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ORIGINAL PAPER

Diversity of epiphytic lichens and their role in sequestration of atmospheric metals

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Abstract Diversity and abundance of five species of epiphytic lichens were assessed in Kolkata, India. Significant correlation between abundance of lichen species and volume of vehicular traffic suggests atmospheric pollution load in urban region. *Parmelia caperata* (L.) Ach. and *Graphis scripta* (L.) Ach. exhibited higher abundance among the five species studied indicating their higher level of tolerance to air pollution. Significant correlations ($p < 0.05$) between levels of heavy traffic and both diversity and abundance of all lichen species were also observed. These findings indicate a potential threat to the survival of the lichen communities in Kolkata. Study further deals with quantifying the effectiveness of lichen species in accumulating metallic elements like Pb, Zn, and Cu. This was achieved by analyzing the most abundant lichen species (*Parmelia caperata*) collected from nine different sites in winter, summer, and monsoon seasons. Metal content in lichen thalli, as analyzed by AAS, shows their elevated levels with the order Pb > Zn > Cu. Relationship between metal content and volume of vehicular traffic suggests that co-associated, metallic elements are emitted as vehicle-derived pollutants as well as diffuse industrial emissions. Accumulation of these metals is higher in winter which is proportionate with the higher degree of metabolism due to higher humidity in this season. Study also demonstrates the dynamics of metal uptake by the lichen at different sites influenced with different degree of vehicular traffic. Overall results confirm suitability of lichen with their potential role in sequestration of atmospheric metal contamination.

Keywords Airborne metals · Bioaccumulation · *Permelia caperata* · Vehicular traffic

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Introduction

Lichen has been recognized as a sensitive biological indicator of environmental condition specifically to air pollution (Bennett and Wetmore 1999; Bargagli et al. 2002; Blasco et al. 2011). Lichens show their sensitivity to air pollution in different ways such as decline in diversity, absence of sensitive species along with morphological, anatomical and physiological changes (Garty 1993; Bajpai et al. 2010a). The decline of lichens around urban region due to air pollution was well studied throughout the world (Loppi et al. 2004; Godinho et al. 2009). Lichen accumulates different gaseous pollutants and particulates containing metals and has been used as bioindicator in pollution monitoring. In polluted environments like cities, however, the nonselective accumulation by lichens continues and leads to sequestrate various pollutants including heavy metals. The majority of lichen species therefore cannot survive in polluted urban atmosphere due to toxicological effects of those pollutants (especially gaseous elements like SO_2 and NOx) if accumulated in a greater amount. This leads to dramatic loss of the epiphytic lichen flora in cities around the world (Adamo et al. 2008; Bajpai et al. 2010a).

Brawn and Odgen (1976) established a relationship between lichens diversity and abundance with the traffic volume in Halifax city (Nova Scotia, Canada), as the automobile exhaust is considered to be the principal source of atmospheric pollution in urban environment. Since then extensive work has been undertaken during the past three decades to study the biomonitoring of airborne contaminants using lichens (Bennett and Wetmore 1999; Uijily and Kumaraguru 2004; Scheidegger and Werth 2009).

Absorption and accumulation of metals by lichens from the contaminated atmosphere were reported worldwide (Clair et al. 2002; Adamo et al. 2008; Bajpai et al. 2010b, 2011). Therefore, lichens have been used to monitor atmospheric depositions of a large number of metals and act as an air filter particularly in urban environment. Metal uptake ability of lichens and its significant correlation with atmospheric metal level has led to their wide-scale application as practical biomonitors of atmospheric contamination (Godinho et al. 2009). Several lichen species are capable of accumulating airborne metals like Cu, Zn, Pb, Ni, and Cd within the intercellular space of the thallus (Rizzio et al. 2001; Bajpai et al. 2011; Bajpai and Upreti 2012). Lichens accumulate metals in their thalli either on the outer surface of the walls of the fungal hyphae or within the walls themselves (Bajpai et al. 2010a). But some of the metals thus absorbed by the lichen thalli gain entry into the cells and ultimately take part in the metabolism. Finally, they may lead to the death due to toxicity of higher content of those metals accumulated (Dzubaj et al. 2008). Levels of atmospheric Cd, Cr, Cu, Hg, Ni, Pb, and Zn around Pistoia in Central Northern Italy were assessed using the widely distributed indigenous lichen *Parmelia caperata* (Loppi et al. 1997). Metal contents in lichen thalli have been shown to correlate with atmospheric metal levels, where decrease of metal concentrations in lichen species was found to be correlated with increase in distance from the source (Cristofolini et al. 2008). Therefore, lichen biomonitoring is an interesting tool for environmental assessment with plenty of applications in the evaluation of most notorious airborne contaminants, including metals.

In India, the perceptible decline in the vegetation cover, the loss of species-specific habitats over the years, the increase in industrial areas and growth of large urban areas are some of the leading factors resulting in the loss and change of diversity of lichens (Upreti 1996; Bajpai et al. 2010a). Another factor with a potential influence in the natural distribution of the lichen species are microclimatic change. Apart from the abiotic factors, structure of bark, bark-wounds and water-holding capacity of bark also influence the diversity of epiphytic lichens. There are several studies on status of lichen diversity in Kolkata city which have scares growth of lichen species (Das et al. 1986; Upreti et al. 2005). In earlier study, 25 lichen species were identified among different localities of the city with most of them found in peripheral area (Upreti et al. 2005) and *P. caperata* was reported as pollution-tolerent species found on the street trees (Das et al. 1986; Majumder et al. 2012). The present study is concerned, with the distribution and abundance of epiphytic lichens and their relation to varying levels of traffic. The objective was to establish whether traffic volume within the city affects the distribution, diversity and abundance of the lichen thalli, with special reference to metal bioaccumulation capacity. The study also focuses on the dynamics of the metal accumulation, thereby aiming to increase the possibilities of sequestration of metallic elements deposited in atmosphere. This study was conducted in Kolkata city (West Bengal, India) in the period of April 2005 to January 2006.

Materials and methods

Study area

Kolkata city is located (22° 25′ N to 22° 40′ N and 88° 20′ E to 88° 35′ E) on the deltaic plateau of lower Gangetic basin, West Bengal, India (Fig. 1). The surrounding area is a flat swampy region with a subtropical climate. Average temperature and humidity of this region is 27 °C and 67 %, respectively, with moderate rainfall of maximum 320 mm during monsoon (Fig. 2). Kolkata is one of the largest metropolis and fastest growing cities in India. Increased urbanization, industrialization and heavy vehicular traffic have resulted in deterioration of air quality in the city. The major contributor of atmospheric contaminants particularly trace elements is mainly vehicular and diffuse industrial emission (Kar et al. 2010). In earlier study on atmospheric particulate pollution, it is reported that the amounts of particulate levels are much higher in Kolkata city (Mean SPM 362 μg/m^3) compared to unpolluted villages (Suburban of Kalyani township, Mean SPM 176 μg/m^3) (Kar et al. 2010). Study also showed the metallic elements (Zn, Cu, Ni, Pb, Co, Fe, and Mn) are significantly higher in aerosols of Kolkata city as well compared to unpolluted villages (Karar et al. 2006; Kar et al. 2010). These previous findings insisted to concentrate on polluted site to assess the biofiltration ability of those airborne metals by lichens.

Sample collection

Nine sampling sites (marked in Fig. 1) were selected on the major arterial roads of Kolkata city for the study of lichen diversity and abundance. At each sampling site ten trees (of 60–120 cm diameter) were selected based on availability of lichens on these tree barks. These trees are *Mangifera*

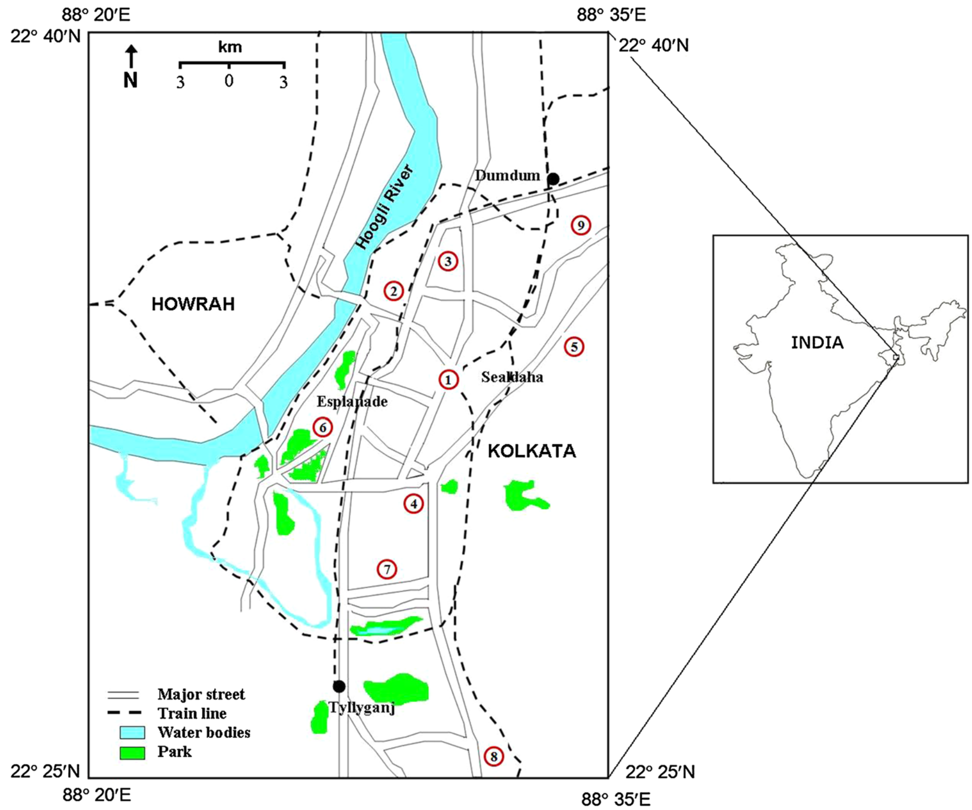

Fig. 1 Study area of Kolkata Metropolis, situated in the fringes of river Ganges. Nine sampling sites, marked in *circle*, were selected along east–west and north–south traverse area of the city and on the major arterial roads with plantation cover

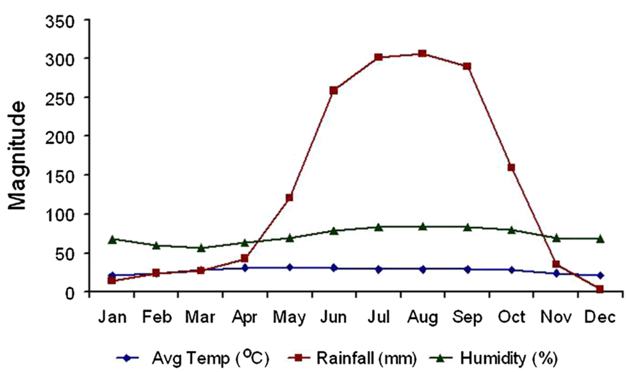

Fig. 2 Variation of temperature, humidity, and rainfall throughout the year 2005 in study area. Magnitude of each parameter represents their average value (source: Alipore Meteorological Department)

indica, *Alstonia scholaris*, *Albizia lebbeck*, *Polyalthia longifolia*, *Putranjiva roxburghii*, and *Anthocephalus chinensis*. Abundance of lichens was determined using the combined cover-abundance scale of Braun-Blanquet (Phillips 1959) (Table 1). The number and abundance of each lichen species growing on the tree trunk at 0.5–2 m from the ground were estimated. Thalli of different lichen species were collected randomly from five to ten trees in each sampling site within 100 m in the year 2005–2006. In each sampling site, three specimen of each lichen species were collected for identification. Thalli of each species were carefully separated from tree bark and cleaned with thin brush to remove dust, fungi and other extraneous materials without washing (Conti et al. 2004). Five lichen species were identified through morphological and anatomical study with the help of a microscope using identification keys (Awasthi 1988, 1991). Only foliose lichen *P. caperata* was chosen for metal content analysis as it has large surface area for possible higher metal accumulation and thallus can be easily detached from tree bark. It was also the most abundant species found in the study area. Total of 36 samples of *P. caperata*, four samples from each site with a mass ranging between 5 and 10 g were collected separately in three seasons i.e., summer (April–May), monsoon (July–August) and winter (December–January). Sample collections were performed using Teflon-coated scalpels to avoid any metal contamination and after sampling lichen thalli were kept in polypropylene packets for further treatment in the laboratory.

Metal analysis

After cleaning, thalli of *P. caperata* were separated from their substratum and mixed together for homogeneity. Next they were dried in an oven (at 60 °C) for 24 h. The dried samples were then powdered using a ceramic pestle and mortar. 0.5 g of dried powder samples were placed in a Teflon bomb and mixed with 2 mL of concentrated HNO_3 (E. Merck, India) and 1 ml of $HClO_3$ (60 % V/V, E. Merk,

Table 1 Abundance of five lichen species in different study sites of Kolkata metropolis along with traffic volume

Study sites	Traffic volume (vehicles/h)	Number of heavy traffic (bus/h)	Lichen species				
			Parmelia caperata	*Graphis scripta*	*Bacidea convexula*	*Pyrenula nitida*	*Trypthelium tropicum*
A.J.C. Bose Road (1)	5,280	1,220	+	–	–	–	–
Mallic Bazar (2)	3,680	840	1	–	–	–	–
Girish Park (3)	2,520	660	2	1	–	–	–
Park Circus (4)	2,440	540	1	–	–	–	–
Eastern Bye Pass (5)	2,060	240	2	1	+	–	–
Maidan (6)	2,000	270	2	2	1	–	+
Southern Avenue (7)	1,840	340	3	1	1	+	–
Narendrapur (8)	1,720	220	3	3	1	1	+
Baguihati (9)	1,260	320	2	2	1	+	–

Combined cover/abundance scale: (Phillips 1959)

+ sparsely or very sparsely present, cover very small, *1* plentiful but of small cover value, *2* very numerous or covering at least 0.05 % of area, *3* any number of individuals covering 0.25 to 0.5 % of area, *4* any number of individuals covering 0.5 to 0.75 % of area, *5* covering more than 0.75 % of area

India). The solution was then allowed to stand for few minutes at room temperature and agitated to avoid bubbling and finally kept overnight. The next day the bomb was placed in a hot air oven (at 120 °C) for 8 h. After cooling, the solution was collected from the Teflon bomb with repeated washing using deionized water. The sample volume was reduced to about 0.5–1 mL using a hot plate at a temperature 60–80 °C. After cooling the volume of the solution was made up to 2 mL with deionized water and filtered through a Millipore membrane (0.45 µm pore size) to prepare it for total metal analysis.

Three heavy metals (Pb, Cu, and Zn) were chosen for metal analysis of lichen thalli due to their dominance in atmospheric aerosols (Karar et al. 2006). Analysis of these metals was undertaken by a spectrophotometric technique using Atomic Absorption Spectrometer (AA400, Perkin-Elmer, NL). For quality control and quality assurance, standard reference materials (NIST, SRM 1570a) were analyzed and the experimental values show good agreement (accuracy: ±6 % and precision: ±5 %) with the certified values. Spearman correlation test has been performed to assess the relationship between different variables like traffic volume, levels of traffic and lichen diversity. We also examined the lichen diversity, traffic volumes and association with metal accumulation using one-way ANOVA to test hypothesis about differences between multiple mean values. F value and CV were calculated to assess the variability of accumulation of metals in lichen species among different sampling sites. The level of significance was considered at $p < 0.05$.

Results and discussion

Abundance and diversity of epiphytic lichens

The present study revealed that five species of epiphytic lichens were found in Kolkata city at nine different sampling sites. These species were *Parmelia caperata* (L.) Ach. and *Graphis scripta* (L.) Ach., *Bacidia convexula* (Müll. Arg.) Zahlbr., *Pyrenula nitida* (Weigel) Ach. and *Trypthelium tropicum* (Ach.) Müll. Arg. Diversity of lichens, their abundance with respect to levels of vehicular traffic was presented in Table 1. *P. caperata* was the most abundant species found at all the sampling sites in Kolkata city while another species *G. scripta* was found at 66 % of the sites (Fig. 3). *P. caperata* can be considered as the most resistant epiphytic lichen (Majumdar et al. 2009; Majumder et al. 2012) whereas *G. scripta* as low resistant. Among the five lichen species found, crustose type lichens were diversive with four species and *P. caperata* was found only as foliose type. The observed lichen diversity was significantly correlated ($R = 0.65$, $p < 0.05$) with traffic volume and traffic status (Fig. 4). High traffic zone consisting 2,000 or more vehicular traffic showed less diversity and abundance of lichens while low traffic zone (<2,000)

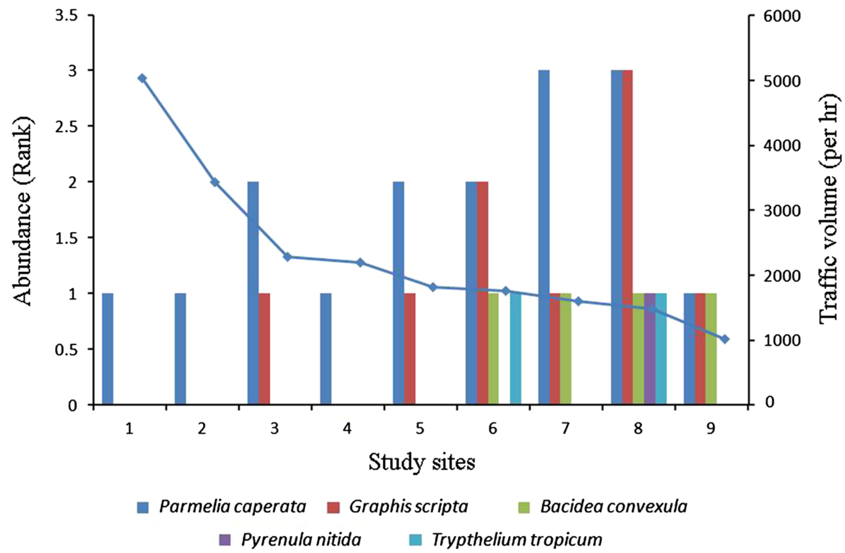

Fig. 3 Diversity and abundance of five epiphytic lichens observed in nine sampling sites of study area. Abundance of each lichen species is represented (*Bar diagram*) by their rank of coverage as described in Table 1. *Line diagram* shows the variation of total traffic volume (per hour) among the nine sampling sites. Sampling sites are ranked based on total traffic volume (per hour)

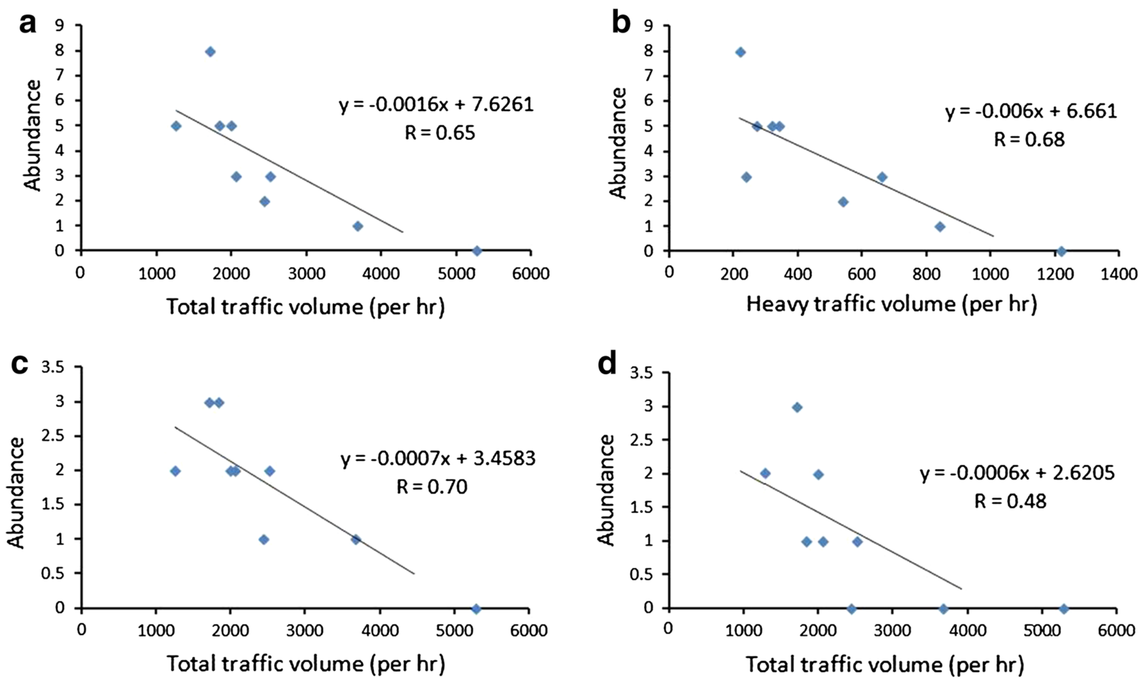

Fig. 4 Relationship between **a** combined abundance of five lichen species and total traffic volume (per hour), **b** combined abundance of five lichen species and total heavy traffic (bus/hour), **c** abundance of *P. caperata* and total traffic volume (per hour), **d** abundance of *G. scripta* and total traffic volume (per hour). Abundance of lichen species is represented by their rank of coverage as described in Table 1

showed higher diversity and abundance (Brawn and Odgen 1976). The coverage of tree trunks by lichens in E M bye pass was much larger than other sites in the city, indicating better air quality along the eastern part of the city. Number of heavy traffic (bus) also found to be responsible for lichen diversity and abundance as revealed in the study (Fig. 4). This was mainly due to atmospheric pollution generated by anthropogenic emissions from automobiles and diffuse industrial activities (Majumdar et al. 2009). Therefore, atmospheric contamination specifically vehicular emission was found to be greatly responsible for this type of lichen diversity and abundance in the study area.

Table 2 Spearman rank correlation coefficient and test of null hypothesis of number of association ($n = 9$)

Correlation tested	*R*	Conclusion at 0.05 level of significance
Total traffic volume vs diversity (all species)	0.65	Signification correlation
Level of heavy traffic vs diversity (all species)	0.686	Signification correlation
Total traffic volume vs abundance of *Parmelia caperata*	0.707	Signification correlation
Total traffic volume vs abundance *Graphis scripta*	0.484	Less signification correlation

Table 3 Trace metal content (Pb, Zn, and Cu) of *Parmelia caperata* in different study sites according to general traffic rank and results of ANOVA

General traffic rank	Seasons	Metal content (μg/g) ($n = 4$)		
		Pb	Zn	Cu
1	Winter	314 ± 14.5	50.4 ± 3.22	25.7 ± 0.74
	Summer	280 ± 12.4	40.2 ± 1.67	15.4 ± 0.36
	Monsoon	267 ± 10.6	19.4 ± 1.84	5.92 ± 0.43
2	Winter	300 ± 15.3	54.6 ± 3.85	29.3 ± 0.47
	Summer	275 ± 15.9	39.7 ± 1.78	18.2 ± 0.58
	Monsoon	280 ± 11.7	30.4 ± 2.83	16.5 ± 0.35
3	Winter	249 ± 13.2	34.6 ± 1.85	39.4 ± 1.38
	Summer	232 ± 11.8	24.6 ± 1.16	21.8 ± 1.17
	Monsoon	220 ± 13.8	14.2 ± 0.82	6.63 ± 0.48
4	Winter	77.6 ± 5.61	34.8 ± 2.75	18.2 ± 0.76
	Summer	69.3 ± 4.75	40.2 ± 2.57	15.6 ± 0.78
	Monsoon	55.8 ± 2.93	30.7 ± 1.24	8.75 ± 0.63
5	Winter	170 ± 6.36	29.8 ± 1.89	11.3 ± 0.56
	Summer	165 ± 9.73	28.5 ± 0.95	13.4 ± 0.77
	Monsoon	150 ± 3.74	30.6 ± 1.46	6.28 ± 0.22
6	Winter	75.6 ± 4.83	32.6 ± 1.93	30.8 ± 1.18
	Summer	70.2 ± 2.88	53.7 ± 1.43	12.6 ± 0.85
	Monsoon	52.7 ± 6.75	20.4 ± 0.97	18.1 ± 2 7
7	Winter	120 ± 3.72	34.7 ± 0.81	22.6 ± 0.72
	Summer	104 ± 6.97	23.4 ± 0.75	5.46 ± 0.25
	Monsoon	110 ± 6.74	19.1 ± 1.36	15.9 ± 0.61
8	Winter	70.5 ± 6.19	19.7 ± 1.26	19.2 ± 0.57
	Summer	66.7 ± 4.26	10.9 ± 0.78	15.7 ± 0.56
	Monsoon	20.2 ± 1.87	5.42 ± 0.24	9.08 ± 0.43
9	Winter	70.8 ± 5.26	30.7 ± 1.45	11.8 ± 0.87
	Summer	65.5 ± 3.59	26.4 ± 1.38	7.04 ± 0.45
	Monsoon	60.9 ± 3.34	20.8 ± 1.13	6.28 ± 0.28
	F value	14.5	9.12	21.7
	p value	0.002	0.008	0.03
	CV	0.14	0.17	0.11

Impact of urban traffic on diversity of epiphytic lichens

In the present study, highest traffic volume was ranked 1 showing lowest score of abundance, while lower traffic volume was related to higher species diversity and abundance. The Spearman rank correlation coefficient of association between two variables in ordered series is calculated (Table 2). The test of correlation coefficient indicates an association between traffic volume and diversity of lichens especially with *P. caperata* ($R = 0.70$, $p < 0.05$) and *G. scripta* ($R = 0.48$, $p < 0.05$). However, there is also a significant correlation ($R = 0.68$, $p < 0.05$)

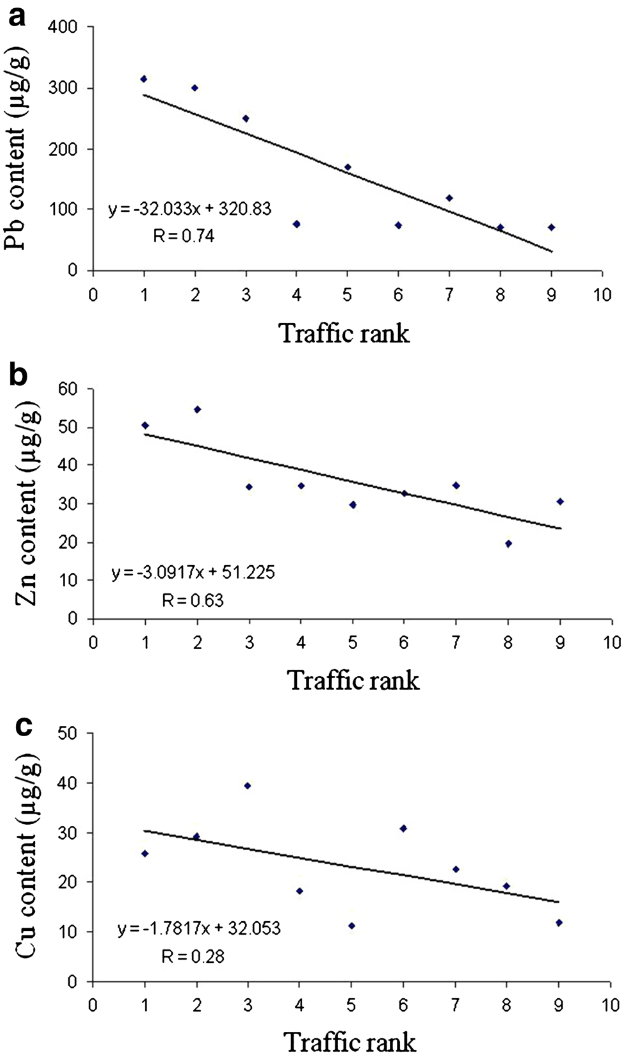

Fig. 5 Relationship between metal contents (winter accumulation) in *P. caperata* and general traffic rank **a** Pb, **b** Zn, and **c** Cu

between levels of heavy vehicle (bus) and lichen diversity. Therefore within the city, the number of vehicles daily passing by a sampling station has an apparent effect on lichen diversity and abundance. In another way, the more buses that pass by a station, the fewer the numbers of species and of individuals.

It is well known that the environmental factors other than air pollution also affect the distribution of lichens (Hauck 2011). Importance of climatic setting is also a key driver of the diversity and abundance of epiphytic lichen community (Ellis and Coppins 2010). Though climatic gradient of entire study area is considered same (Fig. 2), still it has significant influence on the lichen composition and extent of accumulation of airborne contaminants. Thus, at a regional scale climatic setting and pollution regime are both act as a key factor for lichen abundance. However, in the present study, the position of the trees in relation to road/street, the position of the lichens on the tree, and the age of the trees were kept relevantly constant. Thus, observed relationship between traffic volume and species diversity under these circumstances suggests that traffic volume in general has a great effect on lichen distribution in the city.

Metal content in lichen and its implication on atmospheric contamination

Content of metals (Pb, Zn, and Cu) in *P. caperata* in three different seasons and their ANOVA results were presented in Table 3. Among the three metals, accumulation of Pb in lichen thallus was higher compared to Zn and Cu with the ranking of Pb > Zn > Cu. Identically, metal accumulation was found maximum in winter, and minimum in monsoon season. Data shows maximum metal accumulation occurred at A.J.C. Bose Road with high traffic load. Similarly, accumulation of metals in Baguihati road shows minimum with low traffic load. Positive correlation between metal content of lichen thalli and traffic rank was observed in case of Pb ($R = 0.74$, $p < 0.05$) and Zn ($R = 0.63$, $p < 0.05$) (Fig. 5). However, Cu content in lichen does not show any such relationship with traffic ranking. Coefficient of variation is higher in case of Zn (0.17) compared to Pb (0.14) and Cu (0.11). Lower CV of Cu and Pb suggests greater dispersion of metal-associated particles and their subsequent trapping by lichens (Garty 2001).

Present study highlights the metal uptake by *P. caperata* and capture efficiencies of them in urban Kolkata. The metal capture by lichens occurs mostly in winter period as evidenced from the Table 3. Higher uptake of Pb by *P. caperata* reflects its greater presence in atmospheric particulates relative to Zn and Cu (Cloquet et al. 2006; Paoli et al. 2011). Though Pb content is substantially reduced in aerosols in recent days due to ban of leaded fuel for several years (Kar et al. 2010), still its presence indicates its availability in urban aerosols from anthropogenic sources. Considerably high amount of Pb was possibly due to vehicular emission and other industrial activities in and around the city (Russellflegal et al. 2010; Kar et al. 2010, 2013). Pb was found to be efficiently accumulated by lichens from aerosols and metal fall out as reported earlier (Cloquet et al. 2006; Bajpai et al. 2010b). However, relatively heavy traffic conditions by automobiles could have been the primary cause for the Pb accumulation. Cu content in lichen was seems to be within the background level though its variation among different sites suggests diesel engines and unleaded gasoline as possible sources (Majumder et al. 2012). The level of Zn is considered to be higher in such high traffic urban region with possible sources of abrasion of motor vehicle tyres (Garty 2001). However, the usage of these metals in electroplating,

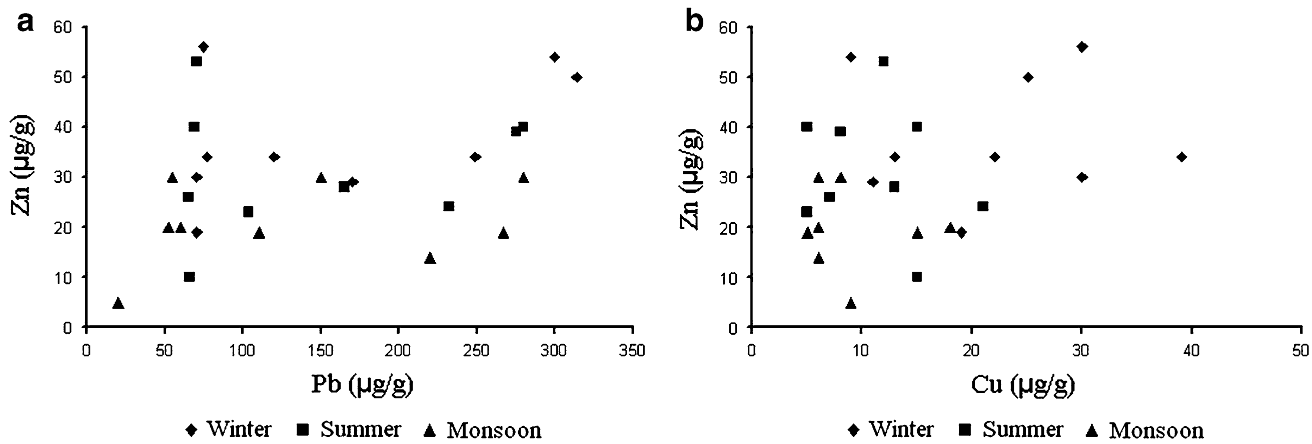

Fig. 6 Relationship between **a** Pb and Zn, **b** Zn and Cu content in *P. caperata* in three seasons (winter, summer and monsoon)

pesticides, fossil fuel combustion in restaurants and residences could have the other source for their availability in atmosphere (Kar et al. 2010, 2013). Irrespective of abundance of these metallic elements in this urban environment, no such significant relationship was observed between Pb, Cu, and Zn indicating their emission from diffused anthropogenic sources (Fig. 6).

Lichen like *P. caperata* with rough surfaces and special morphological character is considered to be more efficient in intercepting particulate matter as well as metallic elements (Garty 2001; Koz et al. 2010). The ability of capturing particulates as well as metals by other group of lichens has been reported elsewhere (Simonetti et al. 2003; Bajpai et al. 2010a). The assessment of metal uptake by lichens across an urban region provides an opportunity to consider the source factors which determine capture efficiency and particulate accumulation. This was evident from the fact that *P. caperata* collected from different sites showed varied quantities of metal accumulation with significant differences ($p < 0.05$) between all sites. The urban environment of Kolkata city is therefore exposed to atmospheric particulate pollution containing heavy metals due to different anthropogenic activities. Therefore, greater accumulation of metals in the lichens was indicative of the possibly greater level of atmospheric pollution load in Kolkata. The specific ability of absorbing and accumulating this type of pollutants from the air, their longevity and resistance to the environmental stresses, make lichens suitable for studies on air quality assessment of airborne contaminants and their sequestration.

Bioaccumulation of metals and their sequestration by lichen community

It is interesting that *P. caperata* selected as most abundant lichen species in study area contains elevated levels of metallic elements in their thallus. Therefore, this lichen species can be regarded as sensitive to metal contamination and has been recommended as a particularly suitable bioindicator of heavy metal burden (Backor and Vaczi 2002; Baptista et al. 2008). Lichens may govern the extent of uptake of metals and the stronger metal accumulators possessed most abundant lichens which gave rise to the effective trapping and filtering the contaminants from atmosphere (Minganti et al. 2003). Considering the metal content of *P. caperata*, the findings indicate a potential influence of bioaccumulative capabilities of this particular species in Kolkata city (Majumder et al. 2012). Moreover, the degree of metal uptake by lichens is affected by combined interactive factors which include anthropogenic origin; efficiency of particulate adsorption, a real coverage of lichens; intensity of precipitation; and degree of traffic disturbance (Garty 2001). Analysis of indigenous lichen species like *P. caperata* in Kolkata city demonstrated spatial and temporal changes in airborne heavy metal levels and their distribution in the study area. Being the most abundant lichen species, *P. caperata* likely favors the polluted atmosphere of Kolkata city.

Atmospheric contamination is an important mechanism which controls the fate of toxic airborne pollutants especially metallic elements and their transfer from the atmosphere to the natural organisms like lichens (Paoli et al. 2011; Kar et al. 2013). Among the contamination processes, emission from source is significant which comprises transport of pollutants either from diffuse or point source and getting dispersed to the surrounding area and finally uptake by natural surface like tree canopy (Kumar et al. 1991; Kar et al. 2006, 2013). This study indicates that the surface of living organism provide a filtration and reaction surface to the atmosphere and also important function to transfer pollutants from the atmosphere to the biosphere. The specific ability of uptake of this metals from the air, their stability and resistance to the environmental stresses, make this lichen species suitable for biomonitoring studies (Hauck 2011). Therefore, biomonitoring of trace metals is an interesting tool for environmental assessment with plenty of applications in the evaluation of most notorious air borne contaminants, including toxic metals. It is clear that available species and location relative to pollution source are critical in determining the effectiveness of metal capture by lichens (Paoli et al. 2011). This study has shown that in the urban environment, lichen is a suitable passive bioaccumulator, useful to assess levels and distribution patterns of inorganic particulates. Finally, the data have implications for the control of sources where protection of people from exposure to metallic particulates might be achieved.

Conclusion

Investigation on diversity and abundance of epiphytic lichens in Kolkata city showed reducing trend due to influence of increased vehicular traffic. Significant correlation was observed between general traffic volume and diversity of five lichen species. The use of epiphytic lichen (*P. caperata*) as bioindicator of the degree of atmospheric pollution with respect to metallic elements is highlighted in the present study. Lichen thalli exhibit significant enhancement of metallic elements with Zn, Pb, and Cu, reflecting surface uptake from atmosphere. The winter accumulation of these metals is higher due to higher abundance of atmospheric particulates. Metal-rich particulate sources are basically anthropogenic input from diffuse vehicular and industrial emission. Their magnitude was seemed to depend strongly as a function of the atmospheric availability of these metallic elements especially Pb. Present study therefore provides the extent of the atmospheric particulate load and possible threat to diversity and abundance of epiphytic lichens in urban Kolkata.

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