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Seasonal Variations in Fine Particulate (PM 2.5) Concentration in Urban and Rural Environments in Pune, India

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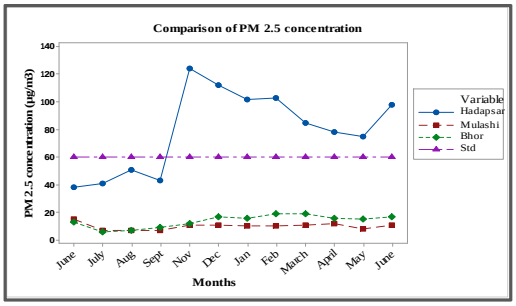
ABSTRACT

Particulate matter (PM) is a term used to describe the mixture of solid particles and liquid droplets in the air. It can be either human-made or naturally occurring. Human-made sources of PM 2.5 are more important than natural sources, because natural sources make a small contribution to the total concentration. Particulate matter (including soot) is emitted during the combustion of solid and liquid fuels, such as for power generation, domestic heating and in vehicle engines. Particulate matter varies in size (i.e. the diameter or width of the particle). In today's scenario its pollution has become a growing health concern over the past few decades globally and its ambient concentrations are of concern with respect to effects on human health and environment. Inhalation of particulate pollutants can have adverse health impacts even its exposure to high concentrations (e.g. during short-term pollution episodes) can also exacerbate lung and heart conditions, significantly affecting quality of life, and increase deaths and hospital admissions. In present work study was carried out to monitor concentration of PM 2.5 for an about one year in urban (Hadapsar and Manjari) and rural (Bhor and Mulashi) area of Pune city. Sampling was carried out by using ambient dust sampler and its quantitative analysis was done by gravimetrically. The observations were statistically analyzed using minitab18 software. The concentration of particulate matter in all the four areas is variable as per the season. In Hadapsar and Manjari the concentration were increased as compare to Bhor and Mulashi. This indicates the particulate matter pollution rate was increased in Hadapsar and Manjari due to urbanization.

Graphical Abstract



Comparison of PM 2.5 concentration in Hadapsar

Keywords: Particulate Matter 2.5, Urbanization, Air Pollution, Concentration, Environment

INTRODUCTION

In 1980s rapid economic growth has been accompanied by rapid urbanization which favours increase in population, industrialization and urbanization. This growth in such a short duration of time has not only led to an improvement in material wealth but also increased the standard of living. This caused severe environmental pollution, particularly air pollution in many urbanized regions of many countries like China, Iran etc [2]. India is also one of the countries which undergoing tremendous change in urban areas that lead to continuous deterioration of ambient air with increase in population, industrialization and urbanization [3]. Some metropolitan cities like Bombay, Calcutta, Bangalore and Pune show typical urban pollution and air quality of these areas is directly linked to the different activities in the city including transport, business and industrial activities. As a major urban air pollutant, the concentrations of fine particulate matter (PM 2.5) has become a growing health concern over the past few decades globally and its ambient concentrations are of concern with respect to effects on human health and environment [4]. Increased rate of mortality and morbidity also have been associated with respirable particulate air pollution [1]. Particulate matter is the particles having size of less than 2.5 microns in diameter. They have both acute and chronic effects on human health and affect different system and organs [6]. Epidemiologic study on long-term exposure to ambient fine particulate matter has documented serious adverse health effects including increased death rate from chronic cardiovascular and respiratory disease, lung cancer and adverse reproductive outcomes [5].

Pune and the surrounding areas also have been recognized as one of the most polluted areas in India for the past several years due to their fastest growing population and developmental activities [3]. Considering their economic growth many people have residences in surrounding small towns nearer to Pune city. In today's scenario, even these small towns around Pune region are also facing problems related to air, water and noise pollution accounted by large number of migrating population, vehicular emission and industrialization. Among them Manjari and Hadapsar are also facing same kind of problems. The rapid growth of Pune and surrounding area has profound impact on the air quality by vehicular emissions mainly due to high proportion of old, poorly maintained vehicles and poor fuel quality. As a major urban air pollutant, the concentrations of fine particulate matter (PM 2.5) are directly affected by both human activity and the surrounding environment [4]. However; urban and rural areas do not exhibit homogenous PM 2.5 concentrations because PM 2.5 is mainly caused by human activities. The average concentration patterns observed between urban and rural areas can be varied and conflicting as a center of human activity, urban area generate a great amount of air pollutant emissions, which can result in larger PM 2.5 concentrations in urban area than in surrounding areas.

This study aims to investigate the ambient air quality status of Hadapsar and Manjari in comparison with Bhor and Mulashi area. Hadapsar and Manjari areas are recently developing areas. The main source of air pollution in this area owes to increase in population as well as vehicular pollution. While Mulashi and Bhor area are comparatively low affected areas as these areas are mostly included in rural and semi urban areas and hence have comparatively less population and vehicular pollution. This study will develop effective monitoring mechanism to monitor concentration of pollutants and help to assess pollution trend in more meaningful way.

MATERIALS AND METHODS

Site Selection: Site was selected on the basis of population, Vehicular Density, Sources of pollutants, geographical location, and sources of emission. Two urban areas i.e. (Hadapsar and Manjari) and two rural areas i.e. (Bhor and Mulashi) were selected as monitoring site. Hadapsar is an eastern suburb of

pune city. Upto 1980 Hadapsar was a little village enclosed by farms but major real estate projects recently established in the surrounding of Hadapsar, about and 8.5 km from the centre of Pune. It was a part of Pune Municipal Corporation. It is also home of industries like Serum Institute of India, Honeywell, Bharat Forge, Kirloskar and Accurate. Manjari is a village which is located 4Km away from Hadapsar. It is suburban area around a pune. It belongs to Desh or Paschim Maharashtra region as well as Pune Division. It is 11 Km away from the district headquarters Pune. The total geographical area of village is 1048.34 hectares.

Bhor and Mulashi are the rural areas as well as control site for the present research study. Bhor is midway between Pune and Satara. Mahad road is passes through Bhor which connects to Konkan area. Bhatghar dam is near to Bhor while Mulshi is a one of the Tehsil place in Pune district, which has its name after a small village in the heart of the Mulshi valley in India. The region is associate eco-tourism hotspot, and outside of village there are many guest houses and gardens. The government offices are in Paud village where as industrialization to some extent has been done in Pirangut and nearby villages. Pune's much talked of IT Park is also in Mulshi Taluka. It is one of the best places to visit near Pune, especially during monsoon.

The air quality was assessed based on measuring Suspended Particulate Matter (PM2.5) and for the assessment monitoring was carried out during three seasons i.e. summer, Monsoon and winter. In order to recognize the concentration and predict hazardous effects of pollutants, the scientific monitoring as well as quantitative analysis of these environmental components is essential. Following materials and methods were used.

Materials: Ambient Dust Sampler (calibrated Temperature, pressure and flow): Polltech make PEM ADS 2.5/10 Model. It is a sampler which is used for determining the concentration in atmosphere of particulate matter of size 2.5 microns and smaller having flow rate 16.67 LPM. Filter Paper: 2 µm PTFE 46.2 mm filter (Preweighted). Calibrated Weighing Balance:Radwag Make XA82/220/2X Model. Non-serrated forceps for handling filters. Non-metallic, non-serrated forceps for handling weights, digital timer/stopwatch. Filter support cassettes and covers. Antistatic, nitrate-free, phosphate-free, sulphate-free, and powder free vinyl gloves. Plastic petri-slide filters containers (Filter Cassette). Zip-lock plastic bags are 6", 9".

Method: Weighing of filter paper, all necessary precautions were taken and interferences were removed (As per NAAQ guidelines) before weighing of filter paper on weighing balance e.g. Body moisture, Oil contact, Handling with forceps etc. Filter is equilibrated prior to pre and post weighing. Preconditioned filter paper was taken by using forceps and weigh properly on balance. Weight is taken at 45 ± 5 % humidity and 25.0 ± 2.0ºC temperature and recorded and gave identification mark on paper.

Sample Collection: For collection of sample NAAQ (National Ambient Air Quality) guidelines were followed. As per the guidelines calibrated (i.e. Temperature, Pressure and flow) dust Sampling instrument (i.e. Ambient dust sampler) were used and was kept away from the source and other interference i.e. 15 meter away from the source or traffic artery. Height of the inlet kept in between 3-10 m, sampling point was decided on the basis of meteorological parameters (i.e. Temperature, pressure, wind speed, and wind direction), population, vehicular density and sources. For each point sampling was carried out for 8 h.

Following flow chart was followed for sample collection, Check the filter for any physical damages. Mark identification number on the filter. Condition the filter in conditioning room/desiccators for 24 h.

Weigh initial weight of the filter. Place the filter on the sampler. Run the sampler for eight hours. Record the flow rate on hourly basis. Remove the filter from the sampler. Keep the exposed filter in a

proper container. Weigh the total time of sampling and average flow rate. Again condition the filter in conditioning room/desiccators for 24 h. Record final weight. Calculate the concentration of PM2.5 in µg m^{3-1}. Quantitative Analysis of filter paper were done by gravimetrically and final weight were recorded from the recorded data concentration of PM 2.5 were calculated by using following formula.

$$\text{PM 2.5 (mg m}^{3-1}) = \frac{(W_1-W_2) *10^6}{\text{Volume}}$$

$$\text{Volume= Time*Flow}$$

Where, W_1= Initial Weight of Filter paper, W_2=Final Weight of Filter Paper

RESULTS AND DISCUSSION

From study it is observed that the main sources of air pollutants in both areas are Industrialization, Growing cities, increasing traffic, rapid economic development and higher levels of energy consumption. Sources of air pollution can be categorized as natural sources and anthropogenic or manmade sources some sources are found common in all location but in urban area number of population, vehicular pollution, construction and Industries are more than rural area on the basis of this evaluation the results obtained are as follows.

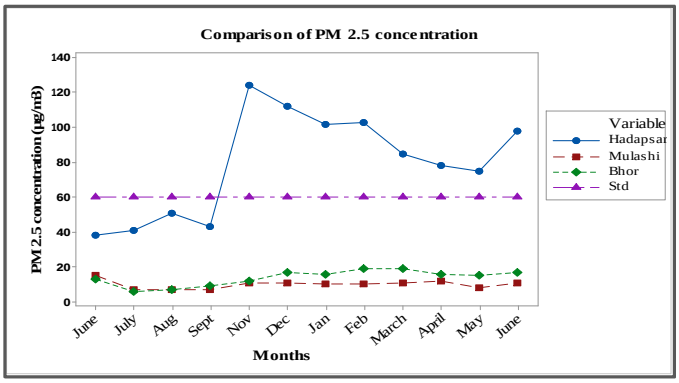


Figure 1. Comparison of PM 2.5 concentration in Hadapsar

Figure 1 shows average concentration of PM 2.5 in Hadapsar, Mulashi and Bhor areas. From overall results it is observe that the concentration of particulate matter in monsoon season is below permissible limit (NAAQ Std.), 43-51 µg m^{3-1}, 6-13 µg m^{3-1}, 7-15 µg m^{3-1} in Hadapsar, Bhor and Mulashi respectively. Whereas, in winter concentration of particulates in Hadapsar area exceeds the permissible limit i.e. 102-124 µg m^{3-1} while in Bhor and Mulashi it is below permissible limit i.e.12-19 µgm^{3-1}, 10-11 µg m^{3-1} respectively. In summer season same observations were noted the concentration exceeds in Hadapsar i.e.75-98 µg m^{3-1} and in Bhor and Mulashi it does not exceeds the permissible limit i.e. 15-19 µg m^{3-1}, 8-12 µg m^{3-1} respectively. From above results it is observe that the pollution in Hadapsar has been drastically increased.

Figure 2 shows average concentration of PM 2.5 in Manjari, Mulashi and Bhor areas. From overall results it is observe that the concentration of particulate matter in monsoon season is below permissible limit (NAAQ Std.). 22-27µg m^{3-1}, 6-13µg m^{3-1}, 7-15µg m^{3-1} in Manjari, Bhor and Mulashi respectively. Where as in winter concentration of particulates in Manjari area exceeds the permissible limit i.e. 95-98µg m^{3-1} while in Bhor and Mulashi it is below permissible limit i.e. 12-19 µg m^{3-1}, 10-11 µg m^{3-1} respectively. In summer season same observations were noted the concentration exceeds in Manjari i.e.67-91 µg m^3-1and in Bhor and Mulashi it does not exceeds the

permissible limit i.e. 15-19 µg m^{3-1}, 8-12 µg m^{3-1} respectively. From above results it is observe that the pollution in Manjari has been drastically increased.

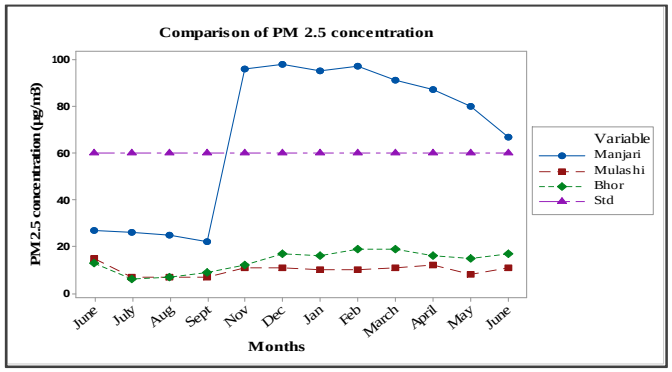


Figure 2. Comparison of PM 2.5 concentration in Manjari

Analysis of concentration of PM 2.5 in different locations: In the above results PM 2.5 Concentrations of each month and every season was studied in different site locations. After the individual site analysis minitab18 software was used to compare and analyzed the concentrations in all the four study regions. Anova test was carried out to check the hypothesis that the PM 2.5 concentrations are in permissible levels and the means are equal to standard. The test was carried out at α= o.o5. The Dunette plot compared each region with one another showing a significant difference in Hadapsar, Manjari, Bhor, Mulashi and Std. The Interval plot compares all the four regions with standard.

One-way ANOVA: Conc. PM 2.5 versus Site location: Null hypothesis, all means are equal (The concentrations of study regions are same as standard) Alternative hypothesis Not all means are equal (The concentrations of study regions are not same as standard).

Significance level α = 0.05
Equal variances were assumed for the analysis.

Factor Information:

Factor	Levels	Values
Site location	5	Bhor, Hadapsar, Manjari, Mulashi, Std

Analysis of Variance: The P value for PM 2.5 concentration in Hadapsar, Manjari, Bhor and Mulashi is less than 0.05. Thus Null hypothesis is rejected and it can be said that the concentration of PM 2.5 is significantly different in all three season. The Dunette comparison was also performed to compare each region concentration with that of standard and with each other to check whether there is significant difference between them. All results are express in µg m^{3-1}. The Tukey graph of confidence interval (Fig.3) showed that the confidence interval for the difference between the means of Hadapsar-Bhor, Manjari-Bhor, Std-Bhor, Mulashi-Hadapsar, Mulashi-Manjari, Std-Mulashi does not include zero which indicates the difference between these means is significant. While confidence interval for the difference between the means of the Mulashi-Bhor, Std-Bhor, Std-Hadapsar, Std-Manjari includes zero which indicates that the difference is not significant (Table 1).

Table 1. Analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Site location	4	49110	1227.5	30.95	0.000
Error	55	21818	396.7	--	--
Total	59	70928	--	--	--

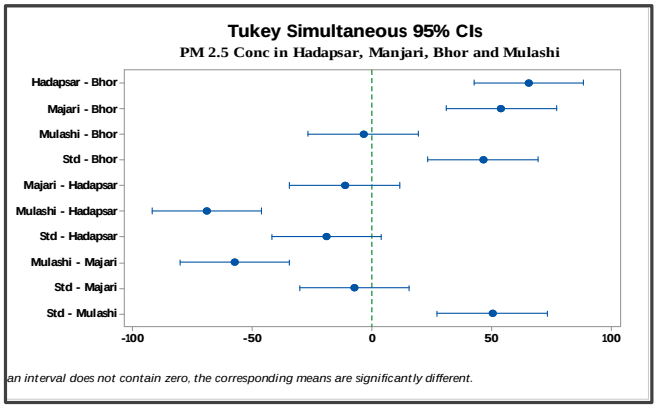


Figure 3. The Tukey graph of confidence interval

The Interval plot of concentration of PM 2.5 Vs site location and standard also states that the concentrations of Bhor and Mulashi was Below the permissible limit as compare to standard than that of Hadapsar and Manjari which states that the pollution rate have been increased in Hadapsar and Manjari (Figure 4).

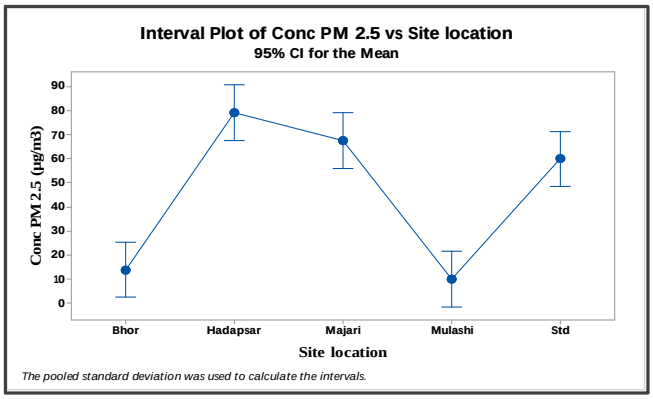


Figure 4. Interval plot of concentration of PM 2.5 Vs site location and standard.

The average concentration of this study provides objective evidence of increasing PM 2.5in ambient air of Hadapsar and Manjari as compare to Bhor and Mulashi. In urban area the concentration of PM 2.5 is exceeds the limit mostly in winter and summer i.e. 102-124 µg m^{3-1}, 95-98 µg $m^{3-1}$and 75-98 µg m^{3-1} 67-91 µg m^{3-1} respectively. The increased concentration of particulate matter in Hadapsar and Manjari is mainly due to Human activities, increased population, vehicular pollution and local metrological conditions. While in rural i.e. Bhor and Mulashi the observed results are below NAAQ standards i.e. 6-13 µg m^{3-1}, 7-15 µg m^{3-1} in monsoon 12-19 µg m^{3-1}, 10-11 µg m^{3-1} in winter and 15-19 µg m^{3-1}, 8-12 µg m^{3-1} in summer. X.Li.states correlation between PM 2.5 and rain fall. The lower concentration of PM 2.5 in monsoon indicates effect of rainfall as rain can clean the air all particles are mix with water and settled on the ground and thus decrease the particulate matter concentration [7]. In winter season the average concentration of PM 2.5 in both the areas are exceeds the limit. The higher PM 2.5 value in winter at Hadapsar and Manjari Indicates the excessive use of fuel for heating during winter and stagnant air mass is formed due to low temperature and low wind speed. Lokman H.T also discover the increase of relative humidity, cloudiness, and lower temperature was found to be highly related to the increase of particulate matter (PM) episodic events [8, 9]. While in summer also concentration of PM 2.5 in Hadapsar and Manjari is exceeds the limit but lower than winter season due to effect of temperature. At high temperature the air convection at lower surface is stronger, which benefits the upward transport of particular matter. Wang J and Ogawa S also observe

the positive correlation in temperature and PM 2.5 concentration in Nagasaki Japan.[9] On the other side the concentration of particulate matter in rural i.e. Bhor and Mulashi is below the permissible limit. This huge significance difference in concentration of PM 2.5 is due to low population, less human activities and interference, vehicular pollution. But if we compare seasonal concentration of PM 2.5 in Bhor and Mulashi then it shows same trend of variation due to impact of meteorological parameters but it does not exceeds the permissible limit [**8**]. Bhor and Mulashi area having very less settlement as compare to Hadapsar and Manjari. The people residing on these areas are still dependent on agriculture. The life style of these people is very simple, conventional and eco-friendly. Most of them are dependent on domestic fuel and natural resources. This is one of the reason behind the less concentration of particulate matter in these areas as well as due to less settlement there is no barrier for the dispersion of pollutant in this areas Both areas having Big dam (Bhatghar Dam and Mulashi dam) which is the good resource for water which is also beneficial for dilution of pollutants.

APPLICATION

Present work is beneficial to study the difference in the air quality status of urban and rural environment. It also highlights negative impacts of unplanned development in Hadapsar and Manjari which creates awareness amongst people residing in this region and also helps to avoid further deterioration of air quality.

CONCLUSION

The average concentration of PM2.5 in Hadapsar and Manjari was found to be greater than the standard permissible limit in winter and summer season as compare to monsoon season. But in rural areas the observed concentration is below the standard limit. The significant difference in observed and standard value indicates the increased in air pollution due to urbanization in Hadapsar and Manjari.

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