# Statistical Analysis of Suspended and Respirable Suspended Particulate Matter ($PM_{10}$and $PM_{2.5}$) Concentrations in Urban Region of Ahmedabad, India

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**Abstract:** ***In this study, the relationship between inhalable particulate (PM10), fine particulate (PM2.5),coarse particles (PM2.5-10) and meteorological parameters such as temperature and relative humidity was statistically analyzed and modeled for the urban region of Ahmedabad during 2018-2019. Ambient air quality was monitored with a sampling frequency of 3 hours at 100 monitoring sites, covering a period of four months from September 2018 to February 2019. The monitoring sites were located near highly trafficked, industrial and congested areas. The 24-h average PM10 were measured using a Portable air sampler (APM 801, Envirotech instruments Pvt.Ltd.). Meteorological parameters such as temperature, relative humidity and wind speed were also recorded during the sampling period. It was found that approximately 6% of PM10 concentrations were exceeding the standard value of 60 µg/m$^3$and approximately 5% of PM2.5 concentrations were exceeding the standard value of 40 µg/m$^3$.The ratios between PM2.5 and PM10 were found to be in the range of 0.380(December)to 1.051(January). Statistical analyses have shown a strong positive correlation between PM10 and PM2.5. The correlation of 0.975 was obtained between PM10 and PM2.5 for the entire site area. Finally, a regression equation for PM10 and PM2.5 and meteorological parameters were developed.***

**Keywords:** PM10, PM2.5, SPSS, statistical analysis, correlation, urban air pollution

## 1. Introduction

The atmospheric aerosol is a highly dynamic system that affects our lives in multiple ways. Deteroiting air quality causes acute and chronic effects, to human health (Moustris et al., 2010; Azid et al., 2015). Reports stated that about 4.2 million premature deaths were annually linked to outdoor air pollution out of which 91% are in developing countries. (WHO 2016; Kalaiarasan et al., 2016; Ashrafi et al., 2018). Amongst all pollutants , PM2.5 AND PM10 are most crucial due to its adverse impact on human health, visibility and climate change(Pope and Dockery, 2006; Chen et al., 2010 ;Khan et al., 2010; Kim et al.,2011; Gugamsetty et al .,2012 ; Lawrence and Fatima, 2014; Ma et al., 2014;Xiao et al., 2014;Liu et al., 2017; Asharfi et al.,2018).PM2.5 and PM10 are the major pollutants responsible of cardiovascular and respiratory diseases, disability and mortality (Brunekreef and Forsberg 2005; Kok et al., 2006; Pope et al., 2006; Dockery and Stone, 2007; Taus et al., 2008; Barmpadimos et al., 2011; McBride et al., 2011; Gugamsetty et al .,2012; Liu et al., 2017,Gangwar et al., 2019).

The objectives of the present study were to collect baseline data of $PM_{10}$ and $PM_{2.5}$ from aselected area of study, to assess the fraction of $PM_{2.5}$ within $PM_{10}$and its temporal and spatial variation and to analyze correlation, in terms of regression analysis, between air pollutants and meteorological parameters in the urban region of Ahmedabad city.

## 2. Monitoring and Analysis

### 2.1 Description of study area

Ahmedabad (23°02'N, 72°32'E) is one of the largest urban areas in western India with a population of more than 7.3 million. Air pollution is emitted from several local sources in Ahmedabad. Available studies suggest that rapid urban growth has led to increase in air pollution from vehicle-related emissions and stationary sources in Ahmedabad. From 2001 to 2018, the number of vehicles, including motorcycles and scooters, doubled in Ahmedabad, while the population grew by 60 %. (RTO, Gujarat). Ahmedabad has two thermal coal-fired power plants: the 800 MW Gandhinagar plant and the 400 MW Sabarmati plant, one of the oldest in India. The city also has more than 3,000 industrial units. Also, each day, Ahmedabad generates 3,500-4000 metric tons of waste. Out of this, just 950 metric ton or less is recycled or processed .Municipal solid waste is being disposed of at the Pirana site, since 1980 .It is measuring 84 hectares, out of which 65 hectares of the site is almost filled up with mountains of heights varying from 22-45 m .Fires are frequent at Pirana and it takes thousands of liters of water to put down a fire. The garbage shaped mountains make the occurrence of fires more frequent and difficult to put out. The fumes emerging out of the landfill fire are severely toxic in nature adding to pollution. (Kumar et al., 2015; Weichenthaletal. 2015)

The site selected is about 25km$^2$ surrounding area of the Pirana landfill site. The Narol-Sarkhej highway and Pirana-Piplaj highway are surrounding the site which leads to major vehicular pollution. Narol and Danilimda are also having many industrial units which increase the pollution levels. So, this area is having complex land use pattern which includes all type of units like agricultural zone, residential, commercial and industrial units, landfill site and national highway and it is the most polluted part of the city according to the SAFAR data. During the sampling period, the prevailing winds were moderate north easterly and wind speed ranged from 2 to 5.5 m/s. and ambient temperature was 20- 40°C and relative humidity varied from 30-60%.

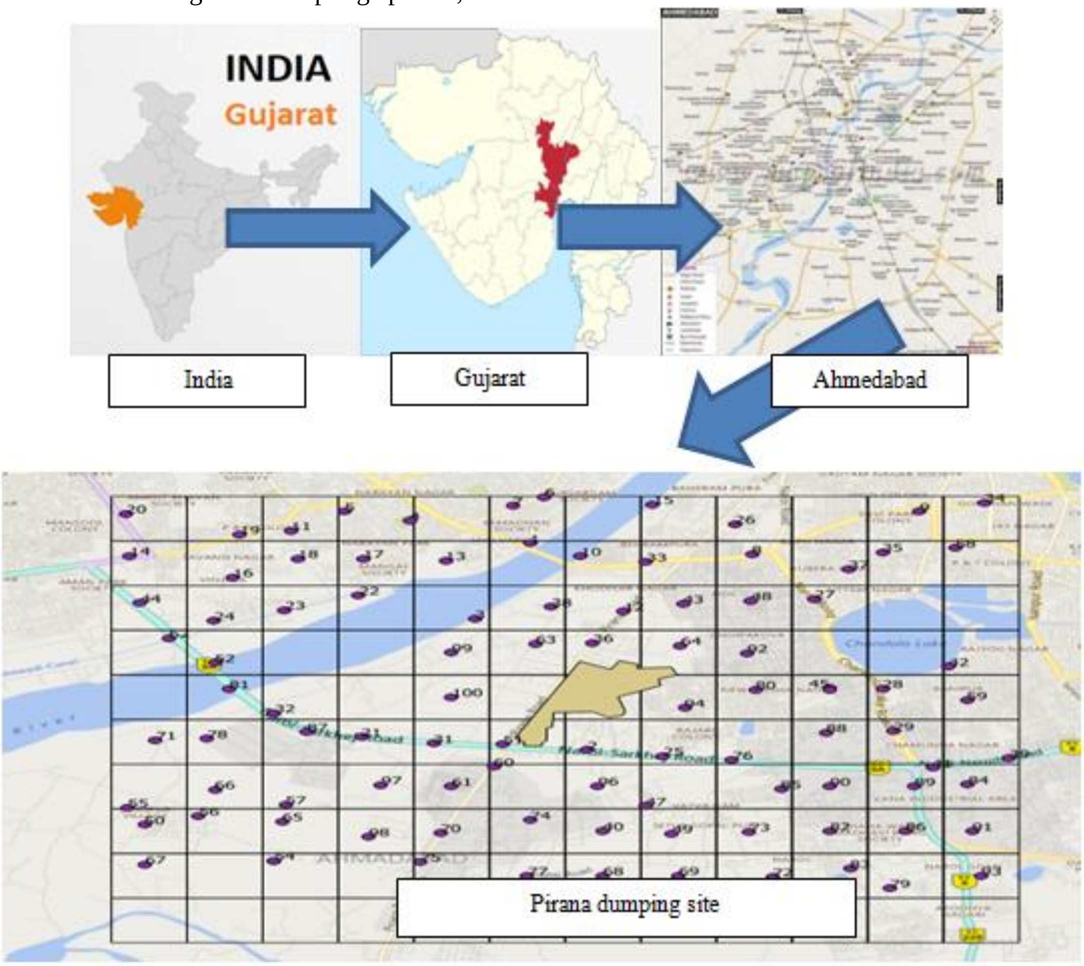


**Figure 1:** Site map of study area, Source: QGIS

### 2.2 Sample Collection

The site selected was divided into 100 grids (~ 500 m x 500 m each) covering the radius of 5km surrounding the site. 100 such samples locations and their main points were selected by using MAPINR application (XYLEM technologies) in every grid and sampling was done at those locations using portable air sampler (APM 810, Envirotech instruments Pvt.Ltd). A total of 100 samples were collected during 100 sampling days over 3-h period from Sept 2018-Feb 2019 at the rate of 2 LPM on the Quartz filter paper ( 37MM Ø , Whatman) which were prebaked at 500°C for 30 minutes in the Muffle furnace(Milestone instruments) for removing any initial contaminants and moisture, then those filters were cooled in the Desiccator, initial weight was measured by microbalance (RADWAG instruments)and then were stored by warping in Aluminum foil and kept in plastic bag with sample ID and details to avoid any outer contamination before sampling . The net PM2.5 was calculated by subtracting the pre-sampling weights from the post-sampling weight according to eq (1) given below

$$C = \frac{(w_1 - w_0) X1000}{TX(R_1 + R_2)/2} \quad (1)$$

Where and are the initial and final filter weights in mg , R1 and R2 are the flow rates in in liters per minute (lpm) at start and just before close of run an T is the sampling time in minutes (APM 801 user manual )

## 3. Results and Discussion

### 3.1 Frequency distribution of PM10 and PM2.5 concentrations

The frequency distributions of $PM_{10}$ concentrations in intervals of 100 µg $m^3$ are shown in Figure 2. A peak in the distribution of $PM1_0$concentrations occurred at 152.88 µg m-3.Approximately 3% of $PM_{10}$concentrations were above 100 µg m-3 and approximately6% of $PM_{10}$concentrations were exceeded the standard value of 60 µg m-3.

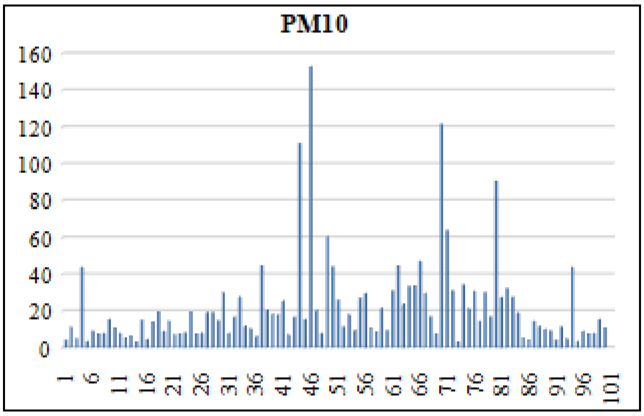


**Figure 2:** Frequency distribution of $PM_{10}$ concentration

**Table 2:** National Ambient Air Quality Standards

| # National Ambient Air Quality Standards for residential area, Central Pollution Control Board, 2012 | | |
|---|---|---|
| Pollutant | Time Weighted Average | Concentration in Ambient Air |
| $PM_{10}$ | Annual | 60 µg/m3 |
| | 24 Hours | 100 µg/m3 |
| $PM_{2.5}$ | Annual | 40 µg/m3 |
| | 24 hours | 60 µg/m3 |
| | | |

On the other hand, the peak for the $PM_{2.5}$ concentrations were between 2 -130 µg/m$^3$ and is shown in Figure 3. Approximately 1% of $PM_{2.5}$ concentrations were above 100 µg m-3 and 5% is above standard value of 40 µg/m$^3$ as shown in Table 2

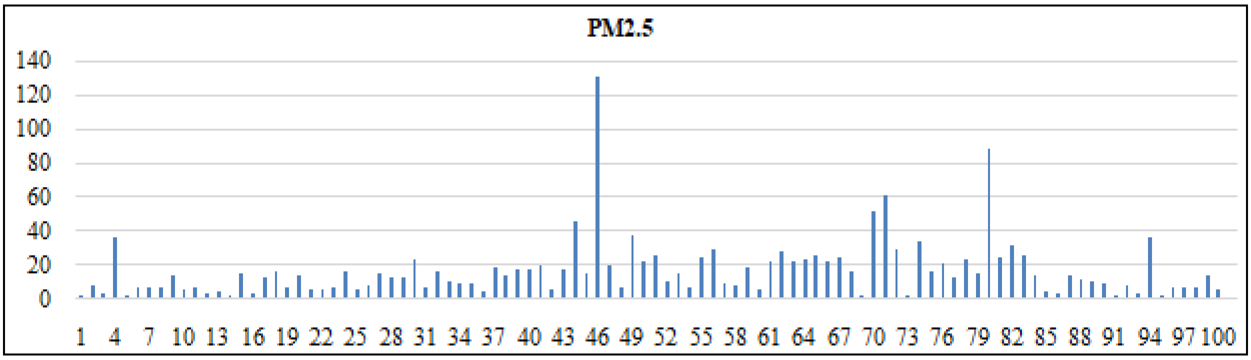


**Figure 3:** Frequency distribution of PM2.5 concentration

### 3.2. Temporal Variation of PM10 and PM2.5

The daily $PM_{10}$ and $PM_{2.5}$ average concentrations for all the sites are presented in Figure 4 and 5 respectively. The average concentrations of$PM_{10}$ and $PM_{2.5}$ for all the sites during the study period were 16.90338 µg m-3 and 21.7906 µg m-3. The maximum and minimum concentration of $PM_{10}$ was 152.8803 µg m-3 and 3.1934 µg m-3 in the month of October and September respectively. The maximum and minimum concentration of PM2.5 was 130.107 µg m-3 and 2.1017 µg m-3 in the month of October and September respectively.

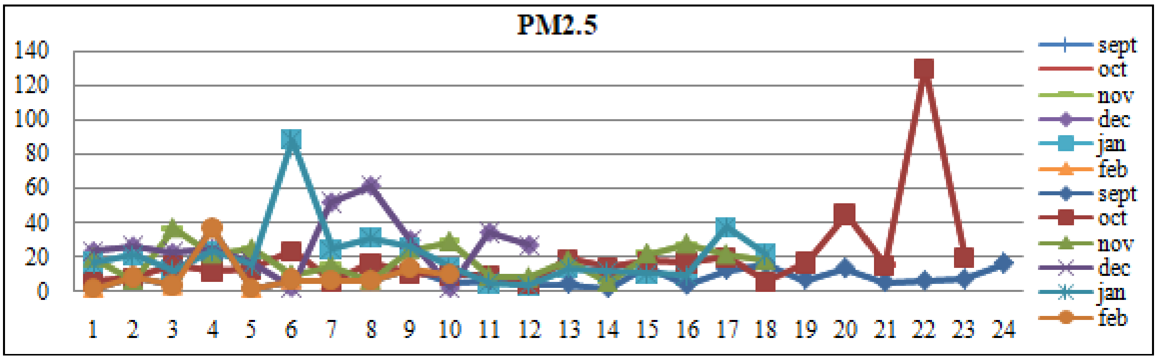


**Figure 4:** Daily $PM_{2.5}$ average concentration for all the sites

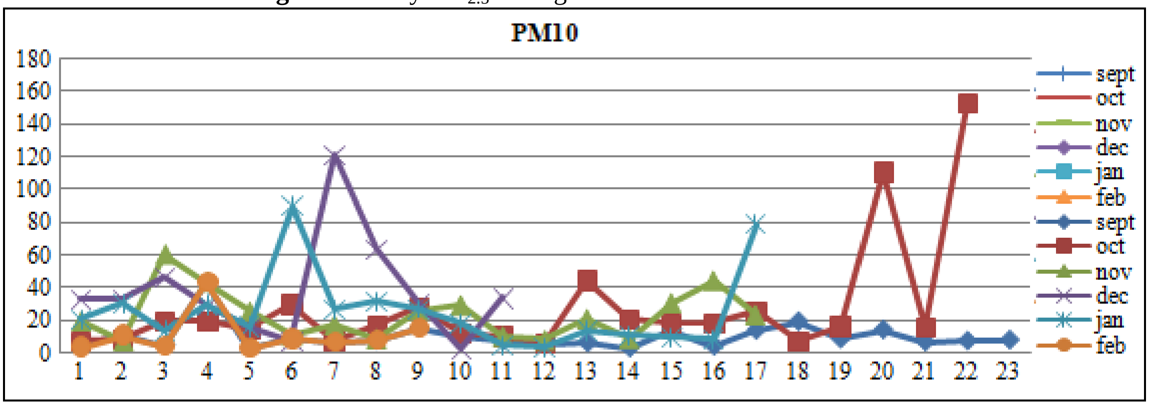


**Figure 5:** Daily $PM_{10}$ average concentration for all the sites

### 3.3 Spatial Variation of $PM_{10}$, $PM_{2.5}$ and $PM_{2.5\text{-}10}$

Figure 6 presents the average concentrations of PM10 and PM2.5 at all the monitoring sites during the study period. The ratio of highest to lowest concentration of all sites varies from 7.6367 to 38.0376 for $PM_{10}$ and 6.458 to 25.72 for $PM_{2.5}$. The ratio of PM2.5/PM10 was the highest in January 2018 near Pirana Piplaj highway (1.0514). The ratio of PM2.5/PM10 was lowest in December 2018 (0.38073) near narol old court area. The concentration of $PM_{2.5\text{-}10}$ was about 22.4281% of $PM_{10}$ concentration.

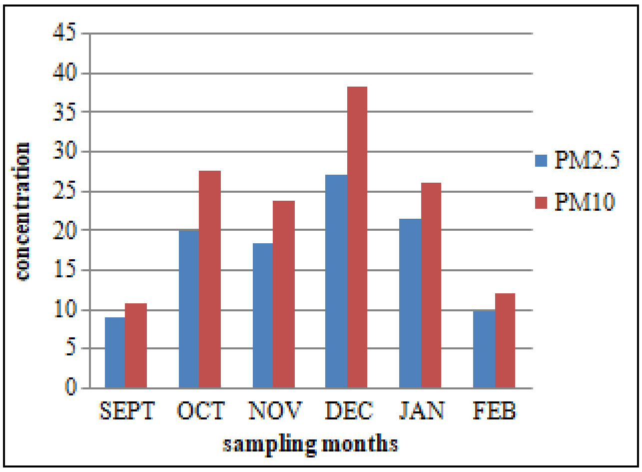


**Figure 6:** Concentrations of PM10, PM2.5 and PM2.5-10 at all the three monitoring sites

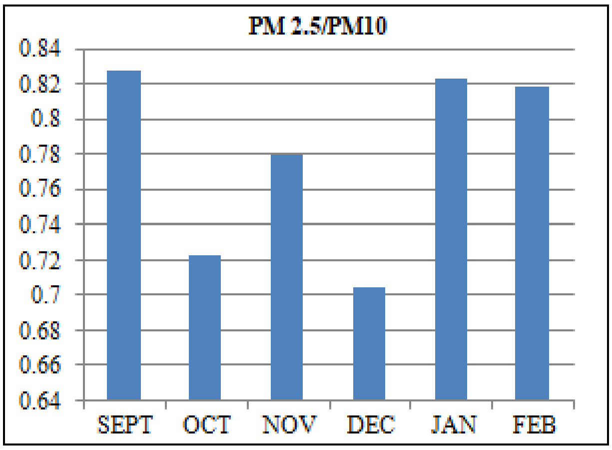


**Figure 7:** PM2.5 / PM10 in sampling months

### 3.4 Relationships between $PM_{10}$, $PM_{2.5}$ and $PM_{2.5\text{-}10}$

The Result from this study has shown that $PM_{10}$ in urban locations is mainly composed of fine particles. The particle size analysis shows that concentration of $PM_{2.5}$ is about 77.57% of $PM_{10}$ concentration for all the sites. The $PM_{2.5}/PM_{10}$ value had shown large variability, and ranged from 0.380 to 1.051. This suggests that the contributions of PM2.5-10 (coarse particle) and PM2.5 (fine particles) to PM10are not similar. Similar results have been reported in a large number of urban and semi-rural areas where annual mean PM2.5/PM10 ratios varied between 0.3 and 0.7(USEPA, 2011).This is expected, since both fine (primary and secondary particles) and coarse particles (road dust re-suspension, which is enhanced in dry winter climates) are associated with local traffic and industrial area.

### 3.5. Correlation between Particulate Data Sets

Figure 8 shows the scatter plots of PM2.5 concentration against that of PM10 concentration. The Figure indicates that these two parameters are highly related to one another with a linear relationship. The least-square regression line for the daily data gave the following equation

$$[PM_{10}] = 1.462[PM_{2.5}] - 2.666 \; [R^2 = 0.979] \quad (1)$$

The regression Equation (1) obtained by using the data for all the monitoring sites. The above equation reveals that the $PM_{10}$ concentration increases with increasing $PM_{2.5}$ concentration.

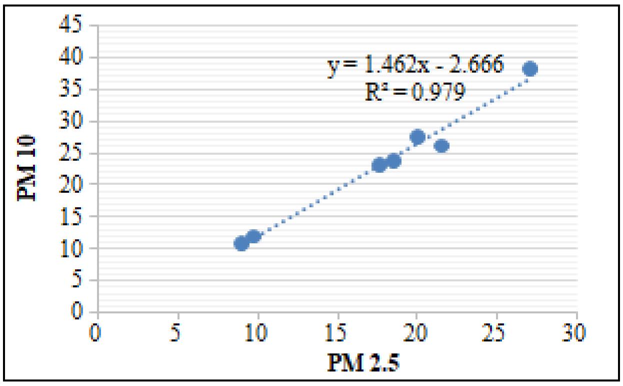


**Figure 8:** Scatter plots of PM2.5 concentration against that of PM10 concentration

## 4. Conclusions

The study provides a valuable baseline data on PM10 and PM2.5 levels and is the first of its kind in which such data has been collected in Ahmedabad city. Data capture rate was high and the accuracy of the results was good. The total data were analyzed to investigate spatial and temporal variation and correlation using the code SPSS in order to gather more understanding on their variability and interrelations.The maximum and minimum concentration of $PM_{10}$ was 152.8803 µg m-3 and 3.1934 µg m-3 in the month of October and September respectively. The maximum and minimum concentration of PM2.5 was 130.107 µg m-3 and 2.1017 µg m-3 in the month of October and September respectively.It was found that approximately 6% of PM10 concentrations were exceeded the standard value of 60 µg m-3. PM2.5 data appears to be a constant fraction (0.38 – 0.90) of the PM10 at all the sites, indicating common influences of meteorology and sources. There were clear associations between PM10 and PM2.5 data sets at all the measured sites. Considering the simplicity of the stepwise regression models, their performance was quite satisfactory, in predicting the observed values. Predictive models explain 97.9% of the variability in the PM2.5 by the PM10 concentration variance respectively.

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