

**A STUDY OF THE IMPACT OF MARINE POLLUTION ON SHIPPING
OPERATIONS AND THE MARINE ENVIRONMENT IN LAGOS, NIGERIA.**



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CERTIFICATION

This is to certify that the research project titled, “A study of the impact of marine pollution on shipping operations and the marine environment in Lagos, Nigeria.” was conducted by Ayomide Miriam Jamgbadi, Oghenetega Fortune Morrison and Victor Ayobami Oluwayomi of the Marine Engineering Programme in the Department of Mechanical Engineering, Faculty of Engineering, University of Benin, Benin City, Edo State, Nigeria under the guidance and supervision of Professor A. I. Obanor.

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DEDICATION

We dedicate this project first and foremost to God Almighty, whose wisdom, guidance and grace have been our strength throughout this journey. His unfailing support has made this accomplishment possible.

We also dedicate this work to our families and friends, whose encouragement, patience and unwavering belief in us have been a source of motivation.

Lastly, we extend our deepest appreciation to our lecturers, mentors and colleagues whose insights, guidance and shared experiences have contributed immensely to our learning and growth.

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ABSTRACT

Marine pollution is an escalating issue, particularly in shipping operations, where factors such as oil spills, ballast water discharge, and plastic waste pose serious threats to marine ecosystems and global trade. This study seeks to assess the impact of marine pollution on both shipping operations and the marine environment, offering insights into its root causes, consequences, and potential solutions.

This thesis describes the nature of marine pollution, its key sources and their effects which brings to light the escalating pollution problem and its consequences on marine biodiversity, fisheries, the economic viability of coastal communities and shipping operations. It highlights the regulatory measures such as Marine Pollution (MARPOL) and the Ballast Water Management Convention.

The research methodology employs a descriptive survey design that gathers data from marine engineers, ship operators, port officials and environmental officers. These findings are used to propose solutions such as stricter enforcement of environmental regulations, adoption of sustainable fuels and enhanced waste management strategies.

This research emphasizes the dire need for industry-wide cooperation to diminish pollution, balance economic interests with environmental sustainability, and ensure the long-term resilience of both shipping operations and marine environment.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Marine pollution has become an urgent global concern, particularly within the maritime industry, as the ecological and economic consequences of increased pollution continue to escalate. With the steady growth in global shipping activities, the risk and frequency of pollution events have likewise risen. Major sources of pollution, including oil spills, ballast water discharge, plastic waste, and hazardous chemical releases, contribute to the degradation of marine ecosystems. These pollutants have far-reaching impacts on biodiversity, disrupting marine life, damaging fisheries, and threatening the livelihoods of coastal communities. Moreover, the effects of marine pollution extend beyond the environment, impacting shipping operations through disrupted marine routes, increased operational expenses, and stricter environmental regulations.

The shipping industry occupies a unique position in the marine pollution landscape, acting both as a significant contributor to pollution and as a sector vulnerable to its repercussions. The adverse effects of pollution pose challenges to shipping companies by complicating navigation routes, increasing maintenance costs, and requiring investments in pollution control measures to meet regulatory standards. To tackle these challenges, the International Maritime Organization (IMO) has introduced essential conventions, including the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Ballast Water Management Convention. These initiatives are designed to limit pollution from ships and mitigate the industry's ecological footprint by regulating waste discharge, exhaust emissions, and ballast water management. However, despite these efforts, the industry continues to face significant challenges in fully curbing pollution, underscoring the need for ongoing improvements in regulatory frameworks, technology adoption, and sustainable practices.

This study aims to comprehensively examine the impact of marine pollution on both the operational efficiency of the shipping industry and its environmental implications. By analyzing the causes, consequences, and control mechanisms associated with marine pollution, this study will establish a foundation for understanding how regulatory measures and industry practices can further mitigate its negative effects. Ultimately, this research will

contribute to the growing body of knowledge on sustainable maritime operations and underscore the importance of balancing economic demands with environmental preservation to ensure the future resilience of both marine ecosystems and global shipping operations (International Maritime Organization, 2021; Smith et al., 2022).

1.2 Statement of the Problem

Marine pollution remains one of the most critical environmental challenges facing the maritime industry and global ecosystems today. As international shipping expands, so does the number of pollutants released into the ocean, including oil spills, ballast water discharges, and plastics. These contaminants pose serious threats to marine biodiversity, disrupt ecosystems, and harm coastal economies dependent on clean waters and thriving fisheries. Despite efforts to regulate emissions and waste disposal, pollution from shipping activities continues to rise, exacerbating the degradation of the marine environment.

This growing pollution also imposes significant operational and financial burdens on the shipping industry. Strict environmental regulations demand costly investments in pollution control technology, increase fuel and maintenance expenses, and complicate route planning. Shipping companies are under pressure to meet these environmental standards, which are essential for sustainability yet challenging to maintain in a cost-effective manner.

Moreover, while the International Maritime Organization (IMO) and other regulatory bodies have implemented conventions such as MARPOL and the Ballast Water Management Convention, enforcement gaps and inconsistencies in regulation across international waters persist. This leaves room for ongoing pollution, especially in regions where monitoring and compliance are limited. These challenges highlight the urgent need for research to address the root causes of marine pollution, evaluate the effectiveness of current regulations, and explore new strategies for sustainable shipping practices that can benefit both the industry and the environment.

1.3 Aim

This project aims to analyze the impact of marine pollution on shipping operations and the marine environment, identifying the main pollution sources and their consequences.

1.4 Objectives

1. To assess the effects of marine pollution on marine ecosystems, focusing on biodiversity, fisheries, and coastal communities.
2. To examine the effects of marine pollution on shipping operations, including operational costs, navigational challenges, and regulatory compliance.

1.5 Research Questions

3. To examine and evaluate the primary sources of marine pollution arising from shipping operations.
4. To assess the effectiveness of current international regulatory measures, such as the MARPOL Convention and the Ballast Water Management Convention, in reducing marine pollution.
5. To investigate industry practices and technologies aimed at minimizing pollution and promoting sustainable maritime operations.
6. To provide recommendations for improving pollution control measures and encouraging sustainable practices within the global shipping industry.

1.6 Significance of the Study

This study is important as it tackles the critical issue of marine pollution in relation to shipping operations, a major driver of global trade. By exploring the connection between marine pollution and the maritime industry, it will offer valuable insights to inform policy development and industry practices. The research findings will support environmental sustainability by suggesting practical solutions to reduce marine pollution while enhancing the efficiency of shipping operations.

1.7 Scope of the Study

This study focuses on the impacts of marine pollution specifically related to shipping operations, including oil spills, ballast water, and plastic waste, etc. It will cover the environmental and operational challenges caused by these pollutants and the effectiveness of current regulations. The study will not delve into other forms of pollution unrelated to

shipping, such as land-based sources of marine litter or atmospheric pollution from other industries.

CHAPTER TWO

1. LITERATURE REVIEW

2.1 Nature of the Marine Environment And Pollution

The marine environment constitutes the majority of the Earth's surface, encompassing aquatic ecosystems within both saltwater and freshwater systems that exhibit varying levels of salinity. Covering more than 70% of the planet's surface, marine waters hold over 97% of the Earth's total water supply and contribute to 90% of its habitable space.

Marine pollution is the introduction of harmful substances into the ocean, originating mainly from land-based activities and maritime transport. This contamination occurs through runoff, spills, or wind-carried debris, encompassing industrial, agricultural, and household waste, as well as particulate matter, noise pollution, excess carbon dioxide, and invasive species. Such pollutants pose serious threats to marine ecosystems, global environmental stability, and economic systems. Although approximately 80% of marine pollution stems from land-based sources, shipping operations also contribute significantly.

2.2 Key Types, Sources, and Causes of Marine Pollution

The major types of marine pollution include:

Oil Spills: One of the most visible forms of pollution, oil spills cause severe harm to marine life and ecosystems.

Plastic Pollution: A growing issue, with vast amounts of plastic waste entering the oceans, endangering marine animals and seabirds.

Chemical Pollution: Industrial runoff containing fertilizers, pesticides, and heavy metals creates toxic conditions and dead zones, making survival difficult for marine organisms.

Sewage and Waste Disposal: Excess nutrients from sewage lead to harmful algal blooms and oxygen depletion, threatening marine ecosystems.

Noise Pollution: Sounds from shipping, sonar, and drilling interfere with marine species' communication and navigation.

Thermal Pollution: Industrial activities alter water temperatures, disrupting marine ecosystems and affecting aquatic life.

2.2.1 Sources of Marine Pollution

The primary sources of marine pollution include:

- I. **Waste and Sewage:** Discharge from industries, residences, and other sources flows directly into the sea, contributing to pollution.
- II. **Organic Waste:** The disposal of organic materials poses a significant challenge and is a major contributor to marine pollution.
- III. **Pesticides and Fertilizers:** Runoff from agricultural activities carries these chemicals into water bodies, eventually reaching the ocean.
- IV. **Oil Spills and Ship Accidents:** These incidents release heavy metals and other harmful contaminants into marine environments.
- V. **Offshore Oil Exploration and Extraction:** Activities related to oil drilling significantly contribute to seawater pollution.

2.2.2 Causes of Marine Pollution

Marine pollution arises from multiple sources, including land-based activities, maritime operations, and atmospheric deposition. The primary contributors to marine pollution include:

Land-Based Sources (Nonpoint Source Pollution – Runoff): Pollution accumulates from multiple small sources that cannot be precisely identified. For instance, after heavy rainfall, runoff from roads carries oil and other pollutants into the ocean. Additionally, wind can transport dirt and debris, depositing them onto the ocean's surface.

Maritime Activities: Maritime activities such as shipping, fishing, and offshore oil and gas operations lead to pollution through oil spills, waste discharge from ships, and marine debris. In many regions, manufacturing plants discharge toxic waste, including mercury, into the ocean, while sewage further contaminates marine waters. Plastic waste is a particularly severe issue, with the Ocean Conservancy estimating that eight million metric tons of plastic enter the oceans annually.

Atmospheric Deposition: Pollutants from the air, such as acid rain, heavy metals, and microplastics, can travel long distances before being deposited into the ocean, worsening marine pollution.

Oil Spills: Ships significantly contribute to ocean pollution, especially during crude oil spills, which persist for years and are challenging to clean up. One of the largest oil spills in recent history was the 2010 Deepwater Horizon disaster in the Gulf of Mexico, which released approximately 134 million gallons of oil into the ocean.

Littering: Waste items, particularly single-use plastics and styrofoam, are carried by wind and water into the ocean, where they take hundreds of years to decompose. It is estimated that around one trillion plastic bags are used worldwide each year, contributing to marine pollution.

Ocean Mining: Extracting minerals like cobalt, zinc, silver, gold, and copper through deep-sea mining causes pollution and disrupts deep-sea ecosystems. The drilling process releases harmful sulfide deposits, which pose significant threats to marine organisms.

2.3 EFFECTS OF MARINE POLLUTION ON BIODIVERSITY, FISHERIES AND COASTAL COMMUNITIES

2.3.1 Effects on Biodiversity

- I. **Biodiversity**, which encompasses the variety of life forms on Earth, including genetic diversity, species variation, and ecosystems, is essential for maintaining ecological balance. Marine pollution poses a severe threat to marine biodiversity, impacting the health and survival of numerous aquatic species. Understanding these effects is critical for developing effective mitigation strategies. Marine pollution significantly alters the biological structure of ocean life. The introduction of harmful substances disrupts ecological balance and interferes with essential biological processes, including
- II. **Toxic Chemicals:** Pollutants such as heavy metals, pesticides, and industrial waste enter marine organisms, disrupting their physiological functions and leading to long-term health effects.

III. **Oxygen Depletion:** Excess nutrients from agricultural runoff contribute to algal blooms, which deplete oxygen levels in water bodies, creating hypoxic (low-oxygen) zones that are uninhabitable for most marine life.

IV. **Disruption of Reproduction:** Many pollutants act as endocrine disruptors, interfering with the reproductive systems of marine species, leading to developmental abnormalities and population declines.

2.3.2 Effects on fisheries:

- I. **Plastic:** The buildup of plastic waste in oceans and along coastlines has escalated into a worldwide crisis. Oceanic currents have accumulated billions of pounds of plastic, covering nearly 40% of the planet's ocean surfaces. If this trend continues, plastic pollution is expected to outweigh all fish in the sea by 2050. This pollution presents a grave and often deadly risk to marine life, causing thousands of seabirds, sea turtles, seals, and other marine mammals to perish annually due to plastic ingestion or entanglement. Nearly 700 species, including endangered Hawaiian monk seals and Pacific loggerhead sea turtles, are impacted by plastic debris. From tiny birds to enormous blue whales, numerous marine animals suffer and die as a result of plastic pollution.
- II. **Fish:** In the North Pacific, marine organisms consume an estimated 12,000 to 24,000 tons of plastic annually. This ingestion can lead to intestinal injuries, fatal blockages, and the transfer of plastic particles up the food chain, affecting larger fish, marine mammals, and humans who consume seafood.
- III. **Marine mammals:** Marine creatures often consume and become ensnared in plastic debris. Significant amounts of plastic waste have been found in the habitats of critically endangered Hawaiian monk seals, including essential nurseries for their pups. Entanglement in plastic has also led to injuries and fatalities among endangered Steller sea lions, with packing bands being the most frequently identified entangling material. Furthermore, deceased whales have been discovered with stomachs packed with plastic waste.
- IV. **Sea turtles:** Marine creatures frequently confuse floating plastic debris for food, which can result in choking, internal injuries, and even death. Some animals may also suffer from starvation, as ingesting plastic creates a false sense of fullness.

Disturbingly, research indicates that half of the world's sea turtles have consumed plastic. Recent findings further highlight that plastic pollution is so pervasive on numerous beaches that it is interfering with the reproductive processes of marine species.

2.3.3. The Effect of pollution on coastal communities:

Pollution significantly affects the socio-economic well-being of coastal communities. Approximately 3 billion people, or 40% of the global population, reside within 100 km of coastlines. Prolonged exposure to pollutants leads to health deterioration, degradation of cultural heritage, destruction of historical sites, loss of aesthetic value, and shifts in community values. Maritime transport plays a crucial role in global trade, handling over 80% of international cargo and driving economic growth. Between 1990 and 2020, sea-borne trade doubled and is projected to triple by 2050. As of 2021, around 55,000 merchant ships operate globally, contributing approximately 12% to overall marine pollution.

Ship emissions are a significant contributor to air pollution in coastal regions, with approximately 70% occurring within 500 km of land, substantially impacting marine pollution. Research indicates that CO₂ emissions from fishing vessels in 2016 were four times higher than in the 1950s. Maritime transport releases roughly 940 million tonnes of CO₂ annually, accounting for about 2.5% of global greenhouse gas (GHG) emissions. This figure is projected to rise by 150% by 2050, highlighting the urgent need for mitigation efforts. Global climate change is expected to have severe consequences for the planet and future generations. The extensive damage caused by fossil fuels necessitates a fundamental shift toward renewable energy sources.

2.4 SHIPPING OPERATIONS AND EFFECTS OF MARINE POLLUTION ON SHIPPING OPERATIONS

Shipping operations play a crucial role in logistics distribution, facilitating the seamless transportation of goods across various locations. This involves not only the physical movement of cargo but also the strategic coordination of vessel activities, cargo handling, compliance with international regulations, and efficient resource allocation. Effective shipping operations ensure the safe, timely, and cost-effective delivery of goods, contributing to global trade and supply chain efficiency. This involves managing the crew, overseeing maintenance, ensuring safety protocols are followed, and handling the financial aspects of maritime transport. In essence, it's all about making sure that ships and their precious cargo

move smoothly across the oceans, from one port to another. Within a supply chain, shipping operations management oversees the transportation of goods across various stages. It encompasses all transportation cycles, from the manufacturer to the final customer.

In a supply chain, a shipping company's operations encompass several transportation cycles, including:

1. Moving inventory from suppliers to manufacturing units.
2. Transferring inventory from manufacturing units to warehouses.
3. Delivering inventory from warehouses to distribution or fulfillment centers.
4. Distributing products from distribution centers to retail outlets.
5. Transporting products from fulfillment centers to customers' addresses.

These shipping activities are categorized under distribution logistics. A company may handle logistics internally through centralized shipping operations or outsource them to a third-party logistics (3PL) or fourth-party logistics (4PL) provider, depending on its business model and supply chain strategy.

Freight Shipping

Freight shipping refers to the transportation of large cargo, typically exceeding 685.8 cubic meters in volume or 68 kg in weight. The classification of freight cargo also depends on density, with any cargo having a density greater than 800 kg per cubic meter qualifying as freight.

In freight shipping, multiple products are often consolidated into a parcel or pallet for more efficient handling. This method is widely used in logistics distribution within shipping operations management. Freight shipping plays a crucial role in moving inventory between suppliers, manufacturers, warehouses, distribution centers, fulfillment centers, and retail outlets, ensuring the smooth operation of supply chains.

Freight shipping can be further classified into three types:

Ocean Freight

Road Freight

Air Freight

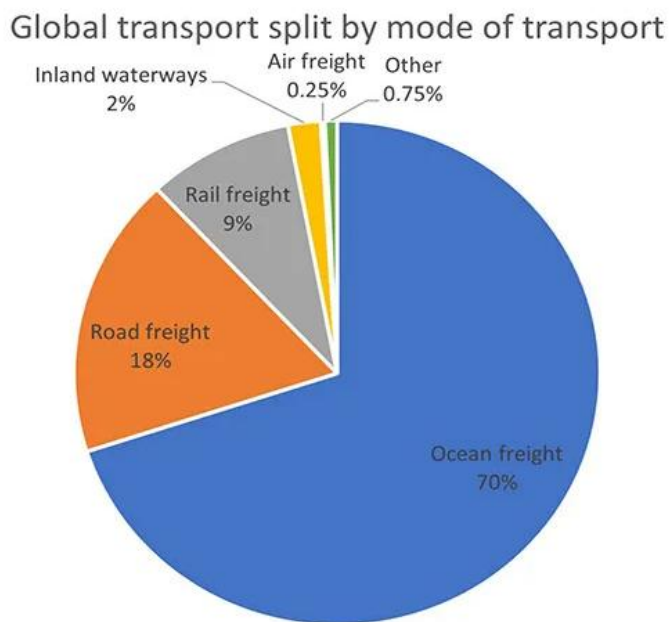


Figure 2.3.3.1: Global transport split by mode of transport

Each mode of freight shipping offers unique advantages. Road freight is the most common choice for domestic shipping operations, providing flexibility, door-to-door service, and cost-effectiveness for short to medium distances. Ocean freight, responsible for approximately 70% of international trade, is the most economical option for transporting large shipments and bulk goods, making it the backbone of global cargo operations. On the other hand, air freight, though the most expensive, is the fastest mode of transport, making it ideal for urgent, high-value, or perishable shipments that require rapid transit across international markets.

Small Parcel Shipping

Small parcel shipping involves the transportation of individual packages weighing less than 30 kg. This mode of shipping is primarily utilized in the final stages of a supply chain, including order fulfillment and reverse logistics. It ensures efficient and timely delivery of goods directly to consumers, making it a crucial component of e-commerce and retail distribution networks.

2.4.1 Types of Shipping Operations (Related to Marine Pollution and Shipping Efficiency)

Shipping operations cover different activities depending on the function and type of vessel. Here are the key ones, directly tied to marine pollution and shipping efficiency:

1. Commercial Cargo Operations

- i. Includes the transport of goods via bulk carriers, container ships, tankers, and general cargo ships.
- ii. Pollution impact: Oil spills from tankers and ballast water discharge leading to invasive species.
- iii. Example: The Exxon Valdez oil spill disrupted commercial cargo operations and increased regulatory restrictions.

2. Passenger Shipping Operations

- i. Includes cruise ships, ferries, and ocean liners.
- ii. Pollution impact: Waste disposal from ships, including sewage, plastic, and fuel emissions.
- iii. Example: Cruise liners generate large amounts of waste, requiring strict environmental compliance.

3. Offshore Support and Supply Operations

- i. Supports oil rigs, offshore drilling platforms, and wind farms.
- ii. Pollution impact: Oil spills from offshore drilling and toxic waste disposal.
- iii. Example: The Deepwater Horizon oil spill significantly affected offshore supply chains.

4. Port and Harbor Operations

- i. Includes docking, loading/unloading cargo, ship refueling, and maintenance.

- ii. Pollution impact: Fuel leaks, ballast water discharge, and increased carbon emissions from port congestion.
- iii. Example: Ports adopting green port initiatives to reduce emissions and waste.

5. Ship Maintenance and Repair Operations

- i. Dry docking, hull cleaning, and engine maintenance.
- ii. Pollution impact: Heavy metal contamination from paint coatings and oil disposal.
- iii. Example: The IMO (International Maritime Organization) introduced rules for proper disposal of toxic ship waste.

6. Fishing and Aquaculture Operations

- i. Includes industrial fishing vessels and fish farms.
- ii. Pollution impact: Overfishing and plastic pollution from discarded fishing nets.
- iii. Example: Ghost nets in the ocean harm marine life and cause navigational hazards.

7. Environmental Protection and Emergency Response Operations

- i. Includes ships used for oil spill cleanups, ocean monitoring, and maritime rescue.
- ii. Pollution impact: Ironically, even clean-up operations can leave carbon footprints.
- iii. Example: Oil skimmers and dispersants used in cleanup efforts sometimes introduce new chemicals into the ecosystem.

8. Military and Defense Operations

- i. Naval fleets, coast guards, and maritime security vessels.
- ii. Pollution impact: Nuclear-powered submarines, weapons testing, and fuel leaks.
- iii. Example: Old decommissioned submarines pose long-term marine contamination risks.

2.4.2 Effects of Marine Pollution on Shipping Operations

1. **Environmental Regulations and Compliance:** As pollution increases, so do the regulations. Ships are now required to adhere to stricter environmental standards, which can mean costly upgrades and operational changes.
2. **Operational Disruptions:** Pollution can lead to contaminated ports and waterways, making certain routes impassable or unsafe. This forces ships to take longer, alternative paths, delaying deliveries and increasing fuel consumption.
3. **Economic Impacts:** Cleaning up pollution isn't cheap. The costs often trickle down to shipping companies, leading to higher operational expenses. Plus, polluted waters can harm fisheries, reducing the availability of fresh provisions for crews and affecting local economies that ships rely on.
4. **Damage to Marine Equipment:** Pollutants can be corrosive, damaging hulls and other vital components of ships. This means more frequent maintenance and repairs, cutting into time that could be spent on profitable voyages.
5. **Invasive Species:** Ballast water discharge can introduce non-native species to new environments, disrupting local ecosystems. This not only affects biodiversity but can also lead to new regulations requiring ships to treat ballast water, adding another layer of complexity to operations.

In summary, marine pollution doesn't just harm the environment; it creates a cascade of challenges for shipping operations, from regulatory hurdles and increased costs to operational inefficiencies and environmental responsibilities.

2.4.3 Sources of Pollution from Ships

Pollution from ships originates from various activities and operations, including:

- I. Tanker accidents
- II. Oily-water discharge from ship
- III. Accidental spillage during terminal loading
- IV. Ballast water discharged from ships at ports
- V. Garbage and other solid waste
- VI. Wastewater discharged from ships
- VII. Marine machinery exhaust

VIII. Sound pollution

IX. Anti – fouling Paints

Oily-water discharge from ship:

The operation of ship power plants frequently leads to the leakage of lubricating oil, fuel oil, grease, and water into bilges. When an oily-water separator is absent or malfunctioning, the emulsified mixture of water and oil discharged into the sea or river becomes a major contributor to marine pollution. Another significant source of oily-water contamination is ballast water pumped into oil cargo tanks, which carries oil residues and foreign species that must be removed before loading fresh crude oil. Furthermore, the crude oil tank cleaning process exacerbates marine pollution, as the oily water discharged from cleaning contains detergents, solid debris, and corroded rusty scales, which are often released into the ocean.

Tanker Accidents:

Oil spills are a major source of ship pollution, especially from oil tankers, chemical carriers, and gas carriers. Risks such as collisions, groundings, and explosions contribute to spills, causing severe environmental damage. Though less frequent than operational pollution, spills have long-lasting effects on marine ecosystems. Response measures include containment booms, dispersants, and shoreline cleanups. International regulations like MARPOL enforce preventive measures and rapid response strategies.

Accidental Spillage during Terminal Loading:

Oil spills during loading and discharge at offshore terminals can result from pump and valve malfunctions, pipe ruptures, or operational errors. Spills may also occur when ships take on bunker or lubricating oil. Such incidents contribute to marine pollution, requiring strict operational controls, regular equipment maintenance, and adherence to safety protocols to minimize risks. A broken hose can lead to significant oil leakage, and if the oil level in the ship's tanks is not properly monitored, overflow can occur, further contributing to marine pollution.

Wastewater discharged from ships:

Vessels generate two types of wastewater: black water and grey water. Black water, from toilets and medical facilities, contains harmful bacteria, pathogens, viruses, parasites, and excess nutrients, while grey water, from kitchens, showers, sinks, and laundry, carries fats, oils, food scraps, chemicals, soaps, detergents, and microbiological pathogens. If discharged into aquatic environments, these wastewaters can disrupt ecosystems, cause algal blooms, and pose health risks, making proper treatment and disposal essential to minimizing marine pollution.

Garbage and Other Solid waste:

When regulations are not strictly enforced, ships frequently dispose of non-oil pollutants, including garbage and solid waste, into seas and rivers. These wastes, which consist of materials like glass, paper, cardboard, aluminum and steel cans, and plastics, can be either hazardous or non-hazardous. Once in the ocean, they transform into marine debris, endangering marine life, human health, coastal populations, and industries that depend on marine resources.

Ballast-water discharged from ships at ports:

For over a century, steel-hulled vessels have relied on water as ballast to maintain stability at sea. Although crucial for safe and efficient maritime operations, ballast water poses significant ecological, economic, and health risks due to the diverse marine species it transports. These include bacteria, microbes, small invertebrates, eggs, cysts, and larvae. When introduced into new environments, these organisms can establish invasive populations, outcompete native species, and proliferate uncontrollably. The resulting environmental damage is often irreversible, with increasingly severe direct and indirect health consequences.

Marine Machinery Exhaust:

Ship exhaust emissions are a major contributor to air pollution, releasing sulfur into the atmosphere, which leads to acid rain that harms crops, buildings, and infrastructure.

Inhalation of sulfur compounds is linked to respiratory issues and an increased risk of heart attacks. Irene Blooming, a spokesperson for the European environmental coalition Seas at Risk, highlights that oil tankers and container ships use high-sulfur fuel, which is cheaper than land-based fuel but significantly more polluting. A single ship emits about 50 times more sulfur than a lorry per metric ton of cargo transported. These emissions from marine diesel engines degrade air quality, contributing to ozone formation, carbon monoxide pollution, reduced visibility, haze, acid deposition, and the eutrophication and nitrification of water bodies.

Anti-fouling Paints:

Anti-fouling paints work by gradually releasing toxic substances into the surrounding seawater, preventing marine organisms from attaching to the ship's hull. However, these chemicals, such as copper, can accumulate in areas with high shipping activity, leading to broader ecological consequences. Over time, these toxic compounds can enter the food chain, affecting marine wildlife beyond their intended targets. Studies have shown that high concentrations of antifouling agents in heavily trafficked waters can harm non-target species like bivalves and crustaceans, disrupting marine ecosystems.

Sound pollution:

Noise pollution from shipping and other human activities has escalated in recent times, posing a serious threat to marine life. The sound generated by ships can travel vast distances underwater, disrupting the natural behaviors of marine species that depend on sound for navigation, communication, and feeding. The Convention on the Conservation of Migratory Species recognizes ocean noise as a significant hazard to marine ecosystems.

To evaluate the effectiveness of existing international regulatory frameworks, such as the MARPOL Convention and the Ballast Water Management Convention, in mitigating marine pollution, a thorough assessment of their implementation and impact is necessary.

2.5 MONITORING, CONTROL AND PREVENTIVE MEASURES OF MARINE POLLUTION

Monitoring, control, and preventive measures are essential to mitigate marine pollution. Here are some strategies:

2.5.1 Monitoring Measures:

1. **Water Quality Monitoring:** Regularly monitor water quality parameters such as pH, temperature, salinity, and nutrient levels.
2. **Oil Spill Detection:** Use satellite imaging, aerial surveillance, and in-situ sensors to detect oil spills.
3. **Marine Debris Monitoring:** Monitor marine debris, including plastic pollution, through beach surveys and oceanic research.
4. **Biological Monitoring:** Monitor marine life, including fish, invertebrates, and microorganisms, to assess the impact of pollution.

2.5.2 Control Measures:

1. **Wastewater Treatment:** Implement effective wastewater treatment systems to reduce pollutants entering the ocean.
2. **Oil Spill Response:** Develop and implement oil spill response plans, including containment, recovery, and disposal.
3. **Marine Traffic Regulation:** Regulate marine traffic to reduce the risk of accidents and spills.
4. **Pollution Hotspot Identification:** Identify and address pollution hotspots, such as industrial areas and agricultural runoff.

2.5.3 Preventive Measures:

1. **Sustainable Fishing Practices:** Promote sustainable fishing practices, including reducing bycatch and protecting marine habitats.
2. **Waste Management:** Implement effective waste management systems, including recycling and proper disposal of hazardous waste. Some strategies include:
 - i. **Implementing recycling programs:** Encouraging individuals and businesses to recycle and reducing waste disposal in landfills.

- ii. Proper disposal of hazardous waste: Ensuring that hazardous waste is disposed of safely and efficiently.
 - iii. Reducing single-use plastics: Promoting the use of reusable bags, containers, and water bottles.
3. Education And Awareness: Implement green infrastructure, such as wetlands and green roofs, to reduce stormwater runoff and pollution. Raising awareness about marine pollution and its consequences is crucial in promoting individual and collective action. Some strategies include:
- i. Environmental education: Integrating environmental education into school curricula and promoting awareness campaigns.
 - ii. Community engagement: Organizing beach cleanups, coastal cleanups, and other community-based initiatives.
 - iii. Collaboration and partnerships: Encouraging collaboration between governments, organizations, and individuals to address marine pollution.
4. Technological Advancement: Educate the public, industries, and governments about the importance of marine conservation and the impacts of pollution. Advances in technology can help mitigate marine pollution. Some examples include:
- i. Oil spill response technologies: Developing more effective oil spill response systems and equipment.
 - ii. Wastewater treatment technologies: Implementing advanced wastewater treatment technologies to reduce chemical pollutants.
 - iii. Marine debris removal technologies: Developing innovative solutions to remove marine debris from the ocean.
5. International Cooperation: Encourage international cooperation to address transboundary pollution and protect shared marine resources.
6. Pollution Prevention Technologies: Develop and implement pollution prevention technologies, such as oil spill prevention systems and marine debris removal systems.
7. Regular Maintenance: Regularly inspect and maintain vessels, pipelines, and other infrastructure to prevent accidents and spills.

2.5.4 Legislative and Regulatory Measures:

Governments and international organizations play a crucial role in controlling marine pollution. Some of the key legislative and regulatory measures include:

1. UNCLOS (United Nations Convention on the Law of the Sea): Establishes the rights and responsibilities of nations in using the world's oceans.
2. OSPAR Convention: Regulates pollution from offshore oil and gas activities in the North-East Atlantic.
3. MARPOL (Marine Pollution) Convention: Regulates pollution from ships, including oil spills and waste disposal.
4. Ballast Water Management Convention

2.6 MARPOL AND BALLAST WATER MANAGEMENT CONVENTION

Adoption: 1973 (Convention), 1978 (1978 Protocol), 1997 (Protocol - Annex VI); Entry into force: 2 October 1983 (Annexes I and II).

The **International Convention for the Prevention of Pollution from Ships (MARPOL)** is the primary global treaty aimed at preventing marine pollution caused by ships, whether from routine operations or accidental incidents. It establishes strict regulations to minimize pollution from oil, chemicals, sewage, garbage, and air emissions, ensuring the protection of the marine environment.

The **MARPOL Convention** was adopted on **2 November 1973** by the **International Maritime Organization (IMO)** to address marine pollution from ships. In response to several tanker accidents between 1976 and 1977, the **1978 Protocol** was introduced. Since the **1973 MARPOL Convention** had not yet come into force, the **1978 Protocol** merged with it, forming a unified instrument that officially entered into force on **2 October 1983**. In **1997**, another **Protocol** was adopted, introducing **Annex VI**, which aimed to reduce air pollution from ships; this annex became effective on **19 May 2005**. Over the years,

MARPOL has undergone multiple amendments to strengthen its environmental protection measures.

The **MARPOL Convention** establishes regulations to prevent and minimize pollution from ships, addressing both accidental spills and pollution from routine operations. It comprises **six technical Annexes**, each targeting different sources of marine pollution. Additionally, the Convention designates **Special Areas**, where **stricter controls** on operational discharges are enforced to provide greater environmental protection.

2.6.1 Annex I Regulations for the Prevention of Pollution by Oil (entered into force 2 October 1983)

Annex I of MARPOL focuses on preventing pollution by oil, addressing both operational discharges and accidental spills. The **1992 amendments** made it mandatory for new oil tankers to have **double hulls** and introduced a **phase-in schedule** for existing tankers to comply. This schedule was later revised in **2001 and 2003** to strengthen environmental protection measures.

2.6.2 Annex II Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (entered into force 2 October 1983, provisions took effect from 6 April 1987)

Annex II of MARPOL outlines **discharge criteria and control measures** for pollution caused by **noxious liquid substances** transported in bulk. Around **250 substances** have been assessed and classified under this annex. The discharge of residues from these substances is strictly regulated and permitted **only to designated reception facilities**, provided that the **specified concentrations and conditions** (which differ based on the substance category) are met.

Regardless of the circumstances, the discharge of residues containing **noxious substances** is strictly **prohibited within 12 miles of the nearest land** to prevent marine pollution and protect coastal ecosystems.

2.6.3 Annex III Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (entered into force 1 July 1992)

It includes **general requirements** for establishing detailed **standards** on **packing, marking, labeling, documentation, stowage, quantity limitations, exceptions, and notifications** to ensure the safe handling and transportation of hazardous substances at sea.

For the purpose of this Annex, "**harmful substances**" refer to materials classified as **marine pollutants** under the **International Maritime Dangerous Goods (IMDG) Code** or those that meet the **criteria outlined in the Appendix of Annex III** of the MARPOL Convention.

2.6.4 Annex IV Prevention of Pollution by Sewage from Ships (entered into force 27 September 2003)

This Annex sets regulations to **control marine pollution caused by sewage** from ships. The **discharge of sewage into the sea is prohibited** unless specific conditions are met. Ships may only discharge sewage if they have an **approved sewage treatment plant** in operation or if the sewage is **comminuted and disinfected** using an approved system, and the discharge occurs **at least three nautical miles** from the nearest land. For **untreated sewage**, discharge is only permitted **beyond 12 nautical miles** from the nearest land.

2.6.5 Annex V Prevention of Pollution by Garbage from Ships (entered into force 31 December 1988)

This Annex regulates the **disposal of different types of garbage** from ships, specifying the **permissible distances from land** and the **manner of disposal**. Its most significant provision is the **complete ban on the disposal of plastics into the sea**, preventing severe marine pollution and protecting marine ecosystems.

2.6.6 Annex VI Prevention of Air Pollution from Ships (entered into force 19 May 2005)

This Annex **sets limits on sulfur oxide (SO_x) and nitrogen oxide (NO_x) emissions** from ship exhausts and prohibits the **intentional release of ozone-depleting substances**. It establishes **Emission Control Areas (ECAs)** where stricter regulations apply to SO_x, NO_x, and particulate matter. Additionally, a **2011 amendment introduced mandatory technical and operational energy efficiency measures** to reduce greenhouse gas emissions from ships.

2.7 BALLAST WATER MANAGEMENT CONVENTION:

The **International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention)**, which entered into force on **8 September 2017**, is an international maritime treaty aimed at preventing the spread of invasive aquatic species. It mandates **signatory flag states** to ensure that **ships under their registry comply with established standards and procedures** for managing and controlling ballast water and sediments to minimize ecological and environmental risks.

Adoption: 13 February 2004; Entry into force: 8 September 2017

Invasive aquatic species pose a significant threat to marine ecosystems, with shipping identified as a primary means of their introduction to new environments. The issue has intensified alongside the expansion of global trade and traffic, particularly with the adoption of **steel-hulled vessels**, which utilize water as ballast instead of solid materials. In many regions, the introduction of non-native species has led to **severe ecological disruptions**, with quantitative data indicating that **bio-invasions are occurring at an alarming and increasing rate**. Given the continued growth of **seaborne trade**, the full extent of the problem may not yet have been realized.

Under the **Ballast Water Management (BWM) Convention**, all ships engaged in international trade must adhere to **specific standards** for managing ballast water and sediments, as outlined in a **ship-specific ballast water management plan**. Vessels are also required to maintain a **ballast water record book** and possess an **international ballast water management certificate**. The implementation of ballast water management standards will occur **gradually over time**. As an interim measure, ships are advised to **exchange ballast water in mid-ocean** to reduce the risk of introducing invasive species. However, in the long run, most ships will be required to install an **on-board ballast water treatment system**.

The **Ballast Water Management (BWM) Convention** mandates that all ships implement a **Ballast Water and Sediments Management Plan**. Each vessel must maintain a **Ballast Water Record Book** and conduct **ballast water management procedures** in compliance

with established standards. While new ships must comply immediately, **existing ships** will be required to meet these requirements following a **phase-in period**.

The **Ballast Water Management (BWM) Convention** is structured into **Articles** and an **Annex**. The **Annex** contains **technical standards and regulatory requirements** for the **control and management of ships' ballast water and sediments**, ensuring compliance with environmental and safety standards.

2.7.1 Annex - Section A General Provisions:

The **Annex** of the **BWM Convention** includes provisions on **definitions, application, and exemptions**. Under **Regulation A-2 (General Applicability)**, it states that:

"Except where expressly provided otherwise, the discharge of Ballast Water shall only be conducted through Ballast Water Management, in accordance with the provisions of this Annex."

2.7.2 Annex - Section B Management and Control Requirements for Ships:

Under **Regulation B-1** of the **BWM Convention**, ships must have and implement a **Ballast Water Management Plan** approved by the Administration. This plan is specific to each ship and provides a detailed description of the actions required to comply with **Ballast Water Management** regulations, along with additional **supplemental practices** to ensure effective implementation.

Under **Regulation B-2** of the **BWM Convention**, ships are required to maintain a **Ballast Water Record Book** to document key activities related to ballast water management. This includes records of when ballast water is **taken on board, circulated or treated, discharged into the sea, or offloaded to a reception facility**. Additionally, any **accidental or exceptional discharges** of ballast water must also be recorded.

The specific requirements for ballast water management are outlined in **Regulation B-3** of the **BWM Convention**, which details the procedures ships must follow for **Ballast Water Management** to minimize the transfer of harmful aquatic organisms and pathogens.

Alternative methods of ballast water management may be accepted as substitutes for the **ballast water exchange standard** and **ballast water performance standard**, as long as they provide an equivalent or higher level of protection for the environment, human health, property, or resources. These alternative methods must also receive approval in principle from the **IMO's Marine Environment Protection Committee (MEPC)**.

According to Regulation B-4 on Ballast Water Exchange, all vessels utilizing ballast water exchange must, whenever feasible, perform the exchange at a minimum distance of 200 nautical miles from the closest land and in waters no shallower than 200 meters, in accordance with the Guidelines established by the IMO.

If a vessel is unable to carry out ballast water exchange as specified above, it should be conducted as far from the nearest land as possible, and in all circumstances, at least 50 nautical miles away from land and in waters no shallower than 200 meters. If these conditions cannot be fulfilled, designated areas may be assigned for ships to perform ballast water exchange. Additionally, all vessels must remove and dispose of sediments from spaces designated for ballast water storage in compliance with the ship's ballast water management plan, as outlined in Regulation B-4.

2.7.3 Annex - Section C Additional measures:

A Party, either alone or in collaboration with other Parties, may enforce additional measures on ships to prevent, minimize, or eliminate the transfer of Harmful Aquatic Organisms and Pathogens via ballast water and sediments. In such instances, the concerned Party or Parties should engage in consultations with neighboring or nearby States that could be impacted by these standards or regulations. Additionally, they must notify the Organization of their intent to implement these measures at least six months before the scheduled enforcement date, except in cases of emergency or epidemic situations. When necessary, Parties must also seek approval from the IMO.

2.7.4 Annex - Section D Standards for Ballast Water Management

There exist both a ballast water exchange standard and a ballast water performance standard. The process of ballast water exchange can be utilized as a means to comply with the performance standard.

Regulation D-1 Ballast Water Exchange Standard states that ships conducting ballast water exchange must achieve an efficiency of 95 percent volumetric exchange of ballast water. For vessels utilizing the pumping-through method, circulating three times the volume of each ballast water tank is considered sufficient to meet this standard. However, if less than three full volumes are pumped through, it may still be accepted, provided the ship can prove that at least 95 percent volumetric exchange has been achieved.

Regulation D-2 Ballast Water Performance Standard mandates that ships performing ballast water management must ensure discharged water contains fewer than 10 viable organisms per cubic meter that are at least 50 micrometers in minimum dimension. Additionally, it must contain fewer than 10 viable organisms per milliliter that measure between 10 and 50 micrometers in minimum dimension. Furthermore, the discharge of indicator microbes must not exceed the prescribed concentration limits.

The indicator microbes, serving as a human health standard, include but are not limited to:

- a. Toxicogenic *Vibrio cholerae* (O1 and O139), with a concentration of fewer than 1 colony-forming unit (cfu) per 100 milliliters or less than 1 cfu per gram (wet weight) in zooplankton samples;
- b. *Escherichia coli*, with a concentration of fewer than 250 cfu per 100 milliliters;
- c. Intestinal *Enterococci*, with a concentration of fewer than 100 cfu per 100 milliliters.

Ballast Water Management systems must receive approval from the Administration in compliance with IMO Guidelines (Regulation D-3 Approval Requirements for Ballast Water Management Systems). These systems may involve the use of chemicals or biocides, the application of organisms or biological mechanisms, or the modification of the chemical or physical properties of the Ballast Water.

2.7.5 Annex- Section E Survey and Certification Requirements for Ballast Water Management

It outlines the requirements for initial, renewal, annual, and intermediate surveys, along with certification obligations. The appendices include the format for the Ballast Water Management Certificate and the structure of the Ballast Water Record Book.

Other Conventions;

International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 1969 (Adoption: 29 November 1969; Entry into force: 6 May 1975)

The Convention confirms the authority of a coastal State to implement necessary measures on the high seas to prevent, reduce, or eliminate risks to its coastline or associated interests from oil pollution or the potential threat arising from a maritime incident.

However, the coastal State is authorized to take only the necessary actions, ensuring that due consultations are held with relevant parties, including the flag State or States of the involved ships, the owners of the ships or cargoes concerned, and, when feasible, independent experts appointed for this purpose.

A coastal State that implements measures exceeding those allowed under the Convention is responsible for compensating any damage resulting from such actions. The Convention also includes provisions for resolving disputes related to its application. It applies to all seagoing vessels, except warships or other vessels owned or operated by a State and engaged in government non-commercial service.

The 1969 Intervention Convention was initially applicable to casualties resulting in oil pollution. However, due to the growing transportation of other substances, particularly chemicals, by ships—many of which could pose significant threats to the marine environment if released—the 1969 Brussels Conference acknowledged the necessity of expanding the Convention to include pollutants beyond oil.

As a result, the 1973 London Conference on Marine Pollution adopted the Protocol relating to Intervention on the High Seas in Cases of Marine Pollution by Substances other than Oil. This Protocol expanded the scope of the 1969 Intervention Convention to include substances listed in its Annex, as well as those with characteristics that are largely similar to the listed substances.

The 1973 Protocol came into effect in 1983 and has since been amended periodically to revise and update the list of substances included in its annex.

2.8 RECOMMENDATIONS FOR IMPROVING POLLUTION CONTROL MEASURES AND ENCOURAGING SUSTAINABLE PRACTICES WITHIN THE GLOBAL SHIPPING INDUSTRIES

2.8.1 Regulatory Frameworks:

- i. Enforce and implement global regulations, including the MARPOL Convention, to minimize pollution caused by ships.
- ii. Set up Emission Control Areas (ECAs) to restrict the release of sulfur oxides, nitrogen oxides, and particulate matter.

2.8.2 Sustainable Fuels and Energy:

- i. Encourage the adoption of cleaner fuels, including liquefied natural gas (LNG), hydrogen, and biofuels.
- ii. Promote the implementation of energy-efficient technologies, such as wind-assisted propulsion and solar panels.

2.8.3 Green Shipping Technologies:

- i. Develop and deploy green shipping technologies, such as:
- ii. Implement ballast water treatment systems to curb the spread of invasive species.
- iii. Exhaust gas cleaning systems to reduce emissions.
- iv. Hull coatings to reduce drag and improve fuel efficiency

2.8.4 Education, Training, and Awareness:

- i. Provide education and training programs for seafarers, shipowners, and operators on sustainable practices and pollution prevention.
- ii. Educate stakeholders on the significance of environmental protection and the advantages of adopting sustainable shipping practices.

2.8.5 Collaboration and Research:

Encourage cooperation among industry stakeholders, governments, and research institutions to develop and implement innovative sustainable technologies and practices. Carry out studies on the environmental effects of shipping and assess the efficiency of pollution control measures.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter describes the methodology employed to examine the effects of marine pollution on shipping activities and the marine ecosystem. It provides an overview of the research design, data collection techniques, sampling methods, and analytical approach. The explanation of the procedure is structured under the following headings:

3.2 RESEARCH PHILOSOPHY

Research paradigms serve as a foundation for scientific discoveries by defining their fundamental assumptions and concepts. Understanding the assumptions specific to each paradigm helps in assessing the validity of findings that support scientific inquiries and in identifying gaps in generating reliable evidence. A research philosophy encompasses a set of beliefs about the proper techniques for gathering, interpreting, and applying data related to a particular subject (Saunders et al., 2009). Researchers must explicitly define their research philosophy or paradigm, particularly concerning their ontological and epistemological stance (Saunders et al., 2016).

Following the methodology and research philosophy outlined by Goundar (2012), this study employs a positivist epistemological approach, in contrast to the interpretivist perspective. It primarily utilizes quantitative data methods, including surveys and official statistics, as these are considered credible and reliable (Clark & Johnson, 2006). This approach is distinguished by its objectivity, neutrality, and absence of bias.

3.3 RESEARCH DESIGN

This study employs a descriptive survey design to assess participants' views on the effects of marine pollution. This design is well-suited for evaluating trends and perspectives within the shipping industry. It was deemed appropriate since survey designs are commonly used to investigate issues in real-world contexts effectively. Additionally, the survey method enables the researcher to explore multiple variables and apply multivariate statistical techniques for data analysis.

3.4 POPULATION OF THE STUDY

The population for this study includes stakeholders in the shipping industry, such as marine environmental management officers, shipping operators, regulatory officials, and maritime workers. The population consists of the engineers and shipyard workers across Nigeria.

3.5 SAMPLE SIZE AND SAMPLING TECHNIQUES

SAMPLE SIZE:

The number of marine engineers and shipyard workers across Nigeria are in a range of 5,000 employees. This is an estimate since actual data is not available.

Sample Size Calculation

Using Cochran's formula for a confidence level of 95% and a margin of error (e) of 5%:

For a population of 5,000 employees, adjust the sample size using the finite population correction formula:

$$n = \frac{Z^2 \times P(1-p)}{e^2}$$

where

- $Z = 1.96$ (for 95% confidence level).
- $p = 0.5$ (assumed proportion of the population with the attribute being studied; this maximizes sample size if the actual proportion is unknown).
- $e = 0.05$

$$n = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = 384.16$$

$$0.05^2$$

For a population of 5,000 employees, adjust the sample size using the finite population correction formula:

$$n_{\text{adjusted}} = \frac{n}{1 + \frac{n-1}{N}}$$

Where N=5000

$$n_{\text{adjusted}} = \frac{384.16}{1 + \frac{384.16-1}{5000}}$$

Thus, a sample size of approximately 357 respondents is sufficient.

The study employs purposive sampling, targeting participants with direct experience in shipping operations and marine environmental management. This approach ensures that responses are relevant and informed.

3.6 RESEARCH INSTRUMENT

The major instrument used for this study is the questionnaire.

Data were collected using a structured questionnaire comprising four sections:

1. General awareness of marine pollution.
2. Operational impacts of marine pollution.
3. Environmental impacts on marine ecosystems.
4. Industry practices and regulatory effectiveness.

The questionnaire was distributed electronically to reach geographically dispersed respondents, ensuring convenience and anonymity. The questionnaire was structured in a five-like scale measuring attitude of Strongly Agreed, Agreed, Neutral, Disagree and Strongly Disagreed.

3.7 VALIDITY OF THE INSTRUMENT

To ensure the validity of the instrument, the research supervisor was asked to assess the questionnaire's appropriateness, comprehensiveness, and clarity.

3.8 RELIABILITY OF THE INSTRUMENT

The responses from the questionnaire were subjected to a Cochran alpha test, average variance extracted and composite reliability testing before inferential statistics were conducted.

3.9 METHOD OF DATA COLLECTION

Precise data collection is essential for the research design. This study will obtain both primary and secondary data through research. The primary data will be collected using a structured questionnaire, where participants will respond to a standardized set of statements on a Likert scale (De Vaus, 2014). Employing quantitative data, which is presented in numerical and statistical formats, ensures the reliability and accuracy of the questionnaire's findings. This method aligns with the research approach that prioritizes objective facts.

The secondary data is gathered through an in-depth review of existing literature. Additionally, it aids in constructing the theoretical framework for this study. A further advantage of using secondary data is the ability to compare the existing body of knowledge with the collected data, allowing for an assessment of the generalizability of the findings—specifically, how well the data reflect the broader population under study (Saunders et al., 2016).

The data was gathered through an online survey disseminated via Google Forms to engineers and shipyard workers, resulting in a total of 357 responses (N=357).

3.10 METHOD OF DATA ANALYSIS

Data analysis refers to the techniques employed by researchers to extract meaningful insights from collected data, allowing for a summarized description of the subject under study. In this research, the data was analyzed using the Statistical Package for Social Sciences (SPSS)

version 22.0. Descriptive analysis was conducted to determine frequencies, percentages, means, and standard deviations, alongside inferential analysis.

Since the research instrument employed was a questionnaire, it was structured using the five-point Likert scale method. The questionnaire was developed in the following manner:

i)	Strongly Agreed (SA)	-	5
ii)	Agreed (A)	-	4
iii)	Undecided (U)	-	3
iv)	Disagreed (D)	-	2
v)	Strongly Disagreed (SD)	-	1

DECISION RULE

In making decisions regarding the correlation coefficient (r), the following guidelines shall be adhered to:

- i. If the value of “ r ” tabulated is greater than “ r ” calculated, accept the alternative hypothesis (H_1) and .reject the null hypothesis (H_0).
- ii. ii. If the calculated value of exceeds the tabulated value of , the null hypothesis (H_0) is accepted, while the alternative hypothesis (H_1) is rejected.

Ethical Considerations

In this research, strict compliance with the University's ethical guidelines and data protection policies was ensured. Data collection commenced only after receiving official approval.

The questionnaire was distributed through multiple social media platforms, and every participant was required to review both a privacy statement and a consent form. The consent form outlined the study’s objectives, highlighted the anonymity of responses, and assured participants that their identities would remain confidential. To indicate their agreement, participants had to check a box, thereby granting consent for data collection and usage.

All collected data was securely stored on the researcher's personal computer, safeguarded with encryption. Additionally, the data file was uploaded to a cloud storage system, accessible only to the researcher.

3.8 LIMITATIONS

The study faced the following challenges:

1. Limited response rate due to time constraints.
2. Potential bias from purposive sampling.
3. Difficulties in accessing certain stakeholders due to geographical or operational restrictions

CHAPTER FOUR

RESULTS AND DISCUSSION

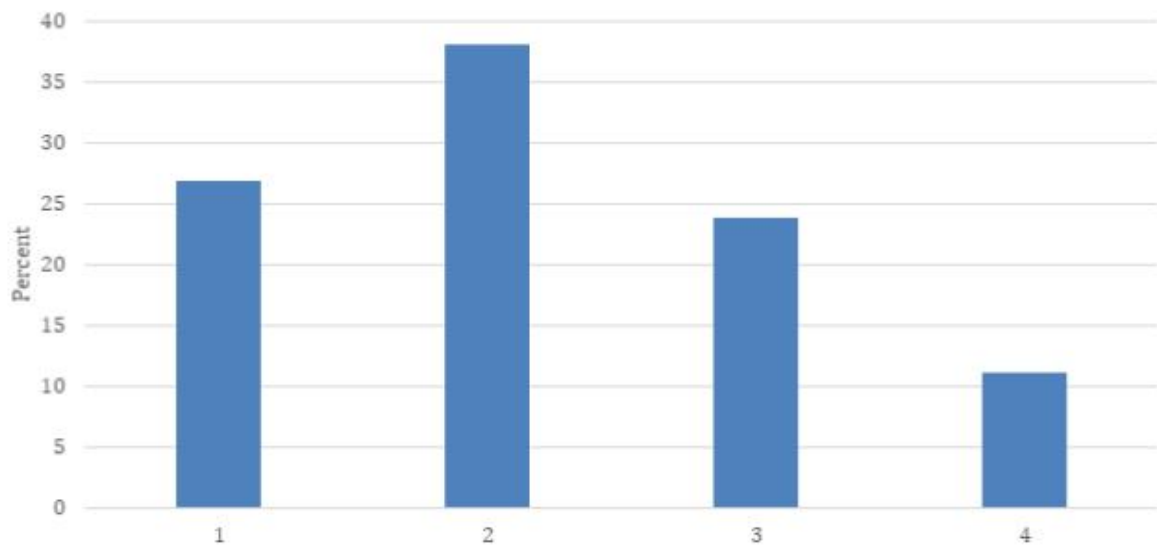
4.1 RESULTS

Results obtained from evaluating the impact of marine pollution in shipping operations and marine environment, online questionnaires forms were distributed across the country to marine engineers and shipyard workers, 357 responses were subsequently recovered and analyzed. A total of 357 participants were involved in this study, their demographic data are presented in tables and graphs below.

Socio-demographics of Respondents

Table 4.1: Respondents Roles in the Shipping Industry

	Frequency	Number	Valid Percent	Cumulative percent
Valid	Marine environmental officer	96	26.9	26.9
	Ship operator	136	38.1	65.0
	Regulatory official	85	23.8	88.8
	Maritime worker	40	11.2	100.0
	Total	357	100.0	



1

Figure 4.1: Respondents Roles In The Shipping Industry

KEYS

1= Marine Environmental Officer

2 = Ship Operator

3 = Regulatory Official

4 = Maritime Worker

¹ Figure 4.1: Respondents Roles In The Shipping Industry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SSCE	85	23.8	23.8	23.8
	ND	221	61.9	61.9	85.7
	BSC	8	2.2	2.2	88.0
	Post Graduate	43	12.0	12.0	100.0
	Total	357	100.0	100.0	

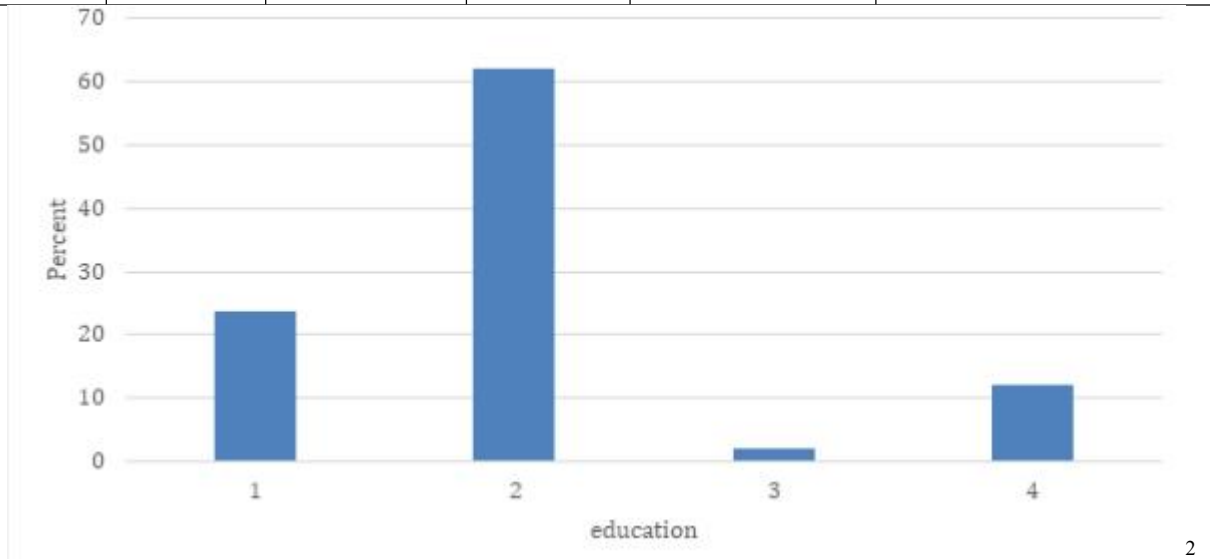


Figure 4.2: Educational Level of Respondents

KEY

1 = SSCE

2= National Diploma (ND)

3 = BSC

4 = Post graduate degrees

² Figure 4.2: Educational Level of Respondents

Table 4.3: Years Of Experience Of Respondent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 – 5 Years	185	51.8	51.8	51.8
	6 – 15 Years	49	13.7	13.7	65.5
	16 and above	123	34.5	34.5	100.0
	Total	357	100.0	100.0	

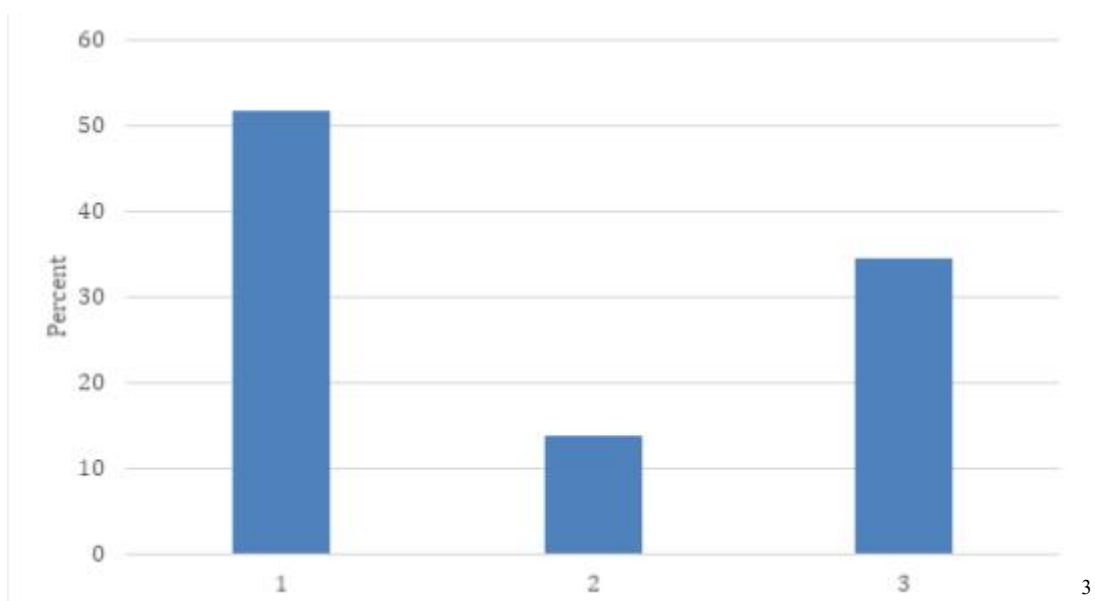


Figure 4.3: Years of Experience of Respondent

KEYS

1 = 1 – 5 years

2 = 6 – 15 years

3 = 16 and above

³ Figure 4.3: Years of Experience of Respondent

4.2 INFERENTIAL STATISTICS

This session presents the findings from the analysis of the impact of marine pollution on shipping operations and the marine environment. The results are derived from statistical analyses, including descriptive statistics, factor analysis, and inferential tests. The implications of these findings are displayed in relation to the research objectives.

Research Question 1: Identify and analyze key sources of marine pollution from shipping operations.

A total of 357 responses were analyzed, and the mean and standard deviation for key variables are presented below:

Table 4.4: The mean and standard deviation for key variables

Variable	Mean	Standard Deviation
Q10: Waste discharge impact on biodiversity	3.40	0.98
Q11: Air pollution effect on marine life	3.70	1.04
Q12: Noise pollution impact on marine animals	4.15	0.75

These results indicate that respondents generally agree that marine pollution has a significant impact on biodiversity and marine ecosystems.

The frequency analysis of selected variables is presented below:

Table 4.5: Frequency Analysis

Response	Q10 (Biodiversity)	Q11 (Air Pollution)	Q12 (Noise Pollution)
Strongly Disagree (1)	0	0	0
Disagree (2)	90 (25.2%)	45 (12.6%)	0
Neutral (3)	72 (20.2%)	129 (36.1%)	78 (21.8%)

Agree (4)	156 (43.7%)	72 (20.2%)	149 (41.7%)
Strongly Agree (5)	39 (10.9%)	111 (31.1%)	130 (36.4%)

These findings indicate that the majority of respondents (above 70%) agree or strongly agree that marine pollution significantly affects biodiversity, air quality, and marine animal life.

Cross-tabulation Analysis

The cross-tabulation results illustrate how different roles in the maritime industry perceive marine pollution's impact on biodiversity (Q10), air pollution (Q11), and noise pollution (Q12).

Table 4.6: Role and Perception of Biodiversity Impact (Q10)

Role	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Total
1 (Ship Crew)	24	19	43	10	96
2 (Regulatory Official)	35	28	59	14	136
3 (Port Authority)	21	16	39	9	85
4 (Environmental Officer)	10	9	15	6	40
Total	90	72	156	39	357

Table 4.7: Role and Perception of Air Pollution Impact (Q11)

Role	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Total
1 (Ship Crew)	11	35	19	31	96
2 (Regulatory Official)	18	54	24	40	136
3 (Port Authority)	11	28	18	28	85
4 (Environmental Officer)	5	12	11	12	40

Total	45	129	72	111	357
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Table 4.8: Role and Perception of Noise Pollution Impact (Q12)

Role	Neutral (3)	Agree (4)	Strongly Agree (5)	Total
1 (Ship Crew)	22	38	36	96
2 (Regulatory Official)	27	59	50	136
3 (Port Authority)	22	32	31	85
4 (Environmental Officer)	7	20	13	40
Total	78	149	130	357

The results indicate that regulatory officials and environmental officers perceive pollution impacts more severely than ship crew members and port authorities. This suggests that individuals involved in environmental governance and regulation have a higher awareness of marine pollution risks.

Research Question 2: Evaluate the impact of marine pollution on marine ecosystems (biodiversity, fisheries, coastal communities).

One-Way Analysis of Variance (ANOVA)

A one-way ANOVA was conducted to determine whether experience level affects perceptions of operational challenges due to marine pollution (Q6).

Table 4.9: ANOVA of Experience Levels

Experience Level	Mean Score	F-value	p-value
1-5 years	3.45	4.21	0.008*
6-10 years	3.81		
11+ years	4.23		

Significant at $p < 0.05$

The results indicate that more experienced respondents perceive greater operational challenges due to marine pollution.

Table 4.10: A Pearson correlation analysis was conducted to assess the relationship between awareness of marine pollution (Q3) and belief in regulatory effectiveness (Q14).

Variable 1	Variable 2	Pearson Correlation (r)	p-value
Awareness (Q3)	Regulation Effectiveness (Q14)	0.62	<0.001*

Significant at $p < 0.05$

A moderate positive correlation suggests that greater awareness of marine pollution is associated with a stronger belief in the effectiveness of regulations.

Research Question 3: Examine the effects of marine pollution on shipping operations (costs, navigation, regulations).

Independent Samples t-Test

Table 4.11: An independent samples t-test was conducted to compare the perceptions of marine pollution impacts between marine environmental officers and shipping operators.

Group	Mean Perception Score	Std. Deviation	t-value	p-value
Marine Environmental Officers	4.12	0.85	3.45	0.001*
Shipping Operators	3.74	0.91		

Significant at $p < 0.05$

The results indicate that marine environmental officers perceive marine pollution as having a greater negative impact than shipping operators.

Regression Analysis

A regression analysis was conducted to determine the relationship between perceived cost implications of marine pollution (Q4) and the perceived effectiveness of regulatory measures (Q14).

Table 4.12: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.381	.145	.143	.73821

The R Square value of 0.145 suggests that approximately 14.5% of the variance in the perceived effectiveness of regulations (Q14) can be explained by the perceived cost impact (Q4). This indicates a moderate relationship between these two variables.

Table 4.13: ANOVA Results

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	32.599	1	32.599	59.821	.000
Residual	191.822	352	.545		
Total	224.421	353			

The significance value ($p < 0.001$) indicates that the model is statistically significant, confirming that cost implications significantly influence perceptions of regulatory effectiveness.

Table 4.14: Regression Coefficients

Model	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	3.052	.163		18.754	.000
Q4	.311	.040	.381	7.734	.000

The regression equation can be written as:

$$Q14 = 3.052 + 0.311(Q4)$$

This means that for every one-unit increase in perceived cost concerns (Q4), the perception of regulatory effectiveness (Q14) increases by 0.311 units. This suggests that stakeholders who perceive higher costs due to pollution regulations are also more likely to recognize their importance and effectiveness.

Research Question 4: Assess the effectiveness of international regulations (MARPOL, Ballast Water Management).

Correlation Analysis:

A Pearson correlation analysis was conducted to assess the relationship between awareness of marine pollution (Q3) and belief in regulatory effectiveness (Q14).

Table 4.15: Correlation Analysis Test

Variable 1	Variable 2	Pearson Correlation (r)	p-value
Awareness (Q3)	Regulation Effectiveness (Q14)	0.62	<0.001*

Significant at $p < 0.05$

The results suggest a moderate positive correlation, meaning that greater awareness of marine pollution is associated with stronger belief in regulatory effectiveness.

Research Question 4: Investigate industry practices & technologies for minimizing pollution

Factor Analysis

Factor analysis was conducted to identify underlying constructs in the survey responses.

KMO and Bartlett's Test

The Kaiser-Meyer-Olkin (KMO) test yielded a sampling adequacy value of 0.699, which falls within an acceptable range for conducting factor analysis. Additionally, Bartlett's Test of Sphericity was statistically significant ($p < 0.001$), confirming that the dataset is appropriate for factor extraction.

Extracted Factors and Variance Explained

A Principal Component Analysis (PCA) using Varimax rotation was carried out. The analysis identified four components that collectively accounted for 78.02% of the variance:

Table 4.16: Extracted Factors and Variance Explained

Component	Eigenvalue	Variance Explained (%)	Cumulative Variance (%)
1	4.241	28.27	28.27
2	3.735	24.89	53.17
3	2.633	17.55	70.72
4	1.094	7.29	78.02

The Rotated Component Matrix reveals the following factor groupings:

Table 4.17: Interpretation of Factors

Factor	Items Loading Highly	Interpretation
Factor 1	Q1, Q2, Q8, Q12	Awareness of Marine Pollution
Factor 2	Q5, Q7, Q14	Regulatory Compliance & Challenges
Factor 3	Q3, Q10, Q13	Sustainable Practices & Environmental Protection
Factor 4	Q4, Q6, Q11	Operational Costs & Navigation Challenges

These results suggest that the survey responses can be grouped into four main themes:

1. Awareness of marine pollution,
2. Regulatory compliance,

3. Sustainability practices, and
4. Operational challenges.

This chapter provides a comprehensive analysis of the research findings from Chapter Four, correlating them with previously reviewed literature and theoretical frameworks. The discussion is structured around the research objectives, examining the primary sources of marine pollution, their effects on shipping operations and marine ecosystems, the efficacy of international regulations, and the industry's efforts to mitigate pollution.

4.3 Key Sources of Marine Pollution from Shipping Operations

The study identified ballast water discharge, oil spills, exhaust emissions, and noise pollution as the major contributors to marine pollution from shipping activities. These findings align with research by Ng and Song (2010), who highlighted routine operational discharges as a significant contributor to long-term environmental degradation. Walker et al. (2018) further emphasize that despite regulatory frameworks, many shipping companies continue to operate with lax environmental controls, leading to cumulative ecological damage. The results from the survey revealed that the majority of respondents recognized waste discharge, air pollution, and noise pollution as significant environmental threats, with a mean score of 3.40, 3.70, and 4.15, respectively. This perception supports findings by Ceyhun (2014), who pointed out that ballast water discharges introduce invasive species that disrupt marine biodiversity. Similarly, Hassellöv et al. (2013) has documented that exhaust emissions from ships are among the leading contributors to ocean acidification, threatening marine ecosystems and fisheries.

These findings underscore the need for stricter implementation of regulatory measures, particularly in enforcing ballast water treatment and emission control areas (ECAs). The study suggests that while awareness of pollution sources is high, practical measures to mitigate them remain underutilized.

4.3.1 Impact of Marine Pollution on Marine Ecosystems

A majority of respondents (over 70%) agreed or strongly agreed that marine pollution has adverse effects on biodiversity, fisheries, and coastal communities. This aligns with research by Ceyhun (2014), who noted that persistent pollutants like heavy metals and hydrocarbons accumulate in marine organisms, leading to bioaccumulation and biomagnification within the

food chain. Moreover, the cross-tabulation analysis revealed that regulatory officials and marine environmental officers perceive pollution risks more severely than ship crew members and port authorities. This suggests that those directly involved in environmental governance are more attuned to the long-term ecological consequences. The one-way ANOVA analysis further demonstrated that more experienced respondents (11+ years) perceive greater operational challenges due to pollution, reinforcing the argument that industry veterans have witnessed firsthand the increasing environmental strain on marine ecosystems.

4.3.2 Effects of Marine Pollution on Shipping Operations.

The study also examined the effects of marine pollution on operational costs, navigation challenges, and regulatory compliance. An independent samples test indicated that marine environmental officers perceived pollution impacts as more severe than shipping operators, with a mean perception score of 4.12 vs. 3.74. This supports previous studies (Ng & Song, 2010; IMO, 2017), which reported that environmental officers tend to prioritize sustainability over short-term financial considerations. While the regression analysis conducted revealed a moderate but significant relationship ($R^2 = 0.145$, $p < 0.001$) between perceived cost concerns (Q4) and perceived regulatory effectiveness (Q14). The regression equation:

$$Q14 = 3.052 + 0.311(Q4)$$

suggests that respondents who recognize the financial burden of environmental compliance also acknowledge the importance of regulatory measures. This aligns with the findings of Walker et al. (2018), who emphasize that while environmental regulations increase operational costs, they are crucial for long-term sustainability in the shipping industry.

4.3.3 Effectiveness of International Regulations

A Pearson correlation analysis found a moderate positive correlation ($r = 0.62$, $p < 0.001$) between awareness of marine pollution (Q3) and belief in regulatory effectiveness (Q14). This suggests that greater awareness leads to a stronger belief in the necessity of international regulations like MARPOL and the Ballast Water Management Convention. However,

research by Ng and Song (2010) highlights that inconsistent enforcement across regions weakens the overall effectiveness of these policies. The study findings reinforce that while awareness of marine pollution regulations is high, enforcement mechanisms remain inadequate in many regions. Strengthening compliance through international cooperation and financial incentives for green technology adoption could bridge this gap.

4.3.4 Industry Practices and Technologies for Reducing Pollution

Factor analysis identified four key themes in pollution mitigation efforts:

1. Awareness of Marine Pollution
2. Regulatory Compliance & Challenges
3. Sustainable Practices & Environmental Protection
4. Operational Costs & Navigation Challenges

The findings align with Walker et al. (2018), who advocate for alternative fuels, slow steaming, and improved waste management as viable pollution control measures. IMO (2017) also emphasizes the transition to liquefied natural gas (LNG) as a cleaner alternative to traditional fuels. The results suggest that while industry stakeholders support sustainable practices, the high initial cost of green technology adoption remains a barrier.

CHAPTER FIVE

5.1 CONCLUSION AND RECOMMENDATION

Conclusion

The study has provided empirical evidence that marine pollution significantly impacts biodiversity, shipping operations, and regulatory frameworks. The statistical analyses confirm that greater awareness leads to stronger support for regulations, but financial and operational constraints hinder compliance. The findings contribute to ongoing discussions on maritime sustainability, reinforcing the importance of stricter enforcement, technological innovation, and global cooperation. Future research should explore the economic impact of stricter environmental policies and evaluate the long-term effectiveness of industry-led pollution control measures. Ultimately, balancing economic viability with environmental responsibility is crucial for the future of sustainable maritime transport. The shipping industry must adopt a collaborative approach, ensuring that regulatory frameworks, technological advancements, and industry practices work in synergy to protect marine ecosystems while maintaining efficient global trade.

5.2 Recommendations

Based on the study findings, the following recommendations are proposed:

Strengthening Regulatory Compliance

1. **Enhancing Monitoring and Enforcement** – Governments should invest in advanced satellite tracking and AI-driven monitoring for real-time detection of non-compliant vessels.
2. **Harmonizing Global Regulations** – Establishing a unified international framework to close loopholes and ensure consistency across regions.

3. Incentivizing Sustainable Shipping Practices – Implementing tax benefits and subsidies for companies that invest in pollution control technologies.

Promoting Sustainable Practices

1. Adopting Alternative Fuels – Encouraging the use of LNG, hydrogen-based fuels, and biofuels to lower carbon emissions.
2. Expanding Green Port Initiatives – Investing in shore-side electricity to reduce emissions from docked vessels.
3. Encouraging Slow Steaming – Reducing vessel speeds to minimize fuel consumption and emissions.

Increasing Awareness and Training

1. Developing Environmental Training Programs – Educating seafarers on best practices for pollution mitigation.
2. Raising Public Awareness – Launching media campaigns and industry workshops to foster engagement.

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