Trend in Lead Content of Airborne Particles and Mass of PM10 in the Metropolitan Bangkok

Voravit Cheevaporn,*,[a] Poonsup Norramit,[b] and Keiichi Tanaka[c]

[a]*Graduate Program in Environmental Science , Burapha University, Bangsaen, Chonburi 20131, Thailand,* [b]*Environmental Impact Evaluation Division, Office of Environmental Policy and Planning, Bangkok 10400, Thailand, and* [c]*Laboratory of Toxicology, Graduate School of Pharmaceutical Sciences, Osaka University, Osaka 565–0871, Japan*
(Received September 16, 2003; Accepted November 9, 2003)

This research investigated lead in airborne particles smaller than or equal to ten micrometer (PM10) in diameter and mass of PM10 in the Bangkok Metropolitan Area. One hundred and thirty two samples were collected by standard high volume technique from the Bangkok Metropolitan Area during 1999–2000, filtered and measured for lead by flameless atomic absorption spectrophotometry. Concentration of lead in air particles (24 hr average) was 73.22 ng/m^3 considerably less than the Thai ambient air quality standard value of 1500 ng/m^3. Highest and lowest concentrations, 299.38 and 2.96 ng/m^3 were found in Yoawarach road and Phahonyotin road, respectively. This and previous studies indicate a reduction in the concentration of lead in airborne particles since the 1991 campaign to use unleaded gasoline. The results of the study also showed a significant correlation between lead contents and mass of PM10. However, no correlation was observed between the concentration of lead in airborne particles and traffic density. This is probably due to the banning of leaded gasoline throughout the country since 1996 so that lead emissions and subsequent elimination of lead emissions via the exhaust system of vehicle is no longer an issue.

Key words —— airborne particle, PM10, leaded gasoline

*To whom correspondence should be addressed: Graduate Program in Environmental Science , Burapha University, Bangsaen, Chonburi 20131, Thailand. Tel.: +66-38-745900 (ext. 3023); Fax: +66-38-393-491; E-mail: voravit@buu.ac.th

INTRODUCTION

The consumption of lead has risen during the past century. The automobile industry used a large amount of lead in car batteries and gasoline additives.[1)] Tetraethyl and tetramethyl lead have been added to gasoline from the mid 1920's to increase the octane ratio of the fuel. Tetraethyl lead in gasoline reacts with oxygen and halogenated scavengers, dicholoroethane and dibromoethane, to yield lead halides which are volatile and emerge through the exhaust system as lead particles. Some 200000 tons of lead used to be emitted into the atmosphere each year from U.S.A. alone until 1975. These emissions are being reduced as unleaded gasoline is increasingly, replacing leaded gasoline.[2)]

In Thailand, before 1991, it was estimated that about 1052 kg/day of lead was released to the atmosphere in the Bangkok Metropolitan Area through exhaust emissions of the released from automobiles in Bangkok.[3)]

The major biochemical effect of lead is its interference with heme synthesis. At high levels of lead in the blood, kidney dysfunction and finally brain damage may occurs due to hemoglobin deficiency.[2)]

Due to its toxic effect, a campaign to use unleaded gasoline was started in Thailand in 1991. A total ban on the use of leaded gasoline has been implemented since 1996 as a strategy to abate air pollution.

Over the past five decades, Bangkok has faced serious pollution problems coincident with rapid development particularly in construction and the increase in the number of motor vehicles.[4)] Particulate particles equal to or less than 10 μm (PM10), in the atmosphere have often exceeded the standard of 120 μg/m^3 (1 month average). The objective of this paper is to evaluate the level and trend of lead contents in airborne particles and the mass of PM10 in Bangkok Metropolitan Area.

MATERIALS AND METHODS

Sample Collection and Analysis of Mass of PM10 —— One hundred and thirty two air samples (PM10) were collected by high volume sampler during the period of May 1999 to June 2000. Twenty-two sampling stations along roadsides covered most of the Bangkok Metropolitan Area as shown in Fig. 1. The high volume sampler used in this study was equipped with glass fiber filter and PM10 inlet

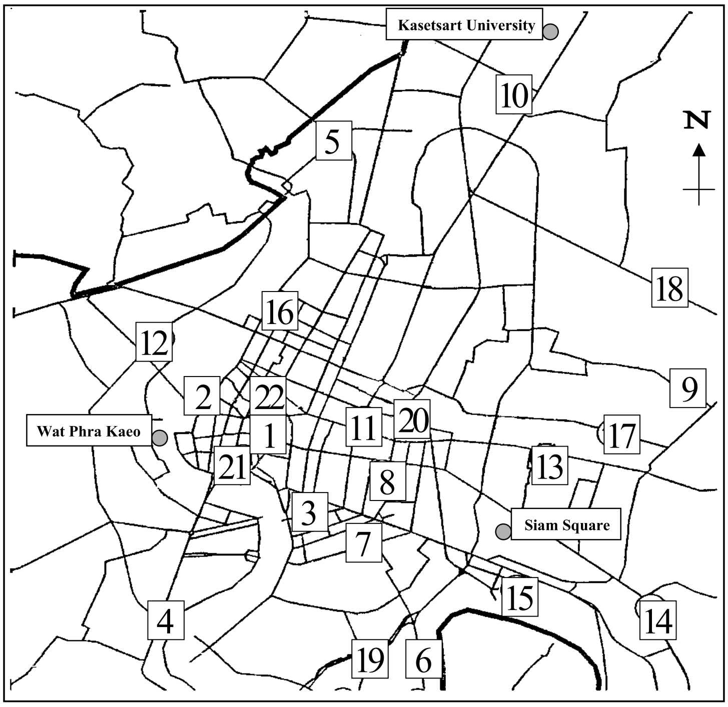

Fig. 1. Sampling Stations in Bangkok Metropolitan Area

to restrict particulates to equal or smaller than 10 μm in maximum diameter for laboratory analysis of lead. Thus, PM10 in the air was collected on glass fiber filter (20.3 × 25.4 cm^2 and pore size 0.3 μm), which was weighed before and after sampling, and the average concentration over the sampling period to provide a measure of weight (mass) of PM10. The total volume of air sampled was estimated from the measured flow rate and the sampling time. The concentration of PM10 in the ambient air is expressed as the total mass of particles divided by air volume, and expressed in micrograms per cubic meter (μg/m^3).

Lead Analysis ——— All of the air filters in this study were analyzed for lead by a nitric acid digestion followed by graphite furnace atomic absorption spectroscopy (GBC FS3000, GBC Scientific Equipment Pty Ltd., Victoria, Australia) as described in the U.S. Environmental Protection Agency (1995).[5)]

The precision/accuracy calibration of these determination was verified by sample check with standard lead samples. Glass fiber filter strips containing 80 to 2000 μg of Pb/strip and blank strips with zero lead contents were used for calibration. Overall, the coefficient of variation was better than 10% for most of the elements studied. Accuracy was checked again standards after every 10 samples.

RESULTS AND DISCUSSION

Lead Concentrations

The concentrations of lead in air particulate collected from the twenty-two stations located along the roadside in Bangkok Metropolitan Area are summarized in Table 1. The concentration of lead in air particles was found to range between 24.23–299.38 ng/m^3. The highest concentration of 299.38 ng/m^3 was observed in Yoawarach road and the lowest concentration of 2.96 ng/m^3 was observed in Phahonyotin road. The average lead concentrations over the sampling sites was 73.22 ± 0.63 ng/m^3. Areas with below average concentration of atmospheric lead were Bangkok-Nontaburi road, Ramkumhang road, Phahonyotin road, Phayathai road, Charunsanitwong road, Petchaburi road, Artnarong road, Samsen road, Sathupadit road, and Lanluang road. Of the areas with higher concentration of atmospheric lead none exceeded the ambient air quality standard of 1500 ng/m^3.

Mass Volume of PM10

The mass volume of PM10 collected from twenty-two stations in Bangkok Metropolitan Area are shown in Table1. The average mass volume of PM10 was found to range between 48.74–204.43 μg/m^3 with the average of 101.78 μg/m^3 which is lower

Table 1. Average Pb Concentrations in Air Particles, Mass of PM10 and Traffic Volume in Bangkok Metropolitan Areas

Station	Average of Pb (ng/m^3)	Average of PM10 (mg/m^3)	Traffic volume (cars/day)
1. Bamrung muang Rd.	108.76	120.00	65577 *c)*
2. Phra Sumain Rd.	93.27	61.51	10579 *a)*
3. Si phraya Rd.	82.71	79.35	33695 *c)*
4. Taksin Rd.	83.48	99.06	46459 *c)*
5. Bangkok-nontaburi Rd.	45.71	94.53	27456 *c)*
6. Rama 3 Rd.	199.60	204.43	24946 *c)*
7. Silom Rd.	132.51	61.29	33385 *c)*
8. Rama I Rd.	67.85	114.69	29592 *c)*
9. Ramkumhang Rd.	37.57	76.05	61518 *c)*
10. Phahonyotin Rd.	24.23	48.74	82362 *c)*
11. Phayathai Rd.	42.64	68.85	45021 *c)*
12. Charunsanitwong Rd.	63.95	94.77	47623 *c)*
13. Petchaburi Rd.	72.82	120.00	53816 *c)*
14. Sukhumvit Rd.	133.41	151.27	321143 *c)*
15. Artnarong Rd.	38.68	153.71	18022 *b)*
16. Samsen Rd.	31.31	97.06	24600 *c)*
17. Rama 9 Rd.	106.05	99.04	42093 *c)*
18. Suklapiban 1 Rd.	85.71	98.26	17997 *b)*
19. Sathupadit Rd.	71.27	71.62	17008 *b)*
20. Ratchapralob Rd.	106.39	132.07	49223 *c)*
21. Yaowaraj Rd.	299.38	78.65	11878 *a)*
22. Lanluang Rd.	35.23	115.14	38576 *c)*

a) Low density traffic: traffic volume less than 12000 cars per day. *b*) Dense traffic: traffic volume falls between 12000–24000 cars per day. *c*) Highest density: traffic volume more than 24000 cars per day. Rd., road.

than the ambient air quality standards for PM10 (120 $\mu g/m^3$, an average over 24 hr). The highest mass volume of 204.43 $\mu g/m^3$ of PM10 was observed in Rama3 road and the lowest mass volume of 48.74 $\mu g/m^3$ of PM10 was observed in Phahonyotin road.

The mass volume of PM10 at Bamrung muang road, Rama3 road, Petchaburi road, Sukhumvit road, Rama1 road, Artnarong road, and Ratchapralob road were found to be equal or above the ambient air quality standard of 120 $\mu g/m^3$ over 24 hr. In general, mass volume of PM10 in many sites of the study were found to exceed the ambient air quality standards for PM10.

Traffic Density

According to the Department of Traffic and Transportation,[6)] traffic volume in most of Bangkok Metropolitan Area can be classified as high density, that is more than 24000 cars/day. Only some areas such as Phra Sumain road, and Yaowaraj road, which are old and narrow can be classified below high density.

Average of traffic volume in Bangkok Metropolitan Area was found to be 50117 cars/day. The highest traffic volume of 321143 cars/day was observed in Sukhumvit road and the lowest traffic value of 10579 cars/day was observed in Phra Sumain road.

Comparison of lead concentrations in air particles from this study (collected during 1999–2000) with those of studies in 1990–1998 of the Department of Pollution Control,[7)] indicates a decline since 1991 or 1992 (Fig. 2). Presumably this is a consequence of the campaign against using leaded gasoline in 1991. After 1996 lead concentrations in air particles has remained at a low concentration of about 10 ng/m^3. This could be attributed to the banning of leaded gasoline over the country since 1996.

Lead was found in the highest concentration of 299.38 ng/m^3 in Yoawarach road, despite it's low traffic volume (11878 cars per day). This is probably because Yoawarach area is in the old city area where most of the roads are narrow. Furthermore, the high buildings may block the exchange of air to the atmosphere. Therefore pollutants such as lead accumulate and produce very high ground level concentrations. However, it is important to emphasize that none of the stations had lead concentration in

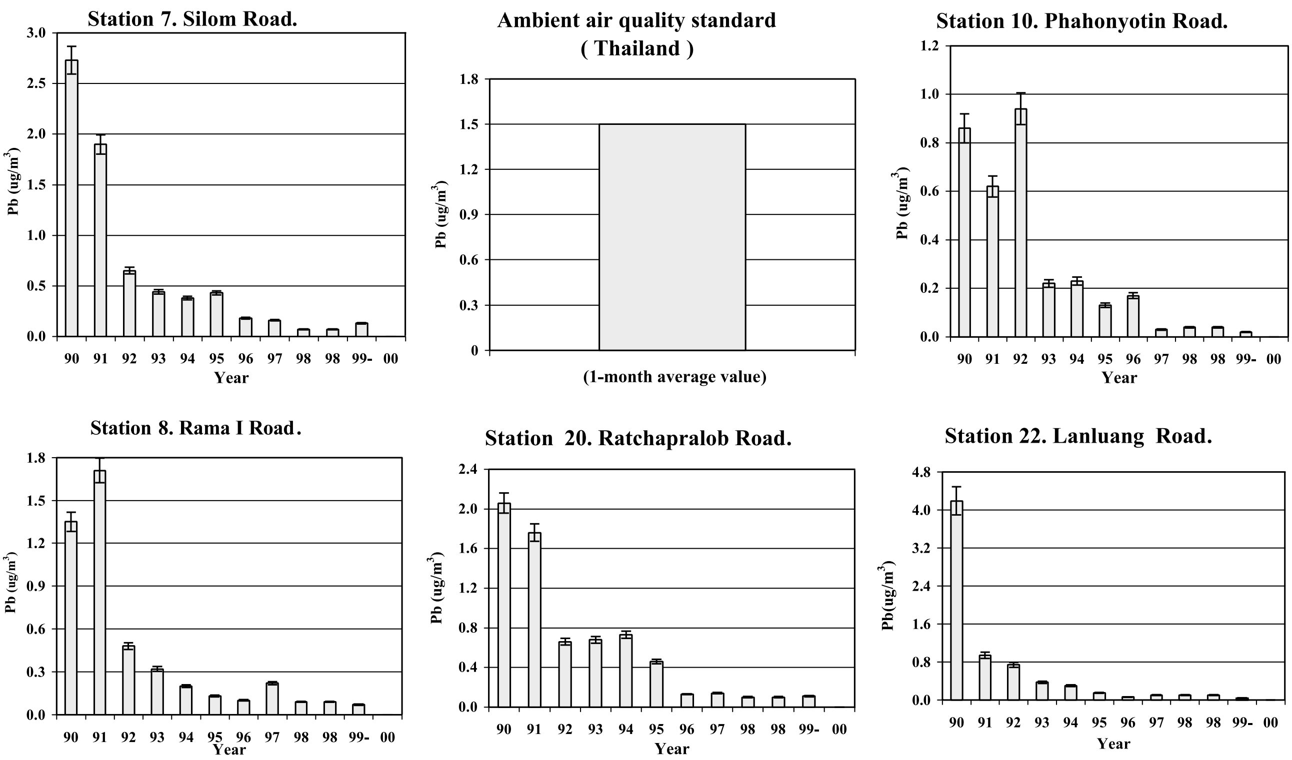

Fig. 2. Lead Concentrations during 1990–2000 in Bangkok Metropolitan Area

excess of ambient air quality standards of an average of 1500 ng/m^3 over one month.

In contrast to the Yoawarach area, the lowest concentration of 24.23 ng/m^3 in Phahonyotin road. This coincides with the mass volume of air particles such as PM10 in the area which was found at the lowest concentration of 48.74 μg/m^3 despite the high traffic volume (82362 cars per day) and construction activities over the past decade. However, the particulate matter abatement measurement of construction activities of this area were implemented and controlled by this District Authority. Furthermore, paving of roadways and addition of vegetation along the road are well managed in relative to other areas. This may reduce the dispersion of the dust into the atmosphere.

In contrast to lead contents in air particulate, results of the study showed that mass volume of PM10 in many areas of Bangkok Metropolitan Area (Table 1) were found to exceed the ambient air quality standards value (120 μg/m^3, an average over 24 hr). By comparing this result with previous studies by Department of Pollution Control,[7)] PM10 showed an increase trend of its mass volume (Fig. 3). This indicated that the particulate matter abatement measurement in the Bangkok Metropolitan Area has not been well implemented. Therefore a special emphasis on the particulate matter abatement measurement is still needed for Bangkok Metropolitan Area.

Statistical analysis showed a significant correlation ($r^2 = 0.96$, $p < 0.05$) between airborne lead and mass volume of PM10 (Fig. 4). This is because lead can be absorbed on the surface of the particles. Therefore, the greater the volume of PM10, the greater the concentration of lead in airborne particles. The results of this study are similar to those reported by Khandekar et. al. in Greater Bombay.[8)]

In general, in most of sites in large city where leaded gasoline is in use, correlation between airborne lead and traffic density was often observed such as in Greater Bombay.[8)] However, in the Bangkok Metropolitan Area, statistical analysis of current data showed a non-significant correlation between airborne lead and the traffic volume (Fig. 5). This suggests that automobile exhaust emission may no longer be a prominent source of airborne lead, largely attributable to the phasedown of lead in gasoline. Airborne lead concentrations has fallen from a maximum value of about 4200 ng/m^3 in 1990 to less than 0.3 ng/m^3 in 1996 to the present. Certainly air quality in Bangkok Metropolitan Area has shown a significant improvement since 1996. Lead residues

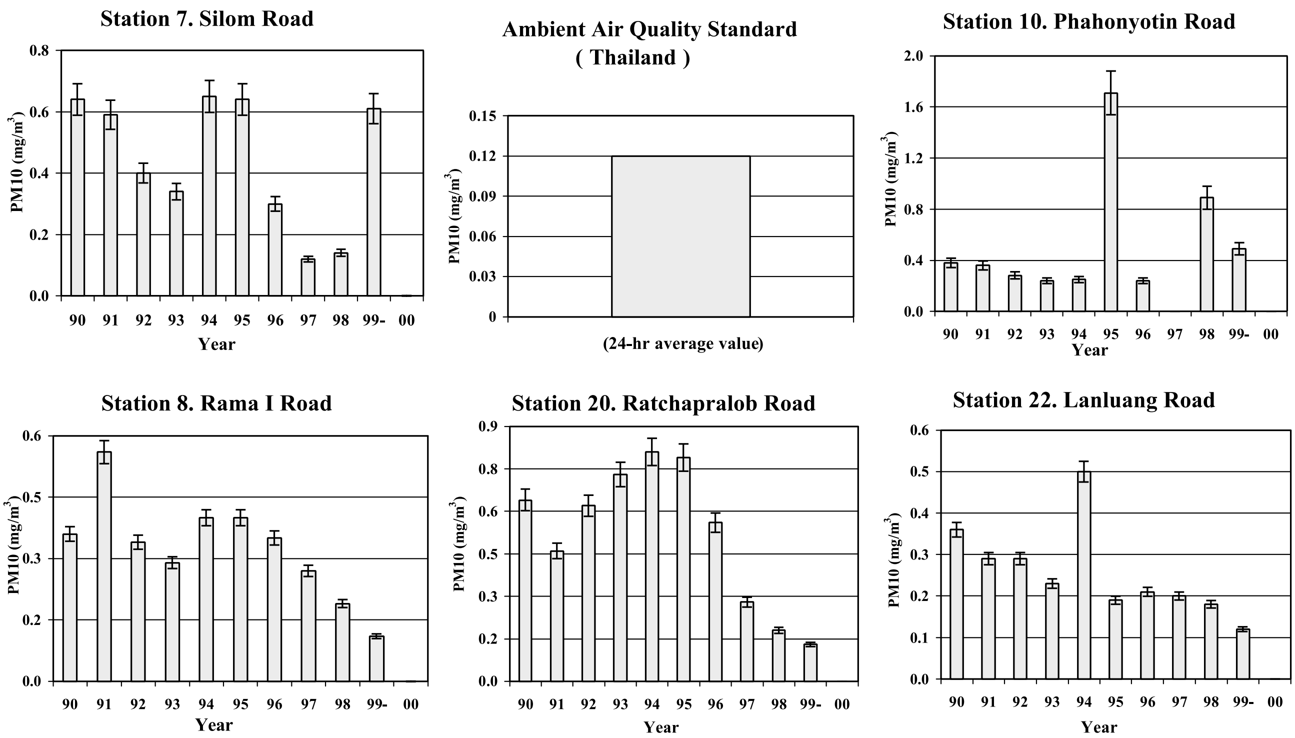

Fig. 3. PM10 Concentrations during 1990–2000 in Bangkok Metropolitan Area

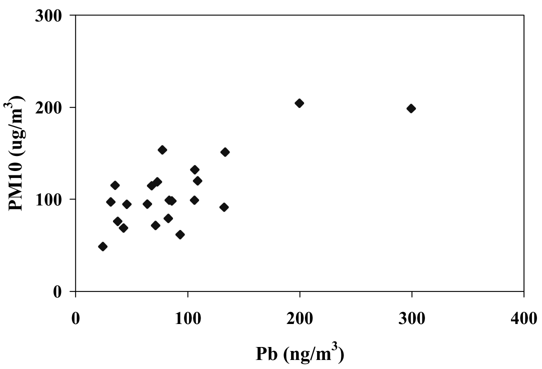

Fig. 4. The correlation between airborne lead and mass volume of PM10 ($r^2 = 0.96$, $p < 0.05$)

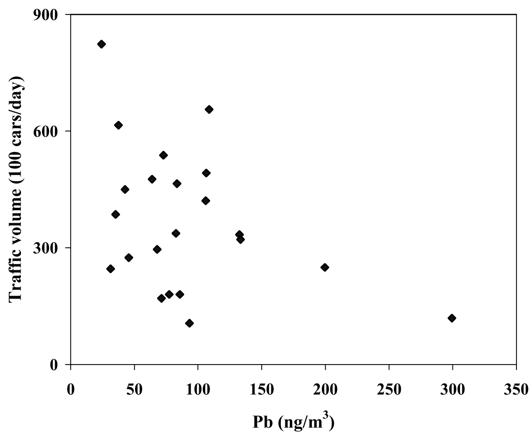

Fig. 5. The Correlation between Airborne Lead and the Traffic Volume ($r^2 = 0.21$, $p > 0.05$)

still present in the city atmosphere are likely due to many sources such as a variety of industries, burning of fossil fuels and the use of lead containing domestic products.

In conclusion, the information obtained from the study indicated that airborne lead has decreased since the banning of the leaded gasoline in 1996. In none of the study sites in Bangkok Metropolitan Area was lead in excess of the ambient air quality standards. Airborne lead concentration in Bangkok Metropolitan Area showed a significant correlation with the mass volume of PM10. However, no significant correlation was found between airborne lead and traffic density of the area. Results of the study showed that PM10 was found to exceed the ambient air quality standards in most sites of the study in Bangkok Metropolitan Area. Therefore particulate matter abatement measurement is still needed and should be emphasized for Bangkok Metropolitan Area.

Acknowledgements The authors wish to thank Department of Pollution Control for providing the laboratory facilities and sample collection for this study. Thanks are due also to Mr. Sontri Kochavat, Mr. Worapon Junngam and Mr. Teera Junpeth, of OEPP, for their valuable comments. We are grateful to Prof. W. Beamish for reading and editing this manuscript. This work was partly supporting by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science, Sports and Culture (13376003).

REFERENCES

1) Fergusson, J. E. (1989) *The Heavy Elements: Chemistry, Environment Impact and Health Effects* (Jack, E. F., Ed.), Pergamon Press, Oxford, England, pp. 22–23.
2) De, A. K. (1989) *Environmental Chemistry* (Anil, K. D., Ed.) Wiley Eastern Limited, New delhi, India, pp. 95–96.
3) Menasveta, P. (1989) *Water Resource and Pollution Problem* (Piamsak, M., Ed.), The Chulalongkorn University Press, Bangkok, Thailand, pp. 20–21.
4) Department of Pollution Control (1998) *Particulate matter abatement strategy for the Bangkok Metropolitan Area report, Volume I* (Anonymous, Ed.), Ministry of Science, Technology, and Environment, Thailand, pp. 4–6.
5) U.S. Environmental Protection Agency (1995) *Reference method for determination of lead in suspended particulate matter from ambient air*, U.S. Environmental Protection Agency, Washington, U.S.A., Appendix G to part 50.
6) Department of Traffic and Transportation (2000) *Data of Traffic density in Bangkok Metropolitan Areas in 1999–2000 report, Volome II* (Anonymous, Ed.), Ministry of Communication, Thailand, pp. 10–19.
7) Department of Pollution Control (1998) *State of air and noise pollution management in Bangkok Metropolitan Area* (Anonymous, Ed.), Ministry of Science, Technology, and Environment, Thailand, pp. 15–20.
8) Khandekar, R. N., Kelkar, D. N. and Vohra, K. G. (1980) Lead, Cadmium, Zinc, Copper, and Iron in the atmosphere of Greater Bombay. *Atmos. Environ.*, **14**, 457–461.