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Assessment of ambient PM_{10} on the basis of characterization of three metals at two locations within Kolkata

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Ambient level of heavy metals were assessed at two locations within Kolkata, West Bengal, India from monthly 24 h average concentrations of Particulate Matter of diameter less than 10 μ (PM_{10}). This assessment utilized monitored samples of PM_{10} conducted by West Bengal Pollution Control Board (WBPCB), the state environmental regulatory agency from April 2013 to March 2016. Among the three metals, Pb concentration was obained maximum in the ambient air of Kolkata. The As metal concentration in ambient PM_{10} attained India's National Ambient Air Quality Standard (NAAQS) of 2009 in most of the cases during the entire study period. For each of Pb and Ni metals, monthly 24 h average concentrations were non-complied with NAAQS during the year of 2014 to 2015 and complied with NAAQS in the two years of 2013 to 2014 and 2015 to 2016. From variation in concentration level of the three metals, pollution level of ambient air in Kolkata is assessed.

Keywords: PM_{10}, heavy metals, ambient air, India, Particulate Matter.

Introduction

Kolkata is a busy, congested and second most populous city of India. In this city, the two sampling sites are located within mixed area of commercial activity, industrial processes and residential establishments. Anthropogenic activities surrounding these monitoring sites were thermal power plant, railway yards for loading and unloading of materials, mint house, galvanizing industries, electroplating units, paint manufacturing, secondary lead smelting units, lead acid battery units, burning of oil as fuel of DG sets, burning of Furnace Oil by industrial boilers and ovens, using coal as fuel for small hotels, slum dwellers and tandoor ovens of hotels, use of pesticides and weed killer, burning of lead containing materials like batteries and plastics, tobacco smoking, use of stainless steel utensils and imitations and finally exhaust of uncontrolled vehicular density on insufficient road space within highly congested city[1(e)]. The results of emissions of these manmade polluting activities especially industrial units were reflected from heavy metal (As, Pb and Ni) characterization of ambient PM_{10} sample in Kolkata. These heavy metals of As, Pb and Ni are trace metals as they occur in environment in trace quantities for the requirement of living organisms. Different sources/anthropogenic activities enrich the concentration of these metals resulting pollution of ambient air. These metals are toxic in nature even in small measurable quantities. Different chemical compositions of these metals in Particulate Matters cause various fatal health diseases particularly for children and aged persons along with property damage. So the maximum permissible concentration level of As, Pb and Ni in ambient air are promulgated as stipulated standard under India's NAAQS of 2009[2(b)]. There is a need for comprehensive study on heavy metal levels of ambient air in Kolkata city as no other existing literature has ever been analyzed over the monthly variation of metal composition in ambient air of this city. This study aims at assessment and analysis of monthly variation in concentration level of metal compositions from characterization of ambient PM_{10} performed by WBPCB during the period from April 2013 to March 2016 in Kolkata. The concentration level of metal content in ambient air of Kolkata are compared with India's NAAQS of the year 2009 (Table 1)[2(b)] which reflect the cases of deviations occurred from stipulated standard due to deterioration of Ambient Air Quality (AAQ) in this city.

Sources of pollution in respect to metal composition of ambient air in Kolkata is discussed from available literature.

From variation in concentrations of the metals characterized in ambient air of Kolkata, pollution level is assessed and this pollution would cause different health diseases.

Materials and methods:

Air samples monitored by WBPCB at two AAQ monitoring stations of Shyambazar and Behala Chowrasta located within the heart of Kolkata during the three periods of April 2013 to March 2014, April 2014 to March 2015 and April 2015 to March 2016 are considered for obtaining metal concentrations of ambient air and these monitored monthly 24 h average PM_{10} samples were subjected to chemical analysis for characterization of heavy metals of As, Pb and Ni following the approved methods stipulated by CPCB[2(c)]. The results of the concentrations of these metals are taken from data bank of WBPCB[2(g)–2(i)]. Monthly variation in concentration of As, Pb and Ni were analyzed and compared with NAAQS of 2009 to explain the monitoring results to the extent possible.

From yearwise variation of metal concentration, pollution level of ambient air in Kolkata is assessed.

Table 1. National Ambient Air Quality Standards (NAAQS) of India, 2009

Pollutants	Time weighted average	Industrial, residential, rural and other areas
As in ng/m^3	Annual	6
Pb in μg/m^3	24 Hours	1
Ni in ng/m^3	Annual	20

Results and discussion

Fig. 1 is plot of variation of monthly 24 h average concentration of As metal obtained from chemical characterization of PM_{10} samples at Shyambazar AAQ monitoring station during the period from April 2013 to March 2016. In the year of 2014 to 2015, the value of As in the figure was obtained at lower level in between 0.07 to 0.28 ng/m^3 with little deviation from its straight line trend with X axis (month). The monthly 24 h average As concentrations are compared with India's NAAQS of 2009 for annual average value of As (6 ng/m^3) as no 24 h average value of As is considered as stipulated standard of India's NAAQS of 2009 till date which may possibly be due to high toxicity of As element requiring more stringent environmental standard. It can be stated that the As values of the year 2014 to 2015 were occurred well below

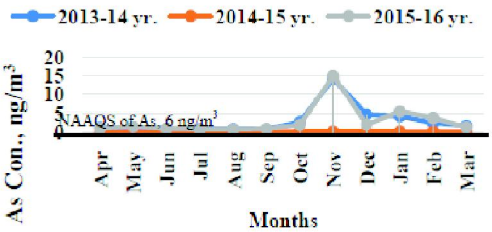

Fig. 1. Concentration of As metal at Shyambazar AAQ monitoring station during the period from April 2013 to March 2016.

India's NAAQS of 2009. For the other two years of 2013 to 2014 and 2015 to 2016, the As concentrations were varied in these two years almost similarly in the range of 0.8 to 14.96 ng/m^3. Except the values of November 2013 and November 2015, all the As values during the entire study period were complied with India's NAAQS of 2009.

In Fig. 2, concentration variation of monthly 24 h average As value in PM_{10} at Behala Chowrasta AAQ monitoring station during the period from April 2013 to March 2016 is presented. Fig. 2 shows similarity with Fig. 1 as the As metal concentrations were observed at lower level ranging from 0.04 to 0.25 ng/m^3 during the year of 2014 to 2015 having more or less uniform trend and almost same type of variations were recorded for the periods of 2013 to 2014 and 2015 to 2016 with values from 0.8 to 15.57 ng/m^3. Except the As values during November 2013, November 2015 and January 2016 which had not attained compliance with NAAQS of 2009, all the other values of As metal during the entire study period were well within NAAQS of 2009.

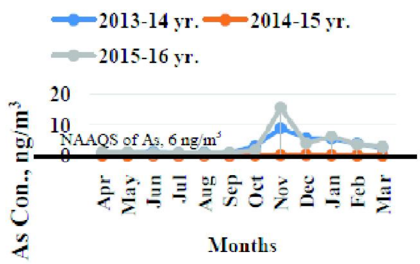

Fig. 2. Concentration of As metal at Behala Chowrasta AAQ monitoring station during the period from April 2013 to March 2016.

Both in Fig. 1 and Fig. 2, comparatively lower As value were occurred during the year of 2014 to 2015 than the two years of 2013 to 2014 and 2015 to 2016. Overall, it is stated from the trends that the As concentrations were attained higher values during the months from October to March (winter time) than the remaining months (summer and monsoon time) of each year due to low ambient temperature, low wind speed and low inversion height for no or less dispersion of air pollutants during winter time as compared to summer/monsoon time for more dispersion/dilution of air pollutants. The As metal concentration was characterized from PM_{10} samples as different As compounds are adsorbed onto the samples of fine particles[2(f)]. So variation in As concentration during a year is consistent with the observation of Mandal and Bandyopadhyay[1(i)] for variation of PM_{10} along a year. In the literature, Manalis *et al.*[1(h)] carried out studies with monitoring of PM_{10} samples for 24 h duration at four locations of Greater Athens Area during the period from 2001 to 2002 and the concentration of As was obtained beyond the threshold limit of European Union regulations (6 ng/m^3 annually) at the two sites, whereas this present study shows that As concentrations in ambient PM_{10} samples attained compliance with NAAQS of 2009 (6 ng/m^3 annually) in most cases as comparative analysis.

Variation of monthly 24 h average concentration of Pb metal obtained from characterization of PM_{10} samples at Shyambazar AAQ monitoring station during the period from April 2013 to March 2016 is plotted in Fig. 3. It is stated from the figure that the Pb values were obtained well below 1 μg/m^3 (India's NAAQS of 2009 for Pb) with more or less uniform trend for the years of 2013 to 2014 and 2015 to 2016. During the period of 2014 to 2015, the concentration of Pb values were varied well above its NAAQS of 2009 in the range of 3 to 14.81 μg/m^3 with a peak value on December 2014.

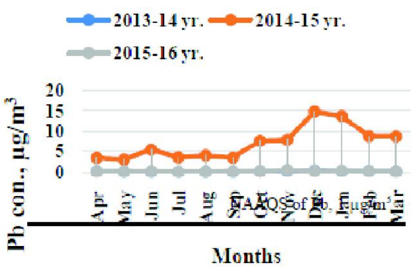

Fig. 3. Concentration of Pb metal at Shyambazar AAQ monitoring station during the period from April 2013 to March 2016.

Fig. 4 is shown variation of monthly 24 h average concentration of Pb metal at Behala Chowrasta AAQ monitoring station during the period from April 2013 to March 2016 and this figure has similarity with Fig. 3. In Fig. 4, for the years of 2013 to 2014 and 2015 to 2016, the Pb levels were maintained more or less uniform trend attaining compliance with India's NAAQS of 2009. The values of Pb in the year of 2014 to 2015, were varying in the range of 3 to 16.01 μg/m^3 without attaining compliance with its NAAQS of 2009 having maximum value on December 2014.

It is overall reflected from the Fig. 3 and Fig. 4 that like the As values, higher Pb values were obtained during the months starting from October to March (winter time) than the Pb values during the months from April to September (summer/monsoon time) of each study year. In a study, Nikolaos *et al.*[1(j)] conducted characterization of ambient $PM_{2.5}$ samples at one semi urban area and one industrial area of Athens basin during the period from 1995 to 1996 and reported that the concentration levels of Pb was 143 ng/m^3, whereas this present study indicates the variation of Pb concentration of ambient PM_{10} in between 60 ng/m^3 (0.06 μg/m^3) to 640 ng/m^3 (0.64 μg/m^3) during the periods from 2013 to 2014 and 2015 to 2016 and in between 3000 ng/m^3 (3 μg/m^3) to 16040 ng/m^3 (16.04 μg/m^3) during the year 2014 to 2015 as comparative analysis. In another literature, Karar *et al.*[1(g)] monitored characterization of ninety nos. PM_{10} samples of ambient air during the period from November 2003 to November 2004 at one residential site and one industrial site within Kolkata, West Bengal, India and they mentioned Pb concentration as 79.1 ng/m^3. Manalis *et al.*[1(h)] also highlighted that Pb level in ambient PM_{10} samples for 24 h duration at four locations of Greater Athens Area was obtained below the permissible threshold limit of European Union regulations (0.5 μg/m^3 annually). But present study shows that Pb level in ambient PM_{10} was complied with NAAQS of 2009 (1 μg/m^3 24 h) during the periods of 2013 to 2014 and 2015 to 2016

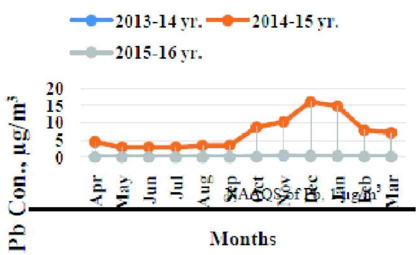

Fig. 4. Concentration of Pb metal at Behala Chowrasta AAQ monitoring station during the period from April 2013 to March 2016.

and non-complied with NAAQS of 2009 during the period of 2014 to 2015.

Fig. 5 displays the variation of monthly 24 h average concentration of Ni from characterization of PM_{10} samples at Shyambazar AAQ monitoring station during the period of April 2013 to March 2016. In Fig. 5, the trends of variation of Ni values for the years of 2013 to 2014 and 2015 to 2016, were more or less similar with the values ranging from 3 to 22.45 ng/m^3. The monthly 24 h average Ni concentrations are compared with India's NAAQS of 2009 for annual average value of Ni (20 ng/m^3) as no 24 h average value of As is considered as stipulated standard of India's NAAQS of 2009 till date which may possibly be due to high toxicity of Ni element requiring more stringent environmental standard. In these two years, only one value of Ni did not attain compliance with NAAQS of 2009 on January 2016. For the period of 2014 to 2015, the Ni levels varied well above its NAAQS of 2009 in the range of 35.09 to 64.43 ng/m^3 with highest value on March 2015.

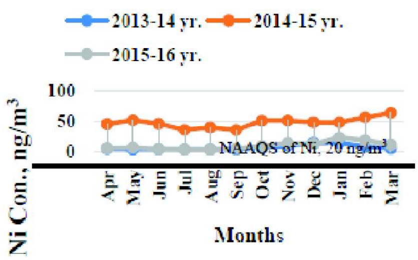

Fig. 5. Concentration variation of Ni metal at Shyambazar AAQ monitoring station during the period from April 2013 to March 2016.

Variation of monthly 24 h average concentration of Ni at Behala Chowrasta AAQ monitoring station during the period from April 2014 to March 2016 is shown in Fig. 6. This figure has similarity in yearwise trend of Ni value with Fig. 5. For the years of 2013 to 2014 and 2015 to 2016, only the Ni value on January 2016 was beyond permissible standard as per India's NAAQS of 2009. For the period of 2014 to 2015, all the Ni values were varying well beyond its NAAQS of 2009 ranging from 33.88 to 58.1 ng/m^3 with maximum value on March 2015.

In the study, Nikolaos *et al.*[1(j)] also showed that ambient $PM_{2.5}$ samples contained Ni as 4.55 ng/m^3, whereas this present study observed Ni concentration in the range of 3

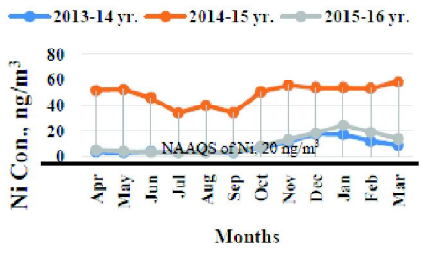

Fig. 6. Concentration variation of Ni metal at Behala Chowrasta AAQ monitoring station during the period from April 2013 to March 2016.

ng/m^3 to 24.41 ng/m^3 during the periods of 2013 to 2014 and 2015 to 2016 and in between 33.88 ng/m^3 to 64 ng/m^3 in the year 2014 to 2015 in ambient PM_{10} samples. Karar *et al.*[1(g)] also mentioned Ni concentration in ambient PM_{10} as 7.4 ng/m^3. Manalis *et al.*[1(h)] also reported that Ni level in ambient PM_{10} samples for 24 h duration at four locations of Greater Athens Area was obtained below the permissible threshold limit of European Union regulations (20 ng/m^3 annually). But present study indicates that Ni level in ambient PM_{10} was in compliance with NAAQS of 2009 in most of the cases during the periods of 2013 to 2014 and 2015 to 2016 and non-complied with NAAQS of 2009 (20 ng/m^3 annually) during the period of 2014 to 2015.

During the three years of 2013 to 2014, 2014 to 2015 and 2015 to 2016, yearwise comparison of concentration percentage for As, Pb and Ni metals obtained in ambient PM_{10} samples, are plotted in Figs. 7 and 8 for Shyambazar and Behala Chowrasta AAQ monitoring stations respectively. In Fig. 7, annual average concentrations of As, Pb and Ni were occurred as 3.001 ng/m^3, 177 ng/m^3 (0.177 μg/m^3) and 6.423 ng/m^3 respectively during the year of 2013 to 2014 and corresponding percentage proportion of As, Pb and Ni are 1.61%, 94.94% and 3.45% respectively. During the year of 2014 to 2015 annual average concentrations of As, Pb and Ni were occurred as 0.154 ng/m^3, 6999 ng/m^3 (6.999 μg/m^3) and 47.766 ng/m^3 respectively and corresponding concentration percentage of As, Pb and Ni are 0.002%, 93.22% and 6.78% respectively. In the year 2015 to 2016, concentration proportion of As, Pb and Ni are 1.56%, 93.63% and 4.81% respectively as annual average values of As, Pb and Ni were occurred as 2.977 ng/m^3, 179 ng/m^3 (0.179 μg/m^3) and 9.21 ng/m^3 respectively.

In Fig. 8, annual average value of As, Pb and Ni in the

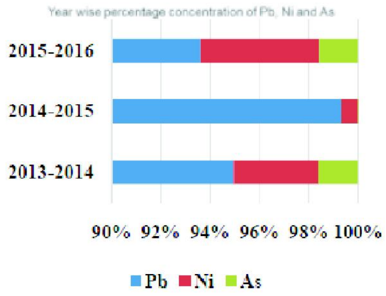

Fig. 7. Yearwise percentage concentration of Pb, Ni and As metals in ambinet PM_{10} at Shyambazar monitoring station.

year of 2013 to 2014 were obtained as 2.963 ng/m^3, 215 ng/m^3 (0.215 µg/m^3) and 7.808 ng/m^3 respectively and percentage proportion of these metals are 1.31%, 95.23% and 3.46% respectively. Annual average values of the year 2014 to 2015 for As, Pb and Ni occurred as 0.153 ng/m^3, 7120 ng/m^3 (7.12 µg/m^3) and 48.44 ng/m^3 respectively and their corresponding percentage contributions are 0.002%, 99.32% and 0.678% respectively. Finally, the annual average metal concentrations of As, Pb and Ni in the year of 2015 to 2016 were occurred as 3.295 ng/m^3, 202 ng/m^3 (0.202 µg/m^3) and 9.88 ng/m^3 respectively resulting percentage proportion of As, Pb and Ni as 1.53%, 93.88% and 4.59% respectively.

In both the figures, percentage of Pb metal concentration was occurred maximum (>93% and <100%) among the three metals and occurrence of As was obtained minimum in ambient PM_{10} samples for each year.

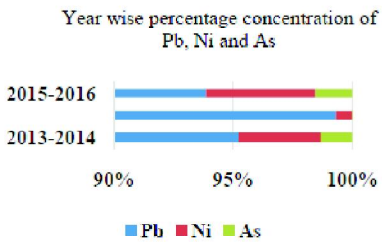

Fig. 8. Yearwise percentage concentration of Pb, Ni and As metals in ambinet PM_{10} at Behala Chowrasta monitoring station.

As there are similarities between Fig. 1 and Fig. 2 for yearwise variation of As metal concentration, the sources which are responsible for occurrence of As metal in ambient PM_{10}, are same for both the locations within Kolkata. This situation arises for other two metals (Pb and Ni) due to consistency of Fig. 3 and Fig. 4 as well as Fig. 5 and Fig. 6. Following are probable common source applicable for occurrence of the three metals within ambient air of Kolkata:

(1) Exhaust of uncontrolled vehicular density on insufficient road space within highly congested Kolkata city, burning of oil/furnace oil[1(c),1(j),1(k)] in DG sets, boilers and ovens of medium sized industries.

(2) Burning of coal[2(f)] in tandoors ovens, small hotels, slum dwellers within Kolkata and thermal power plant of M/s CESC Ltd., Cossipore, Kolkata specific sources within Kolkata for obtaining As in ambient PM_{10} are:

(1) Emission from lead-antimony grid making using As metal additive in lead acid batter units[2(f)].

(2) Use of pesticides, fungicides and weed killers[1(f)].

(3) Burning of scrap woods which was earlier treated with copper chromium arsenic preservative[2(f)].

Specific sources within Kolkata for Pb content in ambient PM_{10} are:

(1) Lead smelting and lead acid battery units[2(e)] within Kolkata.

(2) Burning of lead containing materials like plastics and fuels[1(d)].

Specific sources within Kolkata for occurrence of Ni in ambient PM_{10} are:

(1) Rusting of metal release Ni[1(m)].

(2) Tobacco smoking, use of stainless steel utensils and imitation or low cost jewellery[1(n)].

(3) Welding and battery manufacturing units[1(a)].

Ambient air containing heavy metals at significantly higher level has detrimental health effect. Long time exposure or exposure to higher concentration of As may cause health diseases[1(b)]. High level of ambient As causes skin disease, lung carcinogen, neuropathy and cardiovascular mortality[2(d)]. Schober *et al.*[1(l)] determined correlation between blood Pb level and mortality risk due to cardiovascular disease or cancer. High Ni concentration in ambient air may cause skin allergies, lung fibrosis and cancer of respiratory tract[2(a)].

Conclusions

Occurrence of As metal in ambient PM_{10} at two locations within Kolkata was obtained at lower level below India's NAAQS of 2009 in most of the cases during the entire study period of April 2013 to March 2016 and this assessment signifies that ambient air of Kolkata was predominantly free from As metal pollution. In few cases where the level of As had not attained India's NAAQS of 2009, were occurred on November 2013, November 2015 and January 2016 resulting unhealthy situation. Variation of As level in the years of 2013 to 2014 and 2015 to 2016 were almost consistent and were maintained at higher level in comparison to that of the year 2014 to 2015 (Fig. 1 and Fig. 2).

It is stated from Fig. 3 and Fig. 4 that ambient PM_{10} of Kolkata contained Pb metal which was well below India's NAAQS of 2009 during the years of 2013 to 2014 and 2015 to 2016 causing healthy atmosphere. For the year of 2014 to 2015, ambient air of Kolkata was unhealthy in respect to Pb concentration as its level was maintained well above India's NAAQS of 2009.

Like Pb metal, almost unpolluted ambient air in respect to Ni metal level was prevailed within Kolkata during the years of 2013 to 2014 and 2015 to 2016 as the concentration of Ni metal was below India's NAAQS of 2009 except Ni level of January 2016. For the year of 2014 to 2015, Ni level was well above India's NAAQS of 2009 and the situation was unhealthy (Fig. 5 and Fig. 6).

Among the three metals, Pb level was obtained maximum in ambient PM_{10} for each of the three years.

Overall trend of variation of all the three metals for each of the years implies that the concentration level of these metals had increased during the months of October to March (winter time) as compared to the that for the months of April to September (summer/monsoon).

References

1. (a) V. Bencko, *J. Hyg. Epidemiol. Microbiol. Immunol.*, 1983, **27**, 237; (b) D. Berggren, B. Bergkvist, U. Falkengrengrerup, L. Folkeson and G. Tyler, *Sci. Total Environ.*, 1990, **96**, 103; (c) W. Birmili, A. G. Allen, F. Bary and R. M. Harrison, *Environ. Sci. Technol.*, 2006, **40**, 1144; (d) R. Fernandez-Camachao, S. Rodriguez, J. D. L. Rosaa, A. M. Campaa, D. L. Sanchez, A. Alastueyc, X. Querol, Y. Gonzalez-Castanedoa, I. Garcia-Orellana and S. Nava, *Atmos. Environ.*, 2012, **30**, 1; (e) A. K. Gupta, K. Karar and A. Srivartava, *J. Hazard. Mater.*, 2007, **142**, 279; (f) X. Huang, I. Olmez, N. K. Aras and G. E. Gordon, *Atmos. Environ.*, 1994 **28**, 1385; (g) K. Karar and A. K. Gupta, *Atmos. Res.*, 2006, **81(1)**, 36; (h) N. Manalis, G. Grivas, V. Protonotarios, A. Moutsatsou, C. Samara and A. Chaloulakou, *Chemosphere*, 2005, **60(4)**, 557; (i) P. K. Mandal and A. Bandyopadhyay, *Environmental Quality Management*, 2013, 83; (j) S. Nikolaos, Thomaidis, B. Evangelos, Bakeas, A. Panayotis and Siskos, *Chemosphere*, 2003, **52(6)**, 959; (k) I. Rivas, M. Viana, T. Moreno, M. Pandolfi, F. Amato, C. Reche, L. Bouso, M. Alvarez-Pedrerol, A. Alastuey, J. Sunyer and X. Querol, *Environ. Int.*, 2014, **69**, 200; (l) S. E. Schober, L. B. Mirel, B. I. Graubard, D. J. Brody and K. M. Flegal, *Environ. Health Perspect.*, 2006, **114**, 1538; (m) S. Sinha and S. P. Banerjee, *Atmos. Environ.*, 1997, **31**, 2809; (n) E. O. Uthus and R. A. Poellot, *Biol. Trace Elem. Res.*, 1996, **52**, 23.
2. (a) T. W. Clarkson, in "Biological Monitoring of Toxic Metals", Plenum Press, New York, 1988, pp. 265-282; (b) CPCB: Central Pollution Control Board, Ministry of Environment and Forests, Government of India, New Delhi, India, in National Ambient Air Quality Standards, Air (Prevention and Control of Pollution) Acts, 1981, 2009, B-29016/20/90/PCI-I; (c) CPCB: Central Pollution Control Board, Ministry of Environment and Forests, Government of India, New Delhi, India in Guidelines for the measurement of ambient air pollutants, Vol. 1, National Ambient Air Quality Series: NAAQMS/36/2012-13, 2012; (d) European Commission (E.C.), DG Environment, in Ambient Air Pollution by As, Cd and Ni compounds, Position Paper, Working group on arsenic, cadmium and nickel compounds, Luxembourg, Office for Official Publications of the European Communities, Final version, 2001; (e) C. Li, T. Wen, Z. Li, R. R. Dickerson, Y. Yang, Y. Zhao, Y. Wang and S. C. Tsay, in: "Concentrations and origins of atmospheric lead and other trace specier at a rural site in Northern China", 2005; (f) R. Maggs, in: "A review of Arsenic in ambient air in the UK", Department of the Environment, Transport and the Regions, Scottish Executive, The National Assembly for Wales, 2000; (g) WBPCB: West Bengal Pollution Control Board, Department of Environment, Government of West Bengal, Kolkata, India, in Annual Report: 2013-2014, 2014, Chap. 6, pp. 40-94; (h) WBPCB: West Bengal Pollution Control Board, Department of Environment, Government of West Bengal, Kolkata, India, in Annual Report: 2014-2015, 2015, Chap. 6, pp. 49-107; (i) WBPCB: West Bengal Pollution Control Board, Department of Environment, Government of West Bengal, Kolkata, India, in Annual Report: 2015-2016, 2016, Chap. 6, pp. 96-166.