophisticated method of managing oil spills. These computer-based tools simulate the movement, behaviour, and fate of oil spills in marine environments. These systems can anticipate the route of oil slicks and assess their potential impact on coastal and marine resources by using data such as ocean currents, wind patterns, and water temperature.[84]

6.3 Ballast Water Treatment Systems

Ballast Water Treatment Systems (BWTS) are critical technology used on ships to treat ballast water, which is required to keep the vessel stable during voyages. While ballast water aids safe navigation, it also transports dangerous microbes, bacteria, and invasive species from one location to another. When these organisms are discharged, they may disrupt local ecosystems, making ballast water a major source of ship-sourced pollution, particularly in the form of biological contamination. BWTS are designed to solve this problem by treating ballast water before discharge, thereby eliminating or neutralising hazardous organisms.[85] In so doing they play a crucial role in protecting marine biodiversity, preserving fisheries, and ensuring ecological equilibrium in coastal areas.[86]

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[83] Umezurike Ezugwu, 'Marine Environmental Pollution In Nigeria and its Possible Implication' https://www.researchgate.net/publication/397446993_MARINE_ENVIRONMENTAL_POLLUTION_IN_NIGERIA_AND_ITS_POSSIBLE_IMPLICATION_AND_SOLUTION accesssed March 13, 2026

[84] **Onder Canbulat, 'Ship-Generated Waste Management in İstanbul Ports: An Analytical Methodology to Evaluate Waste Reception Performance (WRP)' (2023) 11(4) Journal of ETA marine Science 259-269< https://www.researchgate.net/publication/375116841_Ship-Generated_Waste_Management_in_Istanbul_Ports_An_Analytical_Methodology_to_Evaluate_Waste_Reception_Performance_WRP> accessed 20 March 2026**

[85] **Carl E, Kim P, 'Aerial Surveillance, Monitoring, and Remote Sensing of Maritime Oil Spills: A Global Survey of Current Capabilities' (2026) < https://www.researchgate.net/publication/400442703_Aerial_Surveillance_Monitoring_and_Remote_Sensing_of_Maritime_Oil_Spills_A_Global_Survey_of_Current_Capabilities> accessed 24 March 2026**

6.4 Sewage treatment systems

MARPOL defines sewage as waste from toilets, urinals and medical facilities. The waste content of ships affects the environment, organisms, and waste treatment procedures. A waste discharge monitoring mechanism is therefore required to optimise monitoring. MARPOL Annex IV strives to ensure that sewage disposal from ships is handled first, and that port authorities ensure safety management systems to comply with marine protection rules. MARPOL regulations govern the disposal of sewage from ships, requiring maintenance before it is disposed of in approved regions.

6.5 Green Sheep Technologies

Green ship technologies represent a critical technological innovation in combating ship-source marine pollution, especially as the global maritime industry transitions towards sustainable practices. These technologies seek to reduce hazardous emissions, increase fuel economy, and minimise pollutant discharge into maritime habitats. In response to mounting environmental concerns, the International Maritime Organization has set ambitious goals, including a 40% decrease in shipping carbon intensity by 2030 compared to 2008 levels.[87] This has led to a widespread adoption of cleaner and more efficient shipping technology throughout the sector. One significant area of innovation is the retrofitting of existing vessels with fuel-efficiency upgrades. Some companies have implemented steps including improved hull coatings and propeller improvements to boost engine performance. These upgrades have resulted in measurable fuel savings of approximately 6% per vessel, lowering greenhouse gas emissions and limiting the release of oil residues and other pollutants into the water.

7.0 Challenges and gaps in the adoption of technological innovations in Nigeria

Despite the growing importance of technological innovations in mitigating ship-source marine pollution, several challenges hinder their effective adoption and implementation in Nigeria.

7.1.1 Weak Enforcement of Regulations: although regulatory frameworks exist, enforcement remains inconsistent and often ineffective.[88] Regulatory agencies frequently lack the capacity and resources to ensure compliance, allowing some vessels to bypass pollution-control

[87] Ibid

[88] Acceleron, 'Our Oceans and Technology: how Digital innovation can help Marine Sustainability' (2021) <https://accelleron.com/charge-magazine/how-digital-innovation-can-help-marine-sustainability > accessed 12 March 2026.

technologies such as oily water separators and emission control systems without facing significant consequences.

7.1.2 High Cost of Technological Systems: the acquisition, installation and maintenance of modern pollution-control technologies, including ballast water treatment systems and monitoring equipment, require substantial financial investment.[89] This creates a barrier for ship operators and port authorities particularly in a developing country like Nigeria where cost considerations often take precedence over environmental compliance.

7.1.3 Inadequate Infrastructure

Many Nigerian ports lack the necessary infrastructure to support technological solutions, particularly modern waste reception and treatment facilities.[90] The absence of such infrastructure limits the effectiveness of pollution-control measures and discourages compliance by vessels operating within Nigerian Waters.

7.1.5 Limited Technical Capacity

The effective operation of advanced technologies depends on skilled personnel, which remains a challenge in Nigeria. There is a shortage of adequately trained professionals within both the maritime industry and regulatory agencies, leading to improper use, poor maintenance, or complete underutilization of available technologies.

8.0 Conclusion

Ship-source marine pollution remains a significant threat to the marine environment, human health and global economic activities. Despite the existence of regulatory frameworks, challenges such as weak enforcement, technological limitations and operational negligence continue to undermine efforts to curb pollution. However technological innovations have emerged as effective tools in addressing these challenges. From advanced monitoring systems to cleaner ship designs and automated waste management technologies these innovations provide practical and sustainable solutions to reduce marine pollution.

[89] **Micromarin, 'The Future of Ship Management: How Digital Platforms Are Transforming the Maritime Industry' (2026) <**https://micromarin.com/blog/how-digital-platforms-are-transforming-the-maritime industry**> accessed 13 March 2026**
[90] Ibid

Nevertheless, the effectiveness of these technologies depends largely on proper implementation, adequate funding and strong institution support. Therefore, a combined effort involving governments, international organizations and private stakeholders is essential.

9.0 Recommendation

The following recommendations are therefore proposed:

Adoption of Advanced Monitoring Technologies: Governments and maritime agencies should invest in modern technologies such as satellite surveillance, remote sensing systems and automatic identification systems (AIS). These tools are essential in detecting illegal discharges and track vessels in real time

Strengthening Regulatory Enforcement: There should be stricter enforcement of existing laws like MARPOL regulations, National Environmental Laws. Moreso agencies such as NIMASA and NOSDRA should be better funded and equipped with modern tools to ensure compliance.

Promotion of Green Ship Technologies: Ship owners should be encouraged to adopt cleaner fuels, ballast water treatment systems and oil water separators to help reduce pollution at the source.

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