

# IDENTIFICATION OF PARTICULATE MATTER HOTSPOTS IN THE CITY OF PRAYAGRAJ DUE TO VEHICULAR EMISSIONS USING DISPERSION MODELLING

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## ABSTRACT

Air pollution is the leading risk factor behind the world – wide mortality. The population size is growing day by day feeding industrial activity through demand channel, vehicular pollution accompanied by rapid urbanization and burning of fossil fuels pose a serious threat to clean air. The major air pollutants under this study in the city of Prayagraj are Particulate Matter (PM<sub>10</sub> and PM<sub>2.5</sub>). Pollution profile of the city localities were from Phaphamau in north to Naini in south of the city and from Bamrauli in the west to Daraganj in the east of the city, all the other important localities were taken under this defined area. PM<sub>10</sub> and PM<sub>2.5</sub> level in Naini region were found to be in the range of 7.0-9.0  $\mu\text{g}/\text{m}^3$  and 3.0-5.0  $\mu\text{g}/\text{m}^3$  respectively. Similarly, all the other important areas of Prayagraj were highlighted and its concentration values were found out using AERMOD dispersion model. The findings of the paper will help the local administration, municipal corporation and various stake holders of the city and the state to take targeted measures to curb down the pollution coming from vehicular sources in the city of Prayagraj. It will also raise public awareness about pollutant levels in their area.

**Keyword:** - Air Pollution, PM<sub>10</sub>, PM<sub>2.5</sub>, AERMOD

## 1. INTRODUCTION

Modelling of air pollution is a numerical method for describing the causal relationship between emissions, meteorology, atmospheric concentrations, deposition, and other variables. Measurements of air pollution provide valuable quantitative data. They can only characterise air quality by talking about ambient concentrations and deposition without providing explicit information on identification at certain locations and times one of the causes of the poor air quality. A dispersion model can be depending on emissions and meteorological data, acclimated to anticipate concentrations at specified downwind receptor locations. These all-air quality models are used to determine if NAAQS and other regulatory requirements, such as the New Added Source Review and Prevention of Significant Deterioration regulations, are being followed. An easy technique to approximate the dispersion process is to use the Gaussian dispersion model. It's worth noting that, as in the coin toss example, this normal distribution only emerges after a period of time. The higher the concentration, the closer you are to the core of a plume. The concentration decreases as you move away from the centerline (toward the curve's edges) and different models display different results.

The model which is been used is the AERMOD, it is a fi state plume model that includes handling of both surface and uplifted sources, as well as simple and multiplex topography, and adds air dispersion is based on the planetary boundary layer turbulence structure and on the scaling ideas. The America Meteorological Society/EPA Regulatory Model Improvement Committee AERMIC was developed to incorporate cutting-edge modelling principles into the EPA's air quality models. AERMIC introduced the AERMOD modelling system, which included air dispersion

based on planetary boundary layer turbulence structure and scaling concepts, as well as handling of both the surface and the elevated sources as well as the simple and complex topography. AERMET, a meteorological data preprocessor that integrate air dispersion based on planetary boundary layer turbulence structure and scaling concepts, and AERMAP, a terrain data preprocessor that incorporates complex terrain using USGS Digital Elevation Data, are both regulatory components of the AERMOD modelling system. AERSCREEN, a screening version of AERMOD; AERSURFACE, a surface characteristics preprocessor; and BPIP PRIM, a multi-building dimensions programme containing the GEP technical procedures for PRIME applications, are all non-regulating components of this system. The AERMOD model offers a big spread range of alternatives for simulating the effects of pollution sources on air quality, making it a well-known choice among modellers for a various other application.

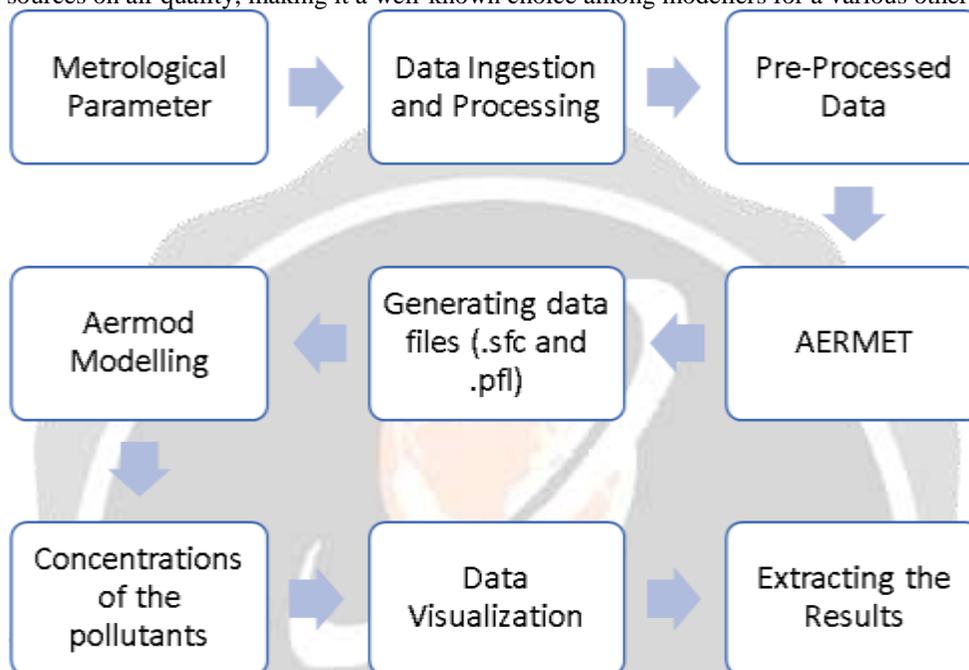


Figure 1, Flowchart of AERMOD

## 2. STUDY AREA

Allahabad is situated in the state of Uttar Pradesh, at a latitudinal-longitudinal coordinate of 25°27'N, 81°44'E. The city rises to a height of around 44 metres above sea level and is located at the confluence of the Ganga and the Yamuna rivers. The city is surrounded on the south and east by Bagelkhand, on the north and east by Awadh, on the west by Kausambi, and on the north and east by Allahabad. Allahabad and Kausambi together make up the lower Doab. According to Allahabad Nagar Nigam, the city has a total area of around 70.05 sq km and a population of approximately 1.1 million people as of census 2001. (1,112,544). Twenty-three major Prayagraj localities were chosen from within the Prayagraj municipal boundaries. Following that, the regions were highlighted on a digital map using Google Earth. The 3x3 grid map of Prayagraj was then been constructed using GIS tool. The selected sites are the 13 major entry exit points and junctions of Prayagraj. The traffic data and the dust sampling were done on these 13 locations of Prayagraj city. An air quality modelling is to assess the impact of emissions from the source on receptor by considering the transport mechanics and finally provide a solution if receptor is in danger and then on the basis of that we decide to control or prevent source emissions and to do this, we need a linkage between source, transport and receptor. The mathematics of this linkages we refer as air quality model. The mechanics of the atmosphere that disseminate a pollutant released by a source are characterized using mathematical formulations in dispersion modelling.

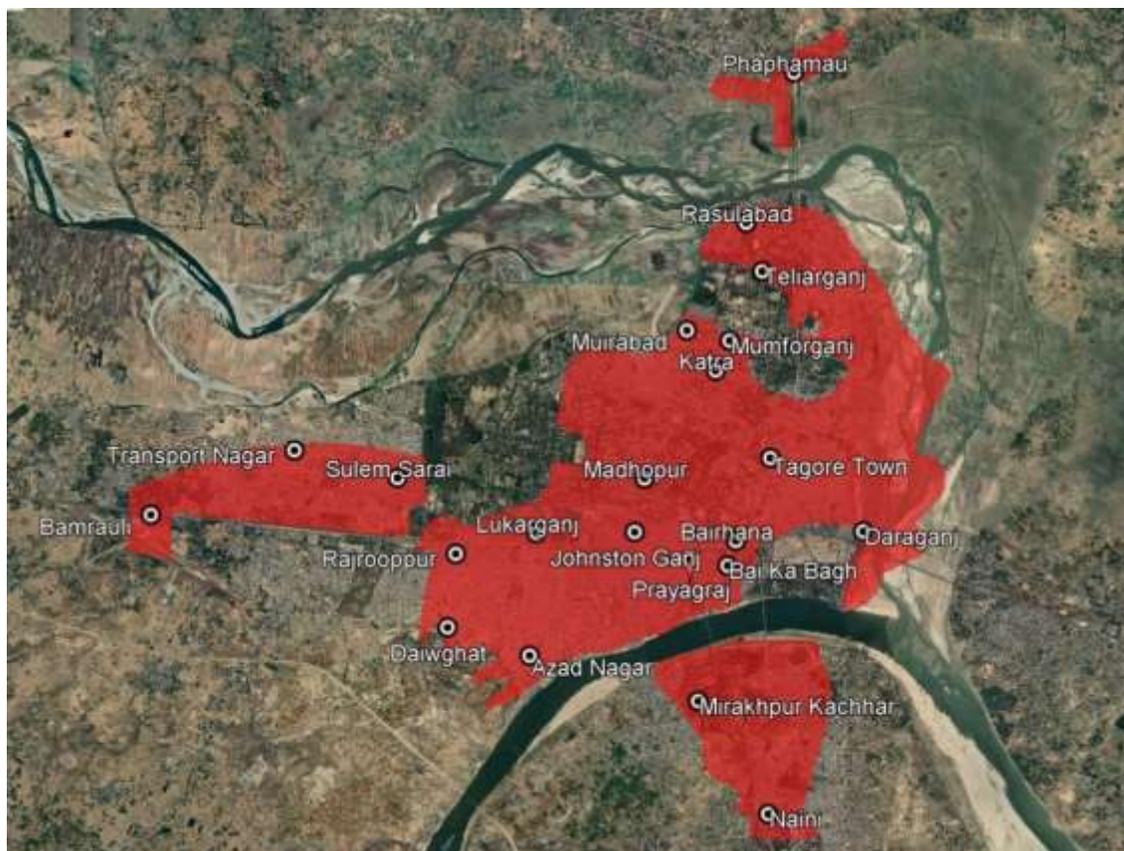


Figure 2, Areas of Prayagraj

### 3. METHODOLOGY

To run AERMOD we need a pre-processor to generate the meteorological data files, the receptor files and the building parameters. AERMOD determine small range impact from the various sources in all types of terrain. AERMOD input file is grouped into five pathways: -

#### CO Pathway – Control Options

The keywords that offer how to control the model run are found in the Control pathway. Dispersion choices, terrain heights options, averaging time options, and others are among them. CO pathway is the first pathway in the input files: -

- Title Info  
The user can mention up to two lines of title information that will display on each of the page of the model's primary output file using two keywords. The first keyword, TITLEONE, is required, whereas the second, TITLETWO, is optional.
- Dispersion Options  
The MODELOPT keyword on the CO route controls the dispersion options.
- Default Options  
In AERMOD, the regulation DFAULT option includes stack-tip downwash, increased terrain effects, calms, and missing data processing. When modelling SO<sub>2</sub> in an urban source, the DEFAULT option in AERMOD also mandates the use of a 4-hour half-life and does not permit for the exponential decay in other applications. If the DCAYCOEFF or HALFLIFE keyword is used to request exponential decay, AERMOD will alert you that the DFAULT overrides the requested exponential and will execute the model without it.
- Alpha Options  
ALPHA signifies that one or more choices from a specific category are being used.
- Beta Options

BETA options refer to scientific changes to the formulation of AERMOD that have been thoroughly evaluated and peer review is done by the scientific community. BETA alternatives will be promulgated as regulatory options in the future.

#### SO Pathway – Source Info

Source emission rates are being kept constant during the modelling period, or they can be modified on the basis of the month, season, hour of the day, or other variables. These variable emission rate variables can be set for a single source or multiple sources. A file other than the hourly emission rates for any or all of the sources included in a model run can also be specified by the user.

#### RE Pathway – Receptor Info

The AERMOD paradigm allows for a great deal of flexibility when it comes to highlight receptor locations. The user has an option of specifying various receptor networks in a single run, as well as mixing the Cartesian and the polar grid receptor networks in the same run. This is beneficial in situations when the user needs a coarse grid across the whole modelling domain compared to the denser grid across the area with the highest projected impacts. Other than the oversight origin at (0,0) in x,y coordinates, there is additional freedom in choosing the origin locations for the polar receptors.

#### ME Pathway – Meteorological Info

The surface boundary layer parameters files and a file of profile variables, such as wind speed, wind direction, and turbulence parameters, are used by the AERMOD model. The meteorological preprocessor for AERMOD, known as AERMET, generates these two sorts of meteorological inputs (EPA, 2021c). The model identifies the format supplied by AERMET as the default format because both the meteorological input files are progressive ASCII files. By default, model will process all handy meteorological data in the supplied input file so the user can easily pick which days or ranges of days they want to process.

#### OU Pathway – Output Options

The source group values, individual source values, or both can be output in the tables by receptor and maximum value tables. Furthermore, when more than two values for individual sources are printed, the user can choose whether the highest source values should be the highest values for each source separately or the contribution of each source to the highest group values or both. The AERMOD model offers numerous sorts of file output products in addition to the table type printed output products discussed above. One of AERMOD's choices is to generate an unformatted ("binary") file containing all estimated concentration values. These files are frequently used for data post-processing. Other than the unformatted concentration files, AERMOD offers a variety of other file output options. The AERMOD model also has an output file option that generates a file of all the occurrences when a concentration value equals or greater than a user-specified threshold. New files are generated for only the average period and source group combinations that the user is interested in. The date of the receptor location and the threshold violation and the concentration value are all stored in these files. Two types of output files are available in AERMOD, both of which are meant to aid model evaluation. Only one value per date is contained in one type of file that write down the concentrations by rank. This file can be used to make Q-Q (quantile) graphs of findings, which pair values from different models and or observable data by rank. The output files also contains findings for arc maxima as well as extensive information about the plume properties associated with the arch maximum.

When just regular sampling is chosen, hourly concentrations are estimated for each measured hour in the usual way. After that, the annual average concentration is easily computed by dividing the sum of concentration for the measured hours by the number of hours sampled, i.e.

$$C = \sum C_s / N_s$$

Where:

C = Determined Concentrations

$\sum C_s$  = Cumulative impacts for the sampled hours

$N_s$  = Number of sampling hours

The basic equation for calculating concentration on a plume centerline can be expressed in this way: -

$$\text{Concentration} = \frac{\text{Amount of material being released}}{(\text{Horizontal and vertical turbulence}) \times (\text{wind speed})}$$

AERMAP is AERMOD's terrain pre-processor, which takes DEM data and provides an elevation and height for each receptor in the domain. AERMAP automatically selects the closest node elevation to the receptor or source in each quadrant, then weights that elevation in relation to the distance from the receptor or source.

The data for the road dust were been collected from the 13 sites of the Prayagraj, the road dust sample then been sieved using mechanical sieving machine and the sum of average of all the road dust sample were then been used to determine the nominal size of the silt in Prayagraj.



Figure 3, Sample Site Location Hanuman Mandir



Figure 4, Sample Site Location Jhusi Konha



Figure 5, Traffic Counting by using Camlytics Software

For vehicular source data collection was done by using a mobile camera at 9 locations of Prayagraj and then the vehicle counting was done by using the camlytics software. Moving further then the 20x20Km<sup>2</sup> area has been marked with the help of google earth which covered our 3x3 grid map of Prayagraj city. The from every grid the important areas of Prayagraj city were then marked using google earth. The important areas of Prayagraj were decided using typical traffic survey and the population survey using google earth and census.

#### 4. RESULTS AND DISCUSSION

The model was run for the vehicular source source and the results were generated for the PM10 and PM2.5 pollutants.

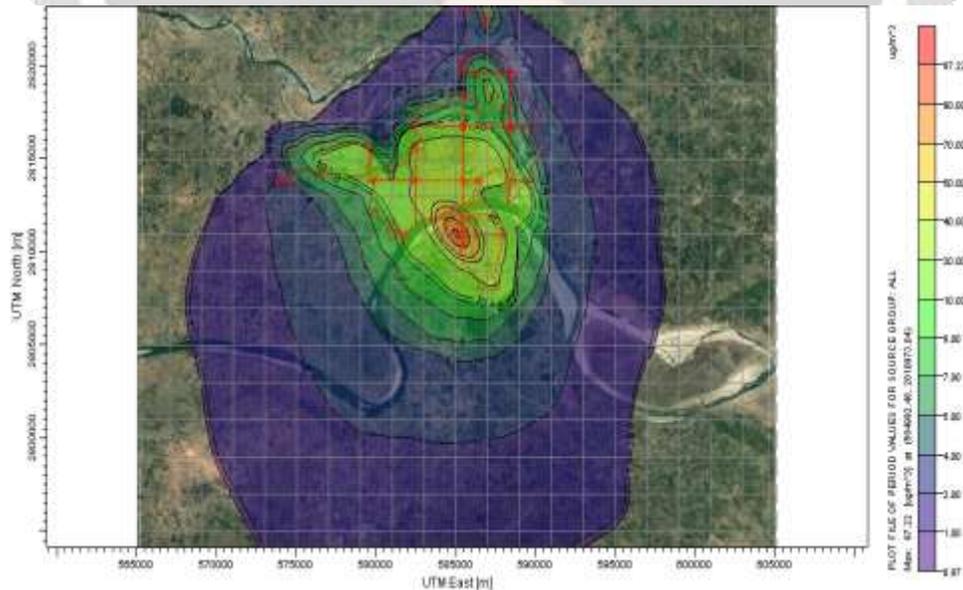


Figure. 6, Concentrations of PM10 for Vehicular Source

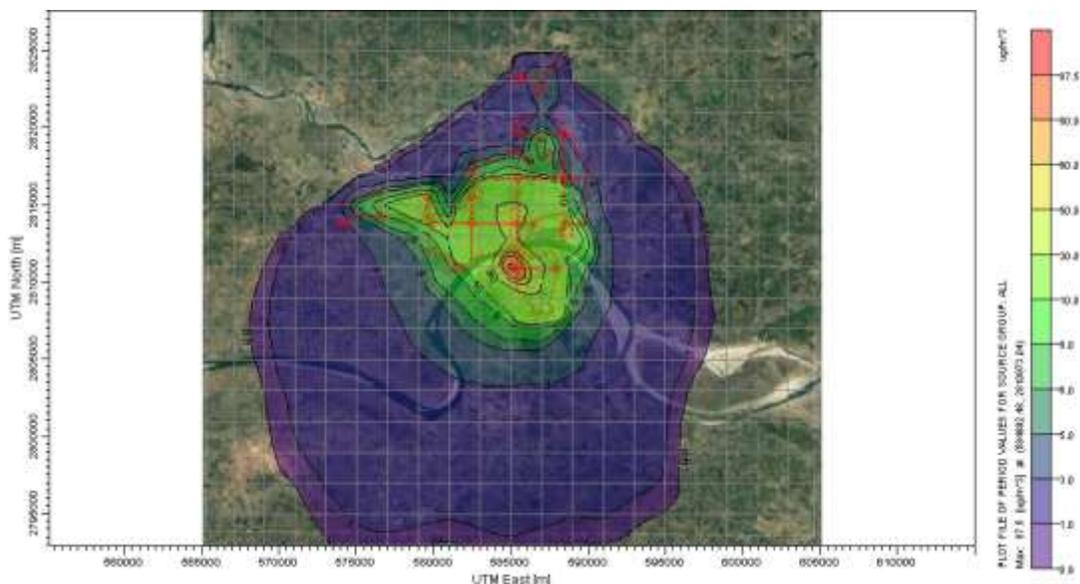


Figure. 7, Concentrations of PM2.5 for Vehicular Source

The concentration results which were generated with the help of AERMOD was then used to perform a statistical analysis.

Table 1, Statistical Analysis of Results of Vehicular Source in Prayagraj City

PM10 From Vehicular Source		PM2.5 From Vehicular Source	
Mean	20.43478261	Mean	15.82608696
Standard Error	3.134391713	Standard Error	2.94776808
Median	18	Median	11
Mode	25	Mode	20
Standard Deviation	15.03201458	Standard Deviation	14.13699908
Sample Variance	225.9614625	Sample Variance	199.8547431
Kurtosis	11.47720674	Kurtosis	9.649372324
Skewness	3.006676889	Skewness	2.695811865
Range	74.5	Range	67
Minimum	5.5	Minimum	3
Maximum	80	Maximum	70
Sum	470	Sum	364
Count	23	Count	23

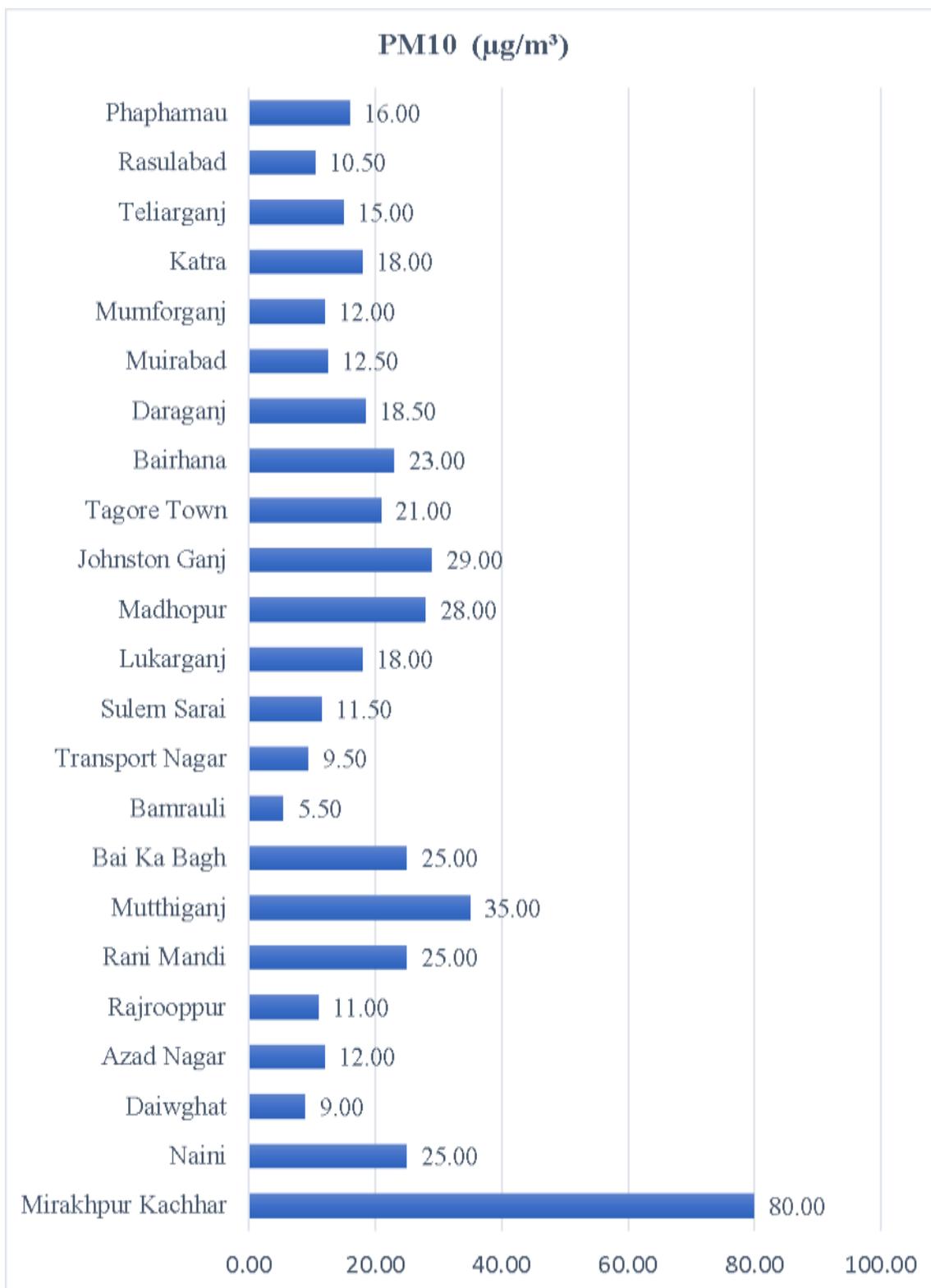


Figure. 8, Area Wise Concentrations of PM10 for Vehicular Source

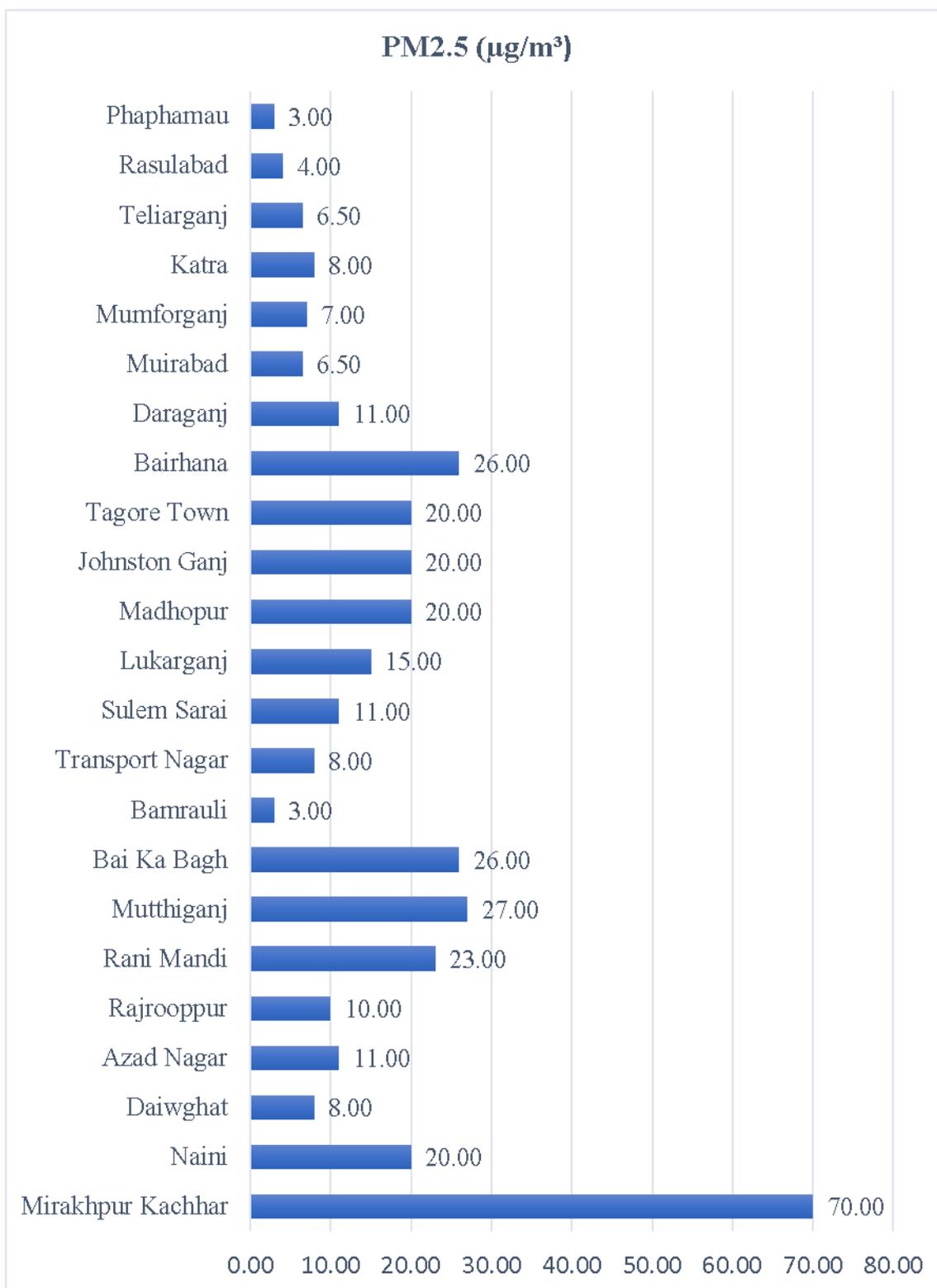


Figure. 9, Area Wise Concentrations of PM2.5 for Vehicular Source

## 5. CONCLUSION

The PM10 concentrations were found to be high in Mirakhpur Kachar area followed by Mutthiganj, Johnstonganj and Madhopur. Similarly, the PM2.5 concentrations were found to be high in Mirakhpur Kachar area followed by the Mutthiganj, Bai Ka Bagh and Bairhana. To curb down this vehicular pollution in Prayagraj city we can shift down towards clean technology like BS-VI and outdate the y diesel vehicle which are older than 15 years. Time to time mechanical or vacuum sweeping of the roads can also reduce the PM particles from the city environment.

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