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Measurement of PM_{10} concentration and its control strategies for Aurangabad, Maharashtra (India)

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ABSTRACT

There are serious issues of the respirable fine particulate matter (PM) in the ambient air in India. It is estimated that about 670 million people comprising 54.5% of population in India reside in the regions prone to the serious growing problems of air pollution and suspended dust particles. Numerous studies in the past had revealed a consistent correlation between the particulate matter concentration, human health and mortality. Aurangabad is one of the rapidly growing city in India with population of 1.5 million and surrounded by five major industrial areas within 20 km range. The city has historical monuments e.g. "Bibi Ka Maqbara" and "Ellora Caves" which are adversely affected from air pollution.

The PM_{10} concentration monitoring is rarely been presented with land use pattern for the Aurangabad city. Therefore, this research aims at monitoring the PM_{10} concentrations at several locations across Aurangabad region. Using the respirable dust sampler developed through collaboration of NEERI-CSIR. It is found that the concentration of PM_{10} was measured highest at the junction opposite to the Railway Station followed by Waluj (an industrial zone) and City chowk at the centre of the city. Therefore, it is evident that air pollution is a serious issue and needs to be brought under control. Hence, strategies have to be adopted for combating the menace of air pollution in the city. As a control measure for PM emissions, the city should promote use of cleaner fuel like CNG, widen major roads, improve the road conditions, paved foot-path for pedestrians, by-pass heavy vehicles and buses passing through the city, make one-way traffic at the narrow heavy traffic roads in the city, ban on open burning and solid waste management.

Keywords: *Respirable particulates, aerodynamic diameter $\leq 10\mu m$ (PM_{10}), dust sampler, control strategies.*

1. Introduction

Air pollution has become a public health problem all over the world. In 2012, air pollution was declared as the largest environmental health risk with almost 7 million deaths globally attributed to it [1]. According to the Global Burden of Disease 2010 report, the particulate matter (PM) air pollution was responsible for about 6% of deaths on a global basis [2,3]. India is an important country in South Asia with a rapidly growing economy and a large but young workforce. However, rapid industrialization and urbanization in the country have resulted in a significant deterioration in urban air quality [4]. Data from the country's major regulator - Central Pollution Control Board (CPCB) [5], showed serious issues that 77% of Indian urban clusters clearly exceeded the National Ambient Air Quality Standard (NAAQS) [6] for respirable suspended particulate matter (PM_{10}) in 2010 [5]. Another key estimate from WHO points that out of 20 world's worst particulate air polluted cities, around 13 cities are in India including the capital Delhi, which is the worst ranked city in terms of air pollution [1]. It is quite alarming to note that the satellite measures of fine particulates created for the entire India reveal that our populations living both in urban and rural areas are exposed to hazardously high levels of particulates. Almost 670 million people comprising 54.5% of the population reside in regions that do not meet the Indian NAAQS for fine particulate matter [7,8]. Numerous studies have revealed a consistent correlation for particulate matter concentration with health than any other air pollutant. Studies show a statistically significant correlation between mortality and ambient particulate matter concentration [3].

1.1 Particulate Matter - Significance

The term "Particulate Matter" (PM) refers to tiny particles which remain suspended in air, in the form of either solid or liquid droplets which originate from various sources that pollute the ambient air. Particulate matter comprises of various organic and inorganic components; the major components include acids, ammonia, sodium chloride, black carbon, water and mineral dust. These respirable particulates having aerodynamic diameter $\leq 10\mu m$ (PM_{10}) are an important part of the atmosphere. PM is widespread and affects more people than any other ambient air pollutant. These particles have a high probability of deposition deeper into the respiratory tract and are likely to trigger respiratory diseases such as asthma, bronchitis, cardio-pulmonary infections [1,7]. Epidemiological evidence has even attributed PM_{10} in cancer and in some cases even premature death. The relative strength of association of air pollutants with mortality were reported as follows: $PM_{2.5} \geq PM_{10} \geq SO_2 \geq H^+ \geq O_3 \geq NO_x$ [9,10]. Further it has been found that for each 10 $\mu g/m^3$ increase in PM_{10} concentration, there is an estimated increase in mortality by almost 1% [10,11,12]. The concentration of fine particulate matter (PM_{10}), ultra fine particulate matter ($PM_{2.5}$) and black carbon particles exposed in the Auto-riksha, New Delhi had been systematically presented by Apte [13].

These particles have also been implicated as carriers of toxic air pollutants including heavy metals and organic compounds [14]. According to WHO Guidelines when PM_{10} particles are present in excess of $50\mu g/m^3$ these are known to adversely affect human health. In view of the air quality status, some of the Indian cities are considered to be among the most polluted cities in the world [15]. It is well known that PM_{10} is a better indicator of total suspended particulate matter [10]. These findings therefore, highlight the need for monitoring of PM_{10} particles for the quantification of particulate load in the ambient air and also to suggest control measures for these particles in the air.

However, to the best of our knowledge no detailed study has been reported on the PM_{10} concentration in Aurangabad city of the state of Maharashtra. Aurangabad city is home to five major industrial areas with presence of various MNCs still city infrastructure is not as per industrial standards. In addition, the city is known for its historical monuments such as "Ellora Caves", "Bibi Ka Makbara" which might be adversely affected from air pollution. Therefore, this research is aimed at estimating PM_{10} concentrations at several locations across Aurangabad city in order to highlight the air quality status of this rapidly growing city.

1.2 Site description

Figure 1(a) shows the Map of Maharashtra state of India. Aurangabad district in the Maharashtra is highlighted (Fig.1a). The region has a rich historical background with popular tourist places for both domestic and international tourists. The city is situated at a latitude of 19°53'59" North and longitude 75°20' East. Aurangabad urban corporation limit has area about 138 km^2. The climate of Marathwada region is generally hot and dry. The average temperature for day ranges from 27.7°C to 38.0°C while it ranges from 26.9°C to 20.0°C during the night. Average annual rainfall in the city and adjoining areas is only 725.8

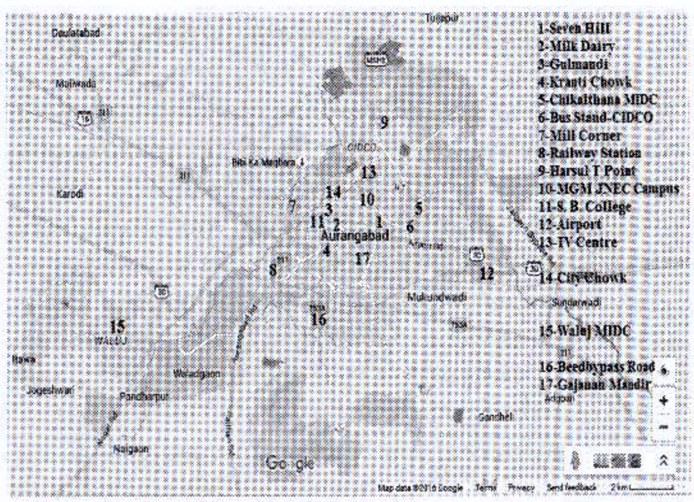

Fig. 1. a) Maharashtra State showing Aurangabad, **b)** Aurangabad city showing sampling locations

mm which is lower than annual average rainfall of India 1083 mm. The relative humidity is extremely low in this region for a major part of the year and ranges between 35 to 50%, while it is 85 to 100% during monsoon. The total area under forest cover is about 557 km^2 which comprises of only 7.6% area of the total land area in Aurangabad. Recent census data revealed that the population of city is about 1.5 million. The city is surrounded by about 1020 total number of industrial units (small, medium and large-scale) and almost 35,000 workers find their employment in these units [16]. The rapid industrial growth of Aurangabad has resulted in urbanization of the city and has also increased air pollution. The number of vehicles has also increased making a significant contribution to the vehicular traffic.

The sampling sites according to their different land use patterns, populations and traffic densities have been selected for monitoring particulate matters. The measurements of PM_{10} have been carried out about 3-5m above the ground as per standard air sampling method as shown in Fig. 2. The description of each site selected with traffic density and land use pattern are given in Table 1.

2. Materials and Methods

PM_{10} monitoring was carried out in selected city site locations during winter Dec, 2015-Jan, 2016. The samples were collected for 24h. PM_{10} samples were collected on whatman filter paper with the help of a respirable dust sampler (Model - APM 460 DXNL, Envirotech, New Delhi) developed through the collaboration of National Environmental Engineering Research Institute (NEERI) and Council of Scientific and Industrial Research (CSIR). The high volume sampler was operated at a flow rate of 1.1 m^3/min. Field blanks were also collected.

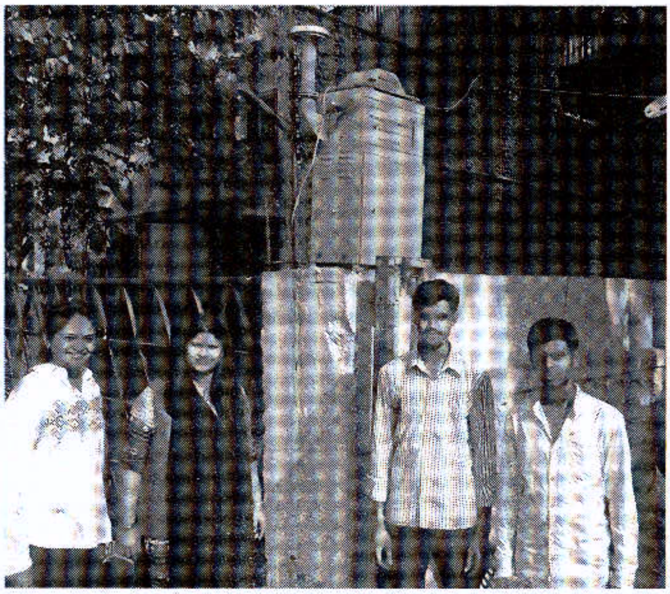

Figure 2. Respirable dust sampler for PM_{10} monitoring at Waluj industrial area with team

Table 1. Sampling at different locations in Aurangabad city and surrounding sites

Location	Description	Traffic Density	Land use pattern
1. Seven Hill	Near to Flyover and commercial complex	High	Mixed
2. Doodh Diary	Maharashtra State Electricity Distribution Co. Ltd.	High	Commercial
3. Gulmandi	Busy densely populated market area	Medium	Mixed
4. KrantiChowk	Near to Flyover and commercial complex	High	Commercial
5. MIDC Chikalthana	Open industrial area with only few units functioning	Medium	Industrial
6. CIDCO - Bus stand	City bus stand buzzing with commuters and bus drivers and cleaning staff	High	Commercial
7. Mill corner	City Police Commissioner Office	High	Mixed
8. Railway Station	City Railway Station with high rush of visitors heavy vehicles and small commercial shops	High	Commercial
9. Harsul T point	Outskirt of city interstate buses, commercial vehicles pass through the area	High	Mixed
10. JNEC-MGM campus	Educational Institution with around 8000 students and 500 faculty members	Medium	Institution
11. SB College, Aurangpura	Unpaved roads, high population density	High	Institution
12. Airport, Chikalthana	Airport is on city outskirts, large open area	Low	Airport
13. TV Centre	Government TV transmission centre	High-Medium	Mixed
14. City Chowk	Densely populated residential area with market	Medium	Mixed
15. MIDC-Waluj	Over 1200 industries	High	Industrial
16. Beed bypass	City outskirts where heavy truck vehicles bypass the city	High	Commercial
17. GajananMandirChowk	Centre of city, densely populated	High	Mixed

Before beginning the sampling all the filter papers were pre-weighed with the help of a analytical weighing balance. The filter paper was desiccated for the duration of 24 h. In order to avoid any sort of contamination, conditioned and pre-weighed filter papers were kept in a zip lock polybag for taking to the field for sampling. Prior to loading the filter papers on the sampler, the initial manometer and timer

Figure 3. Respirable dust sampler for PM_{10} monitoring during setting of air flowrate

readings were noted. Subsequently, the filter papers were loaded on the sampler and after ensuring that the sampler was properly locked, the sampler was started with 1.1 m^3/h. air flow rate at shown in Fig. 3. At the end of sampling period, the loaded filter paper (Fig. 4) was removed with the help of forceps, wrapped in aluminum foil and placed in a zip lock polybag. In the laboratory the loaded filter paper from the sampling site was conditioned in the desiccator to remove the moisture absorbed during sampling as shown in Fig. 5 and covered with glass dome of the desiccator. The dry loaded filter paper was again weighed to determine the PM_{10} mass concentration [14].

3. Meteorological Observations

During the air quality monitoring the wind direction (WD) and speed (WS), temperature, relative humidity (RH) and the rainfall were also recorded at weather station installed on the rooftop of MGM's

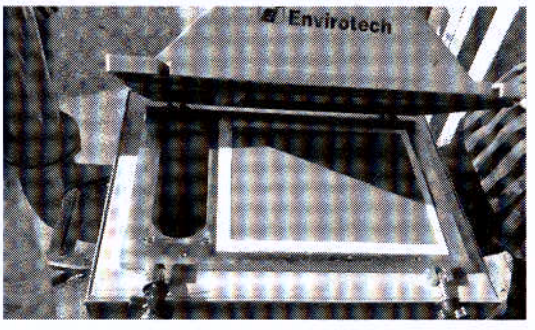

Figure 4. Respirable dust sampler for PM_{10} monitoring showing dust deposite on filter paper

Jawaharlal Nehru Engineering College (JNEC). The average minimum and maximum temperatures were 14 °C and 30 °C during the sampling period. Also the

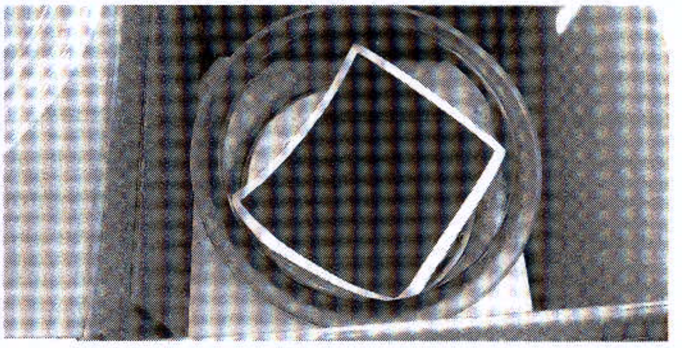

Figure 5. Sampled filter paper put inside the desiccator

average minimum and maximum RH were 26% and 51%, while the prominent WD was towards East with WS ranging from 6 to 14 km hr^{-1}. During the period of sampling there was no rainfall.

3.1 Results

The concentration of PM_{10} in the ambient air is highest at the Aurangabad Railway Station (Table 2). The reason for which could be narrow road, high traffic, numerous encroachments and high floating population greater than 0.1 million commuting from nearby regions to work in the industries. This creates congestion and idling of vehicles which results in the generation of high quantities of particulate matter from heavy vehicles (coming from Paithan road) passing through the junction opposite to the railway station.

Table 2. MPCB data of Aurangabad for January, 2016

	SBES College Particulate matter ($\mu g\ m^{-3}$)	**CADA Office** Particulate matter ($\mu g\ m^{-3}$)
Summer		
April	105	75
May	89	68
Monsoon		
June	78	50
July	76	42
Aug	66	31
Winter		
Nov	123	90
Dec	135	126
Jan	203	140

Source: http://mpcb.gov.in/envtdata/demoPage1.php

Waluj is an industrial zone which has a high concentration of the critical air polluting industries so it is probable that these industries contribute to PM generation. In addition, the control equipments for controlling PM release into the atmosphere are neither effective nor efficient and thereby contributing to a high PM concentration. Another very important reason is that the public response is very low with regard to pollution which does not motivate the industries to focus on controlling pollution.

The other industrial zone Maharashtra Industrial Development Corporation (MIDC) at Chikalthana shows low PM levels on account of relocation of major industries as well as its being converted into a residential zone. City chowk is the centre of the city which has high population, tall buildings, few open spaces or vegetated areas and narrow road which causes high congestion and does not allow dispersal of the particulates generated from traffic, waste disposal and biomass burning. Other locations with high concentrations of PM_{10} are Mill corner, Harsul T-point, Kranti Chowk, Seven Hill, TV Centre and Beed Bypass (Fig.6). All these locations have narrow roads, high traffic density, poor road conditions with pot holes and few crossing points which cause congestion and vehicle idling which are responsible for high pollution. Beed bypass road has continuous heavy vehicles traffic and need to be more widened with four lane road.

Airport being an open spread out area with low population, less traffic and no industries in the vicinity has a low PM concentration. However, airport has just reached above the standard PM_{10} limit. The possible reasons are close vicinity residential area and near by vehicular emissions from Jalna-Aurangabad heavy traffic road and illegal open burning of biomass and waste products at near by dumping yard. The airport authority of India (AAI), Aurangabad division has

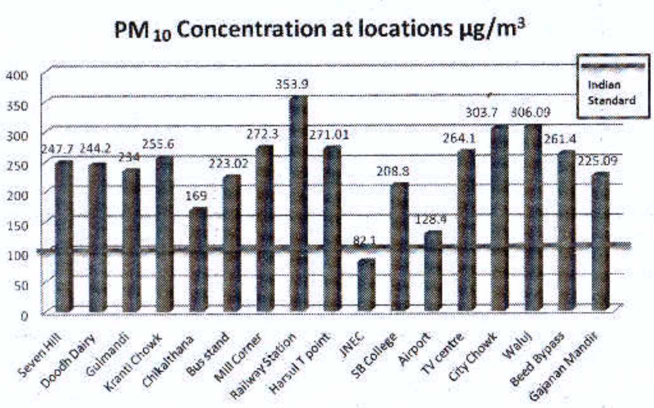

Figure 6. Location wise PM_{10} concentration

complained about the fogg issue at the airport causing visibility for air traffic. It is also important to note that the PM_{10} concentrations exceed the WHO standard ($50\mu g/m^3$) and Indian standard of CPCB ($100\mu g\ m^{-3}$) as shown in Fig. 6. It is clear that the concentrations were almost 3 to 3.5 times higher than the Indian standards suggesting that more efforts should be taken to control the particulate matter pollution in Aurangabad.

When the study results were correlated with Maharashtra Pollution Control Board (MPCB) data for January for Sarashwati Bhuvan Education Society (SBES) College at Aurangpura, it was found that the PM values were 203 $\mu g/m^3$ which were close to the values (208.8 $\mu g/m^3$) reported by this study (Fig.6). It is also clear from the MPCB data (Table 2) that PM pollution is lowest in monsoon season followed by summer and it is highest in winter season. In monsoon, rainfall washes the particles resulting in their low concentration while in summers strong winds result in re-suspension of dust causing higher PM concentration than monsoon. Winter season of the year is associated with low wind speeds and negligible rainfall resulting in highest air pollution level as given in Table 2 which was also been reported by Kavuri and Paul [17] at different locations. Further, the lower solar insolation rates during the winter months lead to lower atmospheric inversion layers where pollutants become trapped close to the ground. Hence, there is increasing in fine particle concentrations [18]. $PM_{2.5}$ data confirms the pronounced seasonal peaks coinciding with lower mixing heights of the winter months. The measured PM pollution in the winter is at least double the concentrations measured during the rest of the season [19].

3.2 Discussion

Various studies have been conducted in different parts of India to assess the PM_{10} concentration [20]. estimated the RSPM concentrations in Indore city at 11 locations, mostly at outer city areas. The average values of respirable dust varied between 39.78 to 649.92 $\mu g/m^3$ for Indore city while Aurangabad city and its adjoining areas show PM_{10} concentration in the range of 82.1 to 343.9 $\mu g/m^3$. Mohanraj and Azeez in 2005 assessed the RSPM levels at six sampling locations in urban and sub-urban Coimbatore [21]. It was found that average RSPM levels ranged between 30 to 149 $\mu g/m^3$. They inferred that urban areas with frequent vehicular traffic and traffic congestion had comparatively high RSPM which exceeded the prescribed Indian standards. Chalka in 2006 conducted monthly and seasonal analysis of RSPM at industrial, traffic, residential and sensitive locations of Ajmer (Rajasthan) in 2004 [22]. They observed highest level of RSPM (488.0 μg/m^3) in months of December and June at industrial site. The level of RSPM crossed the limits of the National Ambient Air Quality Standard (NAAQS) laid down by Central Pollution Control Board (CPCB).

Karar in 2006 investigated the seasonal and spatial variations of PM_{10} in residential and industrial sites in urban area of Kolkata [23]. They found that daily average PM_{10} concentrations ranged between 68.2 to 280.6 μg/m^3 in residential area and 62.4 to 401.2 μg/m^3 in an industrial area. Higher PM values at industrial area was attributed due to heavy traffic flow, emission from nearby industrial area and re-suspension of road and soil dust. Seasonal study showed maximum value of PM_{10} in winter and minimum in monsoon season. Higher winter concentration was attributed to low winds and low mixing heights leading to accumulation of pollutants. Kapoor in 2009 studied the RSPM in and around Udaipur city (Rajasthan) for the duration Nov, 2007 to Oct, 2008 [24]. They concluded that minimum values for RSPM ranged from 48.01 to 369.76 μg/m^3 and maximum values varied between 81.43 to 1032.1 μg/m^3. They concluded that air pollution levels were minimum in residential areas, higher on roads and highest in industrial area. Clearly, the reports in literature are in good agreement with the results presented in this paper suggesting that Industrial areas and high traffic density areas have high particulate matter pollution. The control strategies for the Aurangabad city PM_{10} concentration has become prime important and briefly given in Table 3.

Table 3. Control measures to reduce Particulate Pollution

No.	Policy	Legal	Institutional	Technical
1.	Cleaner fuels like CNG for heavy vehicles, buses in the city	Strict implementation of Air Act should be done by State Boards.	NGOs, Chamber of Marathwada Industries and Agriculture (CMIA) & Educational Institutes should undertake joint monitoring programs as well as mass awareness for educating public about harmful effects of PM pollution in city	Development of low cost sensitive monitoring network for PM.
2.	Vehicles older than 15 years should be taken off the roads	Air quality management initiatives should be undertaken through judicial interventions on public grievances voiced in PIL on air pollution	---	Apportionment studies for fine PM_{10} in the city
3.	Vehicular emission check should be made compulsory	Pollution under control (PUC) certification	---	Higher PM emissions from Diesel vehicles
4.	Monthly stack monitoring should be undertaken by Maharashtra PCB.	---	Stack monitoring in collaboration with Engg. colleges & NGO	---
5.	Vehicles not meant for the city should be made to bypass for reducing congestion and pollution	Widen bypass road for heavy vehicles traffic	---	Idling of heavy vehicles due to traffic have more PM generation
6.	Improve road conditions, widen bypass roads and heavy traffic city roads	Traffic signals & one-way traffic need to be imple-mented for narrow roads	PWD & AMC need to resolve the serious issue in the Aurangabad city	---
7.	Implementation of ban on open burning of solid waste and biomass	Action against private property or society involved in this issue	Aurangabad Municipal Corporation (AMC)	Proper solid waste management & its segregation

Similar studies in other developing countries such as Nepal, Pakistan, Tanzania, etc. have concluded high particulate matter concentration in high traffic areas. Jackson in 2005 assessed the contribution of road traffic to air PM pollution level from 11 different sites in Dar-Es-Salam city of Tanzania during 2002-03 [25]. Hourly RSPM ranged from 98 to1161 μg/m³ which is far exceeding WHO standards (i.e. 50 μg/m³). Simkhada in 2005 assessed RSPM at six selected locations in Bishnumati corridor, Nepal [26]. They found in all locations PM to be in harmful and hazardous zone ranging in concentration from 387.20 to 918.92 μg/m³. Colbeck in 2010 reviewed data on PM in Pakistan [27] and compared it with WHO guidelines. They reported several times higher levels of PM and concluded it to be most serious air pollutant in the country. Colbeck in 2011 assessed PM along major roads of Lahore in Pakistan and found average roadside PM_{10} concentration to be 489 μg/m³ [28].

Another very important point which supports the harmful impact of particulate matter pollution is highlighted by the fact that the higher PM during 2007 as compared to 2006 was associated with an increase in hospitalization for respiratory problems such as asthma and bronchitis in Aurangabad. Cases of premature death due to heart attack during 2006-07 were increased in men in the age group of 40-59 which may be attributed to higher PM_{10} levels. Therefore, it is evident that air pollution is a serious issue in the city which may be further aggravated if it is not brought under control. Hence, strategies have to be adopted for combating the menace of air pollution due to particulate matter in the ambient air of Aurangabad city (Table 3) [29].

4. Conclusion and control strategies

Rapidly growing Indian cities such as Aurangabad have a high concentration of particulates matter suspended in ambient air which is attributed due to automobiles, industries, waste and biomass open burning and dusty footpath creating re-suspension of road dust. Particulate matter (PM) has been implicated in various respiratory, cardio-pulmonary diseases and even cancer. Therefore, clean air should be India's focus for economic growth from growing cities with regard to benefits of longer lives and fewer incidences of PM related sickness. Also people who survive longer are able to contribute to the Indian economy for more years. Need of the hour is to undertake policy, institutional and technical strategies to curb particulate matter pollution from Aurangabad city.

4.1 Conclusion

It is evident from this paper that the Aurangabad city has PM_{10} concentration in the range of 82.1 to 343.9 μg/m³. The average PM_{10} concentration is found to be 213 μg/m³ in the Aurangabad city which is far more than National Ambient Air Quality Standard (NAAQS) of 100 μg/m³ . Hence, this is the serious issue in the city for minimizing the PM level in the ambient air for raising the quality standard of the ambient air in the Aurangabad city to be considered for "Smart City" development in India.

4.2 Control strategies

In this regard, it should be mentioned that the present study was in a short duration and it is important to develop and set a comprehensive monitoring network to provide more accurate information regarding the particulate load especially in highly populated and congested areas. Particulate matter in the ambient air could be controlled by adopting the various strategies as given in Table 3.

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