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Tracking Toxic Metals in the Ambient Air of Agra City, India

D. G. Gajghate, A. D. Bhanarkar

Air Pollution Control Division, National Environmental Engineering Research Institute, Nagpur, 440 020, India

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The status of airborne metals in air in India has been reported by some authors (Bhanarkar et al. 2002; Gajghate and Hasan 1995; Gajghate and Hasan 1999; Chelani et al. 2001). It has been recently observed that respirable suspended particulate matter (RSPM) concentration in air environment of urban centers in India is found to exceed the National Ambient Air Quality Standards promulgated by Central Pollution Control Board (CPCB). This experienced the serious atmospheric pollution problem of faster growing urban cities and indicated significant health problems (NEERI 1994). The fine dust associates with toxic metals remain in urban air for longer duration and transport to pristine area, causing the deterioration of the environment. There have only been sporadic measurements of toxic elements in air environment in Agra and information of elements in RSPM is meager. The present study is undertaken for monitoring of RSPM and analysis of toxic elements in ambient air of Agra city.

During winter 1993, a field survey was conducted on monitoring of ambient RSPM and toxic metals pollution in the city of Agra, India, which is typical historical place in the world. To know the exposure of toxic metals to the tourist and residential population in the city, the study was undertaken to characterise the PM10 for toxic metals in the air environment at various locations. This study highlights the profile of trace metals at residential, commercial, industrial and sensitive locations in the city with particular relevance to Taj Mahal, a monument of international fame.

MATERIALS AND METHODS

The study was carried out in Agra (latitude 24° 10' N, longitude 78° 05' E) which lies in a semi-arid zone of India. The whole area is about 169 m above the mean sea level with atmospheric temperature ranging from 22-42°C (max.) and 7-30°C (min.), relative humidity 25-95%, and rainfall 1000 mm per year. The wind pattern at Agra projects that except summer season in the remaining other, the prevalence of calm conditions is higher with maximum frequency observed in post-monsoon followed by winter. Calm conditions represent the velocity less than 1 m/s. The wind speed in the Agra city is mostly in the range of 1-2 m/s. The prevailing wind direction follows two distinct patterns : during monsoon,

Correspondence to: D. G. Gajghate

winds are from NE-SE quadrant, while in the rest of the seasons, these are from N-W sector. During winter season, the weather at Agra and surrounding region is somewhat similar to extra-latitude region. Atmospheric temperature variation due to lower ambient temperature and calm conditions help to build up pollutant concentration level at lower points in the city. The soil is poor in nutrients as being sandy foam, or loamy sand. It has high exchangeable sodium percentage (ESP) values and moderate water retaining capacity. The study area falls in Indo-Gangetic plain and thus agriculture is the major traditional land use practice. The major air polluting industries include in ferrous and nonferrous foundries, rubber and lime processing units, chemicals, brick kilns and electroplating units. There are around 340 industries of different types. Among all these industries, foundries are the major contributors to the air pollution. If all the units working simultaneously the emission of SPM are around 4098 kg/hr, SO_2 : 878 kg/hr, NO_x : 110 kg/hr, CO : 73573 kg/hr and HC : 169 kg/hr. Besides, there are around 116 brick kilns of different types and capacity emitting SPM : 314 kg/hr, SO_2 : 165 kg/hr, NO_x : 38 kg/hr, CO : 55 kg/hr and HC : 20 kg/hr. The city of Agra also suffers from heavy vehicular pollution just as other metropolis of India. Two national highways pass close to this city of historical monument. The commercial activity of Agra city has increased manifold to meet the demands of the locals and tourist.

A network spread over Agra city was operated activity zonewise to get entire coverage of ambient RSPM and toxic metal concentrations. For Agra city, six sampling sites representing residential, commercial, sensitive and industrial activity were selected. The six sampling locations were selected in the city in a manner that they were presenting truly air quality of respective areas in impacted zones and as far as possible away from direct pollution sources. Description of sampling location with their distance and direction from Taj Mahal as a reference site is presented in Table 1. Meteorology plays a vital role in dispersion of air pollutants. The study is conducted in winter season as it is a critical season for air pollution dispersion. The long term secondary meteorological data collected from India Meteorology Department (IMD) of Agra were analysed to depict the changes of the wind pattern and guided for selection of appropriate impacted zone for monitoring air quality.

Table 1. Details of air quality monitoring stations.

Location	Activity	Sampling Height (m)	Direction from Taj Mahal	Arial Distance from Taj Mahal (km)
1	Sensitive	15	--	0.0
2	Sensitive	15	NW	10.5
3	Industrial	12	N	4.0
4	Industrial	15	NNE	3.5
5	Commercial	15	NNW	3.0
6	Residential	10	NWW	6.0

RSPM monitoring was carried out at six locations in Agra city during winter. High volume sampler used was capable of drawing air through a portion of a clean glass fiber 8" x 10" size with an effective area of not less than 400 cm^2 at the flow rate 1.1 m^3/minute with a permissible variation of 0.3 m^3/minute over 24-hrs. Particulate matter collected on glass fiber filter paper was used for determination of toxic metals. Six toxic metals viz. lead, cadmium, chromium, zinc, iron and nickel were identified for analysis. The analytical method is based on sample preparation by microwave nitric acid digestion and analysis by flame atomic absorption spectrophotometry (FAAS). Samples were prepared by taking known portion of 1" diameter from exposed filter paper. This sample was digested in concentrated nitric acid under microwave in closed Teflon vessels. After cooling the content, it was filtered through the Whatman filter paper no. 42. The final volume was made-up to 100 ml by double distilled water. The filtrate was analysed by FAAS. The details of analytical procedure are given elsewhere (Katz 1977). The instrument was calibrated by aspiring the series of known concentration of standards solution for each metal. The metal concentrations were analysed in the samples and blank solutions. Finally, the concentrations of metals are expressed in $\mu g/m^3$ by taking into account the whole exposed area and volume of air sampled.

RESULTS AND DISCUSSION

The 24-hrly maximum, minimum and average concentration of RSPM in ambient air at six locations are presented in Table 2. The results revealed that average of

Table 2. RSPM concentration at various locations ($\mu g/m^3$)

Location	Maximum	Minimum	Average
1	519	60	271
2	250	126	179
3	315	170	243
4	632	415	519
5	440	112	311
6	491	154	276

RSPM level ranged from 170 to 632 $\mu g/m^3$ at industrial, 154 to 491 $\mu g/m^3$ at residential, 112 to 440 $\mu g/m^3$ at commercial and 60 to 519 $\mu g/m^3$ at sensitive sites respectively. The average RSPM level was high at Agra and exceeded the CPCB standards at all sampling locations. The road traffic, resuspension of road dust, domestic refuse burning and oil and coal used in industries are largest source of PM_{10} emission. These sources at low height contribute significantly to population exposure.

Ambient toxic metal level was detected and quantified at all sampling locations in Agra city. Figure 1 illustrates the levels of Cr, Cd, Pb, Ni, Zn and Fe concentrations in ambient air of Agra city. In study period, toxic metal concentrations in the samples varied depending on the location of sampling site. The profile of trace metals showed that the averaged concentrations of the toxic

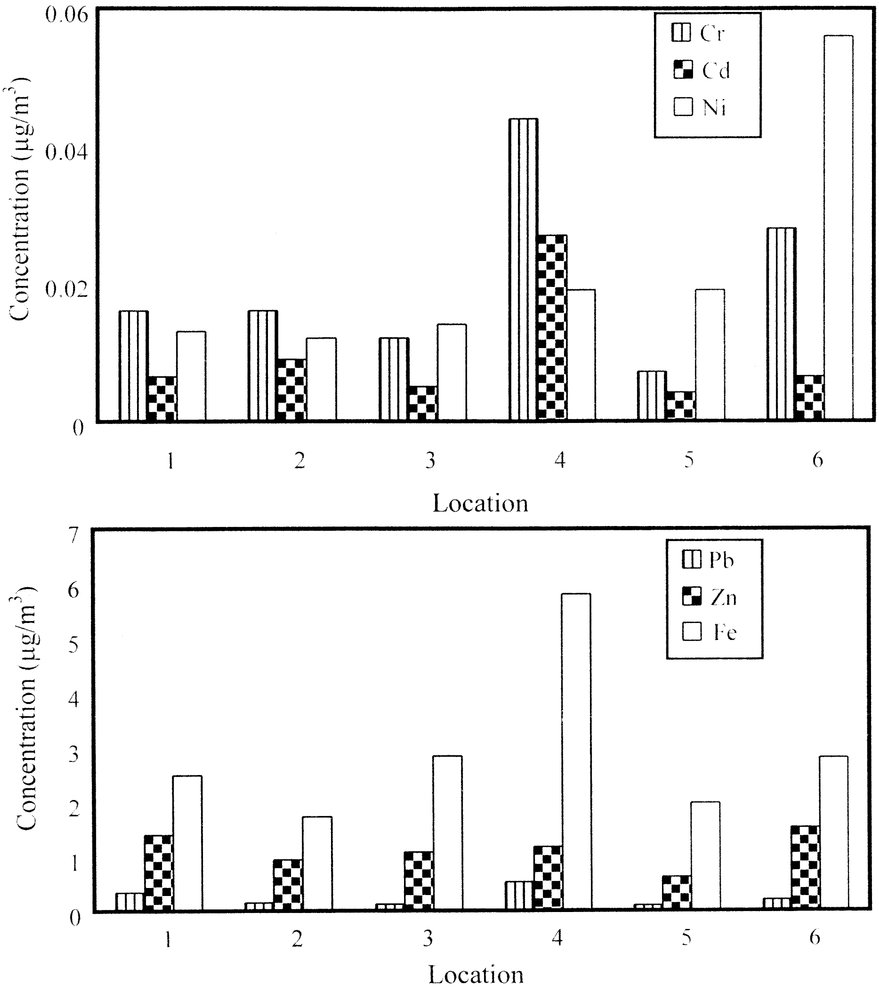

Figure 1. Average trace metal concentration in ambient air.

metals are high at the industrial locations. It was observed that average concentration of chromium varied between 0.007 and 0.044 μg/m^3. The highest level of Cr (0.075 μg/m^3) was observed in sample from industrial site (location 4). The average concentration of ambient Cd ranged from 0.004 to 0.027 μg m^{-3}. However, the highest concentration was about 0.059 μg/m^3 was recorded at industrial site (location 4). The measurement of concentrations of Ni in ambient air varied from 0.012 to 0.056 μg/m^3. The highest concentration as 0.13 μg/m^3 was recorded at the residential site. The average zinc and iron concentrations ranged from 0.62 to 1.52 μg/m^3 and 1.72 to 5.8 μg/m^3 respectively. The highest concentration of zinc 1.94 μg/m^3 was recorded at the residential site. The highest concentration of Fe was about 5.96 μg/m^3 recorded at the industrial site (location 4). The average Pb level ranged from 0.095 to 0.53 μg/m^3. The highest concentration of Pb 0.88 μg/m^3 was recorded at sensitive-I

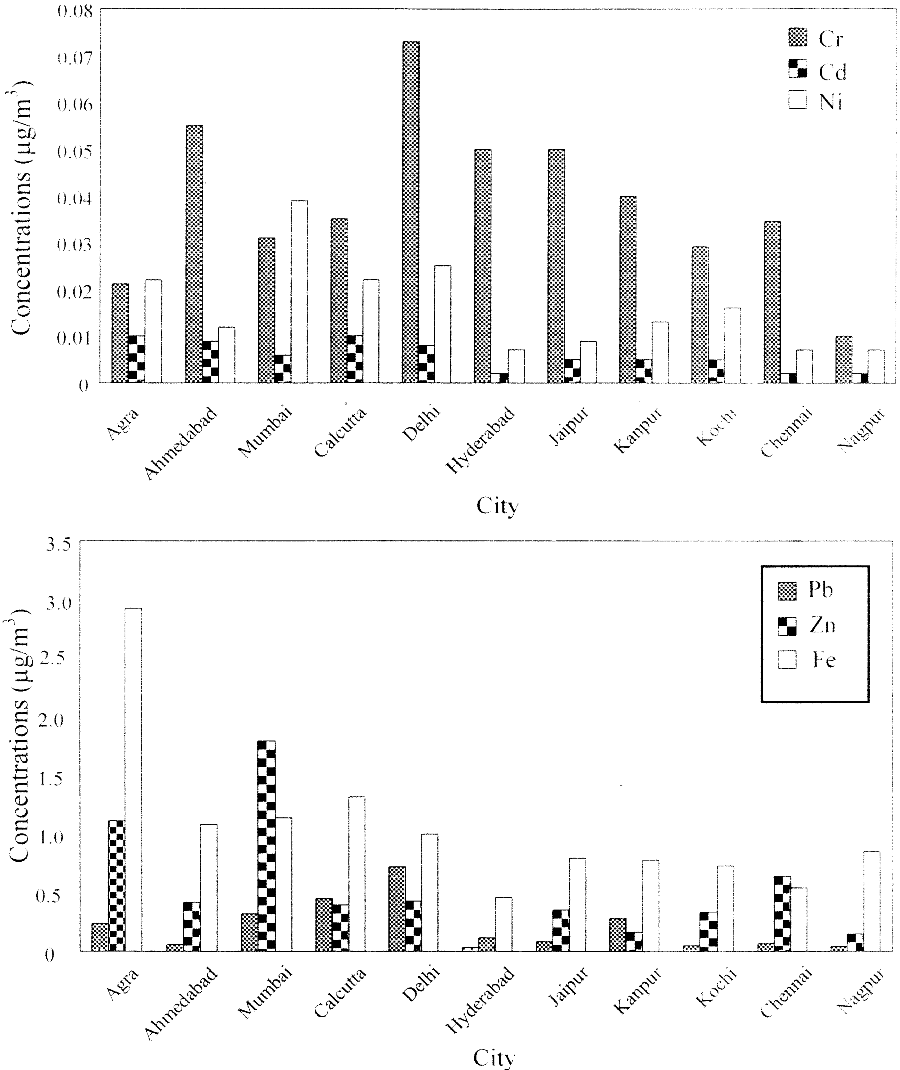

Figure 2. Comparision of trace metal concentration in ambient air of different cities in India during winter 1993

site. The Pb concentration values reached the limit of CPCB standards (0.75-1.5 $\mu g/m^3$).

Figure 2 presents a comparison of toxic metal levels found in this study, with data generated by ten important cities in India namely Ahmedabad, Chennai, Delhi, Hyderabad, Jaipur, Kanpur, Kochi, Kolkata, Mumbai and Nagpur for winter of the same year. Data presented indicates that averaged concentrations level of toxic metals at Agra were comparable with the levels at other cities in India reported by NEERI (NEERI 2000). The lead pollution around Agra is 0.53 $\mu g/m^3$

on average, and it is in same magnitude range with other big cities of India. Auto exhaust was major contribution to the atmospheric lead in Agra that cause the hypertension and kidney disease in adults and lower IQ in children (Mathur et al. 1998). The lead concentration in urban areas ranged from 0.5 $\mu g/m^3$ to 4.6 $\mu g/m^3$ High concentration of Zn and Fe signifies the source of natural dust and industrial activities. It was observed that results of trace metals found in this study viz. Cr, Cd, Pb, Ni, Zn and Fe, the Agra was found to be tenth, second, fifth, fourth, second and first, respectively.

The air pollution in Agra, is caused mainly by small industries, household emissions and vehicular activity. Lead and RSPM were found to be a major pollution problem in Agra. The average RSPM level was high and exceeded the CPCB standards at all the sampling locations. It can be seen that the lead concentration in industrial localities of the area is high due to the high vehicular traffic and industrial activities. The crustal element (Fe and Zn) domination represents high contribution from background natural dust. However, industry originated metals (Cr, Cd and Ni) contributed marginally. The main contributors of air pollution in Agra transport sector followed by industrial units like foundries and brick kilns and burning of garbage. The detailed source apportionment study and emission of inventory of toxic metals is required to confirm the sources. However, swelling of population increased vehicular traffic and unplanned development of industrial activities in and around the city can lead to severe air pollution problems in the near future. To arrest this growing problem, a concerted effort on formulation of air quality management action plan, development of stringent standards, the use of latest technologies and effective enforcement are required to prevent from severe effect of pollutants on health.

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