

Assessment of Dust Sample for PM₁₀ & PM_{2.5} Fraction to E-stablish its Impact in Satna City (M.P.) India

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Abstract:

This research paper aims at establishing baseline PM₁₀ and PM_{2.5} concentration levels in Satna city. The relative contribution of PM₁₀ and PM_{2.5} concentrations are to be investigated in the city because of the city being overcrowded, congested and deteriorating air quality because of vehicular pollution. Dust lying on the roads is rich in fine particles which are lifted up by the movement of vehicles and become airborne in the atmosphere. Dust lifts up from the roads, remains a continuous line source and impacts fine dust levels into the atmosphere. Emissions depend upon the load/weight and speed of vehicles and humidification of the dust besides the type of dust on the roads. Another major source of fine particles are stock piles of construction material in urban centres. Last but not least, climate change resulting from environmental pollution affects the geographical distribution of many infectious diseases, as do natural disasters. The only way to tackle this problem is through public awareness coupled with a multidisciplinary approach by scientific experts. Particulate matter pollution is a significant environmental concern globally, linked to various adverse health effects. This research study employs a systematic approach, combining field measurements, data analysis, and literature review to evaluate the current scenario of PM₁₀ and PM_{2.5} pollution in Satna City. The findings will contribute to a better understanding of the local air quality situation and facilitate the development of effective mitigation strategies.

Keywords:: Dust sample characterization, ambient air pollution, particulate matter, PM₁₀ and PM_{2.5}

1. Introduction:

Ambient air pollution refers to the contamination of outdoor air by harmful substances originating from both natural and anthropogenic sources. It has emerged as one of the most critical environmental challenges worldwide due to its adverse impacts on human health, ecosystems, climate, and overall quality of life (World Health Organization [WHO], 2022). Common sources of ambient air pollution include industrial processes, vehicular emissions, power generation, residential fuel combustion, agricultural activities, construction operations, mining activities, and natural phenomena such as dust storms and volcanic eruptions (UNEP, 2023; USEPA, 2024). These sources release a variety of pollutants into the

atmosphere, including particulate matter (PM), sulfur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO), ozone (O₃), volatile organic compounds (VOCs), and toxic trace metals.

Among these pollutants, particulate matter, particularly PM₁₀ and PM_{2.5}, has gained significant attention because of its ability to remain suspended in the atmosphere for extended periods and penetrate deep into the human respiratory system. PM₁₀ consists of particles with aerodynamic diameters less than 10 µm, while PM_{2.5} includes particles smaller than 2.5 µm. Due to their small size, PM_{2.5} particles can reach the alveolar regions of the lungs and even enter the bloodstream, causing severe health effects including respiratory diseases, cardiovascular disorders, lung cancer, and premature mortality (WHO, 2022; Health Effects Institute [HEI], 2024).

Road dust is recognized as one of the major contributors to ambient particulate matter concentrations in urban environments. Dust deposited on paved and unpaved roads is resuspended into the atmosphere by vehicular movement, wind action, and other mechanical disturbances. The contribution of road dust to ambient PM₁₀ and PM_{2.5} levels varies depending on traffic volume, road conditions, meteorological factors, and surrounding land-use characteristics (Pant & Harrison, 2013). Therefore, characterization of road dust and determination of its PM₁₀ and PM_{2.5} fractions are essential for understanding its contribution to urban air pollution.

Accurate assessment of particulate fractions requires advanced analytical and instrumental techniques. Conventional methods used for particle-size fractionation often involve time-consuming procedures and may not provide sufficient precision for detailed source characterization. Consequently, there is a need to develop improved instrumental techniques capable of rapidly and accurately determining PM₁₀ and PM_{2.5} fractions in dust samples. Impactor-based and dichotomous sampling technologies have been widely recognized as effective approaches for particulate matter fractionation and source apportionment studies (Chow et al., 2020).

The present study proposes the development and application of a sampling and analysis system based on impactor and dichotomous separation principles for the characterization of road dust. The generated data will be used to evaluate the contribution of road dust to ambient PM₁₀ and PM_{2.5} concentrations in urban areas. Furthermore, emission loads from paved and unpaved roads can be estimated using the AP-42 emission factor methodology developed by the United States Environmental Protection Agency (USEPA, 2024). Such information can support air quality modelling, prediction of particulate matter concentrations, and formulation of effective air pollution control strategies.

Fine particulate matter remains suspended in the atmosphere for prolonged periods due to its low settling velocity, facilitating long-range transport and widespread exposure of human populations and ecosystems (Seinfeld & Pandis, 2016). In addition to human health impacts, particulate pollution affects visibility, contributes to haze formation, alters nutrient balances in aquatic ecosystems, damages forests and agricultural crops, and disrupts ecological processes (UNEP, 2023). Therefore, understanding the characteristics and sources of particulate matter is essential for effective environmental management and sustainable urban development.

Mitigation of ambient air pollution requires integrated efforts involving regulatory frameworks, technological advancements, improved transportation systems, cleaner energy technologies, and enhanced public awareness. Comprehensive assessment of particulate matter sources, particularly road dust, can provide valuable information for policymakers and environmental agencies in designing targeted control measures and improving urban air quality. Such efforts are crucial for protecting public health, preserving environmental quality, and achieving long-term sustainability goals.

2. Sources of PM10 and PM2.5

Particulate matter (PM) is a general term for extremely small particles and liquid droplets in the atmosphere. PM10 refers to inhalable particles with diameters that are generally 10micrometres and smaller, while PM2.5 refers to fine inhalable particles with diameters that are generally 2.5micrometres and smaller PM10 & PM2.5 often derive from different emissions sources, and also have different chemical compositions. Emissions from combustion of gasoline, oil, diesel fuel or wood produce much of the PM10 pollution found in outdoor air, as well as a significant proportion of PM10. PM10 also includes dust from construction sites, landfills and agriculture, wildfires and brush/waste burning, industrial sources, wind-blown dust from open lands, pollen and fragments of bacteria. PM may be either directly emitted from sources (primary particles) or formed in the atmosphere through chemical reactions of gases (secondary particles) such as sulphur dioxide (SO₂), nitrogen oxides (NO_x), and certain organic compounds. These organic compounds can be emitted by both natural sources, such as trees and vegetation, as well as from man-made (anthropogenic) sources, such as industrial processes and motor vehicle exhaust.

AQI Category	AQI	Concentration range*							
		PM ₁₀	PM _{2.5}	NO ₂	O ₃	CO	SO ₂	NH ₃	Pb
Good	0 - 50	0 - 50	0 - 30	0 - 40	0 - 50	0 - 1.0	0 - 40	0 - 200	0 - 0.5
Satisfactory	51 - 100	51 - 100	31 - 60	41 - 80	51 - 100	1.1 - 2.0	41 - 80	201 - 400	0.5 - 1.0
Moderately polluted	101 - 200	101 - 250	61 - 90	81 - 180	101 - 168	2.1 - 10	81 - 380	401 - 800	1.1 - 2.0
Poor	201 - 300	251 - 350	91 - 120	181 - 280	169 - 208	10 - 17	381 - 800	801 - 1200	2.1 - 3.0
Very poor	301 - 400	351 - 430	121 - 250	281 - 400	209 - 748*	17 - 34	801 - 1600	1200 - 1800	3.1 - 3.5
Severe	401 - 500	430 - +	250+ -	400+ -	748+* -	34+ -	1600+ -	1800+ -	3.5+ -

* CO in mg/m³ and other pollutants in µg/m³; 2h-hourly average values for PM₁₀, PM_{2.5}, NO₂, SO₂, NH₃, and Pb, and 8-hourly values for CO and O₃.

Table 1. Standard categorization of PM10 and PM10

The table contains the standard categorization of the PM10 and PM2.5

3. Dichotomous Air Sampler

A dichotomous air sampler is a type of air sampling device used to collect airborne particles for analysis in environmental monitoring, occupational health studies, or research purposes. It is designed to separate particles into two size fractions: the inhalable fraction and the respirable fraction. The dichotomous air sampler works by drawing air through an inlet and then dividing the sample into two size fractions using

a size-selective inlet or impactor. This separation is achieved by directing the air stream through a series of nozzles or impaction plates, which allow particles of different sizes to be collected on separate filters. The sampler typically consists of the various components which are inlet, impacted plates, filters, pump and flow controller. The inlet is designed to control the size of the particles entering the sampler. It may include a size-selective inlet, such as a cyclone or impactor, to separate particles based on their aerodynamic size. The impactor plates are used to separate the air stream into two fractions. They are designed with precision nozzle sizes or impaction surfaces that allow particles of specific sizes to impact and deposit onto separate filters. The sampler has two filters, one for each fraction. The inhalable fraction filter collects larger particles, while the respirable fraction filter collects smaller particles. These filters are typically made of materials such as glass fibre or cellulose and are later analysed for particle content. A pump is used to draw air through the sampler at a specified flow rate. It creates the necessary vacuum to pull the air sample through the inlet and onto the filters. The flow controller ensures that the air is drawn through the sampler at a constant flow rate, usually measured in liters per minute (L/min). After sampling, the filters can be removed and analysed using various methods such as gravimetry, microscopy, or chemical analysis to determine the type and concentration of particles collected in each fraction.

Dichotomous air samplers are valuable tools in assessing air quality, investigating occupational exposures, and studying particulate matter in various environments. They provide important data for understanding potential health risks associated with airborne particles and can aid in regulatory compliance and decision-making processes. The dichotomous air sampler is a dual-filter air sampler for the simultaneous collection of the fine PM₁₀ and the coarse PM₁₀ particles contained within PM₁₀. The dichotomous air sampler allows differential mass determination between the fine and coarse fractions contained within inhalable particulate matter. This instrument also allows the user to perform chemical analysis comparison of the two size fractionated samples.

The basic premise of this instrument is the dual flow configuration. This proven technology utilizes two flow-controlled channels that adjust the flow to a constant volumetric flow rate within each channel. Information from standard pressure and temperature sensors is measured, stored and used to make the corrected flow rate possible. A well-engineered user interface and touch screen display allow the operator complete control over this instrument with very little training. Flow data, event markers, pressure and temperature data can be downloaded from any internet connection via an on-board IP address. An optional weather station is available to monitor and log air temperature, barometric pressure, relative humidity, precipitation amount, wind direction and wind speed. All of this information is stored on a very large removable memory card. Traditional 47 mm filter cassettes and the classic PM₁₀ (16.7 LPM) inlet are used for their well-documented reliability and user familiarity.

Dichotomous Sampling: Dichotomous sampling is a technique used in environmental monitoring to separate and collect airborne particles or gases based on their size or other properties. It involves the use of a sampling device that divides the air stream into two separate fractions, typically based on aerodynamic particle size. The fractions collected can then be analysed separately to determine the concentration and composition of specific particles or gases.

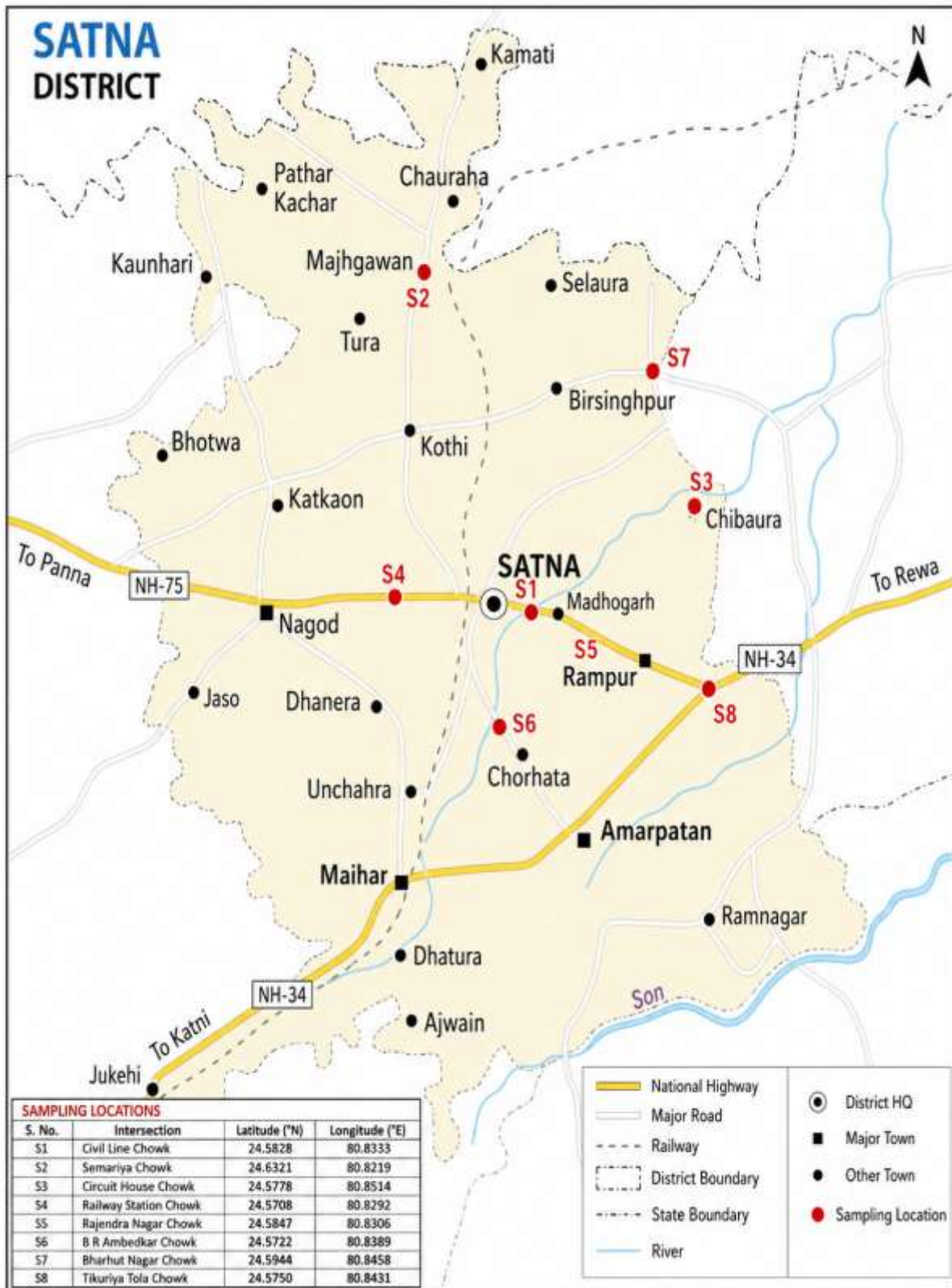
4. Sampling Area and Sample Collection Procedure

Certain Sample collection points have been chosen in Satna city to analyse the concentration of PM₁₀ and PM_{2.5}. Civil Line Chowk , Semariya Chowk ,Circuit House Chowk ,Railway Station Chowk,

Rajendra Nagar Chowk, B R Ambedkar Chowk, Bharhut Nagar Chowk, Tikuriya Tola Chowk. These 8 sample collection points have been taken to collect dust samples.

The materials used to carry out this analysis are brush, dust collection pan, oven and sieves of sizes 600 micron, 250 micron, 180 micron and 75 microns





Map of Satna

Statistics Table for Sampling Stations: Study Area Locations

S. No.	Intersection	Approx. Latitude	Approx. Longitude	Traffic Category
1	Civil Line Chowk	24.5828° N	80.8333° E	Very High
2	Semariya Chowk	24.6321° N	80.8219° E	High
3	Circuit House Chowk	24.5778° N	80.8514° E	High
4	Railway Station Chowk	24.5708° N	80.8292° E	Very High
5	Rajendra Nagar Chowk	24.5847° N	80.8306° E	High
6	B R Ambedkar Chowk	24.5722° N	80.8389° E	Very High
7	Bharhut Nagar Chowk	24.5944° N	80.8458° E	Moderate–High
8	Tikuriya Tola Chowk	24.5750° N	80.8431° E	High

Dust sample Collection Procedure:

1. Collected Dust With the help of Brush and Pan from the road for 3 times in an interval of 15 days for each location.
2. Sieved it down through 600 > 250 > 180 > 75 Micron Sieves.
3. Collected the sieved dust and put it in an oven 90 degree Celsius for 1 Hr.
4. Took a sample of 3 gm dust.

5. Material & Methodology:

A dichotomous air sampler is a device used to collect airborne particles for analysis, typically in environmental monitoring or occupational health studies. It operates by separating particles into two size fractions: respirable and non- respirable.

Ensuring the sampler is clean and in proper working condition. Calibration is done for the sampler according to the manufacturer's instructions, if required. A suitable filter media to the sampler is attached. The filter media should be appropriate for the type of particles to collect and analyse. Sampling duration should be determined based on the specific requirements of study or regulations governing air sampling. Setting of flow rate is carried out of the sampler according to the manufacturer's instructions or as per the sampling protocol. Typically, the flow rate is adjusted to separate particles into respirable and non-respirable fractions. Ensuring that the sampler is operating correctly before initiating the sampling, the sampler at the designated start time is started and the sampler is set to collect samples for the desired duration.

Dichotomous Dust sampler Operation Procedure:

1. Carefully cleaned the dust chamber, impactor and cabinet.
2. Filter put in Deducator with blue silica.
3. Got 20-25% humidity for 24Hrs.
4. Took initial filter paper weight and without filter holder.

5. Put filter paper in Holder **PM10 & PM2.5**
6. Set the run time to 60 mins in data logger for machine run
7. Set the log rate at 2 mins.
8. Started the machine
9. Flow rate set with the help of Rota meter at 16.5 Lpm (Litres per minute) pressure
10. After 60 mins removed the filter holder and weighted the final dust

6. Result and Discussion

We have taken a sample of 8 points in Satna and done analysis with the help of a dichotomous dust sampler and got different results with different days and then aggregate concentration of PM10 and PM2.5 has been determined. All these data are shown in the following table

S. No.	Location	1 May	16 May	30 May	Aggregate Mean
1	Civil Line Chowk	96.00	104.00	119.00	106.33
2	Semaria Chowk	93.00	105.67	123.33	107.33
3	Circuit House Chowk	92.33	100.33	123.33	105.33
4	Railway Station Chowk	103.67	124.00	145.00	124.22
5	Rajendra Nagar Chowk	90.67	92.33	115.00	99.33
6	B. R. Ambedkar Chowk	96.00	108.67	130.67	111.78
7	Bharhut Nagar Chowk	94.00	103.33	113.67	103.67
8	Tikuriya Tola Chowk	95.00	105.33	122.33	107.56

S. No.	Location	1 May	16 May	30 May	Aggregate Mean
1	Civil Line Chowk	27.00	29.00	24.00	26.67
2	Semaria Chowk	23.00	32.00	43.00	32.67
3	Circuit House Chowk	22.00	26.67	33.00	27.22
4	Railway Station Chowk	34.00	42.00	46.00	40.67
5	Rajendra Nagar Chowk	22.33	22.67	29.67	24.89
6	B. R. Ambedkar Chowk	31.00	36.00	40.00	35.67
7	Bharhut Nagar Chowk	21.00	27.67	32.00	26.89
8	Tikuriya Tola Chowk	23.00	30.00	37.33	30.11

A total of 8 collection points were selected in Satna city to analyze concentration of PM10 and PM2.5. In the summer season it is found that heat waves often lead to poor air quality. The extreme heat and stagnant air during a heat wave increase the amount of particulate pollution.

Key Findings:

- Highest PM10 concentration: Railway Station Chowk (124.22 µg/m³)
- Highest PM2.5 concentration: Railway Station Chowk (40.67 µg/m³)
- Lowest PM10 concentration: Rajendra Nagar Chowk (99.33 µg/m³)
- Lowest PM2.5 concentration: Rajendra Nagar Chowk (24.89 µg/m³)
- Most variable PM10 levels: Railway Station Chowk (SD = 18.05)
- Most variable PM2.5 levels: Semariya Chowk (SD = 8.76)

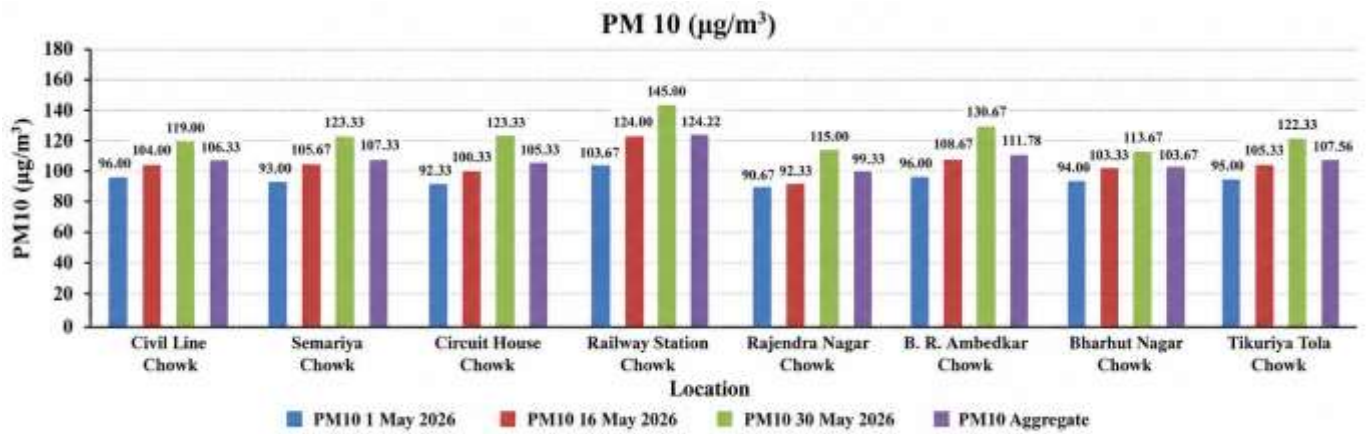
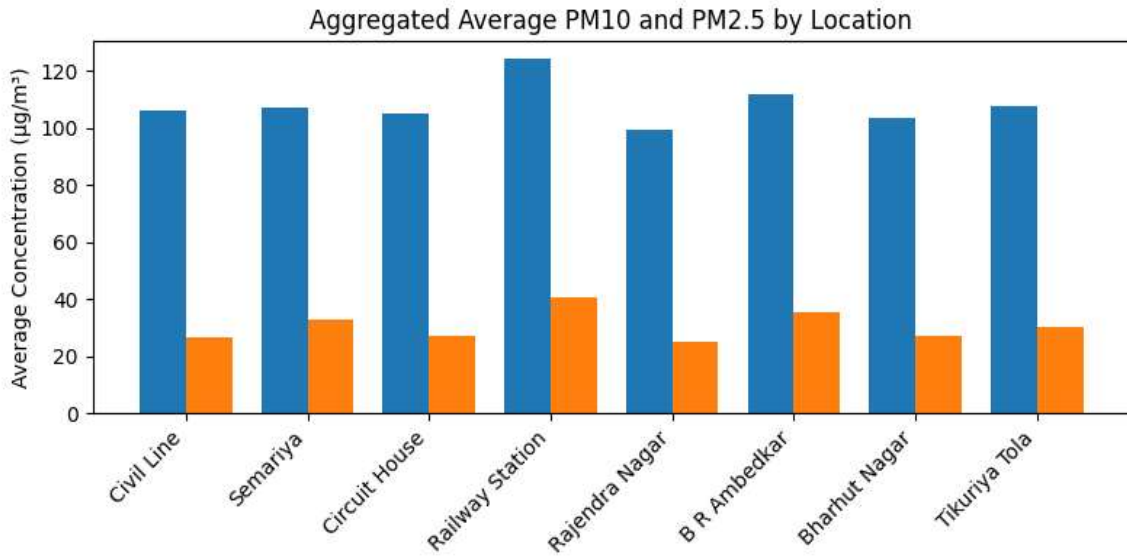


Fig 5.1: Graphical representation of PM10 concentration

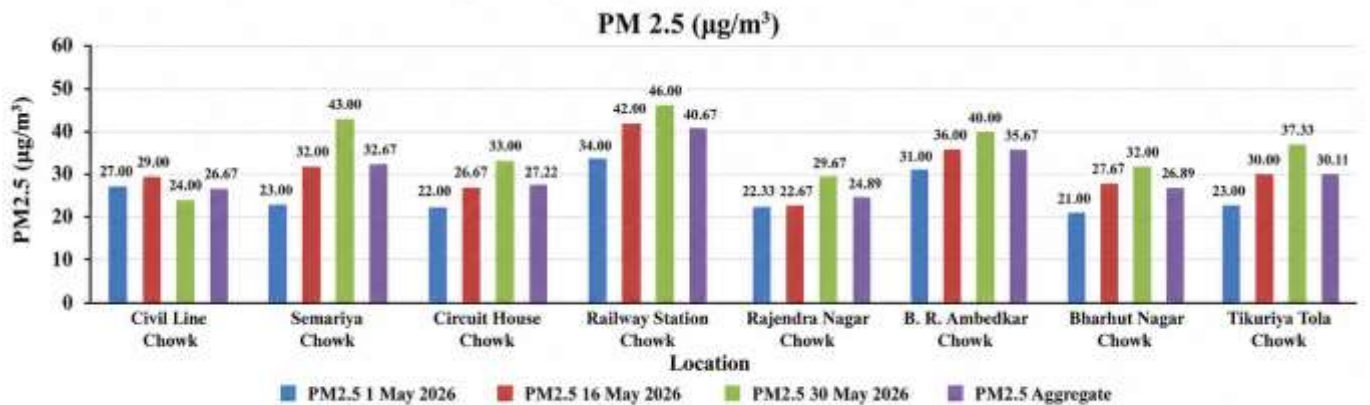


Fig 5.2: Graphical representation of PM2.5 concentration

Fig 5.1: Graphical Representation of PM10 Concentration

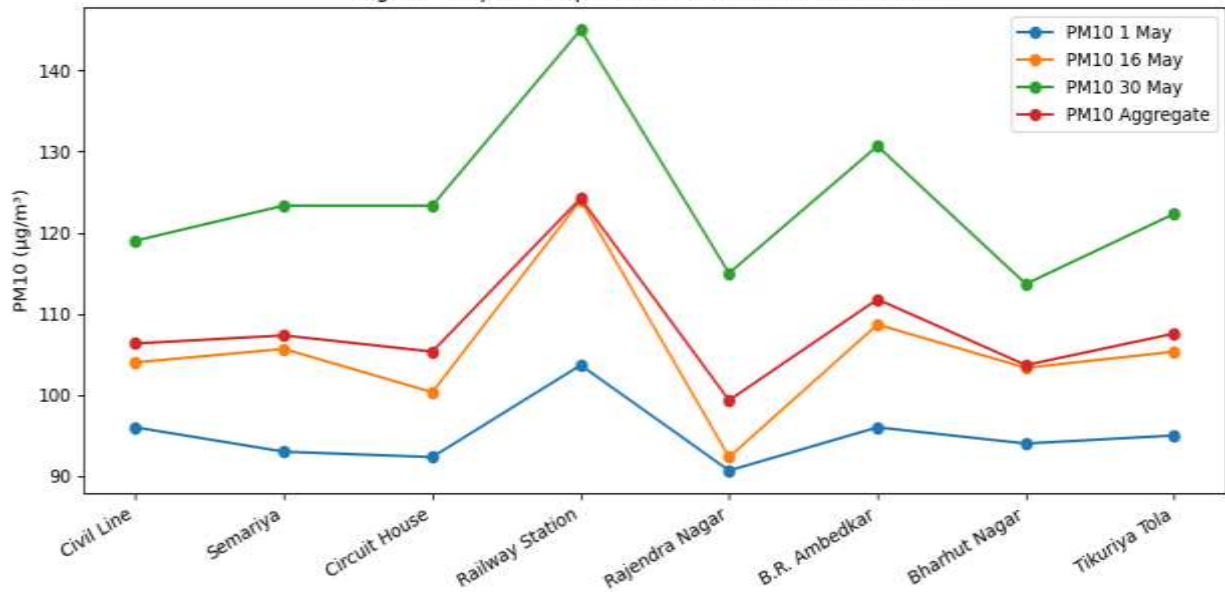
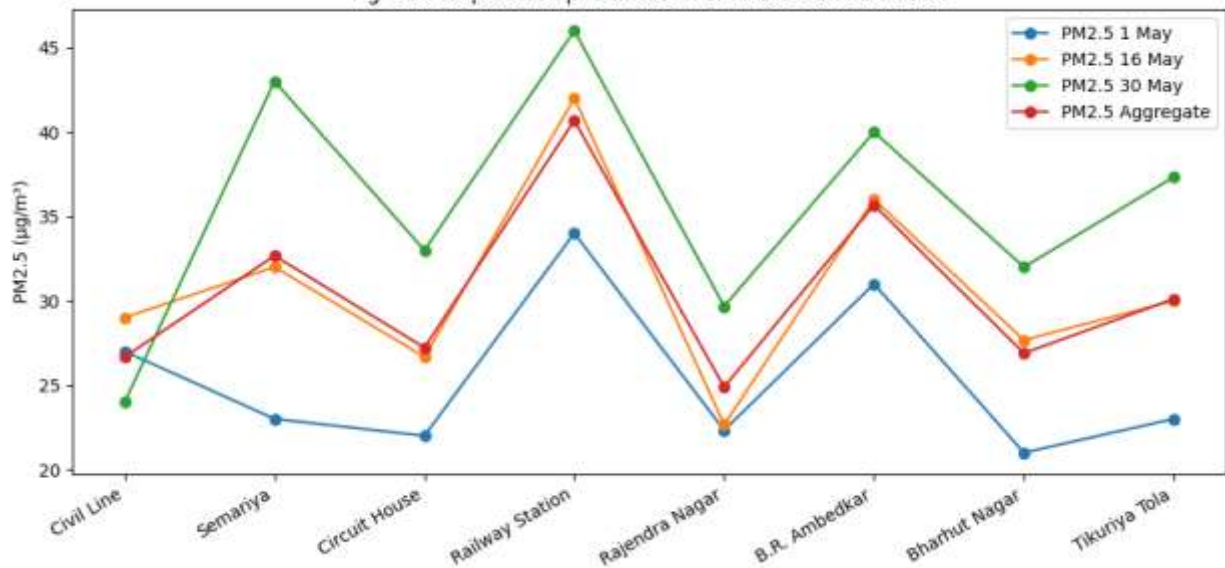


Fig 5.2: Graphical Representation of PM2.5 Concentration



7. Conclusion

The ambient air quality assessment conducted at eight major traffic intersections of Satna City revealed noticeable spatial variations in particulate matter concentrations. The aggregated PM_{2.5} concentrations ranged from 24.89 µg/m³ to 40.67 µg/m³, while PM₁₀ concentrations varied between 99.33 µg/m³ and 124.22 µg/m³. Based on the National Air Quality Index (AQI) classification, PM_{2.5} levels at Civil Line Chowk, Circuit House Chowk, Rajendra Nagar Chowk, and Bharhut Nagar Chowk were categorized as Good, whereas Semariya Chowk, Railway Station Chowk, Dr. B.R. Ambedkar Chowk, and Tikuriya Tola Chowk fell under the Satisfactory category. In contrast, PM₁₀ concentrations at most monitoring locations were classified as Moderately Polluted, except Rajendra Nagar Chowk, which remained in the satisfactory category.

Among all locations, Railway Station Chowk recorded the highest concentrations of both PM_{2.5} (40.67 µg/m³) and PM₁₀ (124.22 µg/m³), indicating the significant influence of heavy traffic movement, vehicular emissions, road dust resuspension, and commercial activities. Conversely, Rajendra Nagar Chowk exhibited the lowest particulate matter levels, suggesting relatively lower traffic density and better environmental conditions. The results indicate that while fine particulate matter (PM_{2.5}) generally remained within acceptable limits, coarse particulate matter (PM₁₀) showed elevated concentrations at several locations, highlighting the contribution of road dust and traffic-related activities to ambient air pollution.

Overall, the study demonstrates that traffic intersections are critical hotspots of particulate pollution in Satna City. Although the observed PM_{2.5} levels indicate relatively good air quality, the predominance of Moderately Polluted PM₁₀ conditions at most locations suggests the need for effective air quality management measures. Regular road cleaning, dust suppression techniques, improved traffic management, promotion of cleaner transportation systems, and increased urban greenery are recommended to reduce particulate pollution and improve the ambient air quality of the city.

REFERENCES:

1. Amato, F., Pandolfi, M., Escrig, A., Querol, X., Alastuey, A., Pey, J., Perez, N., & Hopke, P. K. (2014). Quantifying road dust resuspension in urban environments. *Atmospheric Environment*, 77, 520–529.
2. Chow, J. C., Watson, J. G., Lowenthal, D. H., & Chen, L. W. A. (2020). PM_{2.5} source apportionment and health effects. *Journal of the Air & Waste Management Association*, 70(6), 565–593.
3. Health Effects Institute (HEI). (2024). *State of Global Air 2024*. Boston, MA, USA.
4. Pant, P., & Harrison, R. M. (2013). Estimation of the contribution of road traffic emissions to particulate matter concentrations. *Atmospheric Environment*, 77, 78–97.
5. Seinfeld, J. H., & Pandis, S. N. (2016). *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change* (3rd ed.). Wiley.
6. United Nations Environment Programme. (2023). *Air Pollution and Human Health: Global Assessment Report*.
7. United States Environmental Protection Agency (USEPA) AP-42 Emission Factors. (2024).
8. World Health Organization (WHO) Global Air Quality Guidelines. (2022). Geneva, Switzerland.
9. Srivastava AK, Singh RS, Sachan AK (2002) Level of air contaminants in Jhansi city. *Indian Journal of Environmental Protection* 22: 327-328 Published August 22, 2016.
10. [2] BIS, “Indian Standard Methods for Measurement of Air Pollution: Part IV—Suspended Matter,” Bureau of Indian Standards, New Delhi, 1974, 11 p.
11. [3] CPCB, “National Ambient Air Quality Standards,” 2009.
12. http://www.cpcb.nic.in/National_Ambient_Air_Quality_Standards.php.
13. CPCB, “Standards for Liquid Effluents, Gaseous Emission, Automobile Exhaust, Noise and Ambient Quality, Pollution Control and Law Series,” Ministry of Environment and Forests, Government of India, New Delhi, 1995- 1996.
14. Sharma BS (2005) “Status of ambient air quality of Taj City- Agra”. CPCB 24: 347-351, published online: 14 June 2014.
15. Barnawal J (2017) The Impact of Traffic Related Air Pollution at Various Sites in Noida. *Environ Pollute Climate Change* 1: 136. 10.4172/2573-458X.1000136 Published August 19, 2017.

16. Z. Ali, A. Rauf, S. Sidra, Z. A. Nasir and I. Colbeck “Air Quality(Particulate Matter) At Heavy Traffic Sites In Lahore Pakistan”, 25(3 Supp. 2) 2015 Special Issue Page: 644-648 ISSN: 1018-7081
17. Milind R. Gidde, Pravin P.Sonawane Assessment of Traffic Related Air Pollution and Ambient Air Quality of Metropolitan Cities (Case Study of Pune City) IOSR Journal of Engineering (IOSRJEN) ISSN: 2250-3021 Volume 2, Issue 6 (June 2012), PP 1382-1390.
18. Spandana, B., Rao, S.S., Upadhya, A.R., Kulkarni, P., Sreekanth, V. (2021). PM_{2.5}/PM₁₀ ratio characteristics over urban sites of India. *Advances in Space Research*, 67(10), 3134-3146.
19. Lavanyaa, V.P., Varshini, S., Mitra, S.S., Hungund, K.M., Majumdar, R., Srikanth, R. (2022). Geospatial Modelling for Estimation of PM_{2.5} Concentrations in Two Megacities in Peninsular India. *Aerosol and Air Quality Research*, 22(7), 220110.
20. Singh, R.P., Dey, S., Tripathi, S.N., Tare, V., Holben, B. (2016). A study of PM_{2.5} and PM₁₀ concentrations in the atmosphere of large cities in northern India using ground observations and satellite data. *Journal of Earth System Science*, 125(4), 855-866.