Arsenic in urban particulates – A case study in Kolkata metropolis

Atmospheric particulate pollutants, specifically heavy metals and trace elements derived from different anthropogenic sources, induce a variety of health effects which are currently considered as major problems in the highly urbanized regions of the world. Among the trace elements of airborne particulate matter, arsenic is the commonly known toxic element which causes adverse effects on human health[1]. Arsenic occurs naturally in a wide range of minerals, but its distribution in the environment is due to emission of fossil fuel combustion, industrial activities, widespread use of pigments, pesticides and other human activities reported in recent years[2,3]. Arsenic concentration in urban environment varies considerably in roadside soils[4]. Urban soils are significantly more heterogeneous than undisturbed soils and also human activity plays a dominant role in the changing of these soils[5,6].

Urban particulates can be emitted directly to the atmosphere through combustion processes and it is considered that traffic is one of the main sources of particulate pollution[7–9]. Studies on urban atmospheric particulate matter and on street sediments were carried out in some Chinese cities[10,11]. These results highlight the need to investigate the near-ground deposition of particulate matter with regard to impact on humans and plants.

However, there is lack of adequate knowledge on the impact of anthropogenic activities on chemical composition of urban particulates in Kolkata city with respect to the concentration of trace elements like arsenic. Kolkata is one of the densely populated cities with a history of more than 300 years (lat. 22°25′ to 22°40′N and long. 88°20′ to 88°35′E), located along the fringes of the river Hooghly (Figure 1). The major contributor of trace elements in the particulates is mainly vehicular and industrial emission. Kolkata city has a mixed nature of industries, including several small-scale industries and metal workshops scattered mainly in the north and central parts of the city.

Atmospheric particulate deposition on canopy foliage and street sediment samples were collected in different major roads of Kolkata city along the east/west and north/south transverse area in the last part of the winter (February 2004). In a particular sampling site, 8 to 10 samples were collected and then thoroughly mixed to get the homogeneity. After sieving, the sample was finally prepared for XRF analysis. In the case of particulate deposition on leaves, the leaves were collected from different plants along the roadside at a height of > 2 m. The deposited dust was scratched out from the leaf surface and mixed thoroughly. Trace elements analysis has been carried out by Energy Dispersive X-Ray Fluorescence (EDXRF) technique, using the model SPECTRACE 5000, BECKER HUGES.

The occurrence of arsenic concentration in particulate deposition on canopy leaves and street dust is summarized in Table 1. The highest average concentration of arsenic in particulates deposited on canopy leaves found in C.I.T. Road is 39 $\mu g\ g^{-1}$, followed by Shymbazar, M.G. Road and Sealdaha having 29, 29 and 28 $\mu g\ g^{-1}$ respectively. These values are higher than the arsenic concentration found in other sites like Chingreghata, Maidan and Moulali area. But in case of street dust, the occurrence of arsenic does not show such variation. Though it shows maximum concentration at C.I.T Road having a significant value of 18.71 $\mu g\ g^{-1}$, other sites show moderate arsenic ranging between 2 and 10 $\mu g\ g^{-1}$. These levels of arsenic concentration are also relevant with the values obtained by Chakraborty *et al.*[12], i.e. 2–29 $\mu g\ g^{-1}$ in the city. This type of arsenic concentration in dust fall-out like in street dust, is less compared to the medium arsenic concentration range of 32–113 $\mu g\ g^{-1}$ measured in residential roadside dust in Chihuahua, Monterry and Torren in North Mexico[13].

From the observed data it is seen that arsenic concentration is comparatively higher in dust particulates deposited on canopy leaves than street dust in the city. This presence of higher arsenic in dust deposited on leaves is quite significant. This may be due to prolonged particulate deposition on canopy leaves which remain almost undisturbed, while street dust is disturbed by different anthropogenic influences, including traffic movement. Particulates containing different elements, including arsenic are emitted into the atmosphere from various sources and remain suspended in the urban atmosphere. Sometimes they get dispersed to the surrounding areas due to meteorological factors, specially wind-flow. Subsequently they are deposited on the surface of canopy foliage and on street sediments. C.I.T. Road, showing maximum arsenic concentration, is a high-traffic zone and also surrounded by small industries. Shymbazar, Sealdaha and M.G. Road are also high-traffic zones showing higher amount of arsenic. Metal workshops and small-

Table 1. Concentration of arsenic in particulates deposited on canopy foliage and street dust in Kolkata city

		Concentration of arsenic ($\mu g\ g^{-1}$) (n = 3)	
Site no.	Sampling site	Particulates deposited on tree leaf canopy (> 2 m height)	Street dust
1	Chiriamore (B.T. Road)	23.89 ± 1.13	< 2
2	Shymbazar (Five-point crossing)	29.97 ± 1.08	< 2
3	Sealdaha (Near Railway Station)	28.58 ± 1.22	< 2
4	Moulali (A.P.C. Road)	22.60 ± 1.19	9.89 ± 0.75
5	Chingreghata (E.M. Bye pass Road)	22.08 ± 0.87	10.16 ± 0.96
6	C.I.T. Road (Kankurgachi)	39.63 ± 1.67	18.71 ± 1.14
7	M.G. Road (C.R. Avenue crossing)	29.99 ± 1.23	< 2
8	Maidan (Near Birla Planetarium)	17.82 ± 0.96	8.46 ± 1.06
9	Ultadanga (Near Railway Station)	25.82 ± 1.35	8.40 ± 0.82

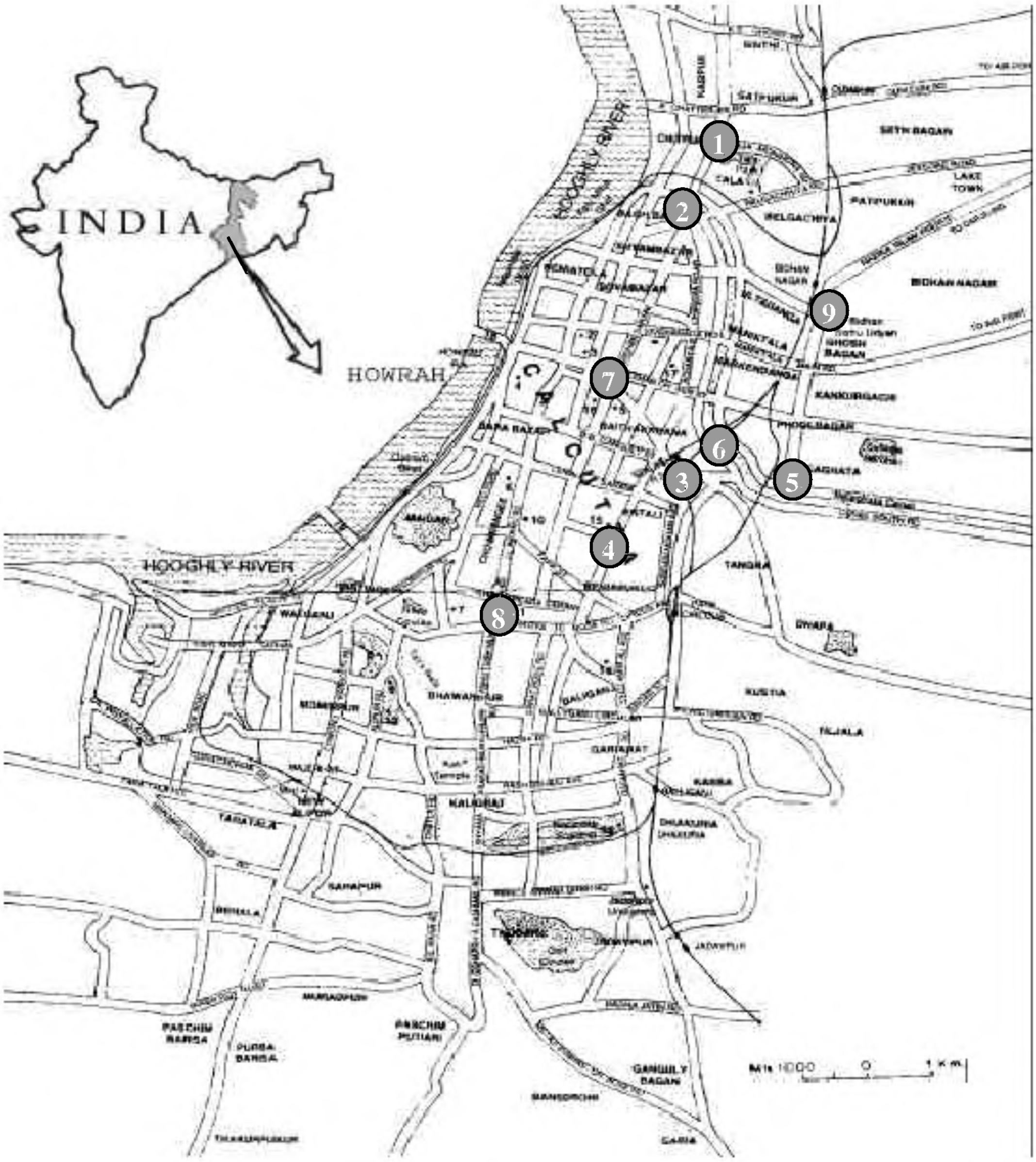

Figure 1. Kolkata metropolitan area – study site.

scale industries are present in those sites which emit particulates into the atmosphere. Commercial fossil-fuel combustion in roadside hotels, tea-stalls, etc. is also more or less responsible for atmospheric particulate emission in these areas. Sites like Maidan and Chingreghata show low concentration of arsenic, having more open space, plantations, and lakes. Only moderate vehicular traffic is prevalent in these sites, with no such commercial and industrial blocks.

Major cities in the world (especially large cities like Kolkata) have mixed classification of land use consisting of residential areas, commercial areas, industrial areas and transport areas. This is supported by Kelly *et al.*[14] who observed that land use had the highest effect on concentration of trace elements in two cities of England. Meteorological factors are also important in atmospheric particulate deposition. Good correlation reported by Deb *et al.*[1] indicates the meteorological factors attributed to arsenic contamination in urban areas. This study determines the distribution of arsenic in particulates deposited on canopy foliage and street dust in Kolkata city, which may play a critical role by affecting the population of the city. Diffuse anthropogenic influences and localized point sources are mainly considered as the major source of atmospheric particulates containing arsenic. Therefore, the data are useful for assessing arsenic contamination and determining the need for remediation. Also, detailed study is required for better understanding of the spatial and temporal distribution of atmospheric particulates containing arsenic with respect to source–factor relationship.

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Observations on guano and bolus of Indian flying fox, *Pteropus giganteus*

Bats are cosmopolitan in distribution, except in the Arctic and Antarctic[1]. The Indian subcontinent harbours a variety of chiropterans, including frugivorus bats[2]. Over 200 species of flying foxes are distributed throughout the tropics and being frugivorous they play a major role in pollination and seed dispersal[3]. The Indian flying fox, *Pteropus giganteus* Brunnich commonly roosts on large trees (e.g. *Ficus*; Figure 1 *a*). They earned the name 'flying fox', as the head and fur resemble a fox (Figure 1 *a*, *b*). Their roosting results in the accumulation of substantial amount of guano on the floor (Figure 1 *c*). They swallow soft fruits (Figure 1 *b*) or extract juice and spit out the remains known as bolus (Figure 1 *d*), containing the residual fruit pulp of fibrous fruits and seeds. Besides fruits, they are also known to feed on juice and pollen of various tree flowers. Although flying foxes are widespread species, they are facing threats mainly due to loss of roost trees, hunting and pesticide use[3,4]. A dramatic decline in their population has been seen due to hunting for food and medicine and are thus placed under least conserved and endangered species in South Asia[3]. Investigations pertaining to ecological values and ecosystem services of flying foxes are warranted in biodiversity conservation measures. This study draws attention to the nutrients and microbial composition of guano and bolus of *P. giganteus* roosting in one of the locations in southwest Karnataka, India.

A huge banyan tree (*Ficus benghalensis*) located at Moodbidri, Dakshina Kannada has been a roosting site for a large number of flying foxes (about 400–500) over the past six years (Figure 1 *a*). Guano and bolus of flying foxes were observed in plenty under the canopy. Some sections of the floor under the canopy were cleared and polythene sheets were spread to collect bat excrement during September 2003. Replicate samples of guano and bolus were randomly collected, weighed and allowed to dry in a hot-air oven (100°C, 24 h) to determine moisture content. Additional samples collected aseptically were air-dried and used for nutrient and microbiological analyses. The pH (1 : 10 w/v in distilled water), total nitrogen, phosphorus and potassium were determined based on methods outlined by Jackson[5]. Bacteria (nutrient agar), actinomycetes (Kenknight's agar) and fungi (Martin's Rose Bengal–

Table 1. Nutrients and microbial composition of guano and bolus of flying fox, *Pteropus giganteus* (range in parenthesis)

Parameter	Guano	Bolus
Total nitrogen (%)	2.6 ± 0.5 (2–3.3)	3.3 ± 0.82 (2–4)
Total phosphorus (%)	4.2 ± 0.8 (3.1–5.2)	4.3 ± 0.6 (3.5–5)
Potassium (%)	0.6 ± 0.04 (0.6–0.7)	0.7 ± 0.04 (0.6–0.7)
pH	7.3 ± 0.1 (7.1–7.4)	7.1 ± 0.3 (6.7–7.4)
Bacteria (cfu/g dry wt)	$29 \times 10^4 \pm 50$ ($25–32 \times 10^4$)	$48 \times 10^4 \pm 28$ ($46–50 \times 10^4$)
Actinomycetes (cfu/g dry wt)	$5.55 \times 10^4 \pm 7.8$ ($5–6 \times 10^4$)	$4.1 \times 10^4 \pm 7.8$ ($3.5–4.6 \times 10^4$)
Fungi (cfu/g dry wt)	$2.9 \times 10^4 \pm 3.5$ ($3.1–4.3 \times 10^4$)	$4.6 \times 10^4 \pm 3.5$ ($4.3–4.8 \times 10^4$)