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$Pm_{2.5}$ pollution : Evolution and seasonal variation in Durgapur, West Bengal and it's impact on plants

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Abstract

Air pollution has been a major worldwide concern in the last few decades. One of the six criterion air pollutants that are regularly assessed is $PM_{2.5}$, or suspended particulate matter. To comprehend the spatial and temporal evolution of the issue in every nation, long-term statistics on air pollution are required. Air pollution damages leaves, causes chlorophyll loss, drops leaves, damages stomata, induces early senescence, and reduces the growth and production of plant species. It also lowers the quantity of photosynthetic activity and membrane permeability. This study provides an overview of the seasonal variations in $PM_{2.5}$ pollution and its alterations in Bidhannagar, Durgapur, W.B., from 2020 to 2022, along with the effects of $PM_{2.5}$ pollution on plants. The average annual $PM_{2.5}$ readings in Durgapur increased significantly between 2020 and 2022. Winter months of December, January, and February (DJF), autumn months of September, October, and November (SON), spring months of March, April, and May (MAM), and monsoon months of June, July, and August (JJA) are when the largest concentrations are observed. An analysis of the effects of $PM_{2.5}$ on plants using the APTI test revealed that plants like *Tamarindus indica* and *Tectona grandis* are more susceptible to $PM_{2.5}$ pollution than plants like *Alstonia scholaris* and *Albizzia lebbeck*.

Key words : Air Pollution, Suspended particulate matter, Aerosol particles, Spatio – temporal evolution, Covid– 19.

India, a rapidly developing nation with an expanding populace, is home to nine of the world's 10 most polluted cities. Suspended particulate matter, or SPM, is the collective term for any airborne particles with an aerodynamic size between 0.01 and 100 micrometers or more. It has been demonstrated that there is a 10-micrometer-sized particle of SPM in the air, and that people may inhale this particle and allow it to enter their respiratory systems. This substance is commonly referred to as PM_{10} or coarse particle. Respirable Suspended Particulate Matter (RSPM) is a subgroup of suspended particulate matter (SPM) that can enter the alveoli of the human respiratory system and is associated with several cardiovascular illnesses. It has an aerodynamic particle diameter of less than 2.5 micro-meters. This material also goes by the designations $PM_{2.5}$ and fine particle. SPM, or substantially larger particles, can have a diameter of up to 100 micrometers. Mucus and cilia in the nose and throat act as filters for these particles. Ultrafine particles, with a diameter of less than 100 nm, have the ability to penetrate cell membranes and alter the base pair of DNA in the lungs and other organ systems. Air pollution causes damage to leaves, loss of chlorophyll, drop in leaves, damage to stomata, early senescence, reduced photosynthetic activity, disturbed membrane permeability, and reduced growth and yield of plant species[7,15]. According to Bernstein[2], primary or secondary air pollutants may be significant interior and outdoor air pollutants in metropolitan environments. The primary air pollutants that are emitted into the atmosphere directly are dust particles, SOx, NOx, CO, ammonia, particulate matter ($PM_{2.5}$, PM_{10}), suspended particulate matter (SPM), respirable particulate matter (RPM), and particulate matter ($PM_{2.5}$, PM_{10}). Ozone, smog, peroxyacyl nitrates (PANs), and other air pollutants are examples of secondary pollutants. The most frequent man-made sources of $PM_{2.5}$ include combustion engines, electricity generation, building, industrial and agricultural processes, residential wood and coal burning, and agricultural processes. $PM_{2.5}$ is most commonly caused by wildfires, sandstorms, and dust storms. $PM_{2.5}$ can have a wide range of chemical and physical compositions and originates from a variety of sources. Compounds like sulfates, nitrates, ammonium, black carbon, and others are frequently found in $PM_{2.5}$. The National Clean Air Programme (NCAP), which was declared by the Ministry of Environment, Forests, and Climate Change (MoEFCC), formally started in 2019. The strategy aims to conduct source apportionment studies, lower PM concentrations by 20% to 30% by 2024 in all identified non-attainment cities, expand air quality monitoring, and execute state-specific, regional, and local clean air action plans.

The evolution and seasonal variability of $PM_{2.5}$ pollution in Bidhannagar, West Bengal, Durgapur, between 2020 and 2022, are reviewed in this paper along with the impacts of the pollution on plants. The Indian state of Durgapur, located at 23.55° N and 87.32° E, is home to a number of small businesses and sizable steel mills that frequently release air pollutants into the surrounding environment. These pollutants include SO_2, NO_2, CO, heavy metals, and other suspended and respirable particulate matter. Graphite carbon, DSP, DPL, ASP, DTPS, and DVC are among the important products made in Durgapur by major manufacturers. These large and small ferro alloy steel factories discharge millions of tons of carbon, harmful gasses, particulate matter, and fly ash into the atmosphere, which contributes to the haze that appears around sunset. The ecology has been significantly impacted by the volume of internal traffic in the city and the

Table-1. Sources of Air Pollutants (Gheorghea IF, Ion B, 2011)

Air Pollutants	Definition	Sources
Particulates	Finely divided solid or liquid particles of microscopic size suspended and dispersed in atmosphere.	Industries, Civil construction, Transportation, Volcanic eruption, Civil war.
Dust	Small solid particles, known as silt (0.5-0.002 mm) and clay (0.002 mm), are produced when bigger aggregates break up.	Agriculture and Industrial activity, Natural storm, topsoil erosion.
Smog	A blend of fog and smoke.	Interactions of hydrocarbons, Oxides and sunlight.
Carbon di oxide	A colorless, odorless, noninflammable gas.	Combustion, Decay of fossil fuels, Release from plants and human respiration, Cigarettes.
Carbon monoxide	A colorless, tasteless, slightly odorous, highly poisonous gas. Burns with blue flame.	Auto exhaust, Industrial process, Forest fires, Cigarettes.
Sulphur di oxide	Oxide of sulphur, a colour less, irritant gas.	Combustion of coal and gas, Transport, Volcanoes, Industries.
Nitrogen oxide	Gaseous oxide of nitrogen. Four (*i.e.* N_2O, NO, N_2O_3 and NO_2) are in gaseous form and the last one (i.e. N_2O_5) is white crystal form.	Automobile exhaust, Combustion, Lightning and electrical storms.
Hydrogen sulphide	A foul smelling gas, colorless poisonous gas.	Sewage treatment, chemical process, Industrial activity, volcanic eruption.
Chloro Fluro Carbon	A poisonous gas.	Refrigerators.
Ozone	A photochemical oxidant. It is a toxic, colorless gas.	Produced in the upper atmosphere by lightning, forest fires, and solar radiation.
Lead	Poisonous metal available in atmosphere as lead oxide, lead sulphide etc.	Auto exhaust.
Hydrocarbons	Approximate 200 types of different sizes and shapes.	Auto exhaust, incomplete combustion of wood and other biofuels.

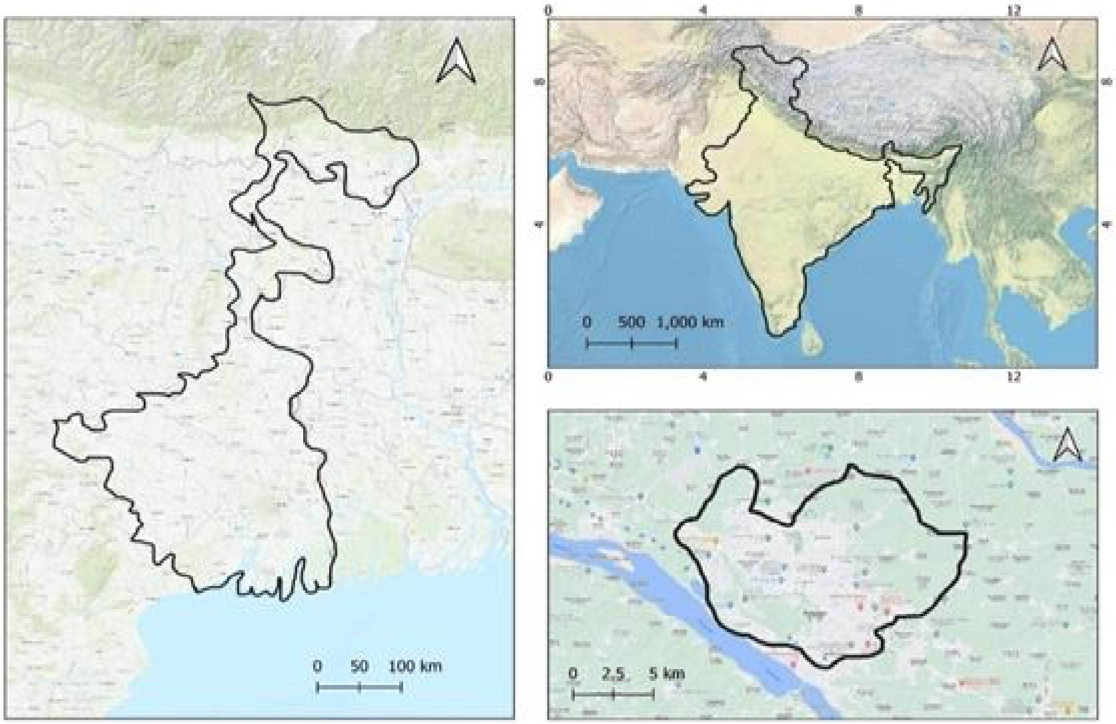

Figure 1. showing maps of India (Top Right), West Bengal (Left), and Durgapur (Bottom Right)

National Highway that runs through it around the clock. Air pollution is caused by unplanned urbanization, an increase in industries, and heavy traffic on a daily and hourly basis. This research area's climate is best described as subtropical, dry, with few deciduous trees and modest precipitation (about 1,500 mm). The average maximum temperature is 45.0 degrees, and the average lowest temperature is 6.0 degrees.

The air quality was reported on the West Bengal Pollution Control Board website. The tolerance and sensitivity of plants under the stress of air pollution are evaluated by computing the Air Pollution Tolerance Index (APTI) of each plant species and examining its physiological and biochemical characteristics. The four main biochemical and physiological markers of leaves—ascorbic acid (AA), pH, total chlorophyll (TCh), and relative water content (RWC)—are used to assess the efficacy of APTI. Each of these four elements contributes to symptomatic reflections brought on by pollution by altering their relative levels inside the plant body. Strong low molecular weight natural antioxidants, such vitamin C or ascorbic acid, are present in most plant cell types, organelles, and apoplast. Ascorbic acid levels increase under stressful conditions like air pollution and are directly in charge of scavenging several reactive oxygen species (ROS) such superoxide, hydroxyl radicals, singlet oxygen, and H_2O_2. The second biochemical indicator is the pH of plant leaves, which is negatively correlated with air pollution, i.e., a reduction in pH is caused by an increase in air pollution. Acidic pollution in the environment lowers the pH of plant leaves; this drop is more pronounced in sensitive plants. Total chlorophyll, the primary photosynthetic device in plant leaves, is a biological indicator that maintains the original output of a given area. There is a decrease in the amount of chlorophyll in highly contaminated areas. Relative water content (RWC) is a measure of a plant's physiological water balance under stress from air pollution. The transpiration machinery of ten plant leaves pulls nutrients and water from the roots; however, in contaminated areas, the entire system malfunctions and transpiration is reduced. Each of the four previously mentioned factors makes a substantial contribution to the ocean of air pollution. The Air Pollution Tolerance Index (APTI) was developed by Singh and Rao in 1983. They started by adding ascorbic acid, leaf extract pH, total chlorophyll, and RWC, and then divided the result by 10. Based on an APTI value scale developed by Mashita and Paise, 2001, a species is classified as highly sensitive if its APTI value is less than 1, intermittently tolerant if it is between 17 and 29, sensitive if it is between 1 and 16, and tolerable if it is between 30 and 100.

APTI= {A(T + P) + R} / 10

Here, A = ascorbic acid content in mg/g of fresh weight, T = total chlorophyll in mg/g of fresh weight, P = pH of leaf extract, and R = relative water content (%).

In this sampling section, 10 to 15 leaf samples from each of the ten plant species were obtained. Leaves facing the road and those near the industrial area were collected at a height of around 1.0 to 1.5 meters. These leaf samples were gathered, packed into different polythene bags, and delivered to the laboratory. There, tap water was used to gently rinse the leaves, and then distilled water was used once again. For further physiological and biochemical testing, they were then separated at a temperature of –40°C. To distinguish between pollution-tolerant and sensitive plant species, several biochemical, physiological, and biological screening techniques can be applied. Ascorbic acid (A), total chlorophyll (T), pH (P), and relative water content (R) were utilized as two physiological and two biochemical properties of plant leaves, respectively. The Air Pollution Tolerance Index (APTI) was developed by Singh and Rao[14] using these variables. After adding ascorbic acid to double the amount of total chlorophyll, the pH of the leaf extract and the APTI formula were combined. The APTI formula is obtained by combining the output with the relative water content once more and dividing the result by 10. The formula to determine APTI is A (T+P)+R/10. Next, APTI values for every plant species should be acquired, and the outcomes ought to be contrasted with the APTI scale. Plant species are classified as highly sensitive to air pollution if their APTI value is less than 1, as sensitive if it is between 1 and 16, as intermittently tolerant if it is between 17 and 30, and as tolerant if it is between 30 and 100.

The following procedures were followed during the study process:

1. pH - Singh and Rao[14]

2. Relative water content (RWC) (%) - Sen and Bhandar[13]
3. Ascorbic acid (mg/gm. Fresh weight) - Mukherjee and Chaudhuri[12]
4. Total chlorophyll (mg/gm. Fresh weight) - Arnon[1]

Information about air quality, including the variation of $PM_{2.5}$ in 2020, 2021, and 2022, was available on the website of the West Bengal Pollution Control Board. The data was analyzed using the statistical technique known as anova. The average annual $PM_{2.5}$ readings in Bidhannagar, Durgapur, increased significantly between 2020 and 2022. There is a noticeable seasonal tendency in Durgapur's $PM_{2.5}$ pollution. Winter months December January February (DJF) have the highest concentrations, followed by autumnal months September October November (SON), springtime months March April May (MAM), and monsoon months June July August (JJA). According to the analysis, there was a significant difference ($p = 0.001406$; *i.e.*, $p < 0.05$) in the $PM_{2.5}$ values for 2020, 2021, and 2022. Furthermore, there is a noteworthy variation in $PM_{2.5}$ levels between the seasons in 2021 and 2022 ($p = 0.000584$ in 2021 and $p = 0.004818$ in 2022; both $p \approx 0.05$). Unlike previous seasons that exhibited a consistent increase in seasonal averages, a reduction was observed in 2020 during the COVID-19 first wave lockout periods ($p = 4.67$, *i.e.*, $p \prec 0.05$). Plants like *Tamarindus indica* and *Tectona grandis* are more vulnerable to $PM_{2.5}$ pollution than plants like *Alstonia scholaris* and *Albizi*a *lebbeck*, according to an examination of the impacts of $PM_{2.5}$ on plants using the APTI test. Every recognized sector, including household cooking, heavy and light industries, road and construction dust, waste burning, and freight and passenger transit, has a fundamental emissions rate that varies with the season. In addition to these consistent emissions, a number of seasonal factors affect pollution levels by causing emissions to rise or fall. It is anticipated that the area's surface temperatures would drop below 10 °C during the winter, making space heating necessary. This is often achieved by burning coal, wood, cow dung, and occasionally even rubbish. This is also the moment when the mixing layer is at its lowest, which more than triples the impact of higher emissions.The burning of post-harvest agricultural residue for 2-4 weeks in October–November and the start of a western disturbance, which causes pollution to move slowly and gives more time for chemical reactions and the formation of secondary particulates, are two other factors that contribute to a notable increase in emissions during the autumn months. Burning agricultural trash and starting forest fires are widespread throughout the year in India, but October and November are the months when the effects are most thoroughly observed and researched. Summertime brings with it sporadic dust storms from the West. The monsoon season in the subcontinent is marked by torrential rains that scavenge most of the airborne particles. $PM_{2.5}$ pollution is caused by increasing emissions from power plants in addition to worsening pollution levels. In contrast to previous seasons that demonstrated a rise in the seasonal averages in 2020, the adjustments for the emission reductions observed during the lockup periods of COVID-19's initial wave are included for March, April, and May.

Table-2. Air Pollution Tolerance Index (APTI) Of Plant Species

Sl. No.	Name of the Plant species	A	P	T	R	APTI
1.	*Accacia auriculiformis* A. Cunn ex Benth.	70.92±8.17	5.13±1.26	1.78±0.63	94.44±9.82	65.30±15.77
2.	*Albizzia lebbeck* (L.) Willd.	77.91±15.01	8.46±2.36	3.02±1.07	83.33±7.72	101.60±35.53
3.	*Alstonia scholaris* (L.) R.Br.	188.85±5.64	5.21±1.68	1.58±0.22	81.76±17.63	136.78±37.33
4.	*Ficus benghalensis* L.	19.04±2.66	7.30±2.00	1.40±0.48	87.35±38.63	24.65±5.68
5.	*Shorea robusta* Gaertn.	92.24±17.00	5.23±0.37	2.15±0.55	86.88±5.35	78.06±19.64
6.	*Bauhinia purpurea* L.	1.39±0.41	6.28±1.11	2.50±0.58	89.52±11.01	10.17±1.33
7.	*Tectona grandis* L.	0.5±0.05	3.82±1.27	2.05±1.49	87.86±2.24	9.08±0.18
8.	*Zizyphus jujube* Mill.	5.93±2.41	6.26±1.53	2.40±1.09	85.71±10.48	14.32±4.65
9.	*Tamarindus indica* L.	3.31±0.48	4.42±0.28	1.56±0.24	86.46±5.69	10.63±0.97
10.	*Aegle marmelos* (L.) Correa	13.10±2.10	7.41±2.37	2.13±0.75	97.18±7.19	22.80±5.56

A = Ascorbic acid content in mg/g of fresh weight T = Total chlorophyll in mg/g of fresh weight
P = pH of leaf extract R = Relative water content (%)
APTI = Air Pollution Tolerance Index

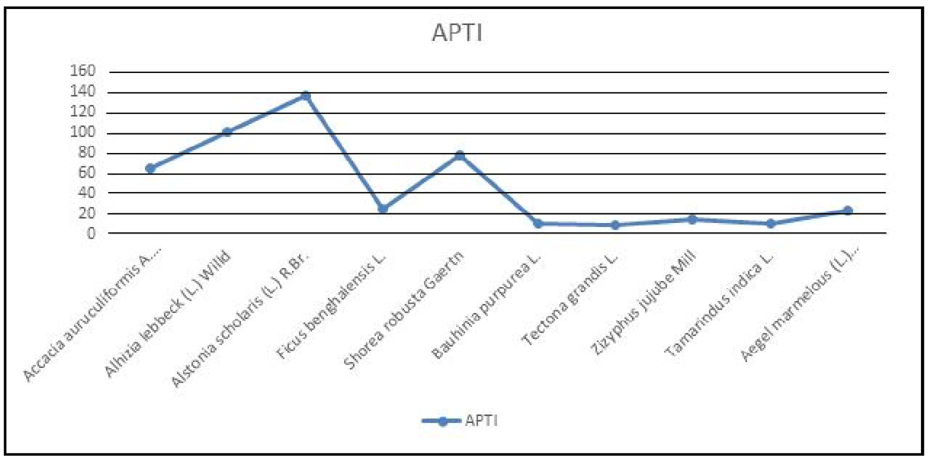

Figure 2. showing APTI values of different plant species

(APTI value <1, the plant species is thought to be highly sensitive to air pollution
APTI value between 1 and 16, it is registered as sensitive
APTI value between 17 and 30, it is thought to be intermittently tolerant
APTI value between 30 and 100, it was classified as tolerant species)

Evolution and seasonal variation of $PM_{2.5}$ during 2020 – 2022 :

Table-3. Evolution of $PM_{2.5}$ during 2020-2022

Anova: Single Factor

Summary

Groups	Count	Sum	Average	Variance
2020	42	2546	60.61905	261.3635
2021	48	3124	65.08333	65.35461
2022	48	3307	68.89583	26.18041

Anova

Source of variation	SS	df	MS	F	P-value	F crit
Betwee Groups	1534.594	2	767.2972	6.897374	0.001406	3.063204
Within Groups	15018.05	135	111.2448			
Total	16552.64	137				

Table-4. Seasonal variation in 2020

Anova: Single Factor

Summary

Groups	Count	Sum	Average	Variance
Winter	12	909	75.75	91.47727
Autumn	11	592	53.81818	165.5636
Summer	12	850	70.83333	55.60606
Monsoon	12	543	45.25	50.02273

Anova

Source of variation	SS	df	MS	F	P-value	F crit
Between Groups	7299.686	3	2433.229	27.36251	4.67E-10	2.821628
Within Groups	3823.803	43	88.92565			
Total	11123.49	46				

Table-5. Seasonal variation in 2021

Anova: Single Factor

Summary

Groups	Count	Sum	Average	Variance
Winter	12	829	69.08333	15.17424
Autumn	12	820	68.33333	53.15152
Summer	12	691	57.58333	91.7197
Monsoon	12	784	65.33333	28.78788

Anova

Source of Variation	SS	df	MS	F	P-value	F crit
Betwee Groups	994.5	3	331.5	7.022065	0.000584	2.816466
Within Groups	2077.167	44	4720833			
Total	3071.667	47				

Table-6. Seasonal Variation in 2022

Anova: Single Factor

Summary

Groups	Count	Sum	Average	Variance
Winter	12	782	65.16667	55.06061
Autumn	12	821	68.41667	32.26515
Summer	12	690	57.5	86.63636
Monsoon	12	758	63.16667	30.15152

Anova

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	756.5625	3	252.1875	4.9421	0.004818	2.816466
Within Groups	2245.25	44	51.02841			
Total	3001.813	47				

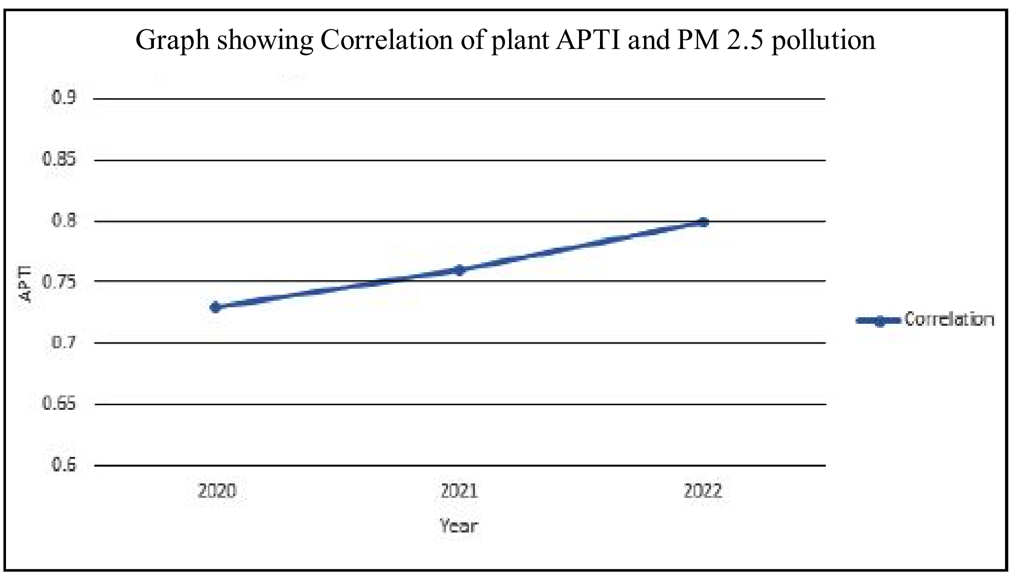

Figure 3. Showing correlation between plant APTI values and $PM_{2.5}$ pollution of different plant species

The COVID-19 pandemic and the ensuing lockdowns (March–April 2020) taught Indian cities that "clean air" and "blue skies" are possible even when it's not raining. Starting on March 24, four lockdown periods were announced in a sequence; the first lockdown period featured the strictest restrictions, while the subsequent lockdown periods gradually reduced them. All across India, there has been an improvement in the quality of the air, with the first phase witnessing the most of the changes. This resulted from industry, particularly power plants, temporarily ceasing operations, which lowered their pollution contribution. Policies allowing for work from home also decreased the need for travel. In India, PM pollution decreased by at least 25% on average throughout each lockdown period, with metropolitan areas contributing up to 70% of the total reduction.

The annual average $PM_{2.5}$ readings in Bidhannagar, Durgapur, increased significantly between 2020 and 2022. Durgapur's $PM_{2.5}$ pollution has a clear seasonal tendency. Winter months December, January, and February (DJF) have the highest concentrations, which are followed by autumnal months September, October, and November (SON), springtime months March, April, and May (MAM), and monsoon months June, July, and August (JJA). The effects of $PM_{2.5}$ on plants using the APTI test indicate that *Tamarindus indica* and *Tectona grandis* are more susceptible to $PM_{2.5}$ pollution than *Alstonia scholaris* and *Albizia lebbeck*.

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