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# CLIMATE CHANGE OVER SOUTH INDIAN COAST DUE TO AEROSOL AND AIR POLLUTION

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**Abstract**: The two most serious dangers to nearly 60 percent of the world's population living in Asian monsoon zones are the growing severity of droughts/floods and decreasing air quality from increased aerosols. These simultaneous challenges have driven a huge amount of study on the effects of aerosols in influencing Asian monsoon weather and climate during the last decade. An aerosol is a colloid of small solid particles or liquid droplets suspended in air or another gas. The excess volume of aerosol in a certain place will have an impact on the health of living organisms as well as the regional climate. The Asian monsoon area is a major source of aerosol emissions from both man - made and natural sources. Aerosol loading patterns are extensively controlled by diverse meteorological and climatic regimens, which in turn are modified by aerosol impacts. Shipping emissions have garnered attention due to their harmful impact on regional climate and air quality at ports and along coasts across the world. As a result, recognising the aerosol in a certain place is critical. $CO_2$, $NO_X$, and $SO_X$ emissions from air pollution cause cloudiness and accelerate climate effect 'Radiative Forcing' (RF). Positive RF causes heat, while negative RF causes cooling. These also have an indirect influence on weather due to the Cloud Condensation Nuclei (CCN) ability of clouds, which has a significant impact of gases and particles. An increase in Sulphur may result in a decrease in Negative RF. Several techniques are applied to assess the range of aerosols, such as LIDAR, photometers, particle analysing methods, and so on; in this case, we utilise a particulate analyser to determine the amount of aerosol. To find out, we maintained the particle counter and analyser on the ship's top deck and examined the aerosol concentration over the atmosphere of the south Indian coast.

**Keywords**: Aerosol, Air pollution, Climate Change, Coast Region, Emission, Particulate Matter, Shipping Emissions

## I. INTRODUCTION

Marine transportation has been identified as one of the most significant and least controlled sources of anthropogenic pollution in the seas and coastal regions [1]. Ship emissions have an influence on the local, national, and international scales [2]. Pollution and atmospheric experts use several emission registries to estimate the probable environmental effect [3]. Marine vessel databases show that ship emissions cannot be ignored when considering the environmental implications of air pollution, despite high uncertainty in these estimates [4]. Human health and safety concerns triggered by air pollution are have become progressively severe in Asian monsoon nations like china and India, owing to greater loading of airborne particulates from waste gas emissions and growing energy demand attributed with the swift pace of industrial growth and modernization [5]. Likewise, inconsistent monsoon rainfall distribution linked with severe flooding or extended droughts has resulted in significant morbidity and mortality and agricultural and property destruction, with terrible socioeconomic consequences. Historically, air pollution and monsoon research have been viewed as distinct issues. Recent research, however, suggests that the two issues are inextricably related and should be researched together [6].

Aerosols potentially impact precipitation primarily through the radiative effects of suspended particles in the atmosphere (direct impact) and/or by intervening and affecting the cloud and precipitation production processes (indirect impact) [12]. Aerosols are categorised into two groups based upon their optical characteristics: those that absorb sun light and those who do not. Both forms of aerosols disperse sunlight, reducing the quantity of solar energy that reaches the Earth's surface and cooling it. Absorbing aerosols, on the other hand, can heat the environment in addition to cooling it. Aerosols can also raise the concentration of cloud condensation nuclei (CCN), elevate cloud quantity, and diminish coalescence and collision rates, resulting in less precipitation [7, 11]. The sea surface temperature (SST) is an important meteorological characteristic that regulates the Earth's climate [13].

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Emissions from the south Indian coastal region have a significant influence on air quality since they occur mostly along the coastline; in worldwide shipping, 70% of emissions are within 222 nautical miles of the land. The problem of poor air quality in coastal regions is exacerbated by ship emissions [8]. Anthropogenic carbon emissions are produced by the combustion of carbonated fuels in coastal regions. Emissions from marine transportation contribute significantly to air pollution and climate change [9-10].

It is clear from the preceding considerations that coastal emissions have a significant impact on air quality and aerosol. As a result, assessing Particulate Matter (PM) and air quality act as an index for any appropriate control strategies. The next portions of this work are organised with the following talks: Particulate Matter classification, Methodology for measuring air quality and PM, sample locations, results and discussions, and conclusion.

## II. PARTICULATE MATTER CLASSIFICATION

Particulate matter (also known as particle pollution) is a phrase applied to denote a mixture of solid particles and liquid droplets suspended in the atmosphere with an aerodynamic diameter of less than 100µm. Large or dark particles that may be seen with the bare eyes and are called ultra-coarse include dust, grime, smut, and smoke. Others are so minuscule that only an electron microscope can detect them [14]. Particle pollution comprises of $PM_{10}$ and $PM_{2.5}$. $PM_{10}$ refers to inhalable particles with diameters of 10 micrometres or less; $PM_{2.5}$ refers to fine inhalable particles with diameters of 2.5 micrometres or less. According to their size, $PM_{10}$ is a coarse particle while $PM_{2.5}$ is a fine particle [15].

$PM_{2.5}$ and $PM_{10}$ can both be aspirated, with some particles settling in various parts of the human body's airways; however, the sites of particle deposition in the lungs are dependent on particle size. $PM_{2.5}$ is more likely to travel into and deposit on the surface of the lung's deeper portions, whereas $PM_{10}$ is more likely to deposit on the surfaces of the upper lung's bigger airways. Particles accumulated on the surface of the lungs can cause tissue damage and swelling. While everyone is affected by $PM_{2.5}$, those with lung and cardiac disorders, children, and the aged are more vulnerable. Ambient particulate matter has proven to be a killer more potent than alcohol and diabetes due to its increasing prevalence. [16].

In India, the annual average of $PM_{2.5}$ is set at 60µg/m$^3$, while in the United States, it is set at 15µg/m$^3$. However, India has ten of the top twenty cities in the world with the highest $PM_{2.5}$ levels. According to studies, every 10µg/m$^3$ rise in $PM_{2.5}$ raises all-cause mortality by 3 to 26 percent, juvenile asthma risk by 16 percent, risk of lung cancer by 36 percent, and heart attacks risk by 44 percent [17].

The Air (Prevention and Control of Pollution) Act of 1981 empowers India's Central Pollution Control Board to set national ambient air quality standards and to test air quality as well as assist governments in developing plans to meet those criteria. Accordingly, Table 1 shows the National Ambient Air Quality Standards (NAAQS) for the pollutants (PM10 & PM2.5).

Table 1: National Ambient Air Quality Standards, as of 2009[18]

| Pollutant | Time Weighted Average | Concentration in Ambient Air | | Methods of Measurement |
|---|---|---|---|---|
| | | Industrial, Residential, Rural and Other Area | Ecologically Sensitive Area (notified by Central Government) | |
| **$PM_{10}$ (µg/m$^3$)** | Annual | 60 | 60 | ▪ Gravimetric<br>▪ Tapered Element Oscillating Microbalances (TOEM)<br>▪ Beta attenuation |
| | 24 Hours | 100 | 100 | |
| **$PM_{2.5}$ (µg/m$^3$)** | Annual | 40 | 40 | |
| | 24 Hours | 60 | 60 | |

The ambient air quality with respect to Particulate Matter in coastal cities as per NAAQS is shown in Figures 1 and 2.

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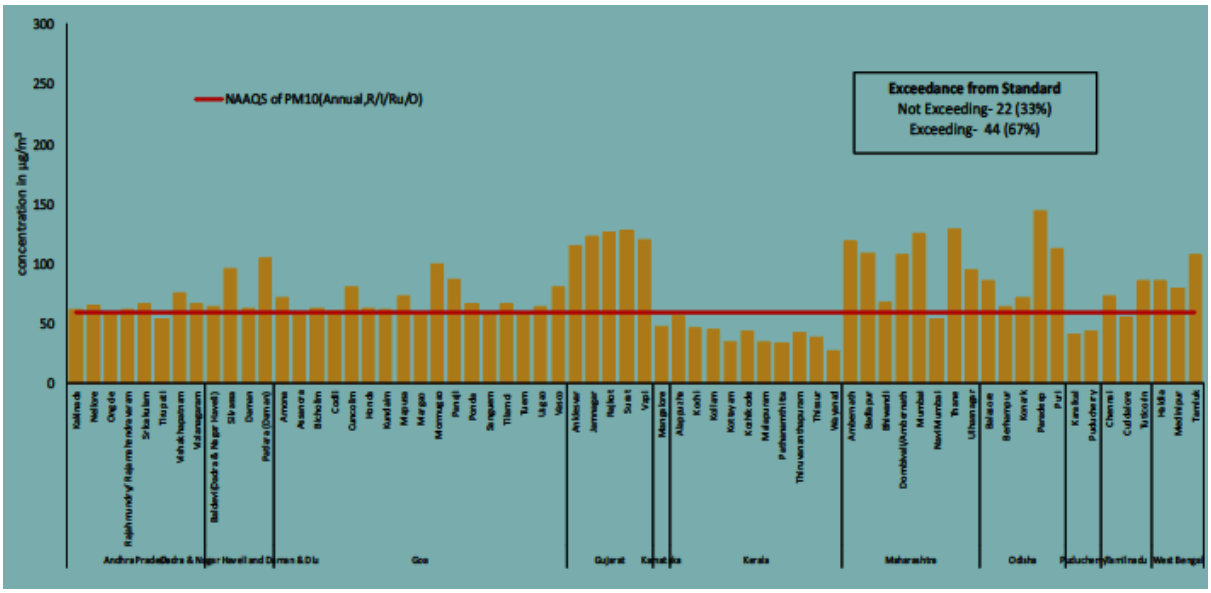


Figure 1: Ambient Air Quality ($PM_{10}$) [19]

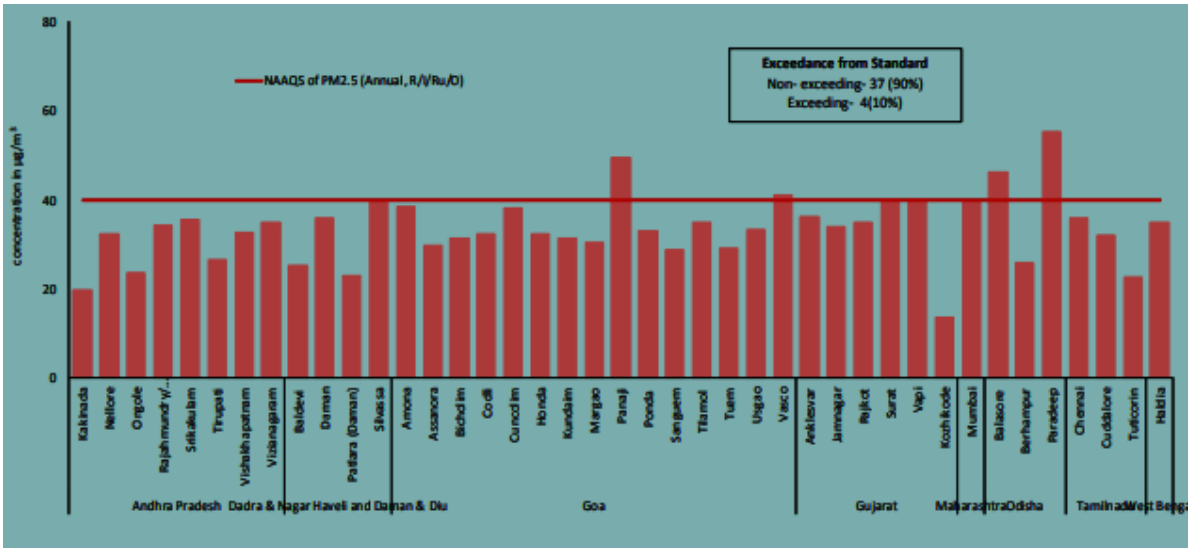


Figure 2: Ambient Air Quality ($PM_{2.5}$) [19]

Pollution is more prevalent around coastal cities, according to the air quality index's breached limits. According to NAAQS statistics for 2019, the exceeded limit for $PM_{10}$ is 67 percent (44 places) and for $PM_{2.5}$ is 10 percent (4 locations).

According to the findings of such pollution studies, $PM_{2.5}$ emissions from shipping cause roughly 60,000 cardiac and lung cancer deaths per year around the world, with the effects concentrating in coastal locations along important trading routes. The majority of deaths happen near coastlines in Southeast Asia, where people are dense and $PM_{2.5}$ concentrations from ships are high.

## III. METHODOLOGY

The environmental effectiveness of larger ship operations in ports was found to be growing after an assessment of air pollution from ships in ports. MARPOL73/78 Annex-VI had a favourable influence on emission projection scenarios [20].

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Figure 3: Sampling Location near Chennai Coast

The surrounding coastal regions of Chennai and Pondicherry were chosen for air quality analysis. The Figures 3 and 4 exhibit the identified sampling locations (4 sites) near the Chennai coast and 9 sites between the Chennai and Pondicherry coasts. Near the shore of Chennai are CH-4, CH-1, CH-7, and CH-6. T2D2, T2D3, T3D3, T5D3, T5D2, T5D1, T3D2, T3D1, and T2D1 are the stations on the coastline length between Pondicherry and Chennai.

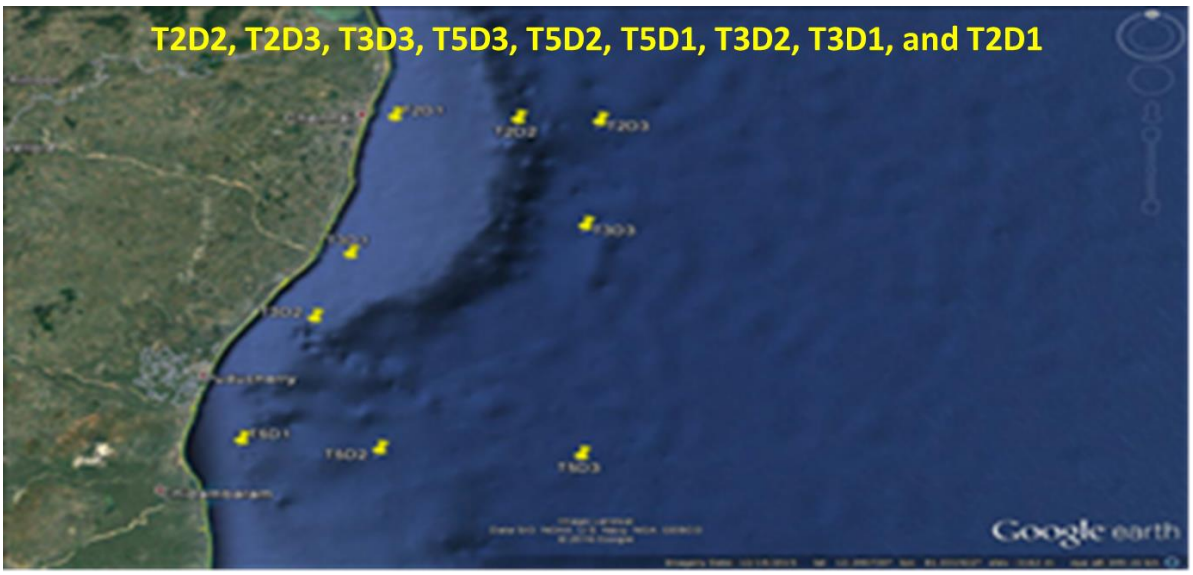


Figure 4: Sampling Location between Chennai and Pondicherry Coast

The quality of the air is affected by a variety of factors, including neighbouring port emission sources, vessel fuel type, engine capacity, age, condition, and power output [21]. The emission range and air quality status of a certain location are determined in response to these criteria. Pollution is primarily caused by the use of low-quality fuel and obsolete engines [22-23].

Coastal emissions were measured for PM2.5 and PM10 using an air quality analyser while on board a ship. Using appropriate chemicals, the amount of SOx and NOx emissions is investigated. The instruments are mounted above the ship near the exhaust manifold to gather ship emissions, and a particle counter is mounted on the ship's deck to count particles.

In the particle analyser, we must preserve the filter paper, before which the weight of the filter paper is recorded. Once set, we must assure that no water droplet or dust is present inside the chamber. When we start the instrument, we must

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update the timer based on the user's preferences, confirm that the timer is set, and start the instrument. After activating the instrument, the blower inside the particulate analyser begins sucking in outside air, causing dust particles in the air to deposit in the air quality analyser. After the specified time, the instrument is turned off. Stop the timer and carefully open the filter paper chamber to remove the filter paper without sticking the dust anywhere else. Check the weight of the filter paper now. Calculate the difference between the initial and final weights, as well as the volume of air sucked from the initial to the final weights and the difference. Then compute the ratio of the two to obtain the particluate weight.

The following equations provide the mathematical expressions for computing the Particulate Matter (PM).

$$PM_{2.5} = \frac{V_d}{V_a}$$

$V_d$ denotes the volume of dust, while $V_a$ denotes the volume of air. The values of Vd and Va are then determined by the equation:

$$V_d = \left(FP_{fw} - FP_{iw}\right)$$

$FP_{iw}$ is the initial weight of the filter paper and $FP_{fw}$ is its final weight.

$$V_a = (V_{aas} - V_{abs})$$

$V_{aas}$ is the volume of air after stopping, while $V_{abs}$ is the volume of air before starting.

$$PM_{10} = \frac{V_d}{\left(T \times FR_{avg}\right)}$$

Where $V_d$ is the volume of dust, T is the time, and $FR_{avg}$ is the average flow rate reading.

The time period T is calculated as,

$$T = (f_t - f_i)$$

Where $f_t$ is the final timing and $f_i$ is the initial timing.

Table 2 contains a list of the equipment utilised for Air Quality Monitoring in this investigation and Table 3 displays weather information along with location coordinates.

Table 2: Air Quality Monitoring Equipment Description

| **Parameter** | **$PM_{10}$** | **$PM_{2.5}$** | **$PM_{10}$ & $PM_{2.5}$** |
|---|---|---|---|
| **Equipment** | Respirable Dust Sampler (Envirotech, APM 460 NL) | Fine Particulate Sampler (Envirotech, APM 550 ) | Dust Monitor Model 1.108 |
| **Sampling Period** | 24 hrs. | 24 hrs. | 24 hrs. |
| **Measuring Principle** | Filtration of aerodynamic sizes with a size cut by impaction | Filtration of aerodynamic sizes with a size cut by impaction | works based on the principle of 1ight scattering with ±2% accuracy |
| **Flow rate** | 0.9 -1.15 $m^3$/min | 0.9 -1.15 $m^3$/min | 0.9 -1.15 $m^3$/min |
| **Analysis method** | Gravimetric | Gravimetric | 1ight scattering |
| **Minimum detection limit** | 1µg/$m^3$ | 1 µg/$m^3$ | 0.1 µg/$m^3$ |

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Table 3: Weather Information Combined With Location Coordinates

| Station ID | GPD | | WD | WS | Cloud Cover |
|---|---|---|---|---|---|
| | Lat (Deg) | Long (Deg) | | | |
| **CH-4** | 13.137 053N | 80.32505E | E | 9.9 | Scattered Clouds (Clouds passing) |
| **CH-7** | 13.145 878N | 80.361064E | E | 7.6 | Sunny (With scattered clouds) |
| **CH-6** | 13.163 311N | 80.367631E | E | 9.28 | Scattered Clouds (Clouds passing) |
| **CH-1** | 13.191 669N | 80.347578E | E | 5.98 | Scattered Clouds (Clouds passing) |
| **T2D2** | 13.039N | 80.75345E | E | 5.701 | Cloudy (No Sun) |
| **T2D3** | 13.038 3N | 81.0102E | E | 8.12 | Cloudy (No Sun) |
| **T3D3** | 12.576 2N | 80.9805E | E | 4.21 | Overcast (Uniform Clouds) |
| **T5D3** | 11.563N | 81.0001E | E | 5.78 | Cloudy (No Sun) (Scattered dark grey clouds with clouds passing) |
| **T5D2** | 11.5672N | 80.3687E | E | 2.01 | Overcast (Dark grey clouds) |
| **T5D1** | 11.5932N | 79.9338E | E | 4.03 | Sunny Pale Blue |
| **T3D2** | 12.1414N | 80.1457E | E | 3.7 | (White haze, Sunny) |
| **T3D1** | 12.427 4N | 80.2484E | E | 2.94 | Cloudy |
| **T2D1** | 13.0394N | 80.3652E | E | 2.66 | Cloudy |

## IV. RESULTS AND DISCUSION

During the sampling time, the wind speed, ship direction, and speed are not constant. Figures 5 through 7 show the graphical representations.

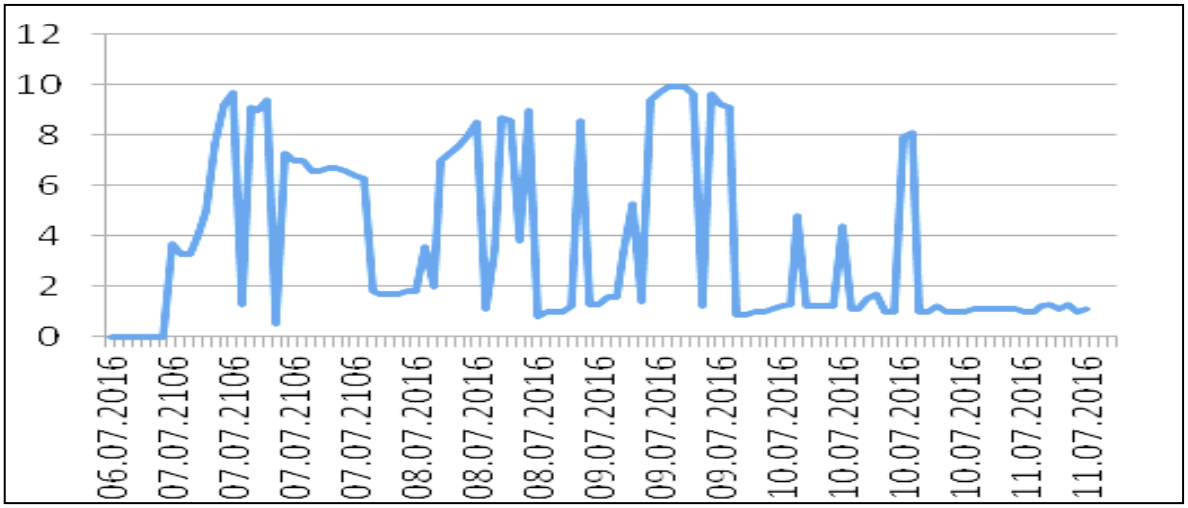


Figure 5: Graphical representation of ship speed (knots) during sampling period

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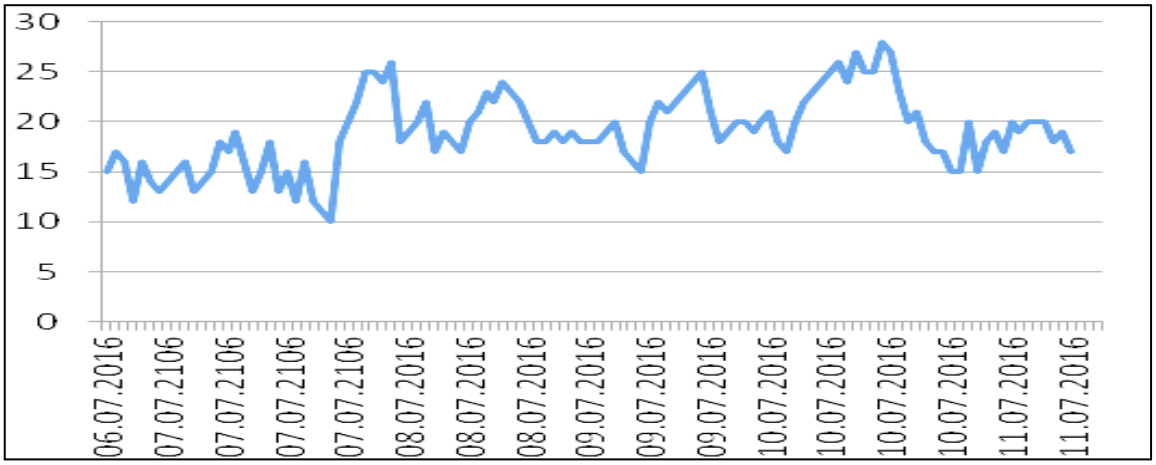


Figure 6: Graphical representation of ship speed (KTS) during sampling period

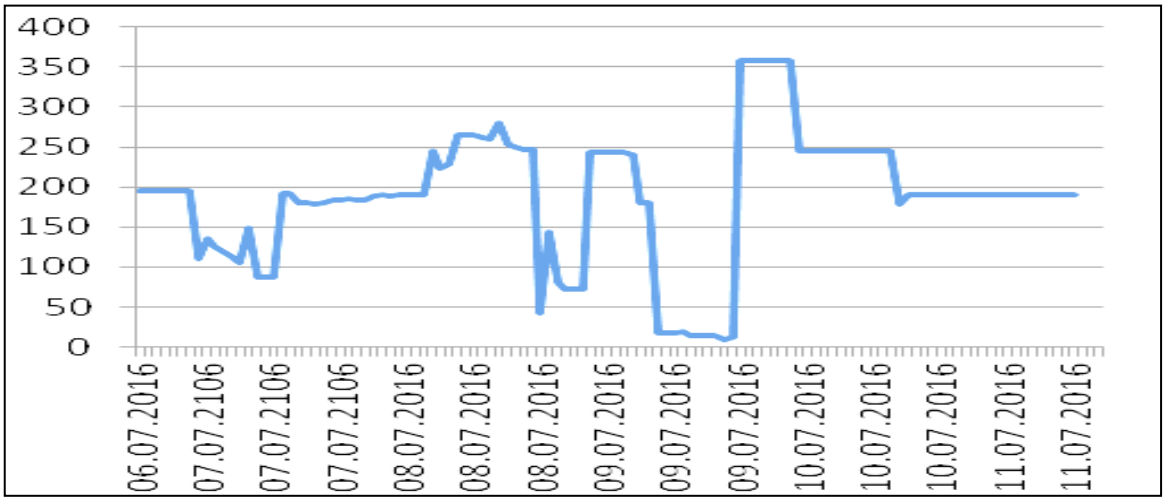


Figure 7: Graphical representation of ship direction (Degrees) during sampling period

Ship exhaust has been proven to boost local maritime cloud albedo by increasing the number of nuclei on which cloud drops develop 23±25. The concentration of particulate was not properly observed due to particle dispersion with regard to wind direction, wind speed, and ship speed. As a result, in order to avoid the problem, a direct connection of the exhaust manifold to the analyser was made. However, due to changes in temperature and humidity, particles stick in the exterior boundary layer, causing smog to form in the pipe line. We need an air-sea interaction study at this point to conclude the terms with properties to analyse the optical depth of the particles, therefore more detailed optical studies are required for analysis.

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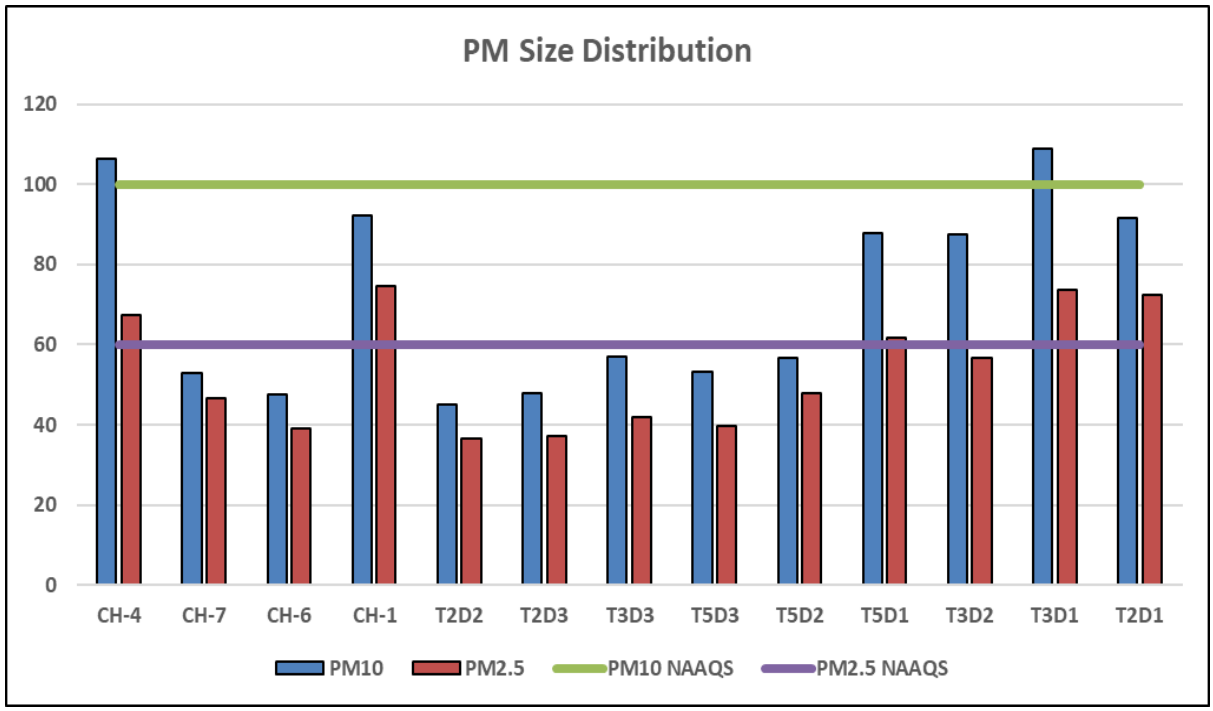


Figure 8: Graphical representation of PM Size Concentration during sampling period

Figure 9: Air Quality Instrument in Upper Deck of Sagar Manjusha

The Figure 8 depicts the findings of the experiment for PM Size Concentration (both $PM_{10}$ and $PM_{2.5}$). For observing the excess level, the NAAQS standard ($PM_{10}$ = 100 & $PM_{2.5}$ = 60) is used as a reference. $PM_{2.5}$ levels are exceeded in five testing locations, while $PM_{10}$ levels are exceeded in two. During manoeuvring, particle size is observed to be greater, and neighbouring coastal region $PM_{10}$ is greater. $PM_{2.5}$ levels on the inside coast are higher due to sea salt deposition.

With the support of NIOT-VMC (National Institute of Ocean Technology – Vessel Management Cell), the air quality analysis process used in this study was deployed for regular use on board Sagar Manjusha ship and is shown in Figure 9.

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## V. CONCLUSION

In this research, it is discovered that particulate matter over the coast region was found to be excessively high. This could be due to excessive sea salt deposition over the coast region, or it could be due to the monsoon pattern of the particular region, which leads to increased air-sea interaction along the south Indian coast. The more haze formation during the summer season is one of the reasons for the formation of sea salt aerosol over the south coast, and during the winter and spring due to the condensation process of the region in interaction with aerosol over the particular area, the cloud condensation nuclei over the region is found to be more, which will affect the weather pattern of particular region.

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