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DUST FALL RATE AND ITS COMPOSITION IN CHANDRAPUR INDUSTRIAL CLUSTER, CENTRAL INDIA

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Abstract

Dust is one of the significant air pollutants in ambient air of Chandrapur industrial cluster. A study was carried out to ascertain the dust fall rate in four sampling locations in the Chandrapur industrial cluster of Chandrapur district, central India. The sampling was carried out by dust fall jar method in winter season (2014-2015) and dust fall rate was estimated gravimetrically. Maximum dust fall rate was recorded in Nakoda 246.67 MT sq km^{-1} $month^{-1}$ (industrial area, downwind direction), followed by CSTPS colony 171.77 MT sq km^{-1} $month^{-1}$ (industrial area, downwind direction) whereas minimum concentration was found in Babupeath 55.54 MT sq km^{-1} $month^{-1}$ (residential area, downwind direction) for December-January. Whereas, during sampling period of February-March maximum dust fall rate was observed to be 278.14 MT sq km^{-1} $month^{-1}$ at Babupeath (residential area, upwind direction) and minimum dust fall rate was observed at Ballarpur 173.74 MT sq km^{-1} $month^{-1}$ (industrial, upwind direction). The results indicated that dust fall rate for the sampling period of December-January in industrial cluster region was higher as compared with residential region. It has been also observed that upwind direction sampling locations had lesser dust fall rate as compared with downwind direction. The composition of dust fall from study area was dominated by water soluble components. Water insoluble components were comprised of inorganic insoluble and volatile matter. Total inorganic component per cent by weight was maximum in dust.

Keywords: Air pollution, Central India, Chandrapur industrial cluster, Dust fall rate, Maharashtra

Introduction

Gaseous and particulate pollutants are significant contributor of atmospheric air pollution. Particles are inherently larger than the gaseous pollutants in the atmosphere and therefore behave differently with increasing diameter. Particles in the atmosphere came from different sources, e.g. combustion, windblown dust, and gas-to-particle conversion processes (Vallero, 2008). Particles in the atmosphere, which range in size from about 0.5 mm down to molecular dimensions, are made up of amazing variety of materials and discrete objects that may consist of either solids or liquid droplets. Various kinds of particles includes aerosols, condensation aerosols, fog, haze, mist, smoke, dust depends on its size. Particulate matter makes up the most visible or obvious forms of air pollution. Carbon black, silver iodide, sea salts are forming very small particulates. Particulate matter may be organic or inorganic in nature. Industrial transport, domestic and natural processes contribute to the sources of particulate matter (Santra, 2014).

Dust fall refers to a particulate sampling method after airborne particles settle by sedimentation into dust fall jar. This method gives an indication of the quantity of larger particles having appreciable settling velocities and relative short atmospheric residence time. Dust fall particles, because of their large size, are offensive to the visible sense and constitute a nuisance to housewives and community (Stern, 1976). The water insoluble component of dust fall was higher in industrial areas than in rural areas. Water soluble organic matter was higher in rural area samples. A lower seasonal variation also occurs, i.e., dust fall increases during the heating season. Under low humidity conditions, water is lost from the droplets of basic air pollutants which react with acid to form salts and a solid aerosol is formed. Thus, leading to increased dust fall during summer season (Manahan, 2001).

Particulate matter present in the atmosphere may organic or inorganic in composition and in liquid or solid physical state. Particulate matter especially in the suspended form, present in the atmosphere is known to have many adverse effects upon health and welfare. Mostly, the sizes of particle are very small. Carbon or soot particles, acid droplets, metallic oxides and salts, silicates and other dust including metallic fumes are of common forms of particulate matter.

The particulate matter or dust can alter the body defense system against foreign materials, damage lungs tissue, aggravate existing respiratory and cardiovascular disease and can lead to cancer. In some cases, particulate matter exposure can even lead to premature death. Adverse health effects have been associated with exposure to particulate matter over both short period (such as a day) and longer periods (a year or more). The people who are most at risk are people with asthma, influenza lungs, heart, or cardiovascular disease, the elderly and children. It has been shown that there is an 18% increase in death from heart disease among people with long term exposure to particulate matter. While exposure the clearly impacts the lungs, long term, chronic exposure to air pollution seem to manifest more in cardiovascular disease than it does in respiratory disease (Air Quality Monitoring Manual, 1978).

According to comprehensive environmental assessment of industrial cluster study carried out by IIT Delhi and Central Pollution Control Board (CPCB), New Delhi, India for 88 industrial clusters in India, the comprehensive environmental pollution index (CEPI) for air environment for Chandrapur industrial cluster was 70.75 (CPCB, 2009). It was declared as the fourth most polluted industrial cluster in India. While computing CEPI for air environment for Chandrapur industrial cluster, dust fall parameter was not incorporated. Hence, an attempt has been carried out to ascertain the contribution of dust fall rate in atmospheric air pollution in Chandrapur industrial cluster region and its composition.

Study area

Chandrapur district is located in the eastern edge of Maharashtra State in Vidarbha region of central India. The Chandrapur district is located between the latitudes $19^0$30' N and $20^0$45' N and the longitudes $78^0$46' E and $80^0$00' E (Figure 1). It has an average elevation of 189 meters above mean sea level. Physiographically, the district is situated within the Wainganga and Wardha river basins, respectively, flowing on the eastern and western boundaries of the district which are the tributaries of Godavari river. It had a population of 20,71,101 of which 32.11 per cent were urban as of 2001 census.

The Chandrapur industrial cluster includes MIDC Chandrapur, Tadali, Ghuggus and Ballarpur area. Chandrapur industrial cluster is famous for its superthermal power station

(2340 MW capacity); one of the biggest in Asia and vast reserve of coal. Chandrapur district also has large reservoirs of limestone. The abundance of lime is supplied to many cement factories like L&T, Gujrath Ambuja, Manikgad in the district. The mammoth coal mines in the district also contribute to heavy industrialization of the district. The district also boasts of having the largest paper manufacturing unit of Ballarpur Industries Limited (BILT), largest manufacturer and exporter of paper in India, in the adjoining Ballarpur city. Various other major industries include a ferro-manganese and silico-managanese plant of Steel Authority of India Ltd. About 700 small and large scale industries are located in Chandrapur district. Around 120 industries from Chandrapur district are categorized in red, 178 in orange and around 400 in green category (Table 1) (MPCB, 2006).

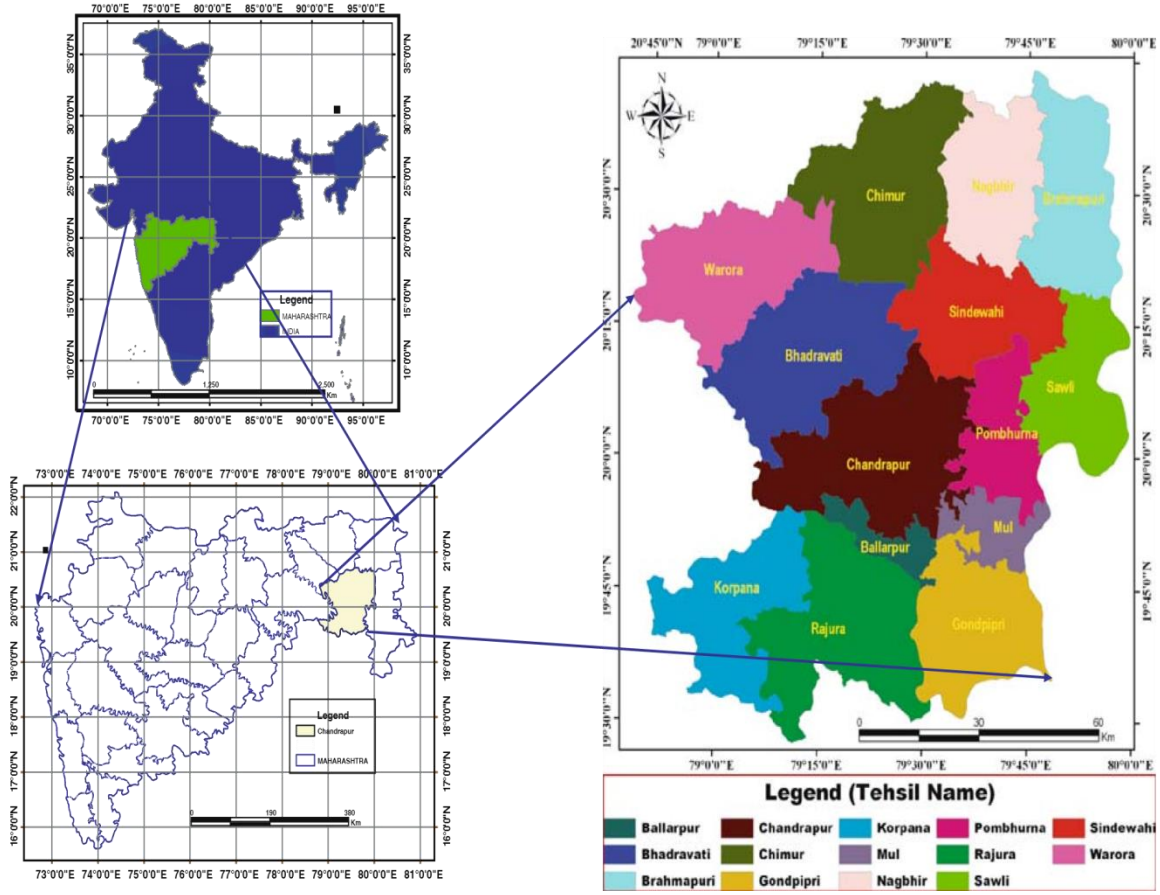
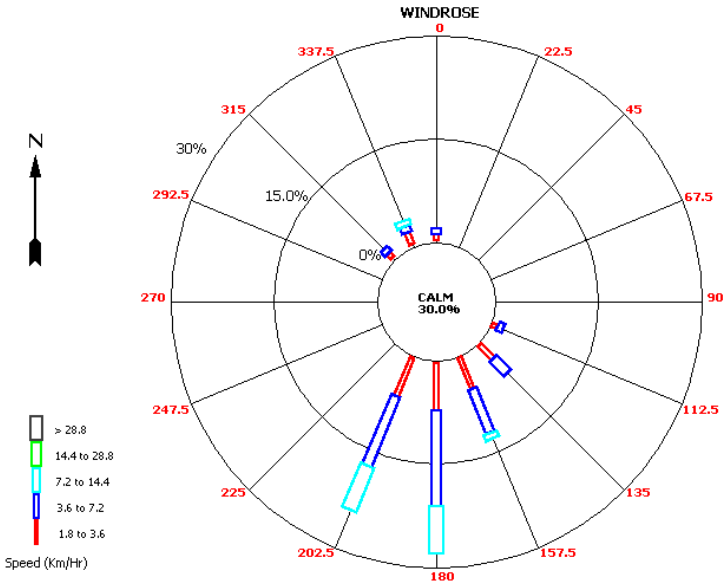


Figure 1. Chandrapur district with differnet talukas in central India (Satapathy, 2009)

Meteorology

The micrometeorological data was recorded with the help of mechanical weather monitoring station placed at a height of 10 m above ground surface to collect wind speed and wind direction data during the study period. The hourly record of wind speed and wind direction data during study period were used for computing the relative percentage frequencies of occurrence in 16 cardinal directions and 5 wind speed classes. These frequencies were computed on 24 hourly basis for winter season as shown in figure 2. The 24 hourly windroses during winter season shows predominat winds were from S, SSW and SSE directions, with dominant wind speed class of 3.6-7.2 km h^{-1}. The calm condition was recorded as 30% of time during study period.



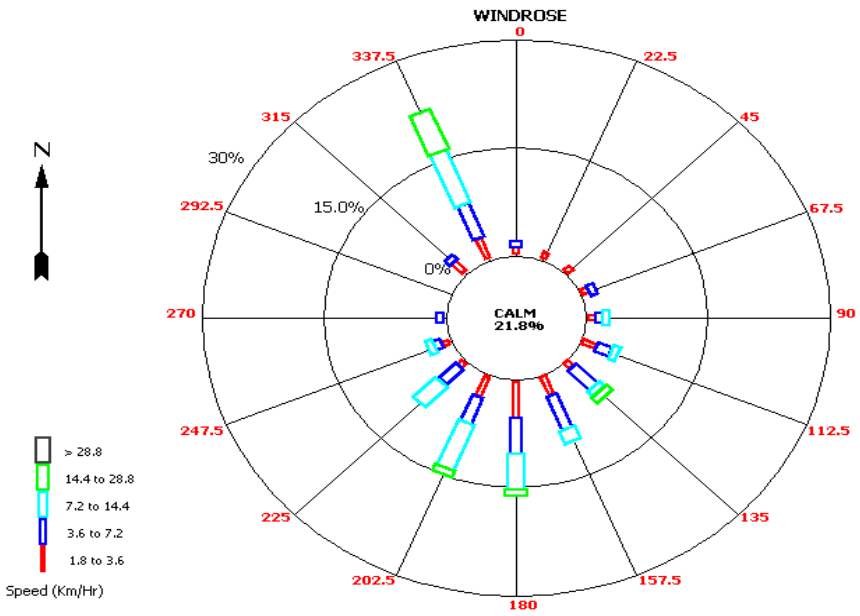


Figure 2. Wind rose from study area (December 2014 and January 2014)

Material and Methods

Dust sampling: Dust samplings were carried out with the help of dust fall jar apparatus as given by Bureau of Indian Standard BIS 5182 (Part 1):2006. To carry out dust fall rate sampling from the study area, taking into consideration the meteorology during the sampling period, four sampling sites were identified. Out of these four, two sampling sites were in upwind direction were as rest two were in downwind direction. Sampling was carried out in a dust fall container having a suitable capacity to hold water in which atmospheric dust can be trapped. Plastic containers were used having a circular opening of greater than 15 cm diameter and length of two to three times the diameter. Samplings was carried out in different sampling areas such as industrial, residential and combine so as to ascertain the impacts of local activities on dust generation.

Dust fall rate sampling was carried out in a plastic container (Fig. 3) which was previously washed with the help of distilled water and 5 L of distilled water along with fungicide (Mercuric chloride, one-tenth of a gram) was added and the container was kept at a height of about 10 feet above ground level. A bird guard was kept around the sampling container so as to protect it from avifauna. The sampling was carried out for a period of one

month, December 2014-January 2015 and February 2015-March 2015. After atmospheric exposure of container for one month, they were brought to the laboratory for further analysis (BIS 5182 (Part 1): 2006).

Figure 3. Dust fall jar for sampling atmospheric dust

Analytical procedure: Sampling containers were brought to the laboratory for analysis of inorganic and organic component. An oven dried and pre weighted glass fiber filter paper was placed over a filtration assembly through which all the liquid in the container was filtered into a graduated cylinder. The filter paper afterwards was oven dried at 105±2 ^{o}C for 2 hours. It was then cooled in a desiccator and re-weighted on an analytical balance and insoluble dust was computed (Air Quality Monitoring Manual, 1978).

For calculating soluble dust, 100 mL of filtrate from graduated cylinder was taken into a clean and pre weighted crucible. The crucible was heated in an oven at 105±2 ^{o}C for a sufficient period of time to evaporate all the liquid. It was then cooled in a desiccator and re-weighted and soluble dust was computed. Total particle fall out rate was computed by addition of insoluble particle fallout rate and soluble particle fallout rate (Air Quality Monitoring Manual, 1978).

Results and discussion

Results of dust fall rate from the study area are depicted in table 2. The prominent wind direction from the study area was from S, SSW and SSE, with maximum wind speed in range of 3.6 to 7.2 km hr^{-1} (Figure 2). Minimum dust fall rate from the study area was recorded in Babupeath 55.54 MT sq km^{-1} $month^{-1}$ (upwind direction, residential area) during December-January. This minimum dust fall rate during the sampling period can be attributed to residential area and winter season. Perhaps due to winter season, with moderate humidity, dust particles which were present in atmosphere agglomerate with water droplets and settles down on ground surface. The results were in accordance with results obtained by Tyagi *et al* (2014). The maximum dust fall rate during this sampling period was observed in Nakoda (246.67 MT sq km^{-1} $month^{-1}$, industrial area). This industrial area had number of cement industries which processes lime stone. During the process of cement production, packaging, handling and transportation fugitive dust emissions may get escaped into atmosphere which may have contributed this increase dust fall rate in this area. In addition to cement industries, open cast coal mines also contributed fugitive emissions into atmosphere. Thus, such an elevated dust fall rate was observed at this sampling location during this sampling period (December-January). The average dust fall rate in Chandrapur industrial cluster was 145.59 MT sq km^{-1} $month^{-1}$ whereas standard deviation was 82.44.

Table 1. Industrial classification in Chandrapur industrial cluster (MPCB, 2010)

Name of industrial area	Highly polluting Industries	Red category industry	Orange/Green category industry	Grossly polluting industry
MIDC Chandrapur	02	08	24	02
Ghugus	01	03	Nil	Nil
MIDC Tadali	Nil	05	Nil	Nil
Ballarpur	01	12	18	01

Table 2. Dust fall rate in the study area

Sampling location	Area type	Dust fall rate (MT sq km^{-1} $month^{-1}$)		Location w.r.t. wind direction
		December-January	February-March	
CSTPS colony	R, I	171.77	268.60	Downwind
Nakoda	I	246.67	227.94	Downwind
Ballarpur	I	108.41	173.74	Upwind
Babupeath	R	55.54	278.14	Upwind
Minimum		55.54	173.74	
Maximum		246.67	278.14	
Average		145.59	237.10	
Standard deviation		82.44	47.52	

I: Industrial area, R: Residential area

However, during second phase of dust fall rate sampling in these sampling locations, a significant increase in dust fall rate was observed in all sampling locations. Minimum dust fall rate was observed in Ballarpur (173.74 MT sq km^{-1} $month^{-1}$, industrial area). A 1.5 fold increase in dust fall rate was observed as compared with December-January sampling period for this sampling location. This increase in dust fall rate during this sampling period can be attributed to onset of summer season, increase in diurnal temperature and lower humidity. These meteorological factors contributed to increase dust fall rate for this sampling location during this sampling period. Maximum dust fall rate was observed to be 278.14 MT sq km^{-1} $month^{-1}$ at Babupeath (residential area, upwind direction) followed by CSTPS colony 268.60 MT sq km^{-1} $month^{-1}$ (industrial area, downwind direction). This increase in dust fall rate was 5.0 and 1.5 times higher respectively than the dust fall rate during December-January sampling period. For February-march, the average dust fall was found to be 237.10 MT sq km^{-1} $month^{-1}$ and standard deviation was 47.52. On comparison of dust fall rate for February-March with December-January it was observed that an increase in dust fall rate was observed in all sampling locations except at Nakoda, where slight decrease in dust fall rate was

observed. It has been observed that an increase of 1.6 fold in average dust fall rate for February-March with December-January. This significant increase in average dust fall rate in February-March in the region can be attributed to onset of summer season which changes meteorological factors such as humidity, solar radiation and temperature leading to the formation of atmospheric dust. In addition to this oxidation of SO_2 (emitted from thermal power plant and other industries from study area) to sulfuric acid in the atmosphere generate condensable products. Once a condensable species is formed in gas phase, the system is in non-equilibrium state. It may pass toward equilibrium by generation of new particles (homogenous nucleation), thus contributing to increase in dust fall during this period.

The average annual dust fall in tons km^{-2} in some regions of world are reported as: Kuwait 16.76-61.30 (Al-Dousari and Al-Awadhi, 2012), Khur Al-Zubir in Iraq 75.92 (Khalaf *et al.* 1980), Al Fahal in Oman 89 (Badawy *et al.* 1992), Riyadh in Saudi Arabia 392 (Modaihsh, 1997), North Diarnena in Chad 142 (Maley, 1982), Crete in Greece 10-100 (Pye, 1992), Arizona in USA 54 (Pewe, 1981), California in USA 6.8-33.9 (Reheis, 2006), Libya 155 (O'Hara *et al.* 2006), Tan Tan in Morocco 175 (Rott, 2001), Boujdour in Western Sahara 219 (Khiri *et al.* 2004), Namoi Valley in Australia 16.9-58.2 (Cattle *et al.* 2002) and Shapotou in China 372 (Li *et al.* 2004).

Studies pertaining to dust fall characterization in India were pertinent to toxic metals such as mercury (Thakur *et al.*, 2004), lead, arsenic (Deb *et al.*, 2002) in urban environment. Whereas studies for variation of dust fall in urban areas and industrial locations are lacking.

The composition of dust collected from the study area is depicted in Table 3.

Table 3. Composition of dust fall collected from study area

Sampling location	Area type	Location w.r.t. wind direction	Sampling period	Water insoluble component per cent by weight		Water insoluble component per cent by weight	Water soluble component per cent by weight	Total inorganic component per cent by weight	Dust fall rate
				Inorganic insoluble	Volatile matter				
CSTPS			Dec.-Jan.	63.6	36.3	11.2	88.80	96.91	171.77
colony	I	Downwind	Feb.-March	22.78	77.21	17.49	82.51	93.10	268.60
Nakoda			Dec.-Jan.	46.15	53.84	2.19	97.80	98.81	246.67

	I	Downwind	Feb.-March	43.91	56.08	31.03	68.96	82.59	227.94
			Dec.-Jan.	42.18	57.81	29.22	70.77	83.10	108.41
Ballarpur	I	Upwind	Feb.-March	80.95	19.04	3.81	96.18	99.27	173.74
			Dec.-Jan.	69.23	30.76	28.57	71.42	84.12	55.54
Babupeath	R	Upwind	Feb.-March	76.92	23.07	4.92	95.08	98.25	278.14

Dust fall rate in MT sq km^{-1} $month^{-1}$, all other values are in per cent

The composition of dust is reported in water insoluble, water soluble and total inorganic component (per cent by weight). Water insoluble component comprise of inorganic insoluble and volatile matter. From the table it can be observed that inorganic insoluble matter (per cent by weight) was lower in industrial area, whereas in residential area it was higher. Volatile matter from water insoluble component was higher in industrial area than residential area during both phase of sampling period. On comparison of water insoluble and water soluble component of dust it was observed that water soluble component was higher than water insoluble component. Maximum contribution in dust was from inorganic component.

Maximum inorganic insoluble matter was observed in Babupeath 69.23 and 76.92 per cent by weight for December-January and February-March sampling period respectively. This higher inorganic insoluble matter in this residential area can be attributed to combustion of pyrite containing coal and fly ash. In CSTPS colony, inorganic insoluble matter was higher (63.6 per cent by weight) for December-January sampling period. This higher inorganic insoluble matter can be attributed to combustion of coal in CSTPS and emissions of fly ash from stack which may had deposited during dust fall sampling. The volatile matter fraction in water insoluble component was 77.21 per cent by weight during sampling period of February-March. This increase in volatile matter may be from combustion of oil, coal or refuse. The heavy metals Sb and Se may be present in this volatile matter fraction. This significant difference in water insoluble component for CSTPS colony can be attributed to different types of coal being used for combustion along with prevailing meteorological conditions.

In case of Nakoda, inorganic insoluble matter was quite similar for both phase of sampling. The water insoluble component can be attributed to metal oxides which are formed whenever fuels containing metals are burnt. At this sampling locations coal was not used and nearby cement industry may be the source of this pollution. The higher concentration of volatile matter at this sampling location (56.08 and 57.81 per cent by weight for December-January and February-March, respectively) can be attributed to oil combustion in vehicles playing in the vicinity of this sampling location.

At Ballarpur paper mill colony during December-January, inorganic insoluble matter was less as compared with volatile matter. As this sampling location was located in residential area and in upwind direction, and further no significant particulate emissions were released from pulp and paper mill hence, inorganic insoluble matter concentration was less. The lesser contribution of inorganic insoluble matter during the sampling period can be attributed to winter season also.

Further, on comparison of dust fall rate with wind direction in study area a trend was observed that sampling locations in upwind direction had lower dust fall rate as compared with locations in downwind direction. The winds which are blowing from upwind directions are comparatively clean having less dust contain in it. However, as they passes through the industrial area they carry with them emitted dust as a result of which downwind direction sampling locations had elevated dust fall rate. Residential area had lower dust fall rate as compared with industrial area except in February-March sampling period. The sampling locations in downwind direction are getting more adversely affected as compared with upwind.

Conclusion

From the results obtained in the study area for dust fall rate it can be concluded that dust is one of the significant air pollutant. Seasonal variations due to prevailing meteorological factors contribute to the dust fall rate. The anthropogenic and industrial activities also contribute significantly for inorganic, volatile and organic matter composition of dust. This dust owing to its size can have adverse effects on human health and economic losses in the region. Inhabitants from study area had reported respiratory diseases, allergy,

eye problems, skin diseases and reduced life expectancy. Further, in adverse meteorological conditions there may be the probability for formation of dust envelop in the study area. Adaptation of cleaner technologies in industries at source, production, transportation and end of pipe can significantly reduce dust emissions into atmosphere. Maintenance of vehicles can also help in reduction of volatile matter in water insoluble component of dust.

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