A STUDY ON THE EFFECT OF SHIPPING POLLUTION IN THE PORT AND TERRITORIAL WATERS OF VISAKHAPATNAM

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Abstract: Shipping contributes to air, water, and soil pollution in coastal and port communities. Pollution caused by the vessels in mid-ocean and the ports differs in terms of causes and effects. Visakhapatnam Port, the second largest port by volume of cargo handled in India, has seen substantial growth in cargo throughput over the past decade, handling 69.84 million tons in FY2020-21. Such bustling port facilities can contribute significantly to pollution due to the extensive ship traffic, cargo, fuel, and waste associated with port operations. Air Quality is analyzed using the calculation of Air Quality Index (AQI) from data collected of NO_x, SO_x, CO_2, and Particulate Matter $(PM)_{2.5}$ in the ambient atmosphere along the port vicinity. Governing factors of water quality, such as salinity, temperature, turbidity, pH, dissolved oxygen (DO), nutrients, and oil traces, are examined to calculate Water Quality Index (WQI). A Cetacean C57 hydrophone and a TASCAM Recorder are used to detect and test the frequency and intensity of anthropogenic noises. Through the analysis of the data collected, the study aims to generate reliable data for water, air quality, and underwater noise, providing a better understanding of shipping pollution and creating a vision towards adopting green initiatives at Visakhapatnam port

Keywords: Air Quality Index (AQI), Water Quality Index (WQI), dissolved oxygen (DO), underwater vibrations, shipping pollution

1. Introduction

The vastness of the oceans has long been a mystery to humans, with early seafarers afraid to stray into the uncharted waters for fear of disappearing off the edge of the earth [4]. However, with the advancement of science, humans have gained a deeper understanding of the oceans and their immense significance. Having seen an exponential increase in the volume of shipments over the last two decades, the maritime industry and ports have become cornerstones in globalization, managing 90% of the world trade measured in weight and volume [10]. With 13 major ports and 176 notified non-major ports scattered around the 7517 km coastline of India on the eastern and western shelf of the mainland, they act as crucial economic provision units, serving as a vital hub facilitating exchange of goods between sea and land transport modes. The Indian Ocean hosts one of the most important trade crossings connecting the Far East with Europe, becoming the epicenter of economic activity with nearly 50% of the world maritime trade, 50% of container traffic, and 70% of energy trade, with various cargo handling analysis from 2000-2018 predicting a steady increase in the coming years [13] [11].

2. Background

The growth of the Indian ports and increasing ship traffic, despite being critical to the country's economic expansion has affected the coastal and territorial waters with emissions of noise, odors, volatile organic substances, and pollution of water and soil by oil chemicals, hull paint, and other hazardous materials [7]. The dense arrangement of roughly one port every 28 km, along the 7517km coastline makes it one of the most fragile eco-zones in the country, arguably facing a greater threat due to pollution compared to the open waters [15]. The entire port industry has faced mounting pressure to ensure that its operations have a minimal environmental impact and to establish social credibility by adhering to standards for compliance, risk reduction, and sustainability due to the growing recognition of the significant of environmental checks [12]. Understanding the dearth of documentation, it is crucial to adopt a long-term approach when estimating emissions from ports [16].

Visakhapatnam Port spreads over approximately 2000 hectares of land and plays a crucial role in India's economic growth and development. The emissions from ships during loading and unloading at the jetty contribute most to the air pollution at the port, in addition to the open stockyard of coal cargo exposed to elements releasing particulate matter, which can be harmful to human health when inhaled. This study aims to assess the air and water quality likewise, noise levels at Visakhapatnam Port. By understanding the level of pollution caused by the port, policymakers, port authorities, and other stakeholders can take necessary measures to mitigate the adverse impacts and promote sustainable practices. In the current study, the measurements and data collection are performed at two locations, - one where major port activities occur, termed the "port area", and the waters about 20 nautical miles along the coast and free from the port and shipping activities, termed "territorial waters".

3. Site Details

For air quality measurements, the residential area, Gnanapuram side of the port was chosen. For water quality measurements, water samples were collected from five different locations inside the port, namely the turning circle(C), fishing harbor station 1(F1), fishing harbor station 2(F2), east berth Q7(E), and west berth Q7(W). The East Q7 handles commodities such as thermal coal, scrap, and fertilizers whereas, the West Q7 handles manganese ore, limestone, gypsum, bauxite, blast furnace slag, and steel. Underwater noise was measured and recorded by deploying a hydrophone in the inner harbor region of the port. The coastal waters of Bheemili, a coastal town near Visakhapatnam is chosen as the site for territorial waters (T).

3. Air, Water and Noise Analyses

3.1. Air Quality Analysis

The ambient air quality was regularly examined in the surroundings of Visakhapatnam Port for the month of January, 2023. The study assessed the presence of common air pollutants such as NO_x, SO_x, and $PM_{2.5.}$ World

Health Organization (WHO) has provided Air Quality guidelines which comprise of scientifically supported suggestions for capping the amount of airborne toxins to keep the environment and public health safe [17]. AQI is calculated using Equation (1).

$$AQI=\frac{C}{C_s}\times 100, \tag{1}$$

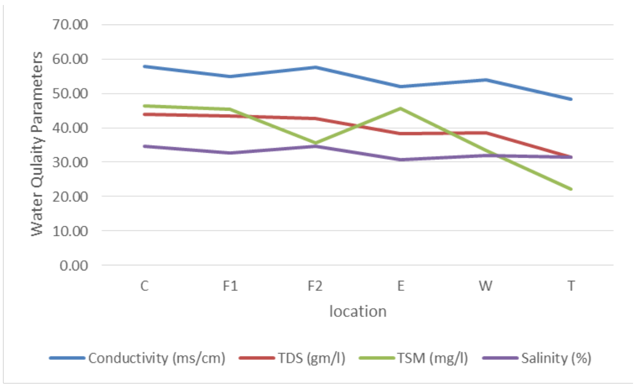
where,

C= Observed value of the air quality parameters pollutant ($PM_{2.5}$, SO_2 and NO_2)

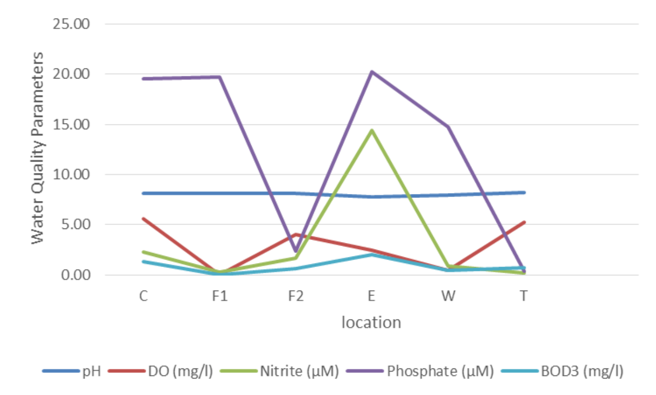
C_s= Central Pollution Control Board (CPCB) standard for industrial area [6].

3.2. Water Quality Analysis

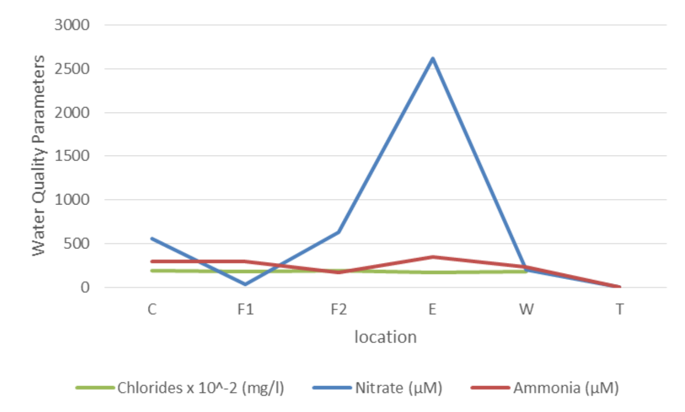
Water samples collected from the sites have been subjected to hydrochemical analysis at the marine biology laboratory of Andhra University, Visakhapatnam, India. Some important parameters have been analyzed and presented as shown in Figure 1.



(a) Conductivity, TDS, TSM and Salinity



(b) pH, DO, Nitrite, Phosphate and BOD_3



(c) Chlorides, Nitrides and Ammonia

Figure 1. Variation of Water quality parameters at various site locations

Important parameters governing water quality - pH, temperature, conductivity, total dissolved solids (TDS), total suspended matter (TSM), dissolved oxygen (DO), and biochemical oxygen demand (BOD) alongside nutrients like ammonia, phosphorous and nitrate were analyzed from the collected water samples [18].

WQI is calculated using the National Sanitation Foundation Water Quality Index (NSFWQI) method using Equation (2).

$$WQI = \sum W_i Q_i = W_{Temperature} Q_{Temperature} + W_{DO} Q_{DO} + W_{pH} Q_{pH} + W_{Nitrate} Q_{Nitrate} + W_{Turbidity} Q_{Turbidity} + W_{TDS} Q_{TDS} + W_{Phosphate} Q_{Phosphate} + W_{BOD} Q_{BOD} \quad (2)$$

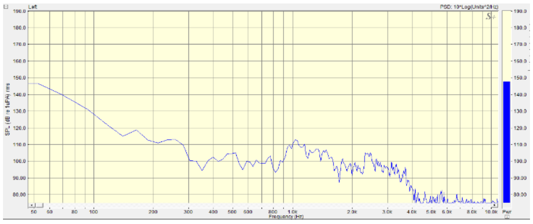
Where,

W_i is the weight associated with the ith water quality parameter; Q_i is the sub-index for the jth water quality parameter.

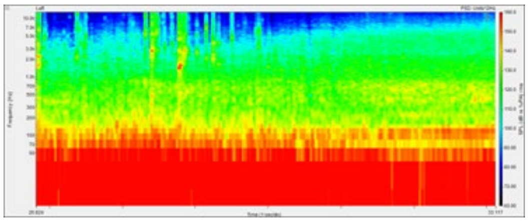
3.3. Underwater Radiated Noise (URN) Analysis

The underwater noise levels of the inner harbor region, one of the points with maximum vessel movements have been measured using Cetacean C57 and TASCAM recorder hydrophones, and, have been compared with those in territorial waters. The hydrophone was lowered in the water to 2m and was connected to the recorder for 30 sec (3 recordings has been taken). Three cases of measurements with calibrated sensors have been taken, first in ambient condition during the loading and unloading from a ship, the second one is taken when tug operation to tow the larger vessels near the jetty is going on, and the third one while the pile driving is being done during the construction work for port expansion. When the frequency of the transmitted noise becomes same as the frequency of the communication signals of marine animals, it affects them adversely [2].

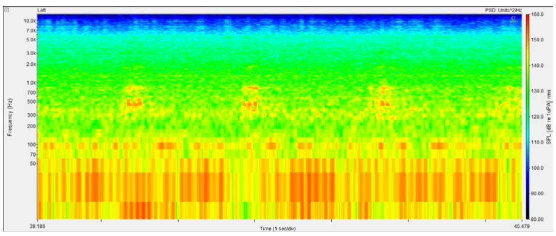
Generally, tug boats generate sound level of 80 dB to 100 dB during normal operations and 120 dB during high maneuvers and emergency conditions [5]. Pile driving is one of the common activities at ports, which can also affect the marine life [8]. A comparison of noise levels at the port during port operations and that in territorial waters is made and presented in Figure 2.



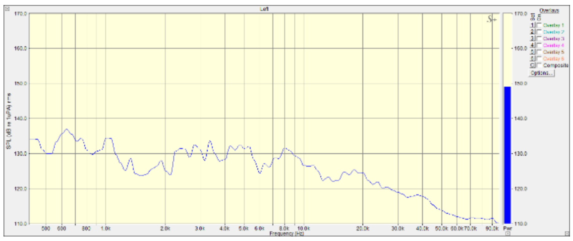
(a) Noise Spectrum in Ambient Conditions



(b) Noise Spectrogram during Tug-boat operations



(c) Noise Spectrogram during Pile-driving



(d) Noise Spectrum in Territorial Waters

Figure 2. URN levels in port and territorial waters

4. Results and Discussions

The data obtained from territorial waters of Bheemili proved that the territorial waters are not affected either by a near-by port or shipping activities, serving as a benchmark for pollution-free port and shipping operations.

The calculated AQI at the port area is 108.33, which falls in a range calling for health-concern. While comparing these values with that of territorial waters it is noted that the average AQI in the month of January 2023 is 81.5 which is in the satisfactory levels. Moreover, in these areas PM_{10} is a concern as against $PM_{2.5}$ in the port. The WHO guidelines set the limit and provisional objectives for typical airborne contaminants, which states that NO_2, SO_2, and $PM_{2.5}$ should not exceed by 25 µg/m^3, 40 µg/m^3 and 5 µg/m^3 respectively [9]. The average amount of SO_2 measured on the basis of 4-hourly value for a short-term exposure of 24 hours is 11.4 µg/m^3. Whereas, the average amount of measured on the basis of 4-hourly value for short-term exposure of 24 hours is 24.7 µg/m^3. Average amount of $PM_{2.5}$ present for 24 hours, on the other hand is 40 µg/m^3. NO_x and SO_x are present within the limit, but at the same time $PM_{2.5}$ exceeded the acceptable range.

Through the analysis, it is found that the turning circle had a WQI of 76.35, Fishing harbor station 1 of 58.2054, Fishing harbor station 2 with 78.2243, East Q7 berth with a WQI of 56.3983 and a WQI of 60.3239 at West Q7 berth. The territorial waters, T have a WQI of 87.7 It can be stated that the quality in territorial water is good and that in various port facilities has not deteriorated owing to port and shipping operations yet needs attention. The pH range is within the acceptable range of 6.5-9.0 [9][3], peaking at 8.15 in the turning circle, indicating no signs of acidification in the local waters or any negative impact on marine creatures, like those from the mollusk family. The data collected on BOD showed a variation of 0-2mg/L, peaking at 2.10mg/L in East Q7, indicating that the organic pollution is also in control [9][3]. The water temperature also meets the regulation set by Association of South East Asian Nations (ASEAN) [1].

The Underwater Radiated Noise (URN) levels in ambient condition with loading and unloading operations performed on the ship is about 148 dB re 1µPa at a frequency of 70 Hz. According to the data collected at ambient conditions, the frequency range has no ill effects on aquatic life, but it remains close enough to potentially interfere with their natural communication system. The tug boat URN levels are about 162 dB re 1µPa at frequency of 50 Hz. Tug boats use their powerful engine to push or pull the ships into their place emitting loud noises. The pile driving pings observed during jetty expansion work with peak Sound Pressure Level (SPL) of 160 dB re 1µPa at an interval of 1 second. To mitigate the potential harm caused by pile driving, the port authorities may impose limits on the sound pressure levels allowed during construction activities. The noise levels in territorial waters are quite low. The ambient levels are around 135 dB re 1 µPa in the lower frequency. Noise level restrictions are recommended in port areas, for example, the U.S. National Marine Fisheries Service (NMFS) recommends an SPL limit of 160 dB for most marine mammals and sea turtles indicating the need to setup limits for URN in ports.

5. Conclusions

Shipping pollution has been a major concern for the International Maritime Organization (IMO) [14]. The analyzed data and results indicate that the environmental conditions at the port are currently satisfactory. However, due to the swift escalation of shipping traffic, there is potential for these conditions to deteriorate rapidly. The development of a green belt in and around the port as a barrier to pollution is underway. To address these concerns, proactive measures have been implemented, such as regular monitoring of noise levels and the adoption of preventive measures to avoid contamination of harbor water. One such measure includes the collection and storage of oily bilge water in dedicated tanks to prevent its release into the surrounding environment. Despite the pre-existing measures for sustenance of environment, the port authorities need to be vigilant towards balancing the environmental status. Therefore, this study has produced data source concerning air quality, water quality, and underwater vibrations in ports, resulting in a greater comprehension of shipping pollution and cultivating a vision for embracing environmentally friendly initiatives at Visakhapatnam port. A time series study will enable tracking the pollution. Future studies will aim at developing an integrated pollution index in ports through continuous monitoring.

6. Acknowledgements

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