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Air Quality Monitoring and Spatial Distribution Mapping of Particulate Matter (PM_1 and $PM_{2.5}$) Using Inverse Distance Weighting (IDW) At Srinagar City, Kashmir

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Abstract: About 27% of the air pollution in India is contributed by vehicles. The continuous increase in the vehicular number, the traffic congestion, and adulteration of fuels in vehicles and improper management of traffic is causing increased air pollution due to vehicular movement. The present study was carried out at 5 locations in Srinagar city with 4 locations being located in high traffic areas of the city and one location situated in the outskirts of the city where traffic movement was less during a period of 1 year from June 2019 to May 2020. PM_1 and $PM_{2.5}$ particulate matter was monitored at every fortnight on the said locations for a period of 1 year using Aerosol Mass Monitor AEROCET-831. The monitoring period coincided with the COVID-19 period too. The readings showed significant differences seasonally and also due to changes in traffic flow due to COVID 19 pandemic. The observed data for concentration of particulate matter was mapped using IDW mapping to see the changes in concentration of pollutants with the change in location.

Keywords: Particulate Matter, $PM_{1,}$ $PM_{2.5,}$ Inverse Distance Weightage, Air pollution, vehicular pollution, COVID19.

I. Introduction

Air pollution has been one of the major concerns of modern world. The Central Pollution Control Board (CPCB) is India's primary air pollution monitoring organisation, with 731 monitoring stations spread around the country (CPCB, 2018). The main causes of air pollution are vehicle exhaust emissions and flue gases, which are released from industries, refineries, and other sources. The diesel exhaust is more cancer-causing. In India, it's thought that diesel exhaust has twice the cancer-causing potential of gasoline pollution (Bhandarkar, S., 2013). According to the Global Air Quality report 2022 published by the Swiss company IQAir, 39 Indian towns were among the top 50 most polluted cities in the world. Data on PM2.5 air quality from 7323 cities in 131 nations, regions, and territories are included in this publication. Around 30,000 regulatory air quality monitoring stations and low-cost air quality sensors were employed to get the data for this research (IQAir, 2022). To comprehend the emission sources, residence time, and dispersion of pollutants in the atmosphere, an analysis of the vertical distribution of such pollutants is required. The majority of pollutants are released from ground-based sources, are typically contained in the Planetary Boundary Layer, and vary in height during the day depending on atmospheric conditions (Samad, A. *et al.*2020). The Environmental Performance Index (EPI) of 2020 showed that India ranked 168 among 180 countries. The researches at Yale and Columbia university say that India's decarbonization agenda needs to accelerate and the country faces a number of serious environmental health risks, including poor air quality. Besides the major concern of increasing population, the exponential increase in vehicular number following the population explosion is commendable in our country. The ministry of Roadways and Transport have shown the registered number of vehicles in the country to have increased from 0.3 million in 1951 to 253 million in 2017. The Compounded Annual Growth Rate of registered vehicles was 10.1% in the country for last 10 years outpacing the CAGR of national highways of 5.54% (Anonymous, 2016-2017).

Srinagar the largest city and the summer capital of the Indian Union Territory of Jammu and Kashmir lies on the banks of Jhelum river and famous Dal and Anchar lakes within geographical coordinates of 34˚5'24"N 74˚47'24"E. The annual average summer temperature and winter temperature stands at 23.3˚C and 3.2˚C respectively with the annual precipitation of 710mm. The 2011 census showed an amassed population of 1273312 in the urban area. This increased population is bringing in more anthropogenic causes for increasing air pollution like increased vehicular population, increased biomass burning, lack of proper traffic management, lack of disposal of old vehicles, etc. The city alone had registered more than 2.91 lakh vehicles as on 31st March, 2017.

II. Materials and Methods

The control site included a more tranquil area of the university grounds where the traffic movement is very little compared to the city limits and the control site is also at far off limits from the city. The study site for the current research was selected based on a greater degree of vehicular movement during the peak hours in the city, traffic congestions, major crossroads or junctions, higher populations, etc. Four of the five contaminated areas were inside the city limits and were among the five locations chosen for an annual air sample collection from June 2019 to May 2020. The Shalimar campus of SKUAST-K, which is 15 kilometres to the north-east of Lalchowk, the main commercial centre of Srinagar, was chosen as the fifth location and used as a control. Figure 1 to Figure 5 shows the different locations of monitoring throughout the whole year like Shalimar, Dalgate, Jehangir Chowk, Parimpora

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and Pantha Chowk respectively. One-minute average values at each location were used to collect the data throughout a 12-month period from June 2019 to May 2020 (with three replications for each sampling at each location). The second and fourth weeks of every month saw the collection of two samples. The sampling was done three times, from 9:00 to 10:30 in the morning, 1:00 to 2:30 in the afternoon, and 4:30 to 6:00 in the evening, to better understand how the pollutant load varied during the day at the relevant locations. A time frame for sampling was chosen based on the number of vehicles using these locations. The quantity of vehicles and their movement varied according to the time of day. The samples were collected, and the particle matter was measured using an aerosol mass monitor (AEROCET 831, Met One Inc., Washington, USA). Figure 6 depicts the photograph of the instrument AEROCET 831. The AEROCET 831 Aerosol Mass Monitor operates on the theory of light scattering. When a particle passes through the detection chamber that only allows single particle sampling, the laser light is scattered by the particle. A photo detector detects the scatting light. By analyzing the intensity of the scattering light, instrument can deduce the size of the particle (Remer et al., 2005). Also the number of the particle counts can be deduced by counting the number of detecting light on the photo detector. The advantage of this approach is that a single analyzer can be used to detect particles with different diameters simultaneously. The instrument counts particle sizes in 7 different size ranges then uses a proprietary algorithm to convert count data to mass measurements in the unit µg/m^3. Fundamentally the AEROCET 831 calculates a volume for each detected particle and then assigns a standard density for the conversion. The concentration of the particulate is determined by dividing the mass of the SPM by the volume of air sampled (WHO, 1976). The standard density value is augmented by the K-factor setting for each measurement range (PM_1 and $PM_{2.5}$). These K-factors can be modified with comet software or with the SK serial port command. K-factor values should be empirically derived via comparison with a reference unit. If a reference unit is unavailable, the recommended K-factor setting is 3.0.

Figure 1: Monitoring site at Shalimar

Figure 2: Monitoring site at Dalgate

Figure 3: Monitoring site at Jehangir Chowk

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Figure 4: Monitoring site at Parimpora

Figure 5: Monitoring site at Pantha Chowk

Figure 6: Aerosol Mass Monitor (AEROCET-831)

III. Results and Discussion

Particulate Matter 1-micron size (PM_1)

The table 1 provided shows PM_1 (Particulate Matter 1 micron) pollution levels at different locations over the course of 12 months. PM_1 refers to fine particulate matter with a diameter of 1 micron or less, which is a serious air pollutant that can have significant health impacts, especially for the respiratory system.

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There is a clear seasonal variation in PM_1 pollution levels, with the highest levels occurring in late 2019 (October to December), followed by a sharp decline in early 2020 (particularly in April). This suggests that pollution might be influenced by seasonal factors, such as heating during colder months or increased vehicular traffic. Besides COVID 19 lockdown restrictions reduced the pollution level due to low vehicular movements. While all locations show similar peaks in December 2019, the absolute values vary slightly from one location to another, possibly indicating differences in local factors like traffic congestion, industrial activities, or geography (proximity to natural pollution sources). PM_1 levels in Shalimar start at 33.37 µg/m^3 in June 2019, decrease slightly in the following months, then peak significantly at 108.90 µg/m^3 in December 2019, before dropping to 19.07 µg/m^3 in May 2020. The sharp rise in December and the subsequent fall suggests that local conditions (possibly related to weather, local sources of pollution, or heating activities) contributed to higher pollution during the winter months along with the vehicular movements. Dalgate shows a higher range of pollution, starting at 37.57 µg/m^3 in June 2019, peaking at 90.83 µg/m^3 in December 2019, and dropping to 32.60 µg/m^3 in May 2020.

The consistent rise in pollution through the latter half of 2019, peaking in December, could be related to increased vehicular emissions or industrial activity. The drop in April-May 2020 could indicate a reduction in human activity (e.g., COVID-19 lockdowns or reduced traffic). Jehangir Chowk had PM_1 relatively high, starting at 36.00 µg/m^3 in June 2019 and peaking at 92.20 µg/m^3 in December 2019, followed by a sharp drop to 34.90 µg/m^3 in May 2020. Similar to Dalgate, there seems to be an increase in pollution towards the end of 2019, with a possible environmental or anthropogenic cause. The sharp drop could be tied to external factors like less vehicular movement or industrial shutdowns. In Parimpora, PM_1 levels begin at 25.73 µg/m^{3}in June 2019, rise steadily to 95.33 µg/m^3 in December 2019, and then decrease to 26.33 µg/m^3 by May 2020. As with other locations, Parimpora shows a significant spike in the winter months, particularly in December. This could indicate local heating sources or the build-up of dust due to lower temperatures, which are common contributors to PM_1 levels in many urban areas. In case of Pantha Chowk, PM_1 levels here range from 34.03 µg/m^3 in June 2019 to 87.80 µg/m^3 in December 2019, with a decline to 30.50 µg/m^3 in May 2020. The trend is similar to the other locations, showing an increase in pollution levels during the second half of 2019, followed by a decrease in early 2020.

December 2019 consistently shows the highest PM_1 levels across all locations, which is likely due to increased heating (burning of wood, coal, or other fuels), vehicle emissions, and possibly fog or temperature inversions, all of which can trap particulate matter in the air during colder months. April 2020 sees a notable drop in pollution levels across all locations. This decline could be tied to reduced human activity as a result of the COVID-19 lockdowns, which led to lower traffic, industrial activity, and overall air pollution. Alternatively, it could be related to changing weather conditions or even the transition to spring, when dust and particulate matter may disperse more easily due to higher temperatures or rainfall. The sharp increase in pollution towards the end of 2019 could be due to a combination of factors such as: Higher vehicular traffic (due to the holiday season), increased use of solid fuels for heating during colder months, stagnant atmospheric conditions (e.g., temperature inversions) that trap pollutants near the surface.

Table 1: Concentration of PM_1 (µg/m^3) at different locations in Srinagar city on monthly basis

Location	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20
Shalimar	33.37	28.40	28.43	46.00	54.17	94.73	108.90	51.23	48.80	29.83	15.10	19.07
Dalgate	37.57	40.50	41.77	50.30	73.03	87.87	90.83	65.13	52.60	46.33	26.30	32.60
Jehangir Chowk	36.00	34.80	40.13	50.60	72.60	85.60	92.20	67.47	56.87	44.43	28.40	34.90
Parimpora	25.73	33.37	35.67	41.43	63.90	82.77	95.33	64.23	53.13	42.97	21.23	26.33
Pantha Chowk	34.03	32.47	37.63	45.23	59.70	83.97	87.80	62.60	55.70	41.07	24.47	30.50
C.D.	**1.37**	**2.19**	**1.25**	**1.12**	**1.61**	**0.65**	**1.49**	**0.65**	**2.56**	**0.79**	**2.23**	**2.68**
SE(m)	**0.41**	**0.66**	**0.38**	**0.34**	**0.49**	**0.20**	**0.45**	**0.20**	**0.77**	**0.24**	**0.67**	**0.81**

As per table 2, the PM_1 levels in Shalimar during summer (30.03 µg/m^3) are the lowest across all locations and seasons. Dalgate, Jehangir Chowk, Parimpora and Pantha Chowk all show moderate levels of PM_1, with Dalgate having the highest summer pollution (39.93 µg/m^3). Summer shows generally lower PM_1 levels compared to other seasons, likely due to higher temperatures and greater air circulation, which help disperse pollutants. The presence of rain in some regions may also aid in the removal of particles from the air. PM_1 levels increase significantly in autumn, with Dalgate having the highest levels (70.40 µg/m^3), followed by Jehangir Chowk (69.60 µg/m^3), Shalimar (64.97 µg/m^3), Parimpora (62.70 µg/m^3), and Pantha Chowk (62.97 µg/m^3). The increase in autumn pollution could be due to dry conditions, reduced rainfall, and the onset of falling leaves, which can contribute to dust and particulate matter. Additionally, the transition to cooler weather might trap pollutants near the ground (due to temperature inversions), leading to higher concentrations of PM_1.

Table 2:Concentration of PM_1 ($\mu g/m^3$) at different locations in Srinagar city on seasonal basis

Location Season	Shalimar	Dalgate	Jehangir Chowk	Parimpora	Pantha Chowk	Mean
Summer	30.03	39.93	36.97	31.60	34.70	**34.65**
Autumn	64.97	70.40	69.60	62.70	62.97	**66.13**
Winter	69.63	69.50	72.17	70.90	68.67	**70.17**
Spring	21.33	35.07	35.93	30.20	32.03	**30.91**
Mean	**46.50**	**53.77**	**53.63**	**48.87**	**49.60**	
	Factor		**C.D**		**SE(d)**	
	Season(S)		0.47		0.23	
	Location(L)		0.53		0.26	
	S×L		1.05		0.52	

Winter sees high PM_1 levels across all locations, with Jehangir Chowk (72.17 $\mu g/m^3$) recording the highest levels. PM_1 levels in winter are higher than in autumn at most locations, indicating that pollution is particularly elevated during this season. This could be due to heating activities (e.g., burning of wood, coal, and biomass), increased vehicular emissions due to colder temperatures, and temperature inversions, which trap pollutants close to the ground. PM_1 levels during spring are the lowest after summer, with Shalimar (21.33 $\mu g/m^3$) showing the lowest PM_1 levels overall. While still higher than summer, spring shows moderate PM_1 levels, with the lowest values observed in Shalimar and Parimpora (31.60 and 30.20 $\mu g/m^3$, respectively). The highest spring levels are in Jehangir Chowk (35.93 $\mu g/m^3$) and Dalgate (35.07 $\mu g/m^3$). Spring generally sees moderate PM_1 levels due to improved air circulation and occasional rainfall, which helps reduce airborne particulate matter. The drop in pollution could also be linked to a reduction in heating and other combustion-based activities compared to winter. Dalgate and Jehangir Chowk consistently show the highest annual PM_1 levels (53.77 and 53.63 $\mu g/m^3$, respectively), which may indicate more significant local pollution sources such as traffic congestion, industrial activities, or construction.

Shalimar has the lowest overall PM_1 levels (46.50 $\mu g/m^3$), indicating that this area may have fewer pollution sources or better air quality due to factors such as green spaces, better traffic management, or more favourable atmospheric conditions. Parimpora and Pantha Chowk show moderate PM_1 levels throughout the year, with their highest readings occurring in winter and autumn.

The critical difference (C.D) for season is 0.47, and the standard error is 0.23. Since the seasonal differences in PM_1 levels exceed this value, it suggests that seasonal variation in PM_1 pollution is statistically significant. The mean PM_1 values vary considerably between seasons, confirming that the time of year has a clear impact on pollution levels.

The C.D for location is 0.53, and the standard error is 0.26. This suggests that the differences in PM_1 levels between locations are also statistically significant. Locations like Dalgate and Jehangir Chowk tend to have higher pollution levels, indicating that local sources of pollution (e.g., traffic, industrial emissions) contribute significantly to variations in air quality. The C.D for the interaction between season and location is 1.05, and the standard error is 0.52. This indicates that the seasonal patterns of PM_1 pollution differ across locations, with some locations seeing larger seasonal variations than others. For example, Shalimar shows a significant reduction in pollution during spring, whereas Jehangir Chowk and Dalgate experience sustained high levels of PM1 across all seasons, particularly in winter.

Table 3:Annual average day time concentration of Particulate matter PM_1 ($\mu g/m^3$) based on time period in Srinagar city

Locations	PM_1			Mean Annual Readings
	Morning	**Afternoon**	**Evening**	
Shalimar	52.33	40.43	46.67	**46.50**
Dalgate	59.40	49.03	52.73	**53.77**
Jehangir Chowk	56.90	50.47	53.60	**53.63**
Parimpora	54.37	44.53	47.67	**48.87**
Pantha Chowk	54.00	44.73	50.07	**49.60**
C.D.	**0.92**	**0.98**	**1.38**	

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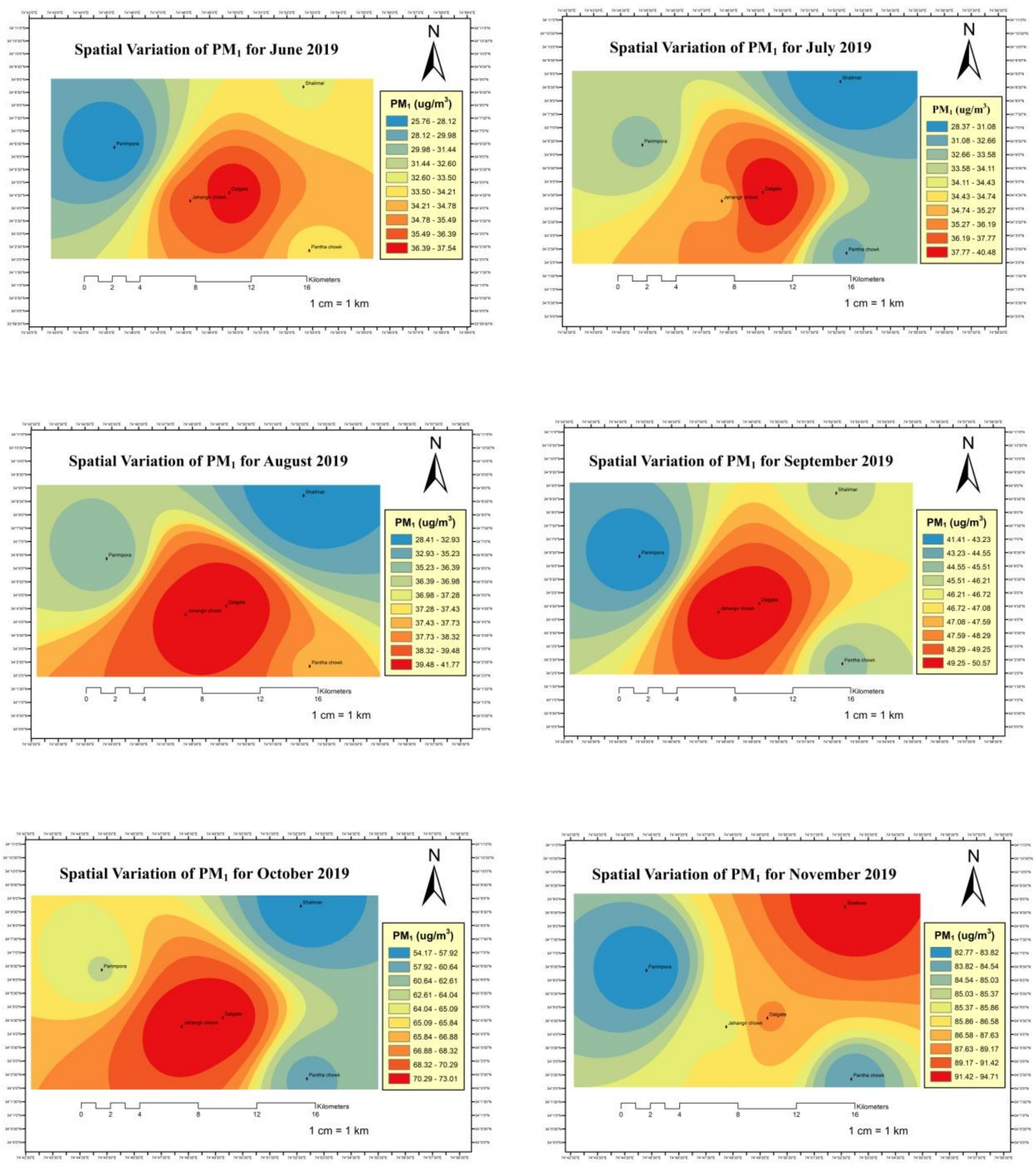
SE(m)	**0.28**	**0.30**	**0.42**	

Higher morning levels of PM_1 (table 3) can be attributed to rush hour traffic and commuting patterns, which significantly contribute to elevated emissions from vehicles and other sources. In the early morning, lower temperatures and limited atmospheric mixing can also trap pollutants near the surface, leading to higher concentrations of particulate matter. In the afternoon, PM_1 levels tend to decrease, likely due to higher temperatures and increased air dispersion, which help dilute and spread out pollutants. The reduction in traffic intensity during the day (after the morning rush) and increased atmospheric mixing also contribute to lower pollutant concentrations. Evening levels are higher than in the afternoon but lower than in the morning. This is likely due to increased vehicular emissions as people return home from work or activities, which could raise PM_1 levels. The cooler temperatures at night may also lead to some atmospheric trapping of pollutants again, although less so than in the morning. This time of day often sees a resurgence in traffic-related emissions (Tong et al. 2020).

Locations like Dalgate and Jehangir Chowk consistently show the highest average PM_1 levels throughout the day, indicating that these areas may have higher levels of traffic density and potentially other sources of pollution (e.g., industrial emissions or construction activities). Shalimar shows the lowest mean PM_1 levels, suggesting it may have relatively lower local pollution sources. The IDW maps are given to pictorially depict the change in concentration of pollutants at different locations. Below Figure 7 pictorially depicts the pollutants concentration maps for all the months of monitoring. 12 maps representing 12 months are given below.



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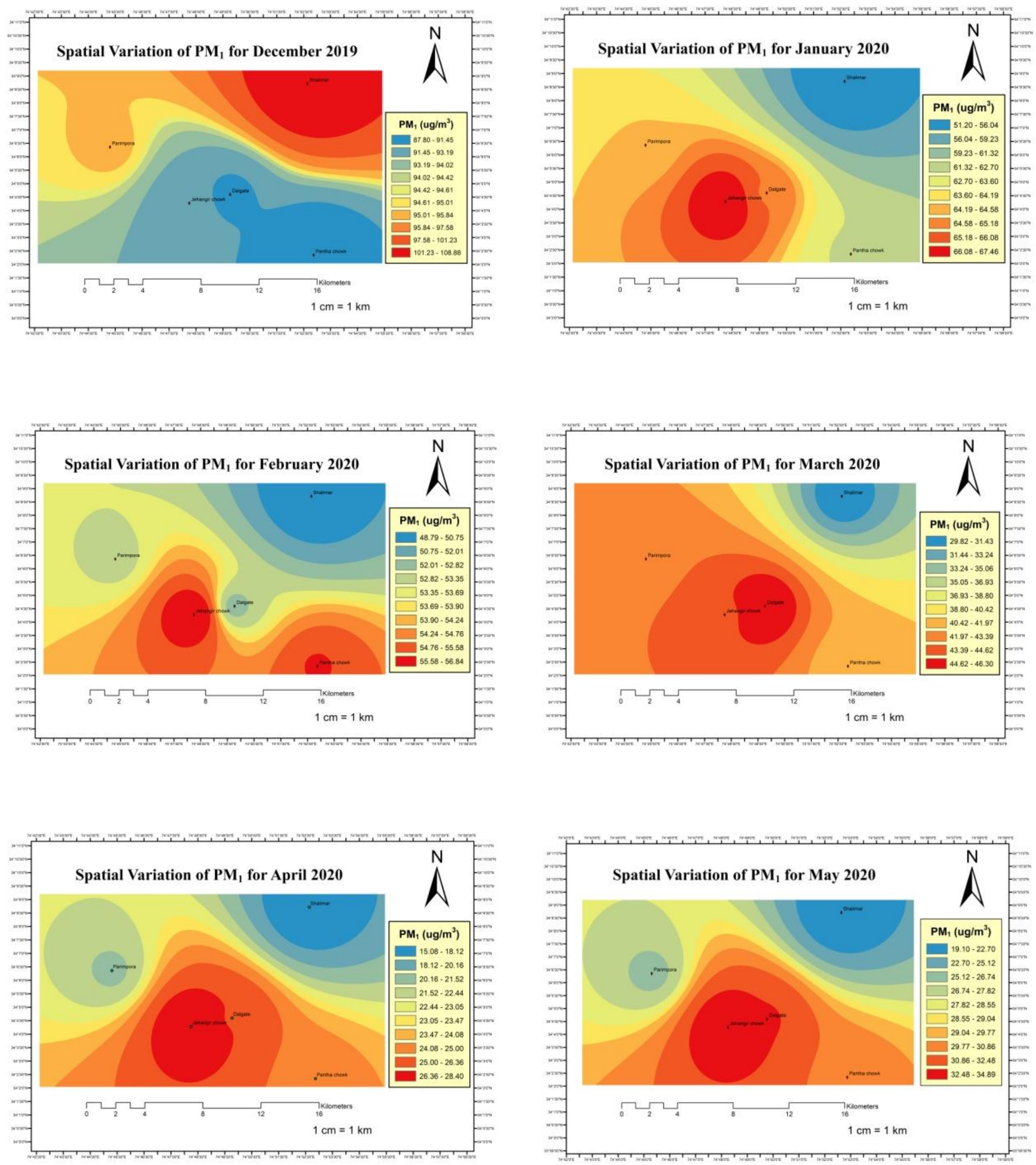

Figure 7: IDW maps showing variation in concentrations of pollutants (PM_1) at different locations during each month from June 2019 to May 2020.

Particulate Matter 2.5 micron size ($PM_{2.5}$)

The data provided (Table 4) shows $PM_{2.5}$ levels (in µg/m³) for various locations from June 2019 to May 2020. There is a significant spike in $PM_{2.5}$ levels during the winter months (November 2019 to January 2020), likely due to factors like increased heating, reduced wind, and atmospheric inversion. $PM_{2.5}$ levels generally start to decrease from February 2020 and continue lowering through May 2020, possibly due to improved weather conditions (e.g., more wind or rain that disperses pollutants). Besides this COVID-19 lockdown was a major reason for the decrease of pollutant level after March 2020. Shalimar shows moderately high levels from June to October 2019 (ranging between 45–87 µg/m³), with a large increase during the winter months (183.70 in November, peaking at 233.67 in December). In Dalgate, $PM_{2.5}$ levels increase steadily throughout 2019, peaking sharply at 577.50 µg/m³ in December 2019. This location has consistently high levels compared to other locations, indicating serious pollution issues, particularly in winter. Jehangir Chowk follows a similar trend to Dalgate, with a sharp increase in $PM_{2.5}$ levels during the winter, reaching 569.77µg/m³ in December. Parimpora starts relatively low in June but sees a dramatic rise in the winter, particularly in December 2019, reaching 497 µg/m³. Pantha Chowk follows the same trend of rising $PM_{2.5}$ during winter, peaking at 571.43 µg/m³ in December 2019.

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Table 4: Concentration of $PM_{2.5}$ (µg/m^3) at different locations in Srinagar city on monthly basis

Location	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20
Shalimar	50.23	45.00	58.50	82.27	87.43	183.70	233.67	77.87	76.80	44.20	28.70	37.53
Dalgate	62.30	68.07	80.67	100.97	137.67	183.37	577.50	123.73	97.60	81.53	50.13	65.10
Jehangir Chowk	68.87	70.67	76.53	99.40	132.30	188.60	569.77	160.17	119.40	77.30	51.83	67.37
Parimpora	50.67	83.50	65.77	80.63	126.33	177.57	497.00	128.67	103.90	75.10	39.90	52.03
Pantha Chowk	72.00	92.40	67.93	90.00	117.77	166.17	571.43	126.47	121.00	72.33	45.43	59.10
C.D.	**10.38**	**10.56**	**1.33**	**4.36**	**5.78**	**7.64**	**40.10**	**7.60**	**8.01**	**3.06**	**3.41**	**4.34**
SE(m)	**3.14**	**3.19**	**0.40**	**1.32**	**1.75**	**2.31**	**12.11**	**2.30**	**2.42**	**0.93**	**1.03**	**1.31**

Table 5: Concentration of $PM_{2.5}$ (µg/m^3) at different locations in Srinagar city on seasonal basis

Location Season	Shalimar	Dalgate	Jehangir Chowk	Parimpora	Pantha Chowk	Mean
Summer	51.27	70.33	72.03	66.63	77.43	**67.54**
Autumn	117.83	140.63	140.07	128.20	124.60	**130.27**
Winter	129.43	266.23	283.10	243.13	272.97	**238.97**
Spring	36.80	65.57	65.50	55.70	58.93	**56.50**
Mean	**83.83**	**135.69**	**140.18**	**123.42**	**133.48**	
	Factor		**C.D**		**SE(d)**	
	Season(S)		3.12		1.54	
	Location(L)		3.49		1.72	
	S×L		6.98		3.43	

All locations show a dramatic spike in $PM_{2.5}$ levels during December 2019, exceeding 500 µg/m³ in some places. This is far above the WHO's guideline for annual $PM_{2.5}$ exposure, which is 5 µg/m³, and even above the 24-hour guideline limit of 15 µg/m³. Dalgate and Jehangir Chowk areas experience the highest pollution, particularly during winter, posing severe health risks to the population, especially those with respiratory conditions. The data reflects severe seasonal pollution in most locations, particularly in winter. Dalgate, Jehangir Chowk, and Pantha Chowk are notably affected, with dangerous $PM_{2.5}$ concentrations in December 2019. Efforts to mitigate pollution, especially during winter, would be crucial to improve air quality and public health in these regions (Li et al., 2015).

The table 5 presents a seasonal summary of $PM_{2.5}$ concentrations across five locations (Shalimar, Dalgate, Jehangir Chowk, Parimpora, Pantha Chowk), alongside their seasonal means and interactions. Below is an interpretation of the seasonal changes and the statistical factors. The mean $PM_{2.5}$ level across locations is 67.54µg/m³, indicating moderate air quality. Pantha Chowk records the highest summer average at 77.43 µg/m³, while Shalimar is the lowest at 51.27 µg/m³. Summer has the lowest pollution levels, likely due to better air dispersion and less heating-related pollution. During Autumn (September–November), the average $PM_{2.5}$ rises sharply to 130.27 µg/m³, signalling a decline in air quality as colder months approach. Dalgate and Jehangir Chowk see the highest autumn averages (140.63 and 140.07 µg/m³, respectively), while Shalimar records the lowest (117.83 µg/m³). The rise in autumn pollution could be due to increased heating, crop burning and other seasonal activities. Winter (December to February) has the highest $PM_{2.5}$ levels, with a mean of 238.97µg/m³, representing a significant increase in pollution. Jehangir Chowk records the highest average $PM_{2.5}$ (283.10 µg/m³), followed by Pantha Chowk (272.97 µg/m³). These values reflect a critical level of pollution, driven by factors such as heating fuel use, atmospheric inversion, and increased combustion activities. The mean $PM_{2.5}$ level during Spring (March-May) drops to 56.50 µg/m³, showing a significant improvement in air quality compared to winter (Mukta et al., 2020). The highest average $PM_{2.5}$ in spring is recorded at Dalgate (65.57 µg/m³), while Shalimar has the lowest at 36.80 µg/m³. Spring offers improved conditions for dispersing pollutants, reducing $PM_{2.5}$ levels. Besides the COVID 19 lockdown during the spring season added to decreasing pollution.

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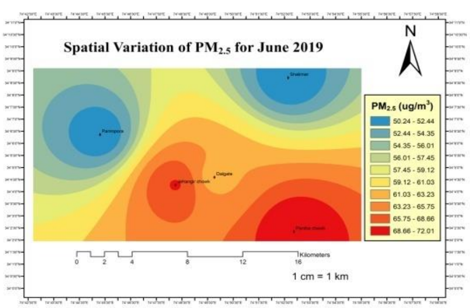
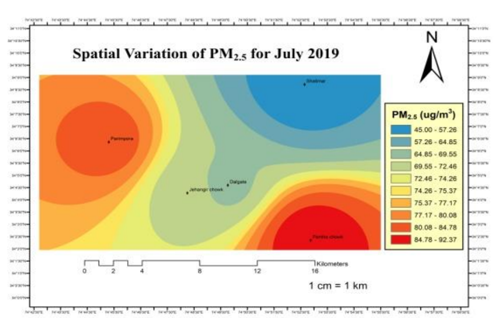
Location-Specific Patterns show that Dalgate and Jehangir Chowk consistently have the highest $PM_{2.5}$ levels across all seasons, with winter being the worst. These locations have higher traffic or industrial activity contributing to sustained poor air quality. Shalimar tends to have the lowest pollution levels in most seasons, particularly in spring and summer, indicating a relatively cleaner environment compared to other locations. Pantha Chowk and Parimpora experience elevated $PM_{2.5}$ levels, particularly in winter, but show improvement in the spring. The Factor C.D. value for season is 3.12 with a standard error (SE(d)) of 1.54, which suggests a significant seasonal effect on $PM_{2.5}$ levels. Pollution levels clearly fluctuate based on the time of year. The Factor C.D. value for location is 3.49 with SE(d) of 1.72, indicating that different locations experience distinct levels of pollution. Some locations are consistently more polluted than others. The interaction effect (season and location combined) is 6.98 with an SE(d) of 3.43. This value suggests that certain seasons affect locations differently. For instance, while Dalgate and Jehangir Chowk experience particularly high spikes in winter, Shalimar and Parimpora may not see as drastic increases.

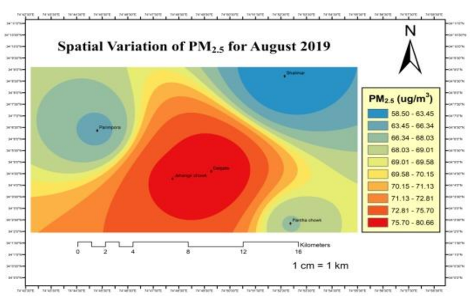
The overall mean $PM_{2.5}$ levels range from 83.83 µg/m³ in Shalimar to 140.18 µg/m³ in Jehangir Chowk. The mean across all locations is quite high, at 122.92 µg/m³, far exceeding the WHO's guideline of annual average for $PM_{2.5}$ exposure, highlighting serious air quality issues. Dalgate, Jehangir Chowk, and Pantha Chowk are the most polluted areas overall. The coloured IDW maps below show the readings as discussed based on the concentrations of pollutants. Based on the colour patterns the pollutants are shown to be high and low. Table 6 verifies the observations where the readings during different time of a day are given on an average basis. The findings are similar to that of PM_1. Figure 8 shows the IDW maps for different months of $PM_{2.5}$ pollutant concentration.

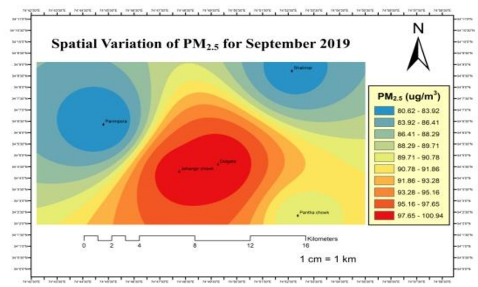
Table 6:Annual average day time concentration of Particulate matter $PM_{2.5}$ (µg/m³) based on time period in Srinagar city

Locations	$PM_{2.5}$			Mean Annual Readings
	Morning	Afternoon	Evening	
Shalimar	98.07	71.67	81.73	**83.82**
Dalgate	173.77	111.07	122.30	**135.71**
Jehangir Chowk	161.63	119.07	139.83	**140.17**
Parimpora	153.37	102.43	114.40	**123.40**
Pantha Chowk	163.03	111.23	126.17	**133.47**
CD.	**12.79**	**4.61**	**2.78**	
SE(m)	**3.86**	**1.39**	**0.84**	









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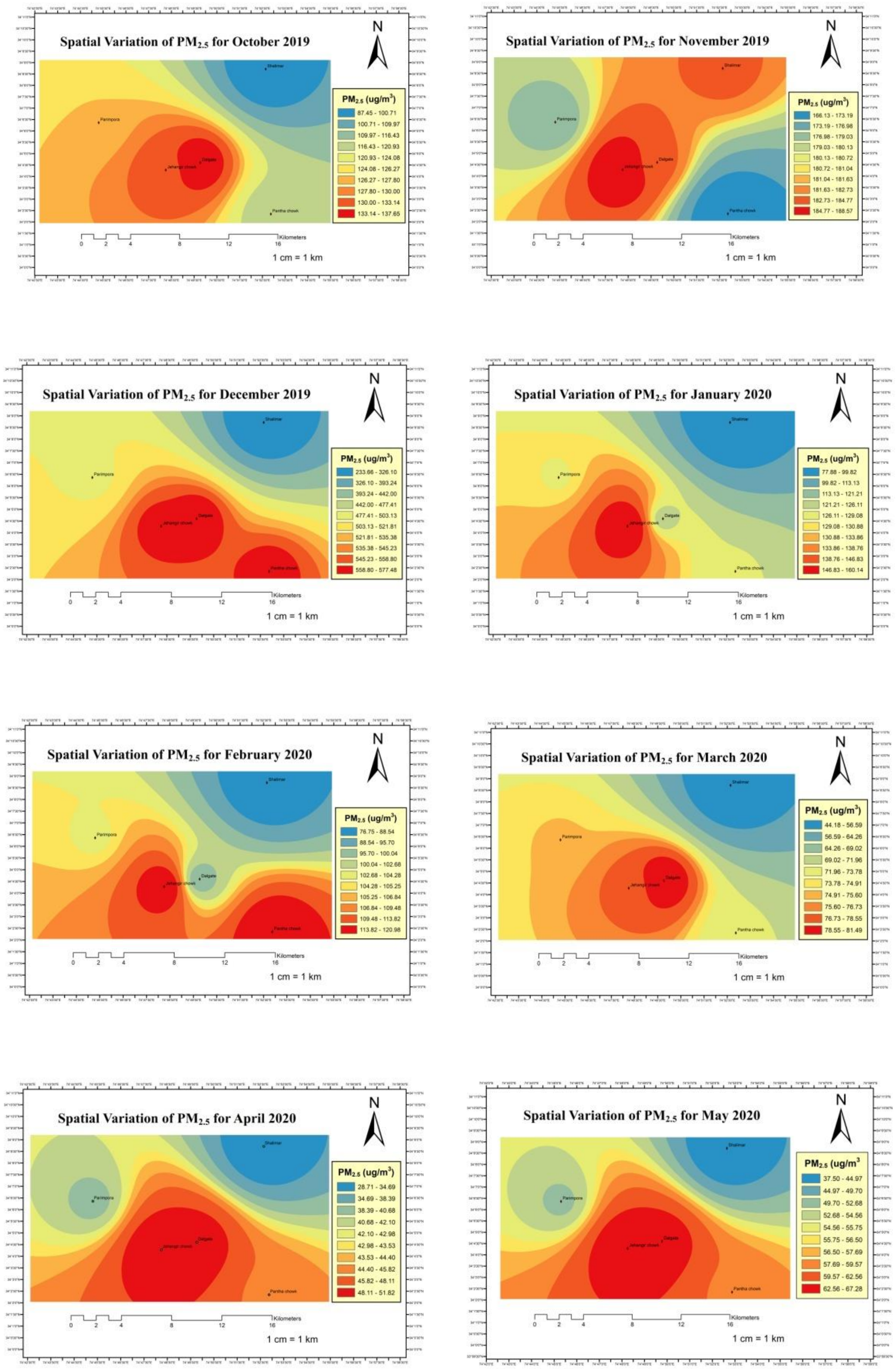

Figure 8: IDW maps showing variation in concentrations of pollutants ($PM_{2.5}$) at different locations during each month from June 2019 to May 2020.

IV. Conclusion

The major observations from the readings suggest that the pollutant levels in the locations of city limits were high. Baring the unusual spike in Shalimar during the December 2019 month which may be due to the localised burning of crops in fields, this location was seen to be the least polluted. Shalimar location being in the outskirts of city near to a village saw less pollution. The

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city areas like Dalgate and Jehangir Chowk showed incredibly high pollutants level. The increased vehicular movement with less managed traffic showed stagnation of vehicles in thes places giving higher pollutant concentrations. Even during the COVID19 lockdown, the locations had higher concentration of pollutants in the city as compared to the Shalimar location.

References

1. Anonymous, 2016-2017. Road Transport year book 2016-2017. Ministry of Road Transport & Highway Transport. Govt. of India.
2. Bhandarkar, S. (2013). Vehicular pollution, their effect on human health and mitigation measures. Veh. Eng, 1(2), 33-40.
3. CPCB (2018). Guidelines for continuous emission monitoring systems (Revision 1). New Delhi, India: Central Pollution Control Board, Government of India.
4. IQAir (2022). World Air Quality Report 2022. https://www.iqair.com/world-air-quality-report.
5. Li, R., Li, Z., Gao, W., Ding, W., Xu, Q., & Song, X. (2015). Diurnal, seasonal, and spatial variation of PM2. 5 in Beijing. Science Bulletin, 60(3), 387-395.
6. Mukta, T. A., Hoque, M. M. M., Sarker, M. E., Hossain, M. N., & Biswas, G. K. (2020). Seasonal variations of gaseous air pollutants (SO2, NO2, O3, CO) and particulates (PM2. 5, PM10) in Gazipur: an industrial city in Bangladesh. Advances in Environmental Technology, 6(4), 195-209.
7. Remer, L. A., Kaufman, Y. J., Tanre, D., Mattoo, S., Chu, D. A., Martins, J. V., Li, R. R., Ichoku, C., Levy, R. C., Kleidman, R. G., Eck, T. F., Vermote, E. and Holben, B. N. 2005. The MODIS aerosol algorithm, products and validation. Journal of the Atmospheric Sciences **62**: 947-973.
8. Samad, A. et al. (2020) “Vertical Distribution of particulate matter, Black Carbon and ultra-fine particles in Stuttgart, Germany,” Atmospheric Pollution Research, 11(8), pp. 1441–1450. Available at: https://doi.org/10.1016/j.apr.2020.05.017.
9. Tong, R., Liu, J., Wang, W., & Fang, Y. (2020). Health effects of PM2. 5 emissions from on-road vehicles during weekdays and weekends in Beijing, China. Atmospheric Environment, 223, 117258.
10. WHO, 1976. Elected Methods of Measuring Air Pollutants. WHO offset publication No. 24E, World Health Organization, Geneva.

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Competing Interests

The authors have no relevant financial or non financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Nikhil Savio. The first draft of the manuscript was written by Nikhil Savio and Farooq Ahmed Lone and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethical Approval

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Not Applicable

Consent to Publish

Not Applicable

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Data Availability Statement

Further data will be available on request if provided the need.