Impact of Maritime Pollution on India's Shipping Industry: An Analysis of Pollutants and Their Effects

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Abstract: This study examines the impact of maritime pollutants on India's shipping industry, with a focus on identifying key pollutants and assessing their environmental effects. The research analyses the relationship between the number of ships, gross tonnage, deadweight, and the volume of pollutants, including gross carbon emissions, CO2, and diesel oil, released into the environment. Additionally, it explores how larger vessels disproportionately contribute to higher pollutant emissions, particularly in terms of gross carbon emissions, CO2, and diesel oil. The findings offer crucial insights into the environmental challenges confronting the maritime shipping industry and present strategic recommendations to mitigate its ecological impact.

Key words: maritime pollutants, dead weight, gross tonnage, environmental impact, disproportionate emissions.

1. INTRODUCTION

The international shipping sector is essential for global trade, with 90% of goods transported by sea (UNCTAD, 2021). This mode of transportation supports economic growth and development worldwide. However, despite its economic advantages, the shipping industry poses significant environmental threats, particularly regarding marine pollution and the disruption of ecosystems. Activities such as dredging, port development, and maritime traffic contribute to habitat destruction in critical ecosystems like mangrove forests, seagrass beds, and coral reefs, endangering biodiversity and ecosystem functions (Halpern et al., 2015).

Addressing these environmental impacts requires a multi-faceted approach, including improved regulations, technological innovations, and collaboration between governments, industry stakeholders, and international organizations. Despite some progress, challenges remain in fully mitigating the environmental damage caused by the shipping industry (UNCTAD, 2021).

Sustainability in the maritime sector has become a strategic priority, driven by market forces, regulatory pressures, and stakeholder expectations. Many companies are now integrating environmental considerations into their business models to enhance competitiveness, minimize risks, and comply with regulations. The complexity of global shipping operations, involving diverse cargo, routes, and vessel types, necessitates comprehensive sustainability practices that span the entire value chain, from port infrastructure to vessel operations (OECD, 2020).

Leadership and governance play crucial roles in fostering sustainable practices within the maritime sector. Companies must incorporate sustainability into their strategic planning and corporate culture, encouraging innovation and continuous improvement to balance economic, social, and environmental objectives (BIMCO, 2021).

This study aims to examine the environmental impacts of shipping, particularly focusing on pollution and habitat disruption. It will explore current management practices, regulatory frameworks, and technological advancements to identify opportunities for improving both competitiveness and environmental performance in the industry.

2. REVIEW OF LITERATURE

Review of literature is essential since it familiarizes the researcher with concepts and conclusions already evolved by earlier analysis. It also enables the here, researcher to find out the scope of study and frame suitable objectives for the proposed evaluation.

1. Jalkanen et al. 2009, 2012, 2018, 2021. The model combines shipping activities with emission factors for air pollutants sulphur and nitrogen oxides, particulate matter, carbon monoxide (SOX, NOX, PM, CO) and CO2. In the recent new development,

also water pollutants (nutrients, i.e. P and N; contaminants, i.e. metals and volumes of various waste streams) and underwater noise were calculated. Consequently, maps of emission to air and discharges to the sea are generated in high spatial and temporal resolution.

2. Faber et al. 2020. Emissions of these substances constitute about two percent of the total CO2 equivalent emissions from ships. Use of Liquified Natural Gas (LNG) as marine fuel mitigates emissions of traditional air pollutants, like NOX, SOX and PM. Careful attention to technical features preventing the loss of methane during ship operation is, however, needed. If unburned methane escapes from ships, use of LNG may lead to larger climate impact than use of diesel fuels.

3. Durate et al. 2021 Natural and anthropogenic activities can generate loud underwater noise, which can disturb marine life. Compared to emission inventories of air pollutants and discharges to the sea, systematic inventories of underwater noise have been until recently largely missing.

4. Nerhagen (2016) and (Naturvårdsverket, 2010). Tichavska and Tovar (2017) have reviewed studies that make use of models relating emissions of air pollutants to impacts on, in particular, human health, which are measured in monetary terms. However, similar models of impacts on aquatic ecosystems are nonexistent. Broad ecosystem assessments about the environmental impacts of shipping.

3. STATEMENT OF PROBLEM

India's shipping industry faces significant environmental challenges due to major marine pollutants such as carbon emissions and diesel oil, sulfur oxides, and nitrogen oxides. These contaminants harm both marine ecosystems and human health. However, there is a lack of comprehensive research on their specific environmental impact in Indian waters. Understanding the relationship between shipping operations and ecological disturbances is essential for guiding policy, improving regulations, and promoting sustainability in the industry.

4. SIGNIFICANCE OF THE STUDY

This study aims to support the preservation of marine ecosystems through effective environmental management practices. By examining the impact of key marine pollutants on India's shipping sector, it provides insights that can help shape regulations to reduce environmental degradation and promote sustainability. The study also seeks to raise public awareness about the environmental effects of maritime operations, equipping stakeholders with knowledge to make informed decisions. Additionally, it offers valuable guidance for industry stakeholders to improve environmental performance and compliance, aligning with global efforts for sustainability in the maritime industry.

5. RESEARCH OBJECTIVES

Main objectives of this Paper are as follows

1. To study the major pollutants and its impacts on Maritime sector.

2. To analyses the major marine pollutants impacts on shipping Industry of India.

6. RESEARCH HYPOTHESES

For analyzing the objectives of the study, the following null hypothesis is to be tested:

H1:A positive relationship exists between the number of operational ships and the volume of marine pollutants released.

H2: There is a strong positive relationship between a ship's gross tonnage and the quantity of pollutants emitted.

H3:Ships with greater deadweight emit disproportionately higher levels of specific marine pollutants.

7. METHODOLOGY

This study collects secondary data from reputable sources, primarily the Directorate General of Shipping, to analyses pollutants (carbon emissions, CO2, diesel oil, heavy fuel oil, and light fuel oil) in relation to maritime metrics (ship count, gross tonnage, and deadweight) to understand the environmental impact of India's shipping operations. For Analysis, used statistical analysis which includes percentages, growth rate, averages, co-variances, standard deviation and correlation. These calculations have been done with SPSS software. The Major Pollutants which include – 1. Gross carbon Emissions, 2. Co2, 3. Diesel Oil, and three marine and shipping major components includes,1. Number of Ships, 2. Gross tonnage and 3. Dead Weight have been analyzed of this study from secondary data source of the selected variables data has taken from year 2019-2022.

8. SCOPE AND LIMITATION OF STUDY

Restrictions on data quality and availability may have an impact on the thoroughness and correctness of the study. It is difficult to separate the effects of shipping due to the complexity of maritime ecosystems. Study generalizability may be impacted by geographical scope restrictions.

9. ANALYSIS

Ratio of Each Pollutants with Different Variables:

Table 1 - Gross Carbon Emissions Per Ships

Calendar Year	Gross Carbon Emissions (MT)	Number of Ships	Gross Carbon Emissions/Ships
2019	5.14	920	0.0055
2020	4.62	876	0.0052
2021	4.96	870	0.0057
2022	4.84	867	0.0055
Average	4.89	883.25	0.005475
Standard Deviation	0.188	21.46	0.0002
Covariance	3.84	2.42	3.65%

Source – Indian Marine Environmental Management Report (2019-2023)

Interpretation - Above table 4 represents that the data from 2019 to 2022, the data shows that the gross carbon emissions per ship in the Indian maritime industry were relatively consistent, averaging approximately 0.005475 million tonnes. There are slight variations, with emissions falling between 0.0052 and 0.0057 million tonnes. To lessen the influence on the environment, monitoring and emission reduction measures must be maintained.

Table 2 - Gross Carbon Emissions Per Gross Tonnage (MT)

Calendar Year	Gross Carbon Emissions (MT)	Gross Tonnage (MT)	Gross Carbon Emissions/GT (MT)
2019	5.14	10.04	0.512
2020	4.62	9.75	0.474
2021	4.96	10.02	0.495
2022	4.84	9.8	0.494
Average	4.89	9.9025	0.49375
S.D	0.188	0.128	0.0155
Covariance	3.84	1.29	3.13%

Source – Indian Marine Environmental Management Report (2019-2023)

Interpretation - Above table -2 represents that the data the gross carbon emissions per gross tonnage (MT) in the shipping industry have fluctuated somewhat between 2019 and 2022, averaging 0.49375 MT. Gross tonnage varied between 9.75 and 10.04 MT, showing a somewhat constant trend whereas emissions varied between 0.474 and 0.512 MT. This suggests that emissions are consistently efficient in relation to tonnage, and that there is room for improvement by using focused emission reduction techniques.

Table 3 - Gross Carbon Emissions Per Deadweight

Calendar Year	Gross Carbon Emission (MT)	Dead Weight (Millions)	Gross Carbon Emissions/DW
2019	5.14	16.7	0.308
2020	4.62	16.6	0.278
2021	4.96	16.5	0.3
2022	4.84	16.3	0.297
Average	4.89	16.525	0.29575
S.D (σ)	0.188	0.14	0.0127
Covariance	3.84	0.84	4.29

Source – Indian Marine Environmental Management Report (2019-2023)

Interpretation - Above table-3 represents that the data The gross carbon emissions per deadweight (MT) in the shipping sector varied slightly from 0.278 to 0.308 MT between 2019 and 2022, averaging 0.29575 MT. Deadweight, which ranged from 16.3 to 16.7 million tons, stayed comparatively constant. According to deadweight, this indicates a constant level of emission efficiency, with room for improvement through focused emission reduction tactics.

Table-4 - CO2 Emissions Per Ships

Calendar Year	CO2Emissions (MT)	Number of Ships	CO2 Emissions/Ships
2019	5.152	920	0.0058
2020	4.642	876	0.0052
2021	4.959	870	0.0057
2022	4.855	867	0.0055
Average	4.902	883.25	0.00555
S.D	0.183	21.46	0.0002
Covariance	3.73	2.42	3.60%

Source – Indian Marine Environmental Management Report (2019-2023

Interpretation - Above table-4 represents that the data the shipping industry's average CO2 emissions per ship from 2019 to 2022 were 0.00555 MT, with small variations ranging from 0.0052 to 0.0058 MT. The fleet size was comparatively steady, with 920 ships out of a possible total of 867. This indicates a steady emission rate per ship, underscoring the necessity of ongoing initiatives in the marine industry to lower carbon emissions and enhance environmental sustainability.

Table-5 - CO2 Emissions Per Gross Tonnage

Calendar Year	CO2 Emissions (MT)	Gross Tonnage	CO2 Emissions/GT
2019	5.152	10.04	0.549
2020	4.642	9.75	0.476
2021	4.95	10.02	0.485
2022	4.855	9.8	0.495
Average	4.89975	9.9025	0.50125
S.D	0.183	0.128	0.028
Covariance	3.73	1.29	5.58

Source: Indian Marine Environmental Management Report (2019-2023)

Interpretation - Above table-5 shows that the data the CO2 emissions per gross tonnage (MT) in the shipping sector ranged from 0.476 to 0.549 MT between 2019 and 2022, with an average of 0.50125 MT. The gross tonnage fluctuated between 9.75 and 10.04 MT, remaining comparatively constant. This shows a constant emission rate in relation to tonnage, even with small changes. The covariance and standard deviation, on the other hand, show some unpredictability and emphasize the significance of ongoing monitoring and emission reduction efforts for environmental sustainability.

Table-6: CO2 Emissions Per Dead Weight

Calendar Year	CO2Emissions (MT)	Dead Weight	CO2 Emissions/DW
2019	5.152	16.7	0.307
2020	4.642	16.6	0.278
2021	4.95	16.5	0.3006
2022	4.855	16.3	0.296
Average	4.89975	16.525	0.2954
S.D	0.183	0.147	0.0107
Covariance	3.73	0.88	3.62

Source: Indian Marine Environmental Management Report (2019-2023)

Interpretation - Above table-6 represents that the data the CO2 emissions per deadweight (MT) in the shipping sector ranged from 0.278 to 0.307 MT between 2019 and 2022, with an average of 0.2954 MT. The deadweight fluctuated between 16.3 and 16.7 million tons, remaining comparatively constant. This suggests that, with only slight variations, the emission rate is constant in relation to deadweight. The covariance and standard deviation, on the other hand, point to some unpredictability and highlight the necessity of continuous monitoring and emission reduction efforts for environmental sustainability.

Table-7
Gross Diesel Oil Consumption Per Ships

Calendar Year	Gross Diesel Oil Consumption (MT)	Number of Ships	Gross DO/Ships
2019	0.397	920	0.00043
2020	0.369	876	0.00042
2021	0.412	870	0.00047
2022	0.41	867	0.00047
Average	0.397	883.25	0.0004475
S.D (σ)	0.017	21.46	2.277
Covariance	4.28	2.42	5,08,826.81

Source: Indian Marine Environmental Management Report (2019-2023)

Interpretation - The table-7 represents that the data During the period of 2019 to 2022, the shipping industry's average gross diesel oil consumption per ship ranged from 0.00042 to 0.00047 MT. The fleet size was comparatively steady, with 920 ships out of a possible total of 867. This shows that, with only slight variations, the rate of diesel oil consumption per ship is constant. To ensure efficiency and environmental sustainability, it is crucial to regularly monitor and manage diesel oil use, as indicated by the standard deviation and covariance, which both show significant variability.

Table-8
Gross Diesel Oil Consumption Per Gross Tonnage

Calendar Year	Gross Diesel Oil Consumption (MT)	Gross Tonnage (MT)	Gross DO/GT
2019	0.397	10.04	0.039
2020	0.369	9.75	0.037
2021	0.412	10.02	0.0403
2022	0.41	9.8	0.0418
Average	0.397	9.9025	0.039525
S.D (σ)	0.017	0.128	0.0017
Covariance	4.28	1.29	4.3

Source: Indian Marine Environmental Management Report (2019-2023)

Interpretation – The table-8 represents that the data: The gross diesel oil consumption per gross tonnage (MT) in the shipping industry ranged from 0.037 to 0.0418 MT, with an average of 0.039525 MT between 2019 and 2022. The gross tonnage fluctuated between 9.75 and 10.04 MT, remaining comparatively constant. This implies a steady rate of diesel oil consumption in relation to tons, with very little variations. The standard deviation and covariance, on the other hand, show some unpredictability and highlight how crucial it is to carefully monitor and control diesel oil usage for both environmental sustainability and efficiency.

10. CORRELATION ANALYSIS

Table-9
Statement of Correlation between No. of Ships with Major Pollutants

Sr. No	State of Nature	r	r 2	Remarks
1	Relationship Between No. of ships with Gross Carbon Emission	0.68	0.4624	Medium Positive Correlation and Relationship Strength 46.24%
2	Relationship Between No. of ships with CO2	0.70	0.49	High Positive Correlation and Relationship Strength 49%
3	Relationship Between No. of ships with Diesel Oil	-0.14	0.0196	Low Negative Correlation and Relationship Strength 1.96%

Source: Indian Marine Environmental Management Report (2019-2023)

Interpretation: The correlation analysis reveals the following relationships between the number of ships and major pollutants: The correlation reveals varying relationships between the number of ships and different environmental metrics. A moderate positive correlation of 0.68 exists between the number of ships and gross carbon emissions, indicating a relationship strength of 46.24%. This suggests that as the number of ships increases, carbon emissions tend to rise correspondingly, though not perfectly. A slightly stronger positive correlation of 0.70 is observed between the number of ships and CO_2 emissions, with a relationship strength of 49%, reinforcing the link between ship count and CO_2 output. In contrast, the correlation between the number of ships and diesel oil usage is weakly negative at -0.14, with only a 1.96% relationship strength, implying minimal and inversely related association between the two.

Table-10 - Statement of Correlation between Gross Tonnage with Major Pollutants

Sr. No	State of Nature	r	r 2	Remarks
1	Relationship Between Gross Tonnage with Gross Carbon Emission	0.91	0.8281	High Positive Correlation and Relationship Strength 82.81%
2	Relationship Between Gross Tonnage with CO2	0.89	0.7921	High Positive Correlation and Relationship Strength 79.21%
3	Relationship Between Gross Tonnage with Diesel Oil	-0.53	0.2809	Low Negative Correlation and Relationship Strength 28.09%

Source: Indian Marine Environmental Management Report (2019-2023)

Interpretation -The correlation analysis between gross tonnage and major pollutants yields the following relationships: The data indicates a strong positive relationship between gross tonnage and environmental emissions metrics. Gross tonnage shows a high positive correlation of 0.91 with gross carbon emissions, with a relationship strength of 82.81%, suggesting that as gross tonnage increases, carbon emissions rise significantly. Similarly, there is a strong positive correlation of 0.89 between gross tonnage and CO_2 emissions, with a relationship strength of 79.21%, reinforcing the link between larger tonnage and higher CO_2 output. Conversely, there is a low negative correlation of -0.53 between gross tonnage and diesel oil consumption, with a relationship strength of 28.09%, indicating that as tonnage increases, diesel oil consumption decreases somewhat, though this relationship is not as strong

Table-11
Statement of Correlation between Dead Weight with Major Pollutants

Sr. No	State of Nature	r	r 2	Remarks
1	Relationship Between Dead Weight with Gross Carbon Emission	0.29	0.0841	Low Positive Correlation and Relationship Strength 8.41%
2	Relationship Between Dead Weight with CO2	0.31	0.0961	Low Positive Correlation and Relationship Strength 9.61%
3	Relationship Between Dead Weight with Diesel Oil	-0.53	0.2809	Low Negative Correlation and Relationship Strength 28.09%

Source: Indian Marine Environmental Management Report (2019-2023)

Interpretation: The correlation analysis between dead weight and major pollutants reveals the following relationships: The data reveals a weak relationship between dead weight and various emission metrics. The correlation between dead weight and gross carbon emissions is low and positive at 0.29, with a relationship strength of only 8.41%, indicating a minimal increase in carbon emissions as dead weight rises. Similarly, dead weight has a low positive correlation of 0.31 with CO_2 emissions, with a relationship strength of 9.61%, suggesting a slight association between increasing dead weight and CO_2 emissions. In contrast, dead weight has a low negative correlation of -0.53 with diesel oil consumption, with a stronger relationship strength of 28.09%, suggesting that as dead weight increases, diesel oil usage tends to decrease moderately.

11.SUMMARY AND CONCLUSIONS

Summary:

The study examines the environmental impact of pollutants from maritime shipping in India, focusing on ship characteristics like count, size, and weight. Findings reveal that larger ships contribute significantly more to carbon, CO_2, and diesel pollutants than smaller vessels. Gross tonnage is identified as the main factor influencing emissions, with a strong positive correlation to both carbon and CO_2 emissions, while the number of ships and dead weight have moderate and weak correlations, respectively. Interestingly, larger and heavier ships are more fuel-efficient in diesel consumption, likely due to design and operational efficiencies. The study suggests that managing gross tonnage is essential for emission reduction, alongside efforts to optimize fuel efficiency in larger vessels.

Major Observations:

• Gross Tonnage as the Key Emission Factor: Gross tonnage is the primary driver of emissions, contributing disproportionately to carbon and CO_2 outputs, highlighting the need to manage emissions based on ship size.

•Moderate Emission Increase with Ship Count: Although an increase in ship numbers correlates with higher emissions, its impact is secondary to ship size.

• Minimal Impact of Dead Weight on Emissions: Dead weight has a limited direct influence on emissions, suggesting it should be a lower priority in emission management.

• Efficiency of Larger and Heavier Ships in Diesel Consumption: Larger ships show lower diesel usage due to operational efficiencies, indicating potential fuel efficiency benefits associated with size.

Recommendations:

• Focus Emission Management on Gross Tonnage: Target emission strategies towards larger vessels, which are the primary contributors to pollution.

• Invest in Alternative Fuels and Advanced Technologies: Promote the use of alternative fuels and technologies to reduce emissions across different ship types and sizes.

• Implement Stringent Fuel and Emission Regulations: Establish stricter regulations on fuel types and consumption to protect marine ecosystems.

• Enhance Monitoring for Proactive Emission Control: Develop stronger monitoring systems for ship characteristics and fuel usage to enable effective emission control.

• Optimize Fuel Efficiency in Larger Ships: Leverage operational efficiencies in larger vessels to improve environmental impact through fuel optimization strategies.

Conclusions: The shipping industry's contribution to marine pollution is closely tied to the size and number of ships, with gross tonnage emerging as a major factor driving emissions. The study highlights that maritime shipping in India, particularly from larger vessels, significantly impacts the environment due to carbon, CO_2, and diesel emissions. Gross tonnage emerged as the primary factor influencing emissions, underscoring the need to prioritize emission control strategies based on ship size. While the number of ships moderately impacts emissions, and dead weight plays a minor role, these factors are less critical than tonnage in addressing pollution. To mitigate the environmental impact, the study recommends focusing on strategies that manage gross tonnage, adopt alternative fuels, and implement stricter emissions regulations. Additionally, enhancing fuel efficiency in larger vessels presents a promising opportunity, as these ships already exhibit fuel-saving advantages. Proactive monitoring of ship characteristics and fuel usage will be essential to maintain sustainable practices in India's maritime industry, ensuring an overall reduction in ecological footprint.

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