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Assessment of heavy metal contents in the ambient air of the Coimbatore city, Tamilnadu, India

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ABSTRACT

Industrialization and urbanization are the two major causes of deteriorating air quality. To evaluate the ambient air quality of the Coimbatore city, suspended particulate matter (SPM) was collected at ten stations and analysed for the heavy metals content. The concentrations of seven heavy metals (Zn, Fe, Cu, Pb, Ni, Cr and Cd) were estimated. The level of SPM was found to be either at permissible or non-permissible limit depending upon the category of the sampling station. 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. 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.

1. Introduction

Air pollution is caused due to both gaseous (oxides of nitrogen, oxides of sulfur, oxides of carbon etc.) and particulate pollutants (organic and inorganic). Heavy metals are particulate inorganic pollutants released in the atmosphere through natural and man made processes such as metallurgical process, garbage incineration, combustion of fossil fuels, weathering of rocks, mining activities etc. [1–3]. Heavy metals are relatively dense and toxic at low concentrations as they can form complexes or ligands with organic compounds and alter them. These modified biological molecules lose their ability to function properly and resulting in malfunction or death of the affected cells [4]. Heavy metals can be transported from one place to another and released in the ambient air through wind-blown dust [5,6]. Studies in occupation and community settings have established the fact that the accumulation of heavy metals in the body by inhalation or ingestion can be responsible for a wide range of health effects such as cancer, neurotoxicity, immunotoxicity and cardiotoxicity leading to increased morbidity/mortality in populations [7–10]. As the toxic effects of heavy metals are now well recognized in urban places, the determination of their concentrations in the ambient air of major cities is significant in air pollution studies [11–13].

Of the major cities in Tamilnadu state, India, Coimbatore is the second and most important commercial and industrial city. The city and its environs have been growing rapidly and industries like cotton ginning and spinning, foundries and general engineering have converted the Coimbatore city into a major industrial hub of the state. As these activities can add significant levels of heavy metals in the atmosphere, regular surveillance and consistent monitoring of heavy metals present in the SPM collected from the ambient air of the city would be much imperative. Against this background, a study was carried out to determine the atmospheric levels of heavy metals as to clarify the status of the city's ambient air quality and to know the probable sources. The concentration of seven heavy metals (Cd, Cr, Cu, Pb, Fe, Ni and Zn) in the SPM of the ambient air in the Coimbatore city was estimated and the contribution of various sectors like foundries, industries, residential and traffic to the atmospheric metal contents has been evaluated.

2. Materials and methods

2.1. Sample collection

The study was carried out between July 2004 and June 2005. Ambient air samples were collected at ten different locations (Avarampalayam, Chinnavedampatti, Chinniyampalayam, Ganapathy, Keeranatham, Kunnathur, Kuruchi, Papampatti, Peelamedu and Singanallur) representing industrial, residential and traffic areas in and around the Coimbatore city (Fig. 1). Considering the city railway

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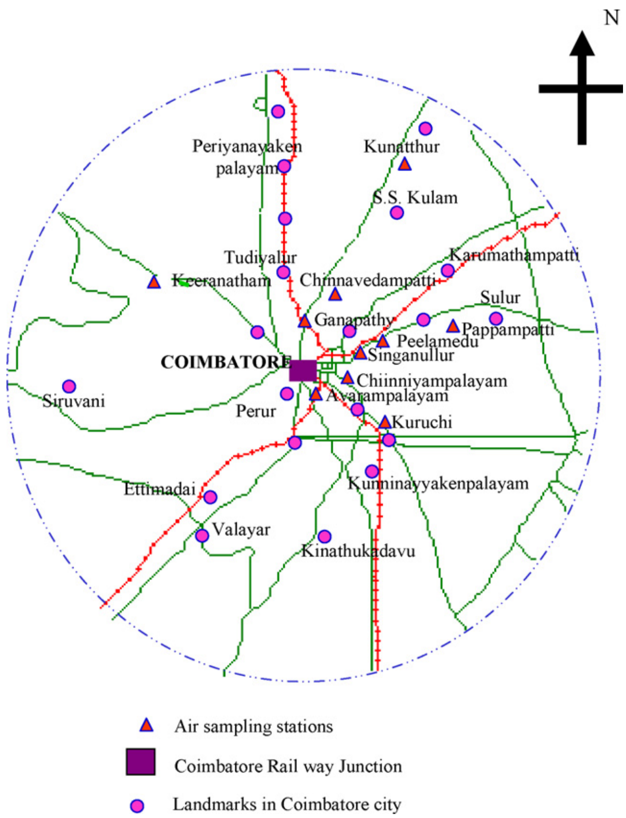

Fig. 1. Location of ambient air sampling stations in Coimbatore city.

station as the centre part, the sampling stations were selected from all directions. The distance between railway station and sampling stations ranged from 4 to 18 km. Using high volume air sampler (Envirotech's APM 415, Envirotech instruments, Upkaran Pvt. Ltd., New Delhi) samples (Sample 1 and Sample 2) each for 24 h were collected from all sampling stations. The sampling details and average flow rate were recorded and carefully maintained through out the study. Daily weather data (relative humidity, temperature, wind speed and wind direction) were obtained from the Department of Meteorology, Tamilnadu Agricultural University (TNAU), Coimbatore. All the collected samples were packed in polyethene covers and transported immediately to the Air Pollution Division, PG and Research Department of Environmental Science, PSG College of Arts and Science, Coimbatore, Tamilnadu, India and analysed for SPM and heavy metals using standard laboratory procedures [14].

2.2. Estimation of SPM

The glass micro fiber filters used in this study were dried in a hot air oven between the temperature ranges of 103 and 105 °C. Subsequently, the SPM collected on the filter paper was estimated following the guidelines mentioned by the United States EPA, Washington, DC [14].

2.3. Extraction and quantification of heavy metals

Sample and control (blank filters) filter papers were processed separately to extract the heavy metals present in SPM 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 [14].

3. Results and discussion

As a result of excessive urbanization and increased human activities, the air quality has been deteriorated significantly in most of the cities. Air has become a major reservoir of several air pollutants particularly heavy metals [1,2]. Heavy metals are injurious to health as their accumulation in the body may lead to several complications [5,7,8]. 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 SPM of the air. This would be helpful to indicate the possible/major sources of SPM to ambient air and to implement remedial and preventive measures.

Table 1
Concentration of test SPM with national ambient air SPM/Pb standards (24 h average)

S. No.	Name of the sampling station	Category of area	Concentration of test SPM ($\mu g/m^3$)		National ambient air quality standards [15] (SPM[a]/Pb[b] concentration in $\mu g/m^3$)		
			Sample 1	Sample 2	Industrial area	Residential, rural and other areas	Sensitive area
1	Peelamedu	Residential and traffic area	208	205	500[a]	200[a]	100[a]
2	Keeranatham	Industrial area	116	120	1.5[b]	1[b]	0.75[b]
3	Chinnavedampatti	Industrial area	95	101			
4	Kunnathur	Industrial area	136	139			
5	Kuruchi	Industrial and traffic area	286	279			
6	Avarampalayam	Industrial and traffic area	296	298			
7	Singanallur	Residential and traffic area	303	320			
8	Ganapathy	Industrial and traffic area	292	304			
9	Pappampatti	Industrial and traffic area	168	196			
10	Chinniyampalayam	Residential and traffic area	191	201			

[a] National Ambient Air Quality Standards of SPM.
[b] National Ambient Air Quality Standards of Pb.

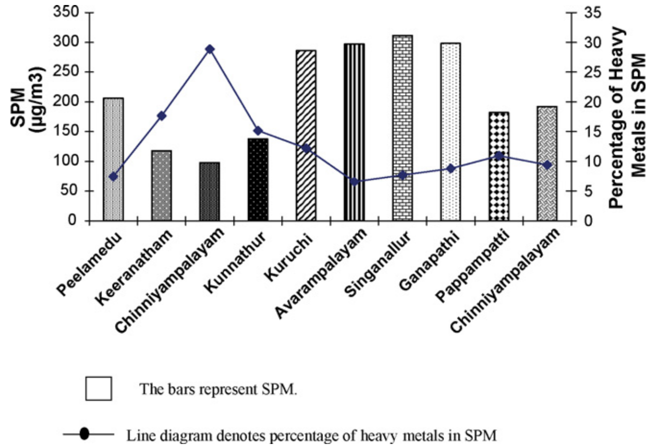

Fig. 2. Average concentration of SPM and heavy metals in ambient air at various sampling stations in Coimbatore.

Table 2
Average relative humidity, maximum and minimum temperature in Coimbatore city from July 2004 to June 2005

S. No.	Month	Temperature (°C)		Relative humidity (%)
		Maximum	Minimum	
1	July	31.1	22.6	58.45
2	August	31.5	22.0	53.16
3	September	31.5	22.3	58.06
4	October	29.9	21.7	63.38
5	November	28.3	21.0	64.7
6	December	29.4	18.2	44.51
7	January	30.5	19.0	43.29
8	February	32.01	19.5	31.92
9	March	34.4	22.2	37.74
10	April	32.4	23.2	47.67
11	May	34.6	22.8	50.58
12	June	32.2	23.8	52.56

Latitude: 11°N, longitude: 77°c\e, and altitude: 426.7 m msl.

In this study, the characterization of heavy metals composition concentrated in ambient air collected from determined stations of Coimbatore city revealed noticeable results. The average concentration of SPM ranged from 98 μg/m^3 (at Chinnavedampatti, an industrial area) to 311.5 μg/m^3 (at Singanallur, a residential cum traffic area). The concentration of SPM representing various sampling stations of the city with national ambient air quality standards as stated by the Central Pollution Control Board (CPCB), India is given in Table 1. Remarkably, Chinnavedampatti showed least concentration of SPM which may be attributed to the low level of vehicular traffic whereas Singanallur is a high traffic area as it includes a major bus stand. The other sampling stations such as Ganapathy, Avarampalayam and Kuruchi, had high levels of SPM of which Ganapathy and Kuruchi are located along the high way of Coimbatore city.

As a general observation of our study, the areas with heavy traffic were found to show relatively more amount of SPM than other sampling stations. However, the high concentration of SPM was not a direct reflection of high level of heavy metal constituents in the SPM (Fig. 2). For example, Singanallur, Ganapathy, Avarampalayam and Kuruchi were identified with low concentrations of heavy metals against their high amount of SPM. Similarly, in the sampling stations such as Chinnavedampatti, Kunnathur and Keeranatham the amount of heavy metals was more in contrast to their low SPM concentration. 'Higher SPM concentration with low levels of heavy metals could be due to the presence of constituents of SPM other than heavy metals such as silicates'. Although there is an ambiguity on the definite sources of these heavy metals, we suspect that the industries like foundries, electroplating units etc. present at some of the sampling stations could act as possible sources of heavy metals emission as at such places we have estimated comparatively more concentration of heavy metals.

The change in ambient weather could influence the total SPM concentration present in the air. During the study period, During the study period, the average relative humidity recorded by the Department of Meteorology, TNAU, Coimbatore, ranged between 31.92% in February and 64.7% in November, and the temperature ranged from 18.2 °C in December to 34.6 °C in May as shown in Table 2. Similarly, the wind speed ranged between 42.5 km/h from southwest to northeast and 1.0 km/h from east to west. The wind speed for all direction was represented in wind rose diagram (Fig. 3). To bring out the impact of weather change, annual average of SPM concentration may be evaluated.

Further, the analysis of SPM for heavy metals revealed the presence of metallic constituents such as Cu, Zn, Pb, Cd, Ni and Fe. The order of average concentration of heavy metals in Coimbatore atmosphere was Zn > Fe > Cu > Pb > Cr > Ni > Cd. Among these heavy metals, Zn was found to be the highest (ranged from 10.55 to 24.96 μg/m^3) while Cd found to be the lowest below the level of detection (BDL). 'The possible sources of Zn in this city could be diverse as Zn is used in dry batteries, construction materials, pigments etc. Further, it could also be emitted from Coimbatore based industries which make paint, rubber, dyes '. Also, considerable number of Coimbatore based foundries use Zn for protective coating on iron, steel and alloys [16–18]. However, the actual reasons/sources for its elevated levels are ambiguous which stress upon detailed studies in this aspect.

Fe is the most abundantly found metal in nature and most widely used by man. However, its concentrations ranked second

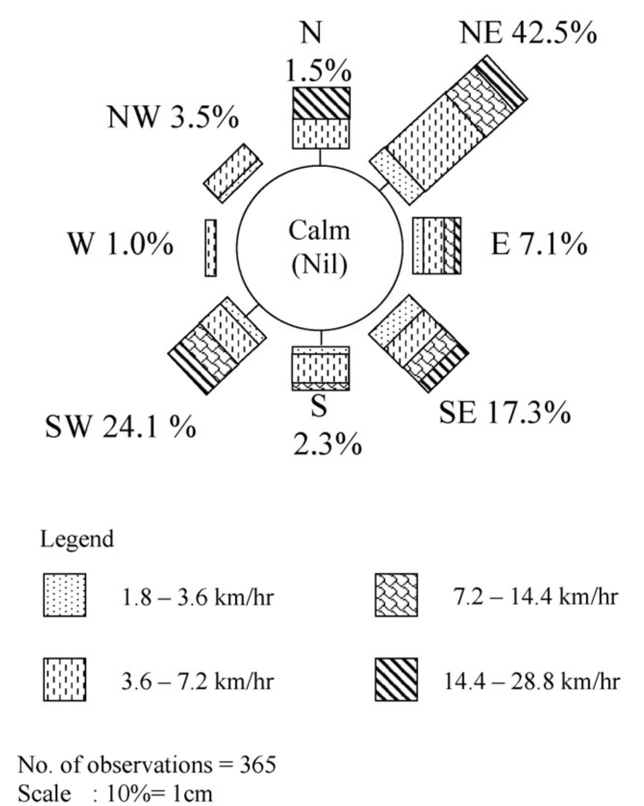

Fig. 3. Coimbatore city wind rose diagram from July 2004 to June 2005.

Table 3
Concentrations of different heavy metals in ambient air at various sampling stations in Coimbatore

S. No.	Heavy metals	Peelamedu	Keeranatham	Chinnavedampatti	Kunnathur	Kuruchi	Avarampalayam	Singanallur	Ganapathy	Pappampatti	Chinniyampalayam	Blank (mg/l)
		Concentration of heavy metals (μg/m^3)										
a												
1	Copper	0.66	0.88	0.51	0.31	0.29	0.46	0.73	0.69	0.53	0.61	BDL
	S I	0.74	0.96	0.70	0.51	0.31	0.54	0.81	0.71	0.68	0.79	BDL
	S II	0.70	0.92	0.60	0.41	0.30	0.5	0.77	0.70	0.60	0.70	
	Mean											
2	Zinc	9.82	12.16	19.28	12.6	8.7	13.3	19.0	17.2	11.6	8.6	BDL
	S I	12.85	18.87	30.64	19.21	12.4	16.9	21.36	26.7	18.27	12.1	BDL
	S II	11.33	15.51	24.96	15.90	10.55	15.1	20.18	21.95	14.93	20.7	
	Mean											
3	Nickel	0.12	0.09	0.23	0.082	BDL	0.13	0.12	0.10	0.12	0.15	BDL
	S I	0.21	0.16	0.39	0.096	BDL	0.20	0.24	0.19	0.26	0.30	BDL
	S II	0.16	0.12	0.31	0.089	BDL	0.26	0.18	0.14	0.19	0.22	
	Mean											
4	Cadmium	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	S I	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	S II											
b												
5	Lead	0.34	0.28	0.32	0.23	0.52	0.43	0.17	0.32	0.43	0.56	BDL
	S I	0.40	0.39	0.44	0.49	0.64	0.52	0.25	0.42	0.71	0.69	BDL
	S II	0.37	0.33	0.38	0.36	0.58	0.47	0.21	0.37	0.57	0.62	
	Mean											
6	Chromium	BDL	0.63	0.17	0.43	0.04	0.39	0.28	0.46	0.51	0.47	BDL
	S I	0.005	0.98	0.31	0.59	0.17	0.48	0.42	0.64	0.71	0.69	BDL
	S II	0.005	0.80	0.24	0.51	0.10	0.43	0.35	0.55	0.61	0.88	
	Mean											
7	Iron	2.3	2.4	1.6	3.2	2.8	1.9	2.3	1.6	3.4	4.9	BDL
	S I	3.4	3.9	2.1	4.1	3.8	2.5	3.6	2.8	4.8	7.1	BDL
	S II	2.85	3.15	1.85	3.65	3.3	2.2	2.95	2.2	4.1	6.0	
	Mean											

BDL, below detectable level.

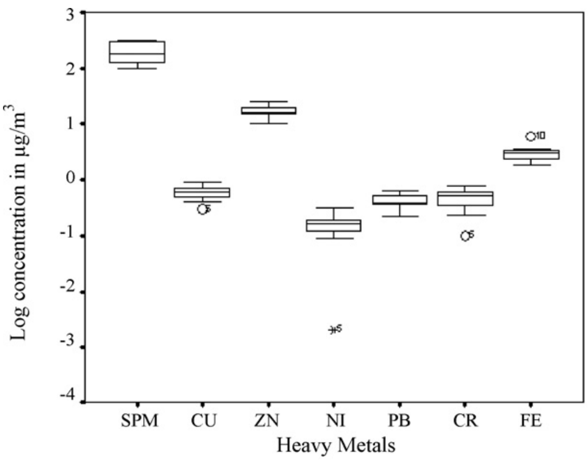

Fig. 4. Distribution of heavy metals in SPM collected at various stations in Coimbatore. The boxes include 50% of the data. The inner line marks the median value and whisker lines extending from the box represent the minimum and maximum values. Small circles represent outliers. Small star represents extreme value.

among the metals found in SPM (values ranged from 1.8 to 6.0 $\mu g/m^3$) in Coimbatore. This was in contrast to the presence of more number of foundries in the city as many of the sampling stations were clustered with foundry units. However, Friberg [16] had represented that fly ash from municipal waste could contribute a considerable amount of Fe. Cu is the third most abundantly used metal in industries next to Fe and Al. Accordingly, it is the third most abundant metal in SPM (values ranged from 0.30 to 0.92 $\mu g/m^3$) collected in Coimbatore. Emissions from industries, which located haphazardly in and around Coimbatore and the usage of Cu may contribute substantially to Cu concentration in ambient air. The average concentration of heavy metals calculated in the ambient air of varying stations in Coimbatore city are given in Table 3a and b.

Further, the concentrations of Pb in SPM at all sampling sites were ranged between 0.21 and 0.62 $\mu g/m^3$. Gasoline powered vehicles are reported to be a major source of Pb in urban areas [16–18]. Rajasekar et al. [19] 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 Coimbatore atmosphere. The introduction of unleaded petrol in Coimbatore during 1999 and subsequent phasing out of leaded petrol may be a possible reason of less concentrations of Pb in Coimbatore air.

The estimated concentrations of Cr and Ni ranged from 0.005 to 0.8 $\mu g/m^3$ and BDL to 0.3 $\mu g/m^3$ respectively. Electroplating industries and automobiles had been suggested as the possible sources of increased concentrations of Cr and Cd found in SPM in the Madurai city [19]. However, in spite of more than 300 electroplating units in and around the Coimbatore city and of heavy automobile traffic, Cd was not detected in all the representative sampling stations.

Although SPM concentration was least at Chinnavedampatti (the percentage mass contribution of metallic contents to mass of the SPM was maximum 28.86%) while minimum at Avarampalayam. The distribution of heavy metals in SPM collected at various locations in and around Coimbatore is illustrated in Fig. 4. To minimize the variations observed in SPM and metal contents, the values are shown in log scale. Wide variation in heavy metals concentration was observed among the SPM. The log SPM indicates larger interquartile ranges. Similarly, the median line is also closer to the bottom edge of the box, indicating tailing towards higher values of SPM. The box length of Ni and Cr was larger and the values were also skewed towards smaller values in the majority of the SPM. The length of the boxes for Cu, Zn, Pb, and Fe was narrower than Ni and Cr. While the location of the median lines indicated more or less uniform distribution of Cu among the SPM, Zn and Pb were skewed towards larger values and Fe was skewed towards smaller values.

The presence of varying concentrations of different heavy metals in the Coimbatore 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 Coimbatore. Similarly, it is estimated that the cupola based foundry units numbering around 1000 with an annual output of 6,00,000 tonnes are operating in and around Coimbatore. 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 Coimbatore have been started several years before the implementation of Air Pollution control Act (1991), they may still be contributing substantially to air pollution.

CPCB, India, has prescribed, standards for SPM, SO_2, NO*x* and Pb but not for other substances. Although in most of the sampling stations, the average concentrations of pollutants were within the limits; standards were not available for other metals evaluated in this study. Similarly, standards were not available for other potentially toxic substances such as organic substances (PAHs, PCBs, Dioxins, etc.). As Indian standards do not describe about the numbers and chemical composition of SPM 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.

4. Summary and conclusion

The study carried out to estimate the concentration of various heavy metals in SPM of ambient air in Coimbatore city identified a part of urban area (Singanallur) with high levels of SPM. Nevertheless, it was found to have low concentrations of heavy metals. The SPM concentration was within the permissible limits at places coming under industrial category. Conclusively, SPM analyses showed the presence of six (Zn, Fe, Cu, Pb, Ni and Cr) heavy metals at detectable and one (Cd) heavy metal at below detectable levels. Although the findings on the rate of heavy metal contents are not alarming in this region, regular survey at appropriate intervals should be implemented to monitor the air quality of the city as to control pollution from industries, foundries and from other sectors. Further, actions may be taken by educating the industrialists to adapt pollution curtailing methods and also to bring awareness among the common public so as to support and follow pollution control strategies.

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References

[1] S.M. Talebi, H. Abedi, Concentration of heavy metals in the atmosphere of the city of Isfahan, Pollut. Res. 23 (2) (2004) 211–214.
[2] S.K. Agarwal, Automobile Pollution, Askish Publishing House, New Delhi, 1991.
[3] D. Langmuir, Aqueous Environmental Geochemistry, Prentice Hall, New Jersey, 1997.

[4] USEPA, Air quality Criteria for Particulate Matter, United States Environmental Protection Agency, Research triangle, NC, Environmental Criteria and Assessment office, Rep. EPA/600/P-95/001aF, 1996.

[5] US EPA, National Air Toxics Program, The Integrated Urban Strategy, United States Environmental Protection Agency's, Federal Reg. 64 (137) 1999a, http://www.epa.gov/ttnatw01/urban/pre.html.

[6] AMAP, Arctic Pollution Issues: A State of the Arctic Environment Report, Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, Olsen & Olsen Academic Publishers, Fredensborg, Denmark, ISBN 82-7655-060-6, 1997.

[7] D.W. Dockery, C.A. Pope III, J.D. Spengler, H.J. Ware, M.E. Fay, B.G. Ferris Jr., F.E. Speizer, An association between air pollution and mortality in six U.S. cities, New Engl. J. Med. 329 (1993) 1753–1759.

[8] C.A. Pope III, M.J. Thun, M.M. Namboodiri, D.W. Dockery, J.S. Evans, F.E. Speizer, C.W. Heath, Particulate air pollution as a predictor of mortality in a prospective study of US adults, Am. J. Respir. Crit. Care Med. 151 (1995) 669.

[9] E.K. Silbergeld, The international dimensions of lead exposure, Int. J. Occup. Environ. Health 1 (4) (1995) 338–340.

[10] E.K. Silbergeld, The elimination of lead from gasoline: impacts of lead in gasoline on human health, and the costs and benefits of eliminating lead additives, draft paper, The World Bank, Washington, DC, 1996, 3.

[11] R.A. Goyer, Results of lead research: prenatal exposure and neurological consequences, Environ. Health Perspect. 104 (10) (1996) 1050.

[12] K. Donaldson, W. MacNee, The mechanism of lung injury caused by PM10, J. Environ. Sci. Technol. (1998) 10.

[13] S.R. Singh, Concentration of fine silica and heavy metals in respirable suspended particulate matter small-scale foundries in Chandigarh, J. Occup. Environ. Med. 5 (4) (2001) 196–200.

[14] US EPA, Method for the determination of inorganic compounds in ambient air United States EPA, office of research and development, Washington, DC, EPA/625/R-96/010a, 1999b.

[15] Pollution Control Legislations, Tamilnadu pollution control board, Pollution Prevention Laws, vol. 1, 1999, pp. 223–224.

[16] Lars Friberg, Gumar, Lord berg, Velimir B. Vouk, Handbook on the Toxicology of Metals, vol. 2, Elsevier Publications, New York, USA, 1986.

[17] K. Kannan, Fundamentals of Environmental Pollution, S. Chand & Co, Ltd., New Delhi, 1991.

[18] R.V. Jeba Rajasekhar, B. Vijay Bhaskar, I. Kulandaisamy, P. Muthusubramanian, SPM concentration ambient air of Madurai city, J. Environ. Sci. 5 (1) (2001) 56–61.

[19] R.V. Jeba Rajasekhar, B. Vijay Bhaskar, I. Kulandai samy, P. Muthusubramanian, Air quality with special reference to heavy metals in Madurai city, Pollut. Res. 23 (2) (2004) 271–274.