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Studies on Ambient Air Quality Status of Kolhapur City, Maharashtra, India during Year 2013

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Abstract: Air pollution is an emerging public health problem in developing countries. Urban activities create more pollution in comparison to rural activities. This paper assesses the ambient air quality status in urban residential area of Kolhapur city. Three sites viz. Shivaji University (SU), Dabholkar Corner (DC) and Mahadwar Road (MR) were selected to spotlight an overview of the total air quality of this region under Maharashtra Pollution Control Board (MPCB) sponsored National Ambient Air Quality Monitoring Project (NAAQM). The air quality was assessed based on measuring four air pollutants namely sulphur dioxide (SO_2), oxides of nitrogen (NOx), Respirable Suspended Particulate Matter (RSPM) and Suspended Particulate Matter (SPM). From these three areas, two areas viz., Dabholkar Corner (DC) and Mahadwar Road (MR), the average concentrations of RSPM and SPM exceeded the prescribed limits of Central Pollution Control Board (CPCB), New Delhi. The average concentrations of air pollutants at Dabholkar Corner and Mahadwar Road areas were higher than that of Shivaji University area. Apart from this the SO_2 and NOx levels in all three areas remain under prescribed limits of CPCB, New Delhi. The average AQI of Dabholkar Corner and Mahadwar Road areas were found higher than the Shivaji University area. The AQI found to be less during rainy season (June to August). As per AQI calculated, the areas viz. Dabholkar Corner and Mahadwar Road have severe air pollution whereas the area Shivaji University has moderate air pollution.

Key words: SO_2 and NOx, RSPM, SPM, air quality index (AQI), air pollutants.

Introduction

The immediate environment of man comprises air on which depends all forms of life. Human beings need a continuous supply of air to exist. The requirement for air is relatively constant about 10-20 m^3 per day (Park, 2009). The air pollution is recognized as an emerging public health problem in developing countries (Nandasena et al., 2010). Air pollution is a severe problem in major urban areas due to increasing number of vehicles, reduced road capacity and few investments in public transportation, especially in developing countries (Silva et al., 2012). Air pollution is a serious worldwide public health problem. The short-term health impacts of air pollution have been studied extensively since the London fog in the mid 20^{th} century and the subsequent series of dramatic episodes in industrialized countries (Boyd, 1960). The advent of technological and scientific innovations in various fields and diverse activities of human race for its sophistication have put extra load on the atmosphere by way of releasing air pollutants (Panda and Panda, 2012). The magnitude of effect estimate varies across cities and countries (Bhuyan et al., 2010). Emission from an individual car, bike or

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heavy motor vehicle is generally low, but addition of new vehicles every year increases the intensity of vehicular pollution day by day. The pollutants impair health, destroy vegetation and reduce the general quality of life (KMC, 2009). In the present paper, an attempt is made to represent the overall ambient air quality in Kolhapur city, a fast growing city area in the district of Kolhapur, Maharashtra, India.

Materials and Method

Study Area

Kolhapur city is known as Karveer Nagari and located on the Sahayadri mountain range on South Western part of the Maharashtra state. Kolhapur city has a network of 586.59 km roads of different width. Most of the roads are tar roads. Only few roads are WBM type. Few small passages are paved with concrete. After formation of Kolhapur Municipal Corporation, in 1972 municipality limit was increased by 66.82 km. There are 7,25,134 numbers of registered vehicles in the Kolhapur city (Kolhapur RTO, 2011). Kolhapur city is one of the cultural and religious places in Maharashtra as it is host of numerous festive occasions all through the year. Also, it is an important place of tourism. Many developmental activities are increasing at alarming rate. At the same time, roads and building construction, brick kilns, increase in road traffic including private as well as government vehicles are responsible for emission of trace gases and particulate matter. With the aim to evaluate the state of ambient air in Kolhapur, a study was carried out to monitor the changes in ambient air quality during January to December, 2013 and the results are presented in this paper.

Sampling Sites

The three sampling locations were selected to reflect the influences from commercial, residential and heavy traffic area in highly populated regions. Shivaji University (SU), Dabholkar Corner (DC) and Mahadwar Road (MR) were the three selected sampling locations. Dabholkar Corner (DC) is situated near central bus stand, railway station and commercial area whereas Mahadwar Road (MR) is densely populated area consisting residential as well as commercial activities. These two sites are one of the overburden areas of dense air pollution due to heavy traffic. Shivaji University (SU) location is least polluted due to few air pollution activities in this area. The locations of the sites are shown in Figure 1.

Figure 1: Location of sampling sites from Kolhapur city.

Measurement Techniques

Particulate matter and trace gas samplings were performed between January and December, 2013. The sampling frequency was twice in a week. Description of the sampling locations is as shown in Table 1. The sampling was done using calibrated Respirable Dust Sampler (RDS) (Model Enviro Tech APM 460 DX) and Respirable Dust Sampler (RDS) (Model Enviro Tech APM 460 NL) with flow rate of 1.0 to 1.2 m^3/min equipped with glass fibre filter paper. The Respirable Dust Samplers (RDS) were equipped with impingers to collect the trace gases (SO_2, NO_2). Sulphur dioxide in ambient air was measured by Modified West and Gaeke Method (IS 5182 Part 2 Method of Measurement of Air Pollution: Sulphur dioxide), Nitrogen dioxide in ambient air was measured by Modified Jacobs and Hochheiser Method (IS 5182 Part 6 Methods for Measurement of Air Pollution: Oxides of nitrogen) and Total Suspended Particulate Matter (SPM) was measured by addition of RSPM (PM10) and non-RSPM. PM_{10} was measured by gravimetric technique (per IS 5182 (Part IV) under HVS-Filtration method on a pre-weighed glass micro fibre filter paper 20.3 × 25.4 cm (8 × 10 in)). Difference in the weight of filter paper gives the amount of dust collected and thus, the concentration is determined. Similarly, non-RSPM was measured by difference in weight of plastic cup (CPCB and MoEF 2004; 2011). The sampling instruments were placed about 3 metre to 10 metre above ground level. The collected samples were brought to laboratory of Department of Environmental Science, Shivaji University, Kolhapur for further analysis.

Air Quality Index (AQI)

The Air Quality Index (AQI) is an environmental index which describes the overall ambient air status and trend of a particular place based on specific standard. It is a tool that transforms the (weighted) values of individual air pollutants (parameters) into a single number or set of numbers (Rao, 1993). There are several methods and equations used for determining the AQI. However, here the belowmentioned equation (Zlauddin and Siddiqui, 2006; Joshi Semwal, 2011; Panda and Panda, 2012) has been used for computation of AQI value.

$$AQI = \frac{1}{4} (I_{SPM}/S_{SPM} + I_{RSPM}/S_{RSPM} + I_{SO2}/S_{SO2} + I_{NOx} / S_{NOx}) \times 100$$

where individual values of Suspended Particulate Matter (I_{SPM}), Respirable Particulate Matter (I_{RSPM}), sulphur dioxide (I_{SO2}) and oxides of nitrogen (I_{NOx}) were obtained on sampling. S_{SPM}, S_{RSPM}, S_{SO2} and S_{NOx} are standards of ambient air quality prescribed by the Central Pollution Control Board of India (CPCB, 2009). The higher the AQI value, greater is the level of air pollution and greater is the health risk. The AQI scale is divided into five categories as depicted in Table 2. It describes the range of air quality and its associated potential health effects.

Table 1: Sampling sites for ambient air quality monitoring of Kolhapur city

S.R.	*Sampling site*	*Location*	*Status*	*Monitoring day and time*
1	Shivaji University (SU)	Longitude - 16.67669 N Latitude - 74.25282 E Elevation - 2000 Feet	Less traffic density, Educational zone	Monday 6 AM to Tuesday 6 AM Thursday 6 AM to Friday 6 AM
2	Dabholkar Corner (DC)	Longitude - 16.70423 N Latitude - 74.24169 E Elevation - 1885 Feet	Heavy traffic density, Bus stand and Railway station	Tuesday 6 AM to Wednesday 6 AM Friday 6 AM to Saturday 6 AM
3	Mahadwar Road (MR)	Longitude - 16.69450 N Latitude - 74.22176 E Elevation - 1855 Feet	Heavy traffic density, Commercial zone	Wednesday 6 AM to Thursday 6 AM Saturday 6 AM to Sunday 6 AM

Table 2: Rating scale of Air Quality Index

Sr. No.	*AQI value*	*Remarks*	*Health concern*
1.	00–25	Clean air (CA)	None/minimal health effect
2.	26–50	Light air pollution (LAP)	Possible respiratory or cardiac effect for most sensitive group
3.	51–75	Moderate Air Pollution (MAP)	Increasing symptoms of respiratory and cardiovascular illness
4.	76–100	Heavy Air Pollution (HAP)	Aggravation of heart and lung diseases
5.	> 100	Severe Air Pollution (SAP)	Serious aggravation of heart and lung diseases; Risk of death in children

Source: Panda and Panda (2012) and Yadav et al. (2012)

Results and Discussion

Month-wise and site-wise observations of ambient air quality parameters, viz. SO_2, NO_X, RSPM and SPM for the year 2013 are graphically represented in Figure 2 to Figure 5 respectively. The monthly average concentrations of pollutants are demonstrated in Table 3. From the three locations studied, DC and MR locations' average RSPM and SPM levels exceeded the CPCB limit while at SU location average RSPM and SPM levels were well within the limit. This high air pollution emission observed at DC was due to the fact that the location was at the heart of the city and nearer to railway station as well as central bus stand and hence, there was high vehicular traffic. There was a high air pollution load at MR site which is a main commercial zone and Mahalaxmi temple and hence, large vehicular activity of the local as well as tourist was observed at this place. On the contrary at SU site all air pollutant levels were well below the prescribed limit as it is located at boundary of the city and having less traffic density.

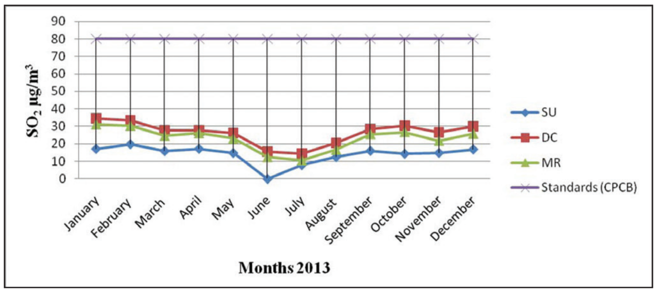

Figure 2. Monthly variation of SO_2 μg/m^3 in three sites in Kolhapur city.

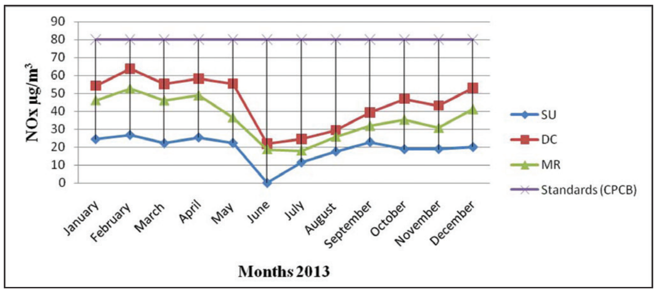

Figure 3. Monthly variation of NOx μg/m^3 in three sites in Kolhapur city.

SO_2

All the SO_2 μg/m^3 values at three sites in the Kolhapur city were well below the prescribed standards of CPCB. However, the highest value (42.09 μg/m^3) was recorded at DC during the month of January, 2013 and the lowest value (5.13 μg/m^3) was observed at Shivaji

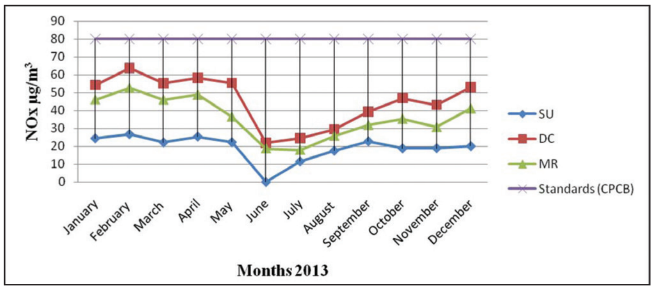

Figure 4. Monthly variation of RSPM μg/m^3 in three sites in Kolhapur city.

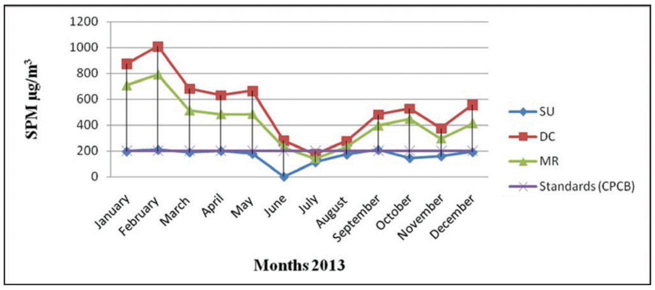

Figure 5. Monthly variation of SPM μg/m^3 in three sites in Kolhapur city.

University site during the month of July, 2013. It was observed that SO_2 concentration was relatively low during monsoon in comparison with summer and winter. This was due to the prevalence of high speed wind and frequent precipitations. Further, it was observed that SO_2 emission, though insignificant, was more at commercial sites (DC and MR) in comparison to SU sites. The concentration of SO_2 were found to be below permissible limit (80 μg/m^3) of NAAQS, but there are several reports that gaseous pollutants are related with respiratory diseases, reproductive and developmental effect even at low concentration (Curtis et al., 2006; Liu et al., 2003). Jayaraman (2007) reported 32.5% increase of hospital admission in Delhi which is associated with SO_2 level below NAAQS.

NOx

The concentrations of NOx determined were below the prescribed limit set by the CPCB at all the three locations. The highest average concentration of NOx (78.12 μg/m^3) was found at DC site, near central bus stand where highest traffic density is observed. The lowest value (9.08 μg/m^3) of NOx was observed at SU. Nitrogen oxides are byproducts in all combustion processes, and road traffic only contributes 35% to the total national emissions; the relative contribution to urban pollution levels, however, is significantly higher (Ali and Athar, 2008). Automobile exhausts

Table 3: Monthly average concentration of atmospheric trace gases and particulate matter in Kolhapur city during the year 2013

Months	*Shivaji University campus*				*Dabholkar Corner*				*Mahadwar Road*			
Parameter	*SO_2 μg/m³*	*NOx μg/m³*	*RSPM μg/m³*	*SPM μg/m³*	*SO_2 μg/m³*	*NOx μg/m³*	*RSPM μg/m³*	*SPM μg/m³*	*SO_2 μg/m³*	*NOx μg/m³*	*RSPM μg/m³*	*SPM μg/m³*
January	17.17 ±2.50	24.45 ±3.81	77.11 ±8.59	197.12 ±33.55	34.43 ±3.58	54.21 ±9.96	219.18 ±71.22	873.13 ±237.69	31.08 ±3.36	46.03 ±7.55	191.33 ±57.65	708.40 ±194.63
February	19.82 ±3.95	26.77 ±4.48	78.71 ±9.15	208.81 ±41.98	33.19 ±3.61	63.74 ±9.65	246.40 ±83.88	1008.79 ±309.53	30.25 ±3.78	52.57 ±9.38	196.78 ±67.51	792.43 ±248.72
March	15.94 ±3.00	22.15 ±4.15	68.65 ±7.33	189.54 ±34.25	27.62 ±4.37	55.14 ±8.45	167.39 ±68.18	680.81 ±330.82	24.54 ±4.35	45.96 ±9.11	138.48 ±51.02	514.26 ±220.71
April	17.20 ±4.15	25.41 ±6.09	73.53 ±15.00	200.76 ±44.58	27.56 ±4.22	58.05 ±9.28	166.10 ±46.04	630.49 ±195.37	26.06 ±3.34	48.80 ±9.27	136.35 ±27.53	483.89 ±133.30
May	14.78 ±4.84	22.28 ±7.41	62.73 ±20.37	178.24 ±59.86	25.95 ±5.97	55.34 ±14.10	177.85 ±68.23	664.42 ±236.83	22.89 ±5.41	36.46 ±8.78	138.59 ±40.94	485.80 ±173.02
June	*	*	*	*	15.39 ±4.90	21.87 ±9.30	75.85 ±23.98	277.68 ±130.64	12.41 ±5.54	18.73 ±8.81	69.58 ±27.80	229.67 ±104.78
July	7.96 ±1.90	11.53 ±2.38	51.07 ±8.76	111.75 ±18.55	14.32 ±5.47	24.49 ±9.09	68.30 ±21.04	175.37 ±57.18	10.44 ±5.66	17.96 ±9.62	61.53 ±31.97	141.53 ±74.74
August	12.50 ±3.64	17.54 ±4.67	65.79 ±13.86	172.89 ±45.47	20.29 ±6.09	29.45 ±9.15	91.43 ±25.05	275.98 ±98.66	16.55 ±6.45	25.75 ±9.15	82.35 ±29.29	232.38 ±91.55
September	16.06 ±7.10	22.76 ±9.94	65.39 ±28.63	208.22 ±91.75	28.21 ±8.00	39.35 ±12.37	118.72 ±33.92	482.59 ±178.76	25.49 ±4.33	31.77 ±5.77	106.39 ±16.68	396.44 ±111.65
October	14.38 ±6.00	18.81 ±7.79	61.46 ±25.34	143.58 ±59.09	30.17 ±7.44	46.81 ±13.87	139.15 ±44.42	527.90 ±294.24	26.68 ±6.94	35.20 ±10.14	121.50 ±33.28	446.91 ±194.59
November	14.85 ±5.64	18.91 ±7.28	61.67 ±21.93	158.90 ±62.35	26.32 ±5.80	43.14 ±11.32	122.62 ±29.52	373.28 ±120.55	21.69 ±4.53	30.70 ±5.81	101.18 ±14.98	295.15 ±64.21
December	16.89 ±3.54	20.06 ±4.46	71.99 ±8.84	191.04 ±31.31	29.98 ±4.49	52.86 ±14.79	148.55 ±28.24	556.47 ±181.15	25.69 ±3.86	41.09 ±10.00	116.43 ±13.56	414.72 ±104.76
Average	**15.23**	**20.97**	**67.10**	**178.26**	**26.12**	**45.37**	**145.13**	**543.91**	**22.81**	**35.92**	**121.71**	**428.47**
Standards	**80**	**80**	**100**	**200**	**80**	**80**	**100**	**200**	**80**	**80**	**100**	**200**

(Figures in underline indicate Ambient Air parameter level above prescribed limit)
* indicates Respirable Dust Sampler machine failure

and certain industrial pollutants contain NO_2 which by photochemical reaction produces O_3 and effects allergic asthmatics by augmenting allergic responses (Steinberg et al., 1991). Vineis et al. (2004) reported that in four out of five studies in Europe and US exposure to higher outdoor level of PM10/PM2.5, vehicle traffic and NO_2 are associated with significantly higher risk of lung cancer. SO_2 and NOx level at three sites were relatively low during monsoon in comparison with summer and winter.

RSPM

RSPM was also found maximum at DC site, which was 362.5 $\mu g/m^3$ in March, 2013 and lowest (37.5 $\mu g/m^3$) levels of RSPM were recorded at SU in July, 2013. Average RSPM values at DC and MR sites exceeded the prescribed limit of National Ambient Air Quality Standard (NAAQS) set by the CPCB. RSPM values were lowest in monsoon due to intermittent precipitation. RSPM levels were high in winter in comparison with summer at all locations. RSPM level crossed the limit at two locations (DC and MR) in the months of January to May and September to December. This was mainly due to the massive transportation of vehicles in the Kolhapur city. The analysis of data clearly shows that respirable suspended particulate matter is emerging as the critical pollutant for primary attention. This particle also plays a central role in environmental problems such as climate change and visibility impairment (Gunasekaran et al., 2012). Respirable Suspended Particulate Matter (RSPM or PM_{10}) disperse to a long distance and they react or damage the mechanisms by chemical reaction with the molecules of respiratory system and bringing about adverse chemical changes. These may reduce the lung capacity in humans (Ghose et al., 2005). RSPM or PM_{10} in the air has been associated with health impairment and increase in mortality, morbidity and asthma (Dorckey et al., 1993). Correlation of metals showed that the RSPM were significantly correlated with Pb, Mn, Cu and Cr indicating that the same sources might be due to the vehicular pollution (Barman et. al., 2010).

SPM

Throughout the study period SPM was found maximum at DC and MR. The highest (1675 $\mu g/m^3$) and lowest (83.33 $\mu g/m^3$) values of SPM were recorded at DC site in the month of March, 2013 and at SU in July, 2013 respectively. Like RSPM, average SPM values at DC and MR sites exceeded the prescribed limit of National Ambient Air Quality Standard (NAAQS) set by the CPCB; also SPM levels were relatively high during winter in comparison to monsoon and summer in almost all the three locations. This trend was due to the fact that in winter, anti-cyclonic condition prevailed which was characterized by calm or very slow wind, there was little dispersion or dilution of pollutants which caused higher levels of SPM. SPM includes all air-borne particles in the size range of 0.5 µ to 100 µ. The actual health damage caused by dust particles depends upon its nature and composition (Binder et al., 1976). Many studies show that Particulate Matter (PM) air pollution is related to adverse health effects resulting in an increase in mortality and morbidity (Merbitz et al., 2012). It has been reported that more than 10,000 premature deaths occurred in Kolkata in 1995 due to SPM (Kazimuddin and Banerjee, 2000).

AQI

The AQI for three sites during year 2013 are given in Table 4 and Figure 6. The AQI values were observed highest (217.99) at DC and lowest (32.83) at SU and in February, 2013 and July, 2013 respectively. It is seen that the AQI values of DC and MR were more than 100 except rainy seasons indicating severe pollution of the ambient air. Severe Air Pollution (SAP) is found at DC and MR in summer and winter seasons. The air pollution is reduced to some extent due to the unexpected rain in the month of November, hence Severe Air Pollution (SAP) was reduced to heavy air pollution (HAP) at DC and MR. Moderate air pollution (MAP) was observed

Table 4: AQI of three sites in the Kolhapur city during year 2013

Sr. No.	*Months*	*AQI*		
		SUK	*DCK*	*MRK*
1.	January	56.92	191.64	160.48
2.	February	60.34	217.99	174.13
3.	March	52.76	152.81	120.93
4.	April	56.79	147.09	117.97
5.	May	49.54	152.92	113.92
6.	June	*	65.32	55.84
7.	July	32.83	51.12	41.95
8.	August	47.45	72.90	62.85
9.	September	54.51	111.12	94.05
10.	October	43.68	124.83	105.58
11.	November	45.83	99.02	78.56
12.	December	53.42	132.58	101.82
13.	Average	50.63	126.61	102.34

* indicates Respirable Dust Sampler machine failure

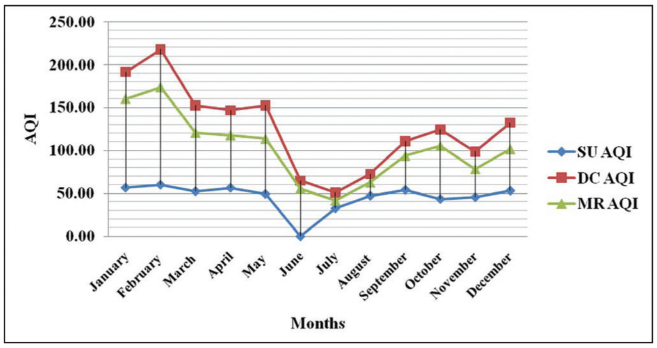

Figure 6: Monthly variation in the site AQI values in Kolhapur city during year 2013.

at SU site throughout the year except monsoon season when light air pollution (LAP) was observed. Also at DC and MR sites in rainy season (month of August) moderate air pollution (MAP) were observed. Light air pollution (LAP) was noticed at SU site from July to August, 2013 and also at MR site in the month of August, 2013 in rainy season. High values of AQI are due mainly to SPM and RSPM emission from various sources.

Conclusion

Computed and analyzed data revealed that Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM) were the major air pollutants at three locations. However, gaseous pollutants (SO_2 and NOx) were well within the permissible limit at all the three locations. The study clearly indicates that it would be more appropriate to consider AQI rather than individual air pollutant level while planning prevention of air pollution in the areas. From AQI values, it was found that there was severe and heavy air pollution at two locations (DC and MR), in conformity with the SPM and RSPM levels. It was also observed that particulate emission was basically transport related and levels were relatively high during winter in comparison to summer and monsoon. To contain the SPM and RSPM concentrations within an acceptable level, it is suggested that massive green plantation must be taken up in the entire area. Trees having high dust trapping efficiency are to be grown alongside the roads and water is to be sprinkled continuously at the source of generation of particulate matter immediately. The measures like limiting vehicle speed at vulnerable localities, conducting public awareness campaigns about the harmful effect of air pollution and educating the drivers to be more eco-friendly; are also to be taken.

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