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Heavy metal pollution of ambient air in Nagpur City

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Abstract Heavy metals released from different sources in urban environment get adsorbed on respirable particulate matter less than 10 μm in size (PM_{10}) and are important from public health point of view causing morbidity and mortality. Therefore, the ambient air quality monitoring was carried out to study the temporal and special pattern in the distribution of PM_{10} and associated heavy metal content in the atmosphere of Nagpur, Maharashtra State, India during 2001 as well as in 2006. PM_{10} fraction was observed to exceed the stipulated standards in both years. It was also observed that minimum range of PM_{10} was observed to be increased in 2006 indicating increase in human activity during nighttime also. Six heavy metals were analyzed and were observed to occur in the order Zn > Fe > Pb > Ni > Cd > Cr in 2006, similar to the trend in other metro cities in India. Lead and Nickel were observed to be within the stipulated standards. Poor correlation coefficient (R^2) between lead and PM_{10} indicated that automobile exhaust is not the source of metals to air pollution. Commercial and industrial activity as well as geological composition may be the potential sources of heavy metal pollution. Total load of heavy metals was found to be increased in 2006 with prominent increase in zinc, lead, and nickel in the environment. Public health impacts of heavy metals as well as certain preventive measures to mitigate the impact of heavy metals on public health are also summarized.

Keywords Ambient air monitoring · PM_{10} · Heavy metals · Urban atmosphere · Health

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Introduction

Heavy metals associated with respirable dust particles having size below 10 μm (PM_{10}) in urban air can penetrate deeper part of lungs and retained there and are not flushed out easily with expiration and are responsible for many health problems. These heavy metals comes from anthropogenic sources such as combustion of fossil fuel, metallurgical process, garbage incineration and wind blown soil dust (Talebi and Abedi 2004; Langmuir 1997; Agarwal 1991) which gets distributed in air over large area (USEPA 1999a; AMAP 1997). Heavy metals are toxic even at low concentration in air. After inhaled, they form complexes or legends with vital protein molecules, denaturing them and resulting in malfunction or death of cell (USEPA 1996). Heavy metals are now correlated with a number of health effects such as cancer, neurotoxicity, immunotoxicity and cardio toxicity leading to increased morbidity/mortality in community (Dockery et al. 1993; Pope III et al. 1995; Silbergeld 1995, 1996). Therefore, study of heavy metals in air of major cities is significant in air pollution studies (Goyer 1996; Donaldson and MacNee 1998; Singh 2001).

Nagpur is the most important city in Maharashtra and is the centre for urbanization, development, industrialization and commercial activity. However, the efforts to enhance the green cover of the city that has scrubbing effect on air pollutants are inadequate. Against this background, considering the importance of air-borne heavy metals for public health, an effort has been made to study the heavy metal concentrations of the atmosphere in PM_{10} in different locations of Nagpur city marked by different activities and their impact on air quality.

Materials and methods

Sample collection

The study was carried out during 2001 and 2006 on the heavy metal concentration in the ambient air of Nagpur City, Maharashtra State, India. Ambient air monitoring for the analysis of PM_{10} and associated heavy metals was carried out at three different locations (NEERI residential area with good vegetative cover, Maskasath Commercial area and Hingna Industrial Area with sparse vegetation) in and around the Nagpur City (Fig. 1). The sampling stations are situated within 10 km area around the centre of Nagpur City i.e. Zero-milestone near Reserve Bank of India Square. Using high volume air sampler (Envirotech's APM 415, Envirotech instruments, Upkaran Pvt. Ltd., New Delhi), samples for 24 h were collected from

Fig. 1 Location of ambient air sampling stations in Nagpur City

all sampling stations. The sampling details and average flow rate were recorded and carefully maintained constant throughout the study. All the collected samples were packed in polyethylene covers and transported immediately to the laboratory and analysed for PM_{10} and heavy metals in PM_{10} using standard laboratory procedures (USEPA 1999b).

Estimation of PM_{10} fraction

The glass micro fiber filters used in this study were dried in a hot air oven between the temperature ranges from 103°C to 105°C. Subsequently, the PM_{10} collected on the filter paper was estimated following the guidelines mentioned by the United States EPA, Washington, DC (USEPA 1999b).

Extraction and quantification of heavy metals

Sample and control (blank filters) filter papers were processed separately to extract the heavy metals present in PM_{10} by acid digestion. The filter papers were cut into small pieces, placed in a conical flask and added with 10 ml of concentrated H_2SO_4 and 5 ml of HNO_3. Subsequently, it was placed on a hot plate for 2 h, and then it was filtered and diluted to quantify the heavy metals using Atomic Absorption Spectroscopy (PerkinElmer 3100 AA, LA, USA) with sensitivity up to ppb (USEPA 1999b).

Results and discussion

Particulate matter <10 μm (PM_{10})

The observations on the dynamics of PM_{10} in the environment of Nagpur during 2001 and 2006 are shown in Figs. 2 and 3, respectively. The data was collected to record temporal changes in the status of air-borne PM_{10} and heavy metals and to correlate them with anthropogenic activity.

The monthly of 24 hourly average values of PM_{10} in 2001 are shown in Fig. 2a, which range from 41 to 281 μg/m^3 in industrial area, from 60 to 188 μg/m^3 in commercial area and from 30 to 155 μg/m^3 in residential area in Nagpur city. Industrial area was observed to be more polluted than commercial area, which in turn was more polluted than residential area. The annual average values at all stations ranged from 75 to 105 μg/m^3, as well as the annual 95 percentile values ranged from 174–247 μg/m^3, which are quite higher than MoEF standard (November, 2009) of 100 μg/m^3. The seasonal average values at all locations are presented in Fig. 2b, where level of the PM_{10} are shown highest in winter at all locations among the other seasons.

The monthly averages of 24 hourly average values of PM_{10} in 2006 are shown in Fig. 3a, which range from 100 to 254 μg/m^3 in industrial area, from 54 to 225 μg/m^3 in commercial area and from 52 to 107 μg/m^3 in residential area in Nagpur city. Industrial area was observed to be more polluted than commercial area, which in turn was more

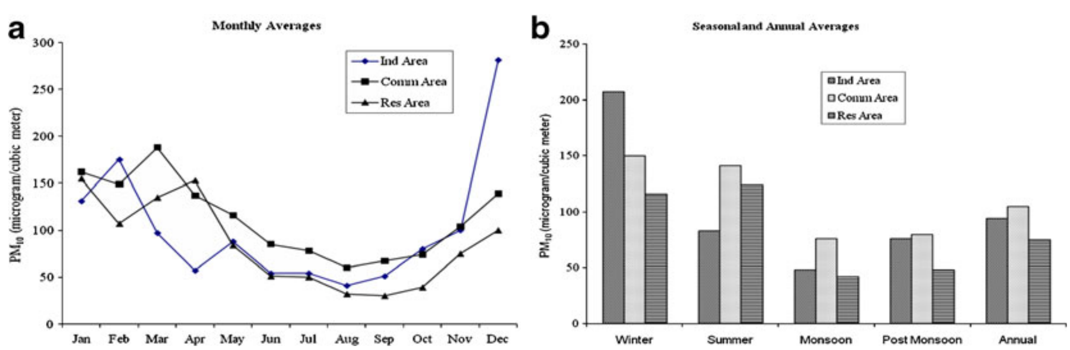

Fig. 2 Monthly (**a**) and seasonal averages (**b**) of PM_{10} in the year 2001

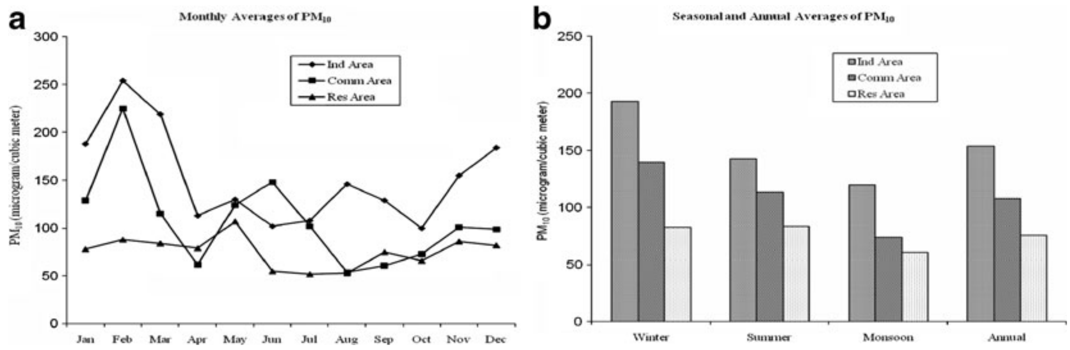

Fig. 3 Monthly (**a**) and seasonal averages (**b**) of PM_{10} in the year 2006

polluted than residential area. The annual average values ranged from 93 to 154 μg/m^3 as well as the annual 95 percentile values ranged from 123 to 274 μg/m^3, which are quite higher than MoEF standard (November, 2009) of 100 μg/m^3. The seasonal average values at all locations are presented in Fig. 3b, which also indicate the similar trend as observed during 2001.

The observations (Table 1) indicate that in commercial area the particulate pollution has increased during 2001 to 2006 period which is the pointer towards increase in traffic and human activity in commercial area. At the same time, decrease in minimum level of particulate matter indicate that duration of traffic during day–night time has been increased due to increase in human activity as a result of increase in population.

In residential and industrial area, in spite of increase in road vehicles during this period, there is decrease in maximum level of particulate matter (Table 1) which may be due to improvement of roads in the city.

The population of Nagpur was 3,436,000 (as per 1991 census) and 4,051,444 (as per 2001 census) showing increase of around 600,000 population in 10 years or 0.6 lakh people in 1 year. Now Nagpur is expanding at a greater rate and we may expect increase in population around 1 lakh people per year. Similarly around 4,515,000 motor vehicles were registered in 2001 which also shows tremendous increase in number per year. This is the reason for higher human activity and higher particulate matter in ambient air.

Table 1 Minimum and maximum values of PM_{10} in the atmosphere

Sampling area	PM_{10} (μg/m^3)	
	2001	2006
Industrial area	41–281	100–254
Commercial area	60–188	54–225
Residential area	30–155	52–107

The observations on PM_{10} in Nagpur City indicate that the levels of particulate matter in the air were exceeding the stipulated limits in Nagpur city. People in Nagpur city are exposed to air pollution affecting their health and aesthetic environment. This is due to increased human activity, urbanization, increased traffic and poor maintenance of roads in commercial area of Nagpur City. Similar observations have been made by Prasad (2004). Prasad (2004) has explained the observations collected by the Envirotech Instruments Pvt. Ltd. during their long years experience in this field. In particular, an interesting relationship between population density and suspended particulate matter (SPM)/respirable suspended particulate matter (RSPM) concentration has been observed which hardly depends upon the local meteorology and climate of the place; rather it depends upon the local polluting sources. Ambient air quality in Nagpur is comparatively bad as compared to Coimbatore City. The level of SPM in Coimbatore City was found to be either at permissible or non-permissible limit depending upon the category of the sampling station

(Vijayanand et al. 2008). As a result of excessive urbanization and increased human activities, the air quality has been deteriorated significantly in most of the cities. In recent years, Kanpur has acquired notoriety as the second most polluted industrial city in India after Ahmedabad in terms of RSPM concentration, followed by Kolkata, Jaipur, Solapur, Hyderabad, Mumbai, Bangalore and Kochi. Kannan and Kapoor (2004) show that particulates encountered in urban areas in India are appreciably higher especially during winter and summer months. Many cities in India are now experiencing air pollution due to urbanization and industrialization for ex. Pune (Gadgil and Jadhav 2004), Greater Mumbai (Gupta and Joseph 2004), Jaipur city (Jain et al. 2004).

Present investigations shows lower concentration of PM_{10} in residential area due to presence of good vegetation. The commercial and industrial area showed higher values of PM_{10} due to sparse vegetation cover as well as increased traffic, human activity and poor quality roads.

Inhalable particles are potentially dangerous for human health. This effect is negatively proportional to their dimensions. Air has become a major reservoir of several air pollutants particularly heavy metals (Talebi and Abedi 2004; Agarwal 1991). Heavy metals are injurious to health as their accumulation in the body may lead to several complications (USEPA 1999a; Dockery et al. 1993; Pope III et al. 1995). Hence, it becomes imperative that the air quality in major urban areas should be monitored consistently so as to characterize the heavy metals composition present in the particulate matter of the air. This would be helpful to indicate the possible/major sources of public health problems due to heavy metals in ambient air and to implement remedial and preventive measures.

Heavy metals in ambient air

The results of heavy metal monitoring in atmosphere in 2001 and 2006 are shown in Figs. 4 and 5. Six heavy metals viz. Cd, Zn, Ni, Fe, Pb and Cr were analysed in PM_{10} particles. The concentrations of heavy metals in 2001 (Figs. 4a to 5f) were observed as zinc (ND–4.90 μg/m^3), Iron (0.12–3.30 μg/m^3), Cadmium (ND–1.98 μg/m^3), Chromium (ND–0.22 μg/m^3), Lead (ND–0.18 μg/m^3) and Nickel (ND–0.06 μg/m^3). The concentrations of heavy metals in the atmosphere in 2006 (Fig. 5a to f) ranged as Zinc (ND–11.67 μg/m^3), Iron (ND–2.04 μg/m^3), Lead (ND–0.52 μg/m^3), Nickel (ND–0.06 μg/m^3), Cadmium (ND–0.06 μg/m^3) and Chromium (ND–0.05 μg/m^3). Total concentrations of all metals in the PM_{10} at all the stations in 2001 and 2006 are given in the Table 2 for the ease of comparison.

The trend of occurrence of heavy metals in ambient air (Table 2) was observed as given below.

$$\text{Fe} > \text{Zn} > \text{Cd} > \text{Pb} > \text{Ni} > \text{Cr}\ (2001)$$

$$\text{Zn} > \text{Fe} > \text{Pb} > \text{Ni} > \text{Cd} > \text{Cr}\ (2006)$$

Zinc and iron were present at highest concentration in both years. However, zinc concentration was extremely high in 2006.

The reason may be the industries in Nagpur using zinc for polishing of steel articles and geological reasons that the Nagpur soils contain the higher concentration of iron. Similar observations have been recorded by Vijayanand et al. (2008) in the aerosols of Coimbatore City. The concentrations of seven heavy metals (Zn, Fe, Cu, Pb, Ni, Cr and Cd) were estimated in Coimbatore City. At majority of sampling stations, concentrations of Zn were found to be maximum than other heavy metals. The order of average concentrations of heavy metals in Coimbatore atmospheric air was Zn > Fe > Cu > Pb > Cr > Ni > Cd which is more or less similar to our observations in Nagpur City. Similar observations are also made by Thakur et al. (2004) at Raipur city. The usage of Zn for protective coating on iron, steel etc. by the industries in Coimbatore city could be the major reason for the higher concentration of this heavy metal in this region. Sharma and Pervez (2004) also indicated a high contribution of toxic elements in the ambient particulate matter by the stack emissions from the selected cement plant along with a good positive correlation coefficient values were between RSPM and metal concentration. Almost all the

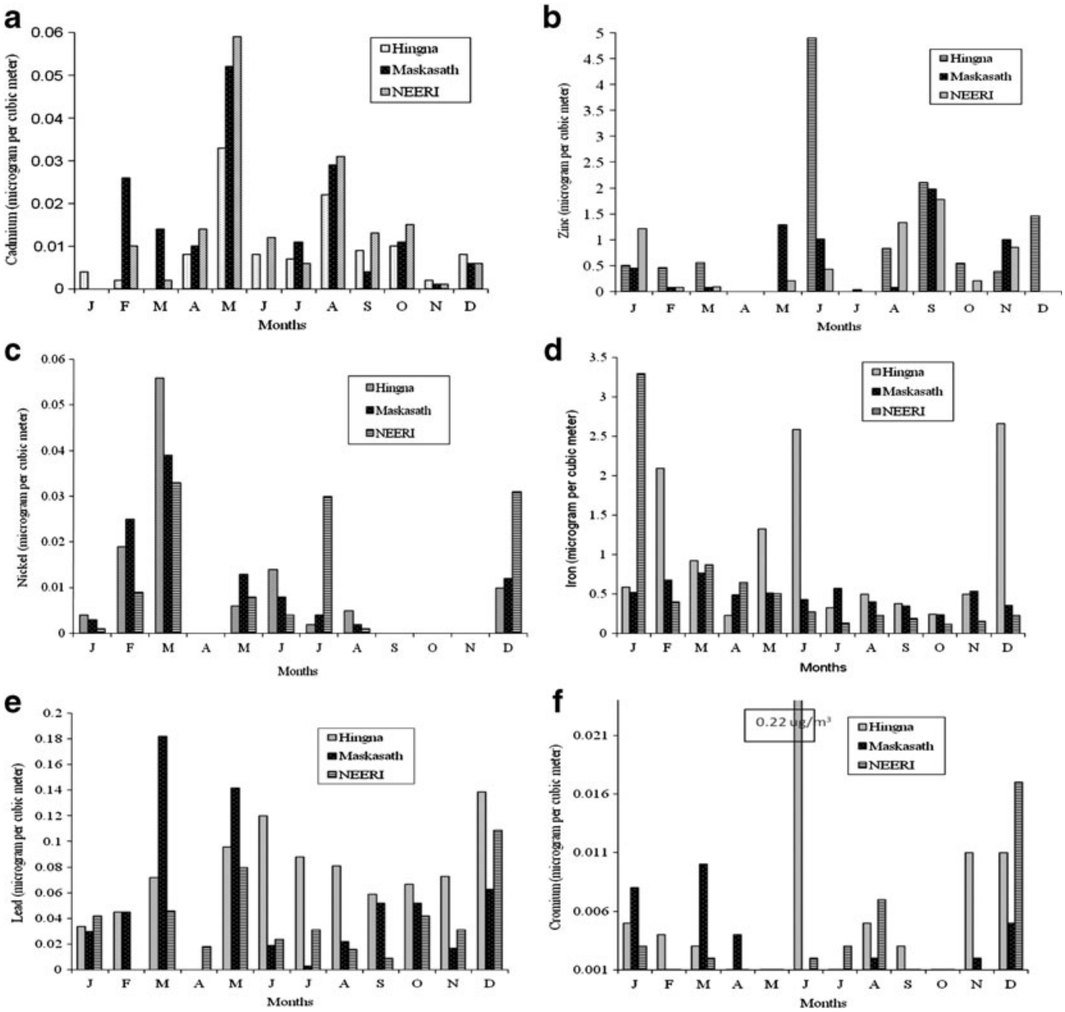

Fig. 4 Heavy metal concentrations in the ambient air of Nagpur City (2001)

elements have shown higher enrichment factor values. Gupta and Joseph (2004) also reported the industries in Kanpur associated with textiles, heavy engineering and tanneries to be the main sources of air pollution.

In the present investigation, out of six heavy metals studied, three metals viz. zinc, iron and lead were observed to be present in significant amount in the particulate matter. However, the concentrations of lead and nickel were observed to be below the stipulated standards viz. 1 μg/m^3 (24 h average) and 20 ng/m^3 (annual average) respectively throughout the study period. Similar observations are made by Koprda and Krištín (2010). Thoracic fraction PM_{10} and respirable fraction $PM_{2.5}$ of aerosols were studied in the urban atmosphere of the largest cities of Slovak Republic (Koprda and Krištín 2010). Results indicate that lead and manganese are the dominant metals in samples. From the centre of Bratislava in winter season. Combustion processes are the main sources of heavy metals in Bratislava. In the industrial zone of Košice prevail manganese and lead, originated from iron and steel processing, in all seasons. Less important concentrations were found for Ni, Cr and As. Particles with higher concentration of iron are usually composed of hematite and magnetite. Particles rich in Ca

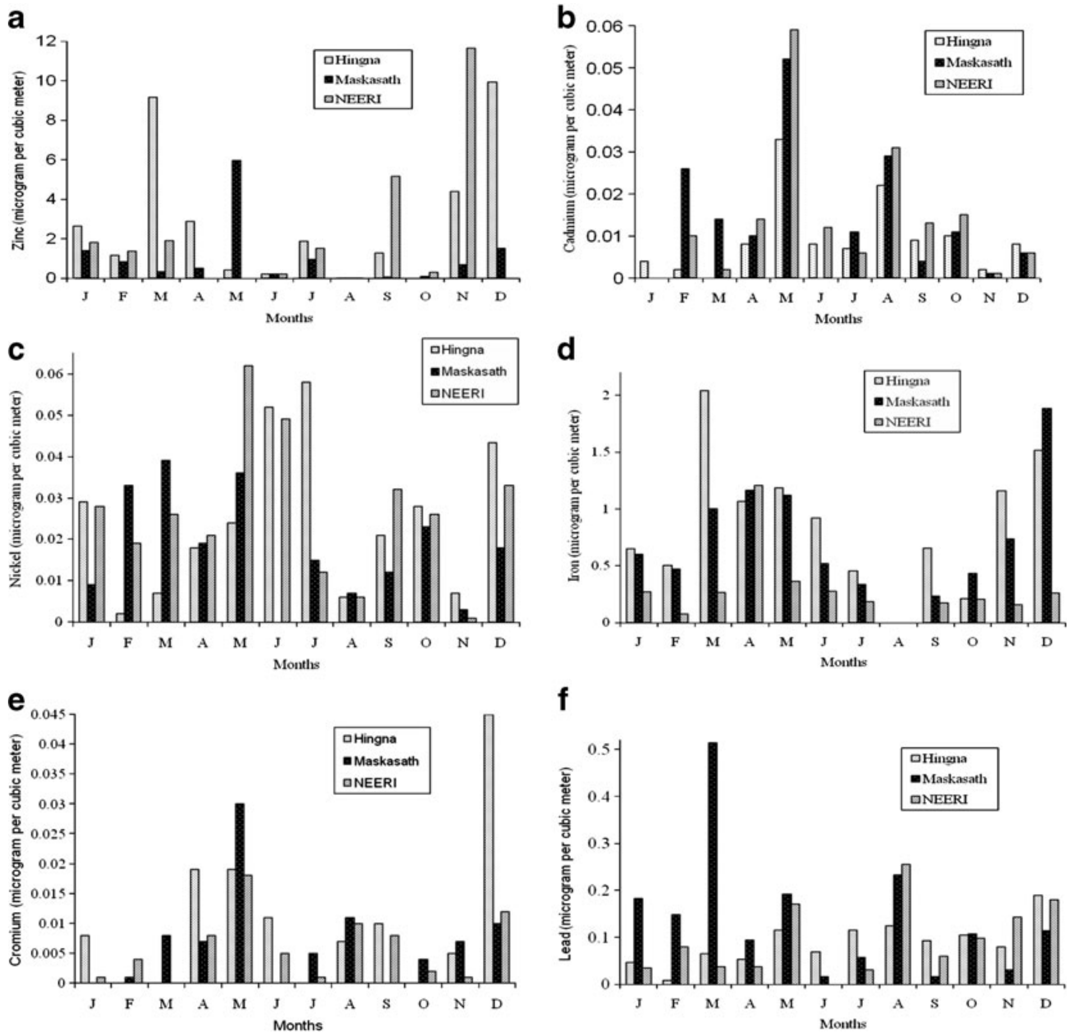

Fig. 5 Heavy metal concentrations in the ambient air of Nagpur City (2006)

consist probably from CaO, high content of Ti could lead to rutil, titanomagnetite, ilmenite, etc. Total heavy metal concentration during the time of observation often exceeded recommended level 150 ng/m^3. The presence of metals in particulate matter in Nagpur can be attributed to geological formation of soil in the city as well as industrial activity in the city.

Table 2 Total load of heavy metals in aerosols in 2001 and 2006

Metal	Concentration (μg/m^3)	
	2001	2006
Fe	25.28	22.32
Zn	23.87	70.67
Pb	1.95	3.91
Ni	0.34	0.82
Cd	3.15	0.45
Cr	0.33	0.28
Total	54.91	98.44

The presence of varying concentrations of different heavy metals in the Nagpur ambient air could be a reflection of increased vehicular transport, industrial emissions particularly emissions from foundries. There is a sharp and alarming rise of vehicles resulting in heavy vehicular transport in Nagpur. Similarly, it is estimated that the cupola based foundry units numbering around 1,000 with an annual output of 600,000 tonnes are operating in and around Nagpur. The furnaces (cupola/induction), generators and shot blasting machines can act as the sources of air pollutants. Since most of the foundry units operating in and around Nagpur have been started several years before the implementation of Air Pollution control Act (1991), they may still be contributing substantially to air pollution.

Urban soil acts as a sink for heavy metals and many other pollutants as shown by many research carried out in recent years (Biasioli et al. 2005; Chen et al. 2005). These studies showed heavy metals loading from a number of different sources related to human activities, such as vehicular emissions, industrial discharges and urban development.

In 2001, iron and zinc were more or less equal and were dominants among all heavy metals. In 2006, these metals were again the highest in aerosols observed; however, Zn concentration was approximately three times more than that in 2001.

In 2001, Cadmium and Lead were the next metals obtained in greater amounts followed by nickel and chromium. In 2006, Lead was the metal as next highest in the aerosols followed by nickel, cadmium and chromium.

The values of correlation coefficient between lead and PM_{10} are given in Table 3. It ranges from 0.0381 to 0.1108 in 2001 and from −0.4254 to 0.1117 in 2006. This indicates that the source of lead is not automobile exhaust but may be the industrial operations in Nagpur city.

Total load of heavy metals in aerosols was observed to be increased in 2006 (98.441 $\mu g/m^3$) by 179.4% as compared to 2001 (54.906 $\mu g/m^3$). In 2006, the concentration of Zinc, Lead and Nickel was increased by 295.9%, 204.8% and 243.1%, respectively, while the concentration of all other metals decreased marginally except cadmium that was decreased significantly by 85.8% as compared to 2001.

Table 3 Correlation Coefficient between PM_{10} and lead content

Sampling location	2001	2006
Industrial area	0.0381	−0.4254
Commercial area	0.1108	0.0105
Residential area	0.0607	0.1117

Further, the concentrations of Pb in SPM at all sampling sites were ranged between below detectable limit (BDL) to 0.515 $\mu g/m^3$. Gasoline powered vehicles are reported to be a major source of Pb in urban areas (Kannan 1991; Jeba Rajasekhar et al. 2001).

Jeba Rajasekhar et al. (2004) had reported a significant positive correlation between the concentrations of Pb and that of SPM. But in the present study, no such correlation was found. This indicates that gasoline powered vehicles are no longer the major source of Pb to Nagpur atmosphere. The introduction of unleaded petrol in Nagpur during 1999 and subsequent phasing out of leaded petrol may be a possible reason of less concentrations of Pb in Nagpur air.

Industrial area and to some extent commercial area are observed to be the major sources of heavy metals to the atmosphere. Similar observations have made by Koprda and Krištín (2010), Vijayanand et al. (2008) and Sharma and Pervez (2004).

CPCB, India has prescribed standards for Pb, Ni and As but not for other substances. Although in most of the sampling stations, the average concentrations of lead and nickel were within the limits; standards were not available for other metals evaluated in this study. As Indian standards do not describe about the numbers and chemical composition of particulate matter in air, this study highlights the lacuna of ambient air quality standards practiced in this country. These facts underscore the increased attention to tackle the air pollution problems.

Public health and heavy metals in atmosphere

Epidemiological studies have shown that there is a significant association between the concentration of air pollutants and adverse health impacts (Ostro et al. 1995). The importance of the link between air pollution and health is underscored in a study by Pope III et al. (2002), who shows that residents who live in an area, in California, that is severely impacted by particulate air pollution are at a greater risk of lung cancer at a rate comparable to non-smokers exposed to second-hand smoke. It is observed in this study that there is an excess risk of approximately 16% dying from lung cancer due to fine particulate air pollution. Air pollution contributes to illnesses like eye irritation, asthma, bronchitis, etc., which invariably reduce efficiency at work. There is evidence of a high percentage of chronic illnesses like asthma, BP, Tuberculosis, heart disease, etc., and this has created widespread concern in Kanpur. The study estimates that a representative individual from Kanpur would gain Rs 165 per year if air pollution was reduced to a safe level. The extrapolated annual benefits for the entire population in the city are Rs 213 million (Gupta and Joseph 2004). This indicate that the public health problems will be reduced by implementing integrated management of air pollution in Nagpur through improvement of roads, dense plantations in city, Strict enforcement of air quality standards etc.

Prevention of heavy metal poisoning through air route

- ❖ Avoiding exposure to polluted air
- ❖ Balanced nutritional status is extremely important in protecting the man from metal poisoning.
- ❖ In order to detoxify when the diagnosis is certain, requires giving the body all the essential nutrients to allow the process to occur.
- ❖ All vitamins, minerals, trace elements, proteins and fats must be supplied.

Conclusion

The respirable particulate matter (PM_{10}) was observed to be increasing with increase in human activity during the period from 2001 to 2006 in the urban environment of Nagpur City. The ambient concentration of PM_{10} as well as heavy metal load on this particulate matter was recorded to be higher in 2006. The efficient control of dust pollution in urban environment is thus necessary to avoid public health problems due to exposure of public to toxic heavy metals associated with respirable particulate matter.

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