e-ISSN No.: 2582-4228

Journal of Indian Association for Environmental Management

Journal homepage: www.http://op.niscair.res.in/index/php/JIAEM/index

Air Pollution and Particulate Matter in the Kolkata Metropolitan Area, India

Dr. Joy Karmakar
Lecturer, Serampore College, Hooghly, India
Joykarmakar49@gmail.com

Submitted: 05 February 2024Revised:11 April 2024Accepted: 12 April 2024

***Abstract*:A recent report from the US-based Health Effects Institute (HEI) has identified Delhi and Kolkata as the two most polluted cities, in terms of exposure to hazardous fine particulate matter ($PM_{2.5}$). In order to tackle this issue, regulatory measures were implemented in Kolkata in 2018 to meet the National Ambient Air Quality Standards (NAAQS). This study aims to analyze the levels of $PM_{2.5}$ in the Kolkata Metropolitan Area (KMA) from 2021 to 2023. The findings indicate that the main sources of $PM_{2.5}$ are transportation, households, and industries, although their contributions vary across the metropolitan area. The mean and median concentrations of $PM_{2.5}$ are highest in Kolkata and its adjacent areas, including Bidhannagore and New Town Kolkata. Additionally, it has been observed that $PM_{2.5}$ levels remain high during both winter and summer seasons.**

***Keywords*:Particulate matter, Metropolitan Area, Kolkata, NAAQS, Air Pollution**

I. INTRODUCTION

In recent decades, climate change and air pollution have emerged as significant global concerns. The spread of urban areas experiencing extreme weather events such as heavy rainfall, extreme temperatures, floods, and droughts has become a serious threat to human health. The escalating air pollution levels and the effects of climate change present major challenges for rapidly expanding cities in the present era. Developing nations like India, transitioning from predominantly rural to increasingly urban societies, are confronted with critical obstacles in terms of climate action and sustainable development. A report from the World Health Organization (WHO) reveals that more than seven million individuals worldwide lose their lives annually due to diseases associated with $PM_{2.5}$ pollution. (WHO, 2015). India, a swiftly developing nation with a growing population, is grappling with severe air pollution. Remarkably, out of the ten most polluted cities in the world, nine are located in India. (WHO, 2016).In recent years, there has been significant attention drawn to the escalating air pollution levels in many of India's megacities. Over the past few decades, this increase in air pollution has had noticeable impacts on human health, leading to the prevalence of conditions like asthma and cardio-respiratory illnesses (Sarathand & Ramani, 2014; Shaw & Gorai, 2020). According to a recent report released by the US-based Health Effects Institute (HEI), the majority of global cities surpass the air pollution guidelines set by the World Health Organization (WHO), resulting in significant health risks. The report highlights that Delhi and Kolkata rank as the top two most polluted cities in terms of exposure to hazardous fine particulate matter ($PM_{2.5}$) (Mohan, 2022). In the Indian metropolitan cities, there exists a prevalent exposure to unhealthy and unhygienic conditions attributed to air pollution (Dutta et al., 2021). Over the past few decades, the persistent and concerning rise of urban air pollution has emerged as a significant environmental issue in these Indian megacities (Faheem et al., 2021).

The global research emphasis has been on studying a specific air pollution parameter known as $PM_{2.5}$, which pertains to fine particulate matter with a diameter smaller than 2.5 mm. Particulate Matter ($PM_{2.5}$), comprising fine aerosol particles with a diameter of 2.5 microns or less, is among the six criteria air pollutants that are regularly monitored. It is widely recognized as the most detrimental to human health due to its widespread presence in the environment and its association with a wide range of adverse health effects.

Kolkata Metropolitan Area (KMA) encompasses not only the city of Kolkata but also several neighboring districts and municipalities. The KMA is one of the most populous and economically significant regions in India, with a rich and a thriving industrial and commercial sector. The KMA plays a vital role in the economic growth and development of the state of West Bengal. The region faces various urban challenges, including traffic congestion, and environmental concerns. The air quality of the Kolkata Metropolitan Area (KMA) has been a subject of concern due to the high levels of air pollution. Factors such as industrial activities, vehicular emissions, construction, and urbanization contribute to the deteriorating air quality in the region. The main pollutants of concern include particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO2), sulfur dioxide (SO2), and volatile organic compounds (VOCs). These pollutants have adverse effects on human health, causing respiratory problems, cardiovascular issues, and other health complications. To address the deteriorating ambient air quality nationwide, the government of India launched the National Clean Air Programme (NCAP) in 2019. Kolkata is listed under the non-attainment city list under the NCAP due to annual ambient particulate matter concentration above the National Ambient Air Quality Standard since 2015 (TERI, 2023). The NCAP is the first pan-India policy aiming for a 20-30% reduction in particulate matter pollution by 2024 compared to levels in 2017 (CREA, 2022).

This paper focuses on examining the spatio-temporal variation of $PM_{2.5}$ (particulate matter with a diameter of 2.5 micrometers or less) in the Kolkata Metropolitan Area (KMA) and aims to comprehend the factors that contribute to $PM_{2.5}$ levels within the metropolitan area.

II. Materials and Methods

This work presents the variability, trend and exceedance analysis of $PM_{2.5}$ measured at 12 stations located in Kolkata Metropolitan Area (KMA) and its beyond for less than two years (2021-2023). An exceedance occurs when the concentration of a pollutant surpasses the established air quality standards or limit values. These air quality standards have been established worldwide by various agencies through the implementation of air quality directives, acts, or guidelines. The Air (Prevention and Control of Pollution) Act in India and the Air Quality Guidelines set by the World Health Organization (WHO) establish crucial thresholds for air pollutant concentrations and national ambient air quality standards (NAAQS) that should not be surpassed. These limits are defined for both daily and annual periods. An episode of high $PM_{2.5}$ levels is characterized by the consistent presence of $PM_{2.5}$ levels exceeding the defined thresholds for three or more consecutive days. This paper has calculated the number of pollution episodes and the duration of each episode. Furthermore, the paper has computed the exceedances in a year, the count of episodes, and the length of $PM_{2.5}$ pollution episodes for each city. Exceedances refer to $PM_{2.5}$ levels surpassing 25 (as per WHO guidelines) and 60 (as per India's standards). Diurnal, seasonal, and monthly patterns of $PM_{2.5}$ have shown across the 11 stations of the KMA and its surrounding.

Study Area

Table 1 presents the 11 monitoring locations along with the corresponding temporal duration of the data. These monitoring locations are distributed across six districts, namely Kolkata, North 24 Parganas, South 24 Parganas, Hooghly, Howrah, and Nadia.

TABLE 1
Air Quality Monitoring Stations in KMA

Monitoring Location	Data Recording Period		Duration
	Starting Time	Ending Time	
Serampore	1st November 2021	31st March 2023	17 Months
Kolkata	1st January 2022	31st March 2023	15 Months
New Town Kolkata	1st October 2021	31st March 2023	18Months
Bandel	1st September 2021	31st March 2023	19 Months
Barasat	1st September 2022	31st Aug. 2023	12 Month
Barackpore	1st June 2022	31st May 2023	12 Months
Belghoria	2nd July 2022	31st Aug. 2023	14 Months
Kalyani	1st December 2021	31st March 2023	16 Months
Budge Budge	1st May 2022	31st May 2023	13 Months
Howrah	1st March 2022	31st March 2023	13 Months
Bidhannagar	1st September 2022	31st Aug. 2023	12 Months

Source: West Bengal Pollution Control Board, compiled by the author

It's noteworthy that Budge Budge, Barrackpore, and Bandel host thermal power stations. Within the Kolkata Metropolitan Area (KMA), Howrah, Barrackpore, Belghoria, and Kalyani serve as significant industrial centers. These areas boast a variety of industries including gas plants, jute processing units, textile factories, and rolling mills. Similarly, Bidhannagar, akin to Kalyani, is one of the largest meticulously planned towns in the KMA. However, Bidhannagar distinguishes itself as the thriving IT hub of the state. Conversely, Kalyani's industrial base encompasses manufacturing plants, textile mills, and agricultural processing units. New Town Kolkata is also a meticulously planned urban area, featuring a range of IT industries, hotels, and educational institutions.

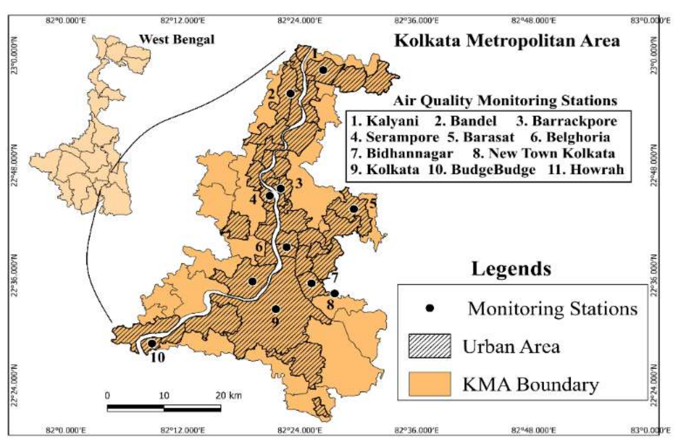


Fig: 1: Location of the Study Area

The west bank towns of Hooghly River include Bandel, Serampore and Howrah while east bank town includes Kolkata, Budge Budge, Belghoria, Barrackpore and Kalyani. Kalyani stands as the northernmost town from Kolkata, while Budge Budge lies to the south. It is worthwhile to mention that monitoring stations are strategically located in a variety of places, including colleges, government offices, hospitals, factories and residential areas.

Data Source

Hourly observations of the $PM_{2.5}$ concentrations at 11 monitoring sites in our study period were collected from the real-time monitoring data system of the West Bengal Pollution Control Board (WBPCB). In order to uphold the integrity and dependability of the original data, the paper implemented rigorous data quality control measures on the hourly $PM_{2.5}$ concentration data prior to analysis. This was done in accordance with regulations concerning the validity of air pollutant concentration data. As part of this process, any abnormal data points were eliminated to ensure accurate and consistent results. Data has been gathered from various stations for durations ranging from a minimum of 12 months to a maximum of 19 months. It's worth noting that the majority of monitoring stations were set up between 2021 and 2022. To ensure consistency and mitigate the effects of the COVID-19 pandemic, data collection was conducted from the end of 2021 through 2023. The National Clean Air Programme (NCAP) has proposed expanding the National Air Quality Monitoring Programme (NAMP) network. The plan aims for all NAMP stations to have $PM_{2.5}$ monitoring capabilities by 2024. Although 360 stations with $PM_{2.5}$ monitoring were included in the NAMP network as of 2022, the goal is to increase this number to 1,500 stations (CREA, 2022). Therefore, it is apparent that there is a limitation to get long temporal data.

Sources and Composition of $PM_{2.5}$ in KMA

Air pollutants, and particulate matter in particular, are emitted into the atmosphere from many categories of sources and have various environmental impacts, including hazardous effects on human health. Meteorology plays a crucial role in regulating air quality, while local emission sources, primarily household and traffic emissions (Singh et al., 2018), significantly impact the local air quality. The various sectors, including energy generation, industry, transport, communal, and household usage, contribute to the emission of particulate matter into the atmosphere in comparable proportions. Among these, the fine fraction known as $PM_{2.5}$ poses the greatest risk and consists of atmospheric aerosols and heavy metals like lead (Pb), nickel (Ni), cadmium (Cd), arsenic (As), and mercury (Hg). These substances enter the atmosphere as both particulate matter and aerosols. The subsequent subsection will delve into the composition of $PM_{2.5}$ and its sources specifically in KMA.

Composition of $PM_{2.5}$

When analyzing particulate matter pollution, it is customary to differentiate between primary and secondary pollution. Primary pollution consists of substances such as carbonaceous particles, heavy metals, and minerals that are directly emitted by sources or re-suspended as a result of road traffic. On the other hand, secondary pollution is formed through chemical reactions in the atmosphere, leading to the creation of aerosols and other related compounds. Analyzing the chemical composition of $PM_{2.5}$ provides crucial insights into the contributions of specific sources and aids in understanding aerosol properties and processes. It has been observed that the chemical components of $PM_{2.5}$ vary significantly among different locations worldwide (Snider, et.al, 2016). According to Philip et al. (2014), global population-weighted $PM_{2.5}$ concentrations are primarily influenced by particulate organic mass, secondary aerosols, mineral dust, as well as secondary inorganic aerosols like sulphates, nitrates, and ammonium. In both Kolkata and Howrah, (NH4)2SO4 and organic matter were found to have a significant contribution, followed by non-crustal mass. This high contribution of (NH4)2SO4 indicates the inorganic nature of fine particulates in Kolkata and Howrah. The contribution of particulate matter originating from geological sources ranged from 4% to 11%, while the contributions from sea-salt and NH4NO3 were negligible. Additionally, the contribution of secondary organic carbon (SOC) to organic carbon (OC) was observed to be approximately 28%. In addition, it is observed that, $PM_{2.5}$ is contributed by secondary ammonium sulphate in the range of 25% to 50%, while the contribution of ammonium nitrate falls between 0% and 3% (CSIR-NEERI, 2019).

Potential local sources of $PM_{2.5}$

In the early 2000s, an analysis revealed the distribution and contributions to emissions from different sectors in KMA. The transport sector, industries, and domestic sectors accounted for approximately 50%, 48%, and 2% respectively. Within the industrial sector, around 56% of the emissions were attributed to large- and medium-scale industries, while approximately 44% were traced back to small-scale units operating within the city limits. It was noted that these small units relied on outdated technologies and employed energy-inefficient heating installations such as boilers or furnaces powered by coal (GoWB, 2018). According to a recent report by CSIR-National Environmental Engineering Research Institute (2019), it was observed that the primary sources of $PM_{2.5}$ in the Kolkata Municipal Corporation (KMC) are road dust, transport exhaust, and households, which together contribute to 75 percent of the total pollution. On the other hand, in the Howrah Municipal Corporation (HMC), the dominant sources of $PM_{2.5}$ are industry and road dust, accounting for 75 percent of the total pollution. Following table 2 shows the different sources of $PM_{2.5}$ in KMC and HMC.

The primary sectors in KMC that generate $PM_{2.5}$ comprise gas plants/coal gasification, jute processing, bakeries, basic chemicals, and milk and milk product manufacturing. On the other hand, in HMC, the industries responsible for $PM_{2.5}$ emissions include rolling mills, steel and steel product manufacturing, gas plants/coal gasification, jute processing, and ferrous and non-ferrous as well as textile industries.

In addition to the industrial sector, the transportation sector also significantly contributes to the emission of $PM_{2.5}$ in KMC and HMC. Mangranj et.al. (2022) in their study highlighted that apart from transport and industrial sector, the major sources of $PM_{2.5}$ include municipal solid waste burning, diesel generators and cigarettes and mosquito coils. Biswas, Pal and Saha (2022) also noted that the major pollutant of Kolkata city is PM2.5 which is primarily sourced from the vehicle, industrial sector, construction sector, etc.

III. Results and Discussion

Spatial and Temporal Distribution of $PM_{2.5}$ in KMA

The levels of $PM_{2.5}$ in a particular location are influenced by a combination of factors including emissions, geography, and meteorological conditions (Alimissis et al., 2018; Ganguly et al., 2019). Previous studies by Sreekanth et al. (2018) have reported diurnal and seasonal variations in $PM_{2.5}$ levels for five Indian cities over a period of less than four years, specifically from 2013 to 2016. The following table 2 shows basic information of $PM_{2.5}$ in KMA.

Out of the 12 monitoring stations in an around KMA, Bidhannagore exhibits the highest mean $PM_{2.5}$ concentration, followed by Kolkata, Howrah, and Kalyani. The mean values recorded at these stations are twice the prescribed standard set by the World Health Organization (WHO). The lowest mean $PM_{2.5}$ concentration is observed in Barackpore, followed by Barrackpore and Budge Budge. The median values of $PM_{2.5}$ exhibit almost a similar trend as the mean values. The maximum $PM_{2.5}$ value is recorded in Serampore, while the minimum value is recorded in Bidhannagore. Temporal trends show greater consistency in Barrackpore, Barasat, Howrah, and Bidhannagar, while they are more fluctuating in Serampore, Kalyani, Bandel and Belghoria.

TABLE 2
Descriptive Statistics of $PM_{2.5}$ in KMA

Location	Mean	Median	SD	CV (%)	Maximum	Minimum	Count
Serampore	49.13	46.33	43.77	89.09	1151.77	0.97	11672
Kolkata	53.23	50.43	34.65	65.10	473.25	1.4	9535
New Town Kolkata	50.60	46.49	33.70	66.61	796.59	0.18	12813
Bandel	45.33	42.66	33.89	74.76	672.38	0.78	12293
Barasat	46.71	42.12	25.74	55.10	193.39	0.9	8689
Barackpore	38.37	36.79	18.99	49.51	192.93	0.81	8640
Belghoria	40.07	40.05	29.40	73.37	337.24	1.62	7643
Kalyani	51.33	44.97	41.50	80.85	645.67	1.3	10133
Budge Budge	44.06	43.58	26.62	60.43	247.54	0.14	8199
Howrah	52.32	50.38	28.82	55.09	187.72	1.41	8625
Bidhannagar	62.27	58.00	30.51	50.01	195.00	0.29	8509

Source: Calculated by the author based on WBPCB data.

The analysis of table 2, which displays the mean $PM_{2.5}$ concentrations, reveals that Kolkata, along with Howrah, Bidhannagore, and New Town Kolkata, exhibits the highest spatial concentration of $PM_{2.5}$ in the southern region of KMA. Conversely, Kalyani in the northern region displays the highest mean concentration of $PM_{2.5}$. Belghoria, Budge Budge, and Bandel demonstrate a moderate mean concentration of $PM_{2.5}$. The lowest mean concentration of $PM_{2.5}$ is observed in Barrackpore. Median distribution of $PM_{2.5}$ also exhibits, the areas with the highest spatial concentration of $PM_{2.5}$ include Kolkata, Howrah, Bidhannagore, and New Town Kolkata. Kalyani and Bandel exhibit a moderate spatial concentration of $PM_{2.5}$. On the other hand, Barrackpore, Belghoria, Kalyani and Serampore, show the lowest spatial concentration of $PM_{2.5}$. This indicates that the areas near Kolkata experience consistently higher spatial concentrations of $PM_{2.5}$ throughout the year. Maximum and minimum figure also indicates that areas having thermal power plant and industry showed higher concentration of $PM_{2.5}$ compare to other areas.

Inter-AnnualTrends in $PM_{2.5}$

To analyze the $PM_{2.5}$ trend in the KMA (Kolkata Metropolitan Area), the time series data is divided into two components: trend and seasonal variations. In order to assess the inter-annual trend of $PM_{2.5}$, the hourly data is compared to the standard limit of 60 $\mu g/m^3$ set by the National Ambient Air Quality Standards (NAAQS). A positive trend suggests an excess of $PM_{2.5}$, whereas a negative trend indicates a deficiency of particulate matter in the atmosphere. In simpler terms, a negative trend signifies a good quality of air in the locality.

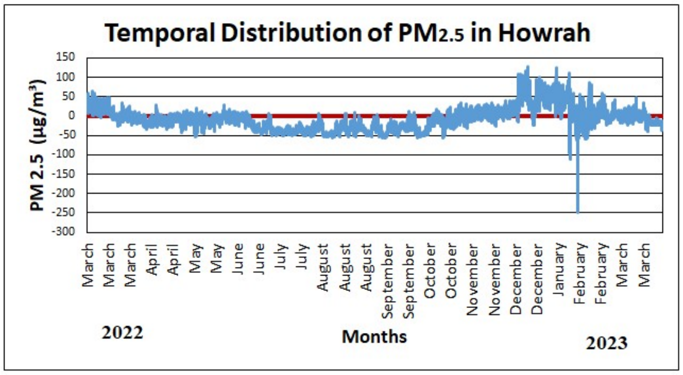


Fig. 4

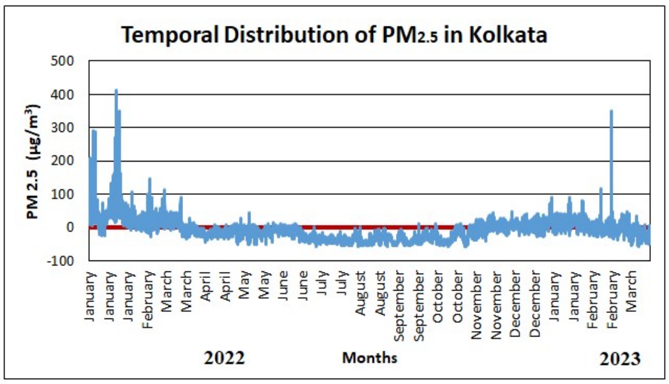


Fig. 5

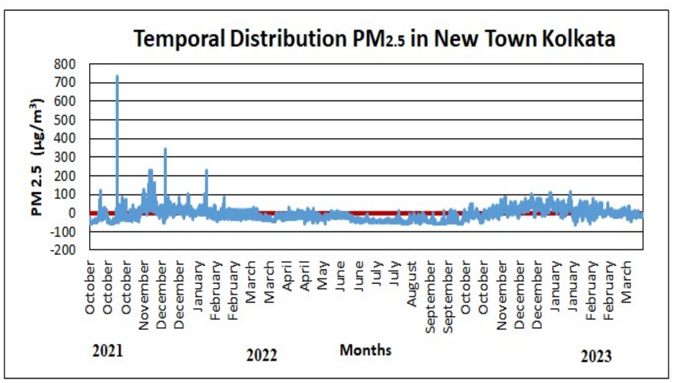


Fig. 6

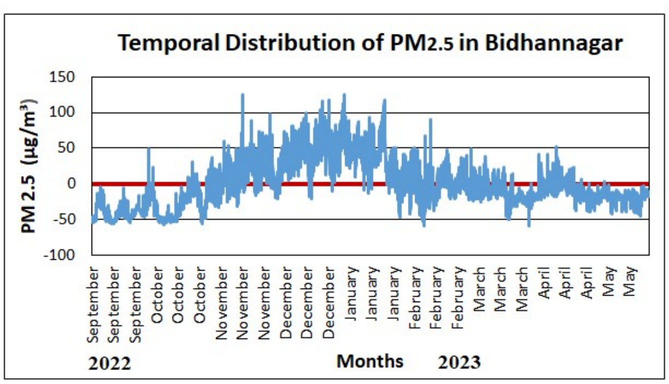


Fig. 7

The trends observed in $PM_{2.5}$ levels at various monitoring stations indicate that the concentration of particulate matter tends to be high during the months of November to February, while it remains low from March to September. In simpler terms, the concentration of $PM_{2.5}$ is higher during the winter season and lower during the monsoon season.

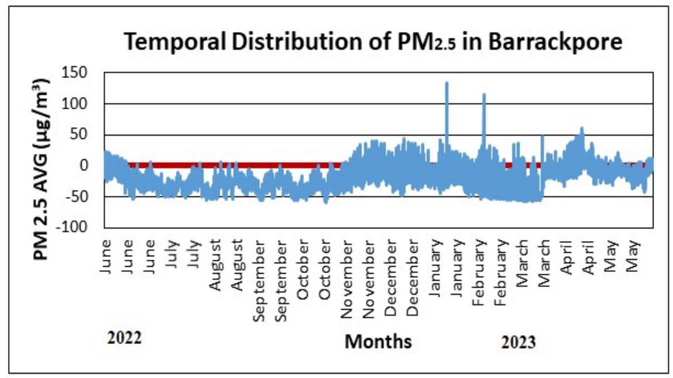


Fig. 8

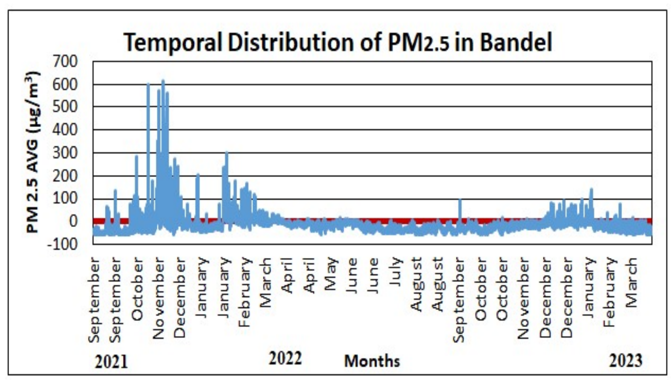


Fig. 9

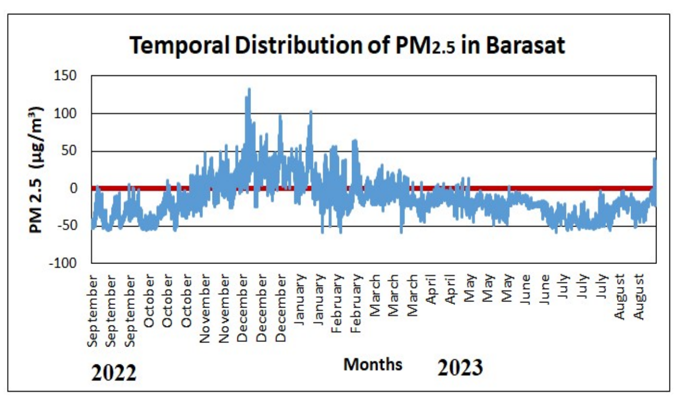


Fig. 10

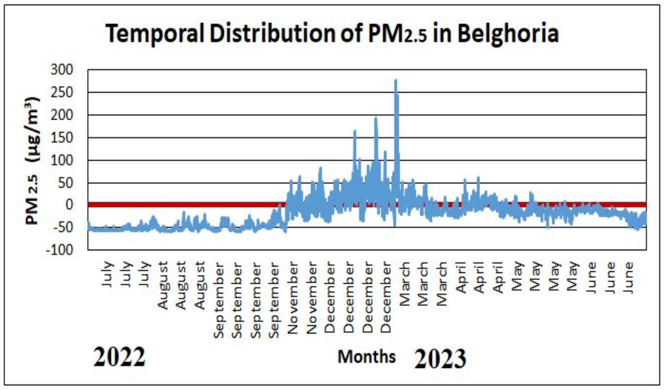


Fig. 11

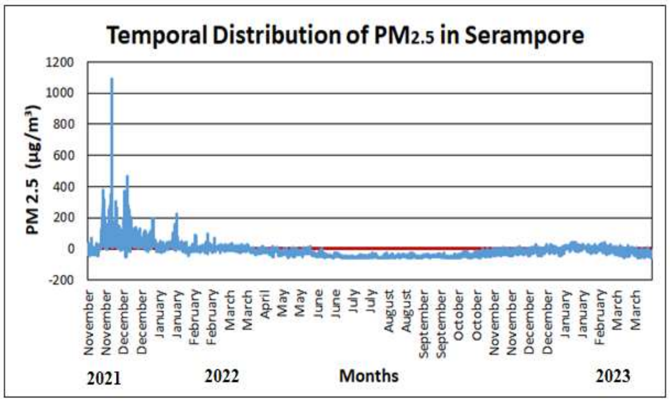


Fig. 12

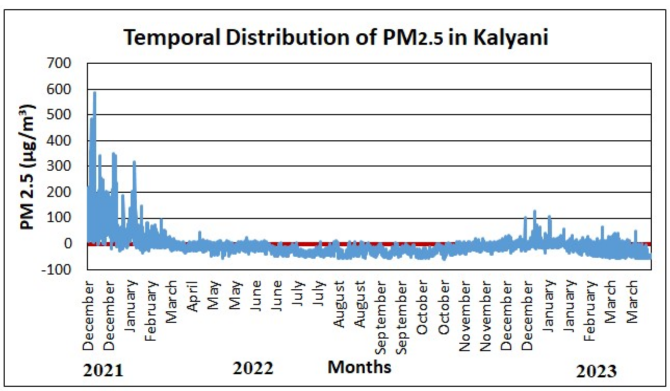


Fig. 13

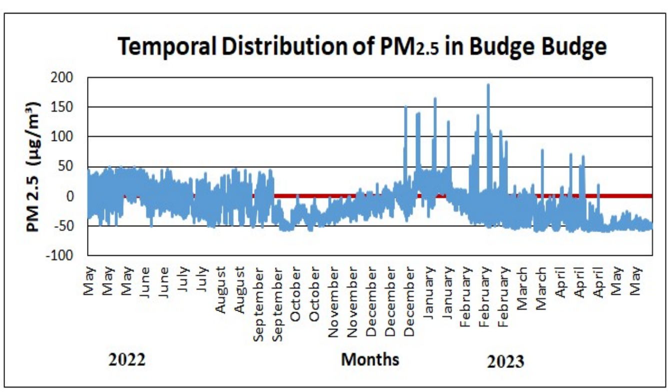


Fig. 14

Source: West Bengal Pollution Control Board, 2021-23

Nevertheless, the distribution of positive and negative trends in $PM_{2.5}$ levels varies across different monitoring stations. In both Kolkata and Howrah, the lowest concentration of $PM_{2.5}$ is observed during the month of July. However, in Kolkata, the highest concentration of $PM_{2.5}$ occurs in February and January. It is noteworthy that certain monitoring stations such as Belghoria, Serampore, and Barackpore consistently maintain $PM_{2.5}$ concentrations below the standard limits for at least two months during the monsoon season.

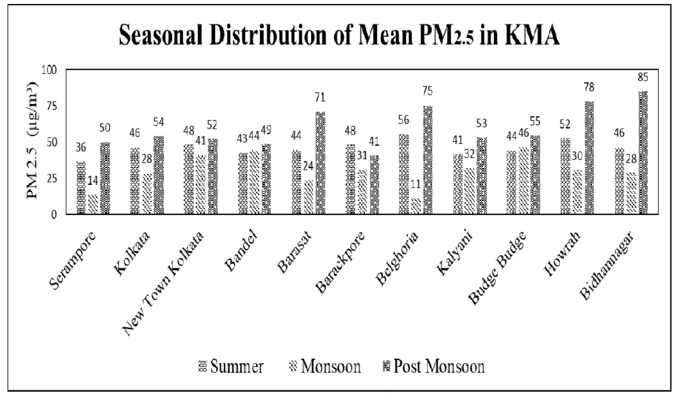


Fig 15

Source: West Bengal Pollution Control Board, 2021-23

Based on the data presented in Figure 15, it is clear that the average concentration of $PM_{2.5}$ varies throughout the seasons. During the monsoon season, the mean concentration of $PM_{2.5}$ remains below the standards prescribed by the World Health Organization (WHO) in stations such as Serampore, Barasat and Belghoria. Conversely, in Bandel, Budge Budge, and New Town Kolkata, the concentration of $PM_{2.5}$ remains high during the monsoon[1] season. In the post-monsoon period, the maximum concentration of $PM_{2.5}$is observed in Bidhannagare, Barasat, Belghoria, and Howrah, while Barrackpore exhibits the lowest concentrations.

Analysis of $PM_{2.5}$ Exceedances and Episodes

Two different standards have been taken to calculate the exceedance of $PM_{2.5}$ across the 12 monitoring stations. In this section, we have analyzed the WBPCB data of $PM_{2.5}$ to study the number of threshold exceedances of daily mean $PM_{2.5}$ as per the WHO (25 µg/m3) and Indian NAAQS (60 µg/m3) values for a year.

[1]The monsoon period typically spans from June to October. Following the monsoon season, the post-monsoon period occurs from November to February. The summer season encompasses the months of March to May.

Fig 16

Source: West Bengal Pollution Control Board

Analysis of figure 16 reveals prolonged $PM_{2.5}$ concentration above Indian standards in Bidhannagore, Kolkata, Serampore, New Town Kolkata, Howrah, and Barasat for Over Four months annually. Conversely, Barackpore exhibit lower $PM_{2.5}$ concentration for 10 months, indicating prevalence of good air quality for this monitoring station.

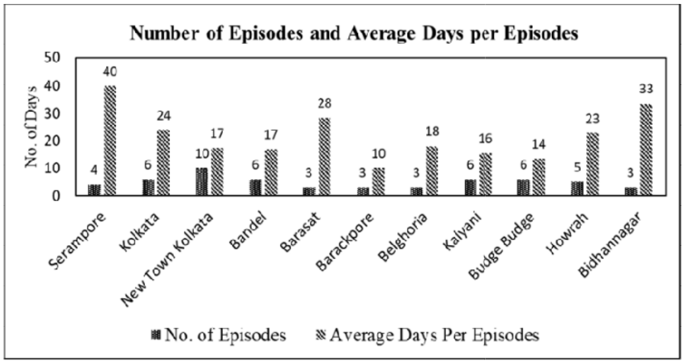


Fig 17

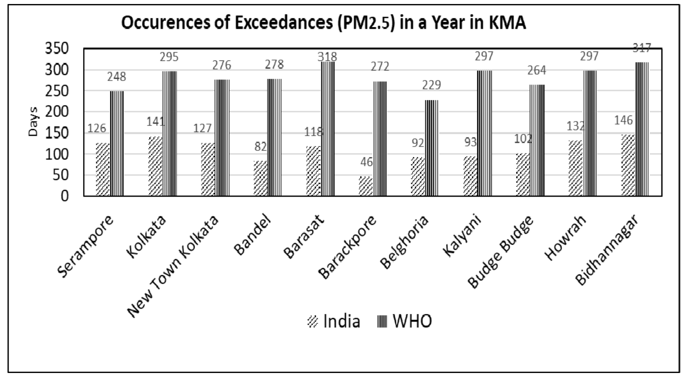
Source: West Bengal Pollution Control Board

When analyzing the adherence to the WHO standard, it is noteworthy that nearly eight months out of the year exhibit higher $PM_{2.5}$ concentrations across all monitoring stations. It is crucial to emphasize that the concentration of $PM_{2.5}$ fluctuates on an hourly basis, making the mean value essential for understanding the prevailing conditions. The figure 17 provides information on the number of episodes and the average duration of each episode related to air quality in different locations. In the case of Serampore, there were a total of four episodes, each lasting an average of 40 days. This implies that the PM2.5 concentration remained above 60 for approximately 160 days in a year. Similarly, Bidhannagar experienced three episodes, with an average duration of 33 days per episode, indicating that the PM2.5 concentration remained above 60 for nearly 100 days. Conversely, Barackpore had fewer episodes, with average durations of 10 and 23 days, respectively. These figures provide an overview of the number of episodes and the average duration of each episode, giving an indication of the frequency and duration of air quality issues in each location.

Recommendations and Measures Implemented to Improve Air Quality

On October 8, 2018, the National Green Tribunal Bench instructed the Government of West Bengal to establish an Air Quality Monitoring Committee (AQMC). The purpose of this committee was to create a suitable action plan aimed at achieving the National Ambient Air Quality Standards (NAAQS) and to prepare an air quality action plan specifically for the "Non-Attainment City" within the state. Some of the important measures taken is as follows.

The Kolkata Metropolitan Area (KMA) has initiated the



phasing out or scrapping of commercial vehicles that are more than 15 years old (GoWB, 2018). Additionally, the implementation of Bharat Stage-IV norms has been put into effect for Kolkata City, aiming to regulate vehicle emissions and improve air quality. Furthermore, the adoption of an integrated automated network system for traffic light signals has been implemented in the KMA, enhancing traffic management and efficiency. Kolkata Traffic Police also take measures like The MLCP(Multi Layered Car Parking) project at few places in the city which shall alleviate the pollution caused by parking related issues (GoWB, 2018). Introduction of camera based citation prosecutions & instant communication of information to the violators through SMS alerts is another innovative move by Kolkata Traffic Police. To cater to the needs of the fast paced dynamic environment the existing signaling system has been completely revamped & substituted with automated synchronized signaling across the city. Road Users are made conversant about the real time ground level scenario& updates on travel time through state of the smart VMS which not only is informative in nature but sensitizes the pedestrians about their rights & responsibilities (GoWB, 2018).

Some important recommenations of the same report include transportation of materials (building materials) in covered condition. No construction materials are left uncovered at roadside. Wrap construction area or building in geotextile fabric, installing dust barrier or other actions as appropriate for the location is being undertaken. Sprinkling of water prior to the levelling or any other earth movement activities to keep the soil moist throughout the process is being done. Water is applied to maintain soils in a visible damp and crusted condition for temporary stabilization. Disposal of debris from the construction site is done at the earliest in consultation with the local authority following proper environmental management practice (GoWB, 2018). Some of these recommendations are yet to be implemented in the State to attain National Ambient Air Quality Standards. However, it has been observed that even after implementing some measures, the ambient concentrations of particulates in theKolkata Metropolitan Area decreased by 15 percent in 2023, as noted in the reports of National Clean Air Program[2] (NCAP) (CREA, 2023).

[2] The National Clean Air Programme (NCAP) was launched in 2019 as a dynamic document focused around formulating and renewing action plans for

IV. CONCLUSION

This study aimed to analyze the levels and distribution of $PM_{2.5}$ in the Kolkata Metropolitan Area (KMA). Numerous reports have highlighted the poor air quality in the Kolkata Municipal Corporation (KMC) area, specifically regarding the concentration of $PM_{2.5}$. This paper focuses on the role of $PM_{2.5}$ in air pollution in the KMA. The study reveals that significant sources of $PM_{2.5}$ include households, industries, and the transportation sector, although their contributions vary across different monitoring stations. The mean concentration of $PM_{2.5}$ is higher in Kolkata and its immediate surrounding areas. Additionally, Kalyani in the north also records a higher mean concentration of $PM_{2.5}$. The concentration of $PM_{2.5}$ remains high during both winter and summer seasons. Despite various measures implemented, the concentration of $PM_{2.5}$ exceeds the National Ambient Air Quality Standards for a minimum of 3 to 4 months at each monitoring station. Moreover, the concentration of $PM_{2.5}$ remains above the standards for a range of 10 to 40 days per year. However, it has been noticed that after implementation of some measure prescribed by AQMC, there is slight improvement in the ambient concentration of particulate matter but its still far from satisfactory. Therefore, additional measures are required to effectively combat air pollution in the city.

Conflicts of Interest

The author declares no conflicts of interest exists regarding this paper

Availability of Data

All the data are accessed from online and available in government website and can be provided if required

V. REFERENCES

Alimissis, A., Philippopoulos, K., Tzanis, C.G., Deligiorgi, D., (2018). Spatial estimation of urban air pollution with the use of artificial neural network models. *Atmospheric. Environment*. 191, 205–213.

Biswas, T., Pal, C. S., Saha, A. (2022) Strict lockdown measures reduced PM2.5 concentrations during the COVID-19 pandemic in Kolkata, India, *Sustain Water Resources Management* 8(6). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9576136/

CREA (2023) Tracing the Hazy Air 2023: Progress Report on National Clean Air Programme (NCAP), The Centre for Research on Energy and Clean Air (CREA) https://energyandcleanair.org/wp/wp-content/uploads/2023/01/Tracing-the-Hazy-Air-2023_-Progress-Report-on-National-Clean-Air-Programme-NCAP_10th-January-2023.pdf

combating particulate matter pollution through periodic reviews based on scientific inputs

CSIR-NEERI (2019). PM_{10} and $PM_{2.5}$ Source Apportionment Study and Development of Emission Inventory of Twin Cities Kolkata and Howrah of West Bengal, West Bengal Pollution Control Board, Kolkata

Dutta, S., Ghosh, S., and Dinda, S. (2021). Urban Air-quality assessment and inferring the association between different factors: a comparative study among Delhi, Kolkata and Chennai Megacity of India. *Aerosol Sci. Eng*. 5, 93–111. doi:10.1007/s41810-020-00087-x

Faheem,M., Danish,M., and Ansari, N. (2021). Impact of Air Pollution on Human Health in Agra District.*International Research Journal of Education and Technology*, 1 (6)

Ganguly, N.D., Tzanis, C.G., Philippopoulos, K., Deligiorgi, D., (2019). Analysis of a severe air pollution episode in India during Diwali festival–a nationwide approach. *Atmósfera* 32 (3), 225–236.

GoWB. (2018). Comprehensive Air Quality Action Plan for Kolkata, Air Quality Monitoring Committee, Dept. of Environment, Government of West Bengal,

Karmakar, J. (2020). Air Pollution in Kolkata: Emerging Challenges and Dynamics, Journal of Atmospheric Science Research, 3(4)

Mangaraj, P., Sahu. S. K., Beig, G., Yadav, R. (2022) A comprehensive high-resolution gridded emission inventory of anthropogenic sources of air pollutants in Indian megacity Kolkata, *SN Applied Science* 4 (117), Springer

Mohan, V. (18th August 2022) Delhi, Kolkata most polluted cities globally by PM2.5, *Times of India*, https://timesofindia.indiatimes.com/india/delhi-kolkata-most-polluted-cities-globally-by-pm2-5-says-study/articleshow/93628175.cms (Accessed on 15th June 2023)

Philip, S., et.al. (2014). Global chemical composition of ambient fine particulate matter for exposure assessment. *Environmental Science and Technology*. 48 (22), 13060–13068.

Sarath, K. G., & Ramani, V. K. (2014). Source emissions and health impacts of urban air pollution in Hyderabad, India. *Air Quality, Atmosphere and Health* 7, 195–207. doi: 10.1007/s11869-013-0221-z

Shaw, N., and Gorai, A. K. (2020). Study of aerosol optical depth using satellite data (MODIS Aqua) over Indian Territory and its relation to particulate matter concentration. *Environment, Development and Sustainability*. 22, 265–279. doi: 10.1007/s10668-018-0198-8

Singh, V., Sahu, S.K., Kesarkar, A.P., Biswal, A., (2018). Estimation of high resolution emissions from road transport sector in a megacity Delhi. *Urban Climate*. 26, 109–120.

Snider, G., et.al. (2016). Variation in global chemical composition of PM2.5: emerging results from SPARTAN. *Atmospheric Chemistry and Physics*. 16, 9629–9653. https://doi.org/10.5194/acp-16-9629-2016

TERI (2023) Air Pollution Source Apportionment and Carrying Capacity of Kolkata and Howrah City, The Energy and Resource Institute, New Delhi.

WHO (2015). Countries: China: Country Health Profile. World Health Organization. Available online at: http://www.who.int/countries/chn/en/

WHO (2015). Countries: China: Country Health Profile. World Health Organization. http://www.who.int/countries/chn/en/ (accessed on 10th June 2023)

WHO (2016). Global Urban Ambient Air Pollution Database

https://www.who.int/phe/health_topics/outdoorair/databases/cities/en/ (accessed April 10, 2021).