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ORIGINAL PAPER

Impact assessment of anthropogenic activities on air quality, using lichen *Remototrachyna awasthii* as biomonitor

R. Bajpai · V. Shukla · D. K. Upreti

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Abstract The study was carried out with an aim to assess the heavy metal (HM) and polycyclic aromatic hydrocarbons (PAHs) in the air of a biodiversity as well as tourist-rich area of Western Ghats by applying a most frequent growing lichen *Remototrachyna awasthii* (Hale and Patw.) Divakar and A. Crespo, as biomonitor. Thalli of *R. awasthii* were collected from eight sites of Mahabaleshwar area located in Western Ghats. Samples were prepared for HM and PAHs quantification by ICP-MS and HPLC, respectively. Total metal concentration (HM) ranged from 644 to 2,277.5 $\mu g\ g^{-1}$ while PAHs concentration between 0.193 and 54.78 $\mu g\ g^{-1}$. HM and PAHs concentrations were the highest at Bus Stand while control site (Lingmala Fall) exhibited the lowest concentration of HM as well as PAHs followed by samples from Wilson point (both these sites are having trekking route). It was also evident from this study that vehicular emission played a significant role in the release of HM and PAHs as pollutants in the environment. The effectiveness of *R. awasthii* as biomonitor could be further investigated by comparing this species with other biomonitors.

Keywords Biomonitoring · Heavy metals · Polycyclic aromatic hydrocarbons · Health risk assessment · Western Ghats

R. Bajpai (✉) · V. Shukla · D. K. Upreti
Lichenology Laboratory, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow 226001, India
e-mail: bajpaienviro@gmail.com

V. Shukla
Department of Environmental Sciences, Babasaheb Bhimrao Ambedkar (Central) University, Raebareli Road, Lucknow 226025, India

Introduction

Tourism is one of the fastest growing economic sectors in the world, similarly, in developing countries like India, tourism has become one of the major sectors of the economy, contributing to a large proportion of the National Income (up to 6.23 % to the national GDP) and generating huge employment opportunities (8.78 % of the total employment). However, on the other hand, it also possesses some adverse effects on the surrounding environment. One of the most important adverse effects of tourism on the environment is increased pressure on the carrying capacity of the ecosystem in each tourist locality. Increased transport and construction activities leads to large-scale deforestation and destabilization of natural landforms. Flow of tourists to ecologically sensitive areas results in destruction of rare and endangered species due to trampling and disturbing of natural habitats, which directly affects bio-diversity, ambient environment and air-quality profile of the tourist spot (Lalnunmawia 2010).

Attractive landscape sites, lakes, riversides, and mountain tops and slopes, are often transitional zones, characterized by species-rich ecosystems. Western Ghats as a mega biodiversity region, with varied flora, fauna, tropical and deciduous rainforest, grasslands, scrub and montane forests is consisted with one of the richest collections of flora and fauna and is among the world's eighteen biodiversity hotspots (Lalnunmawia 2010).

Lichens are being utilized worldwide for monitoring changes in the air quality due to anthropogenic activity (mainly vehicular and industrial). Various researches have established the role of lichens as biomonitor of inorganic and organic pollutants (Conti and Cecchetti 2001; Garćia et al. 2009; Ratola et al. 2010).

Vehicular activity resulting due to tourism adds on to the normal levels of emission due to daily anthropogenic activities (Shukla et al. 2012b). Vehicular activities not only emit significant quantity of metallic pollutant but also are major source of health hazardous compounds, PAHs. An attempt has been made to characterize, simultaneously, inorganic as well as organic pollutants in a biodiversity-rich area which is heavily influenced by tourist activity and, thus, assess the impact of tourist activity on ecosystem.

In India, lichens are being effectively utilized in biomonitoring pollutants (inorganic and organic) in different urban and industrial centres of the country (Bajpai et al. 2009, 2010; Satya et al. 2011; Shukla et al. 2010, 2012a; Shukla and Upreti 2009), however, the present study is the first attempt to assess air quality of tourist centre located in Western Ghats, the zone that is declared as ecologically sensitive by Ministry of Environment and Forests, Government of India, New Delhi in the year 2009, with a commonly growing foliose lichen *Remototrachyna awasthii* as biomonitor.

Remototrachyna, broad lobed Asian *Hypotrachyna* clade, is a recent segregate and new genus described by Divakar et al. (2010), which differs from *Hypotrachyna* clade in lobe morphology, rhizinae length, hymenium height, exciple structure and ascospore size. Broad lobed *Remototrachyna* has wide distribution in South and Southeast Asia and found to be frequently growing on twigs and trunks of *Memecylon* sp. and shrubs in the study area.

Materials and methods

Study areas

Mahabaleshwar is a tourist city with a population of 12,780 (2001 India census) situated in Satara district of Maharashtra. It is one of the highest hill stations in the Western Ghats, and is located at 17.55N 73.40E–17.92N 73.67E, at an average altitude of 1,390 m. Mahabaleshwar is a vast plateau of 150 km^2, bounded by valleys on all sides with the highest peak of 1,438 m at Wilson point.

Mahabaleshwar is a popular holiday resort and an important pilgrimage site for Hindus. With another popular and scenic hill resort, Panchgani in close vicinity (about 20 km), most tourists often visit both places together. In recent times, Panchgani has been facing ecological problems because of poorly controlled commercial activities, excessive traffic, and temperature inversion (because of humidity) from the new dams which have been built in the vicinity for water storage.

Urban and peri-urban areas of Mahabaleshwar were surveyed for collection of lichen in May 2010. Lichen specimens were collected from trees which were fulfilling the standard criteria of (a) trunk more than 35 cm in diameter, (b) trunk inclination less than 75° (15° deviation from vertical), (c) apparently healthy and (d) height, 1.5–2 m above the ground following Pinho et al. (2004). Lichen samples were collected from eight sampling sites of Mahabaleshwar (Table 1). *Remototrachyna awasthii* is a wide-spread species in the study area and found to be

Table 1 Description of the sites selected for the collection of lichen specimen in the Mahabaleshwar, India

S. no.	Localities	Longitude latitude	Altitude (m)	Remark	No of vehicles/hour	
					2 wheelers	4/6 wheelers
1	Bus stand	17°55′34.41″N° 73°39′31.59″E°	1,378	Road crossing, maximum anthropogenic pressure	**95**	46
2	Venna Lake	17°55′54.00″N° 73°40′03.85″E°	1,318	Road side, polluted	40	35
3	Lingmala fall (control site)	17°55′16.79″N° 73°41′37.73″E°	1,124	Away from road side, non polluted	0	02
4	Devi Path	17°55′16.20″N° 73°40′10.89″E°	1,417	Road side, moderate traffic load	35	19
5	Wilson point	17°55′20.31″N° 73°40′16.98″E°	1,436	Road side, mild vehicular activity	02	0
6	Panchgani	17°51′35.75″N° 73°47′22.69″E°	1,247	High anthropogenic activity	89	**53**
7	Old Mahabaleshwar	17°57′51.53″N° 73°40′12.34″E°	1,131	Road side area, moderately polluted	10	18
8	Pratapgarh Fort	17°56′05.59″N° 73°34′40.45″E°	1,033	Fully exposed rocky area having moderate vehicular activity	0	12

Highest values are indicated in bold

frequently growing on twigs and trunks of *Memecylon* tree sp. and shrubs.

Thalli of lichen *R. awasthii* with consistent diameter (3 cm) were sorted out in triplicate from the 50 samples collected from each site for further analysis. Reason for the collection of 50 samples lies on the fact that the thalli of consistent size was to be segregated from the bulk, as well as, apart from HM and PAH analyses, other analyses were to be carried out, and above all, voucher sample were to be deposited in lichen herbarium (LWG). In the laboratory, composite samples from each site were removed from the bark with sharp knife and sorted to remove extraneous material.

Heavy-metal analysis

The dried lichen samples (3 replicates) were ground to powder (weight $\approx$1.0 g each) and digested in mixture of concentrated HNO_3 and $HClO_4$ (v/v 9:1) for 1 h. Residues were filtered through Whatman Filter paper No. 42 and diluted up to 25 ml with double-distilled water. Analysis was done with ICP–MS (Perkin Elmer SCIEX ELAN DRCe). Stock standards were used from Merck, India.

Polycyclic aromatic hydrocarbons

Lichen samples (2 g each in triplicate) from each site were weighed and thimble (Whatman No. 42) was prepared for extraction of PAHs in Soxhlet apparatus with 100 ml of Dichloromethane (Merck, AR) for 16 h according to the procedure of Environmental Protection Agency (EPA), EPA 8310 (US EPA 1986). The extract was passed through anhydrous sodium sulfate (Qualigen, AR) to remove moisture and concentrated up to 2 ml under vacuum in Buchi rotary evaporator. The extract was cleaned by silica gel (100/200 mesh size, Qualigen) column according to the EPA method 3630 (US EPA 1986). Final extract was solvent exchanged to acetonitrile (Merck, AR) and final volume was made to 2 ml in umber-coloured volumetric flask. Sample was stored in dark at 4 °C till the analysis was performed. End analysis was performed using high-performance liquid chromatography.

High-performance liquid chromatography (HPLC) consisting of 515 pump (Waters Milford, MA, USA) and uv–visible detector (2,487, Waters). The chromatogram was observed at 254 nm. Empower™ software was used for processing. Reverse Phase C-18 (Symmetry column, Waters make) (250 nm × 4.6 mm i.d. and 5-μm particle size) with acetonitrile and Milli-Q water in ratio of 70:30 as a solvent at flow rate of 1.5 ml min^{-1} in isocratic mode at 27 °C temperature was used. Recovery percentage of PAHs ranged from 81 to 92 for spiked sample. Reference solvent was also prepared in triplicate. PAHs were identified by their retention time, and were quantified by their respective peak areas. Standards of PAHs were procured from Sulpelco, USA. Limit of detection for individual PAHs ranged between 10 and 30 ng l^{-1}. The 16 (United States-Environmental Protection Agency, US-EPA priority) PAHs, analyzed.

Statistical analysis

The data obtained were subjected to one way analysis of variance (ANOVA) to evaluate the probable correlation pattern between the metal content from different sites using statistical program, INDOSTAT (Hyderabad, India) and MS EXCEL.

Results and discussion

To assess the impact of vehicular activity resulting due to tourism on the surrounding environment, metal and polycyclic aromatic hydrocarbons were estimated in lichen samples collected from eight sites of Mahabaleshwar and near by areas. Perusal of Table 2 shows variation in the metal concentration (Al, As, Cd, Cr, Fe, Pb, Mn, and Zn). Total metal concentration ranged from 644 to 2,277.5 μg g^{-1}. The variation in the total metal concentration is higher at sites with high anthropogenic activity being the highest at Bus Stand (2,246 μg g^{-1}) and Panchgani (2,278 μg g^{-1}) while Lingmala fall, a remotely located site has minimum concentration of metals (644 μg g^{-1}). The result shows a direct correlation between metal concentration in the ambient environment and vehicular activity.

Table 3 shows variation in the PAHs profile at different sites. PAHs concentration was the maximum at Bus stand (54 μg g^{-1}) while Lingmala Fall has minimum concentration of all PAHs (0.19 μg g^{-1}). Besides the vehicular emissions, no other prominent sources of air pollutants were found nearby the sites.

Biomonitoring of heavy metals

Metal profile at eight sites clearly shows that the variation in the metal concentration is related with vehicular activity which has been supported by earlier work. According to Pirintsos et al. (2006), enhanced levels of Cu, Zn, Fe, Cd and Ni indicated motor vehicles as the originators.

Table 1 clearly indicates that three sites, Bus stand, Venna lake and Panchgani which are exposed to heavy traffic activity, are having higher concentration of most of

Table 2 Mean and standard deviation of heavy-metal concentration in *Remototrachyna awasthii* in Mahabaleshwar

	Bus Stand	Venna lake	Lingmala fall (C.S)	Devi Path	Wilson point	Panchgani	Old Mahabaleshwar	Pratap garh
Al	125 ± 12.5[b]	1,109.8 ± 2.4[a]	304.6 ± 3.73	966.9 ± 2.97[a]	318.4 ± 2.58	**1,295 ± 5.3[a]**	1,021.9 ± 3.32[a]	992.3 ± 5.20[a]
As	2.7 ± 0.14[a]	**3.96 ± 0.04[a]**	0.183 ± 0.09	1.39 ± 0.07[a]	0.23 ± 0.05	2.79 ± 0.08[a]	1.8 ± 0.04	1.04 ± 0.05
Cd	1.48 ± 0.07[a]	**1.83 ± 0.11[a]**	0.113 ± 0.09	0.316 ± 0.03	0.123 ± 0.11	1.08 ± 0.05[a]	0.923 ± 0.07	1.1 ± 0.035[a]
Cr	2.6 ± 0.04[a]	2.05 ± 0.03[a]	0.93 ± 0.04	1.653 ± 0.04[a]	0.926 ± 0.05	**3.01 ± 0.06[a]**	1.796 ± 0.02	1.383 ± 0.06
Fe	8.9.1 ± 3.1[a]	**966.4 ± 3.4[a]**	318.9 ± 1.23	732.3 ± 3.02[a]	306.8 ± 2.29	898.3 ± 8.2[a]	795.4 ± 5.58[a]	806.9 ± 2.21[a]
Pb	**18.8 ± 1.1[a]**	12.9 ± 0.15[a]	0.243 ± 0.05	9.62 ± 0.89[a]	BDL	15.06 ± 0.7[a]	9.36 ± 0.08[a]	7.14 ± 0.06[a]
Mn	**31 ± 0.49[a]**	26.9 ± 1.57[a]	3.98 ± 0.15	20 ± 0.09[a]	7.3 ± 0.07[a]	28.6 ± 0.56[a]	20.89 ± 0.60	22.58 ± 0.33[a]
Zn	**45.9 ± 0.3[a]**	38.5 ± 0.52[a]	15.06 ± 0.78	20.4 ± 0.90[a]	16.31 ± 1.29	33.6 ± 0.55[a]	29.1 ± 0.55[a]	26.2 ± 0.3[a]
Total metal	2,245.9	2,162	644	1,752.7	650.16	**2,277.5**	1,881.3	1,858.6

Numbers in bold are the highest values of each metal. Results are expressed as mean ± SD ($n = 3$) in μg g^{-1} of dry weight

C.S. Control Site

[a] (Higher value) and [b](lower value) significantly different from the control site

the metals. Among the individual metals, lead and zinc concentration is the highest in samples from Bus Stand which is justified with its location, as at this location, samples are exposed to vehicular exhaust and other anthropogenic activity. The level of Al and Fe noted in this study showed that both are the most abundant elements accumulated in the lichen thallus. Some authors have suggested that the occurrence and distribution of Al and Fe as pollutants in the environment originate mainly from soil particles (Frati et al. 2005). However, the increased concentrations noted from the high traffic areas which resulted in variations as to the level of both elements from the different areas may suggest the effect of anthropogenic sources on the level of these elements in the area. The concentration recorded for As and elements such as Cd, Cr, Pb, Mn and Zn showed that they are major pollutants at high traffic areas and also indicated the effect of vehicular emission on the release of these elements in the surrounding environment.

Arsenic concentration ranges between 3.96 and 0.183 μg g^{-1} in the study sites, the Venna lake showed the highest concentration of arsenic (3.96 μg g^{-1}) followed by Bus Stand (2.70 μg g^{-1}) and Panchgani (2.79 μg g^{-1}) area heavily affected by anthropogenic activities. Non-significant values of arsenic were observed at Old Mahabaleshwar and Pratapgarh with respect to control site. It may be due to the anthropogenic origin of arsenic, as both the sites are peri-urban in location and subjected to moderate vehicular activity.

The recorded significant differences in elemental concentrations among exposure areas may further emphasize the acceptance of lichen organism to monitor pollutants from the atmosphere.

Polycyclic aromatic hydrocarbons in lichens

In the absence of industrial activity (major source of pollutants), vehicular activity seems to be responsible for the major input of organic and inorganic contaminants in and around Mahabaleshwar.

To characterize the PAHs emission sources, the ratios of BaP (Benzo (a) pyrene) and BghiP (Benzo (ghi) perylene) were compared. The mean of BaP/BghiP ratio in this study was found more than 1. The BaP/BghiP ratio higher than 0.6 indicates the presence of traffic emission (Pandey et al. 1999). As the location is a tourist spot, therefore, higher BaP/BghiP ratio supports the view that the vehicle activity is the major source of PAHs (Table 4).

According to Zhang et al. (2005), the ratio of Ind/BghiP (Indeno/Benzo (ghi) perylene) is the best diagnostic ratio for source identification of gasoline/diesel engine exhaust. Caricchia et al. (1999) reported that the Ind/BghiP ratio for gasoline engines is about 0.4, while the ratio for diesel engines approaches 1. In the present study, the Ind/BghiP ratio was found to be between 0.1 and 0.3, indicating the predominant contribution of gasoline engines in the samples.

Another diagnostic ratio of BaP/(BaP + Chr) could be used to estimate the vehicular contribution to the air pollution which ranged between 0.5 (for diesel engine) and 0.75 (for gasoline engine) (Halek et al. 2010). In the present study, the mean ratios of BaP/(BaP + Chr) were found to be 0.27–0.40, which indicate diesel-engine exhaust is also a source of PAHs emission in the air.

From the diagnostic ratios, it is clear that traffic emissions are the sole contributors of PAHs it may be by gasoline- or diesel-driven vehicles. Thus, diagnostic ratios

Table 3 Mean US-EPA priority PAHs concentration (mean + SD) in Mahabaleshwar

	Bus Stand	Venna lake	Lingmala fall	Devi Path	Wilson point	Panchgani	Old Mahabaleshwar	Pratap garh
Naphthalene	6 ± 0.2	5.666 ± 0.32	BDL	2.13 ± 0.15	0.156 ± 0.042	5.47 ± 0.42	2.5 ± 0.47	3.13 ± 0.115
Acenaphthylene	17.23 ± 0.49	14.466 ± 0.47	0.076 ± 0.02	8.7 ± 0.36	1.26 ± 0.089	10.73 ± 0.50	6.966 ± 0.20	9.63 ± 0.47
Acenaphthene	4.36 ± 0.38	3.433 ± 0.35	BDL	1.32 ± 0.057	BDL	4.4 ± 0.36	2.3 ± 0.44	2.7 ± 0.17
Fluorene	2.76 ± 0.15	3.1666 ± 0.21	BDL	0.59 ± 0.044	BDL	2.83 ± 0.15	1.24 ± 0.05	2.066 ± 0.04
Phenanthrene	4.34 ± 0.23	3.656 ± 0.07	BDL	2.78 ± 0.25	BDL	1.78 ± 0.10	0.93 ± 0.05	1.183 ± 0.02
Anthracene	0.57 ± 0.07	0.5 ± 0.04	BDL	0.086 ± 0.03	BDL	0.37 ± 0.05	0.943 ± 0.17	0.05 ± 0.03
Fluoranthene	2.97 ± 0.13	2.453 ± 0.59	0.056 ± 0.03	1.576 ± 0.34	0.05 ± 0.04	3.213 ± 0.12	1.55 ± 0.29	1.716 ± 0.26
Pyrene	9.69 ± 0.51	10.49 ± 0.85	0.06 ± 0.02	6.54 ± 0.39	0.046 ± 0.03	8.806 ± 0.69	5.96 ± 0.55	3.706 ± 0.50
Benzo (a) anthracene	0.45 ± 0.08	0.33 ± 0.02	BDL	0.066 ± 0.015	BDL	0.396 ± 0.02	0.09 ± 0.02	0.043 ± 0.025
Chrysene	1 ± 0.21	0.89 ± 0.05	BDL	0.096 ± 0.04	BDL	0.786 ± 0.08	0.16 ± 0.02	0.063 ± 0.01
Benzo (b) fluoranthene	1.20 ± 0.04	1.07 ± 0.05	BDL	1.066 ± 0.15	BDL	1.366 ± 0.085	0.89 ± 0.07	0.913 ± 0.07
Benzo (k) fluoranthene	1.18 ± 0.03	1.05 ± 0.05	BDL	0.996 ± 0.14	BDL	1.40 ± 0.04	0.876 ± 0.04	1.05 ± 0.18
Benzo (a) pyrene	1.96 ± 0.13	1.8 ± 0.06	BDL	1.05 ± 0.04	BDL	1.04 ± 0.09	0.116 ± 0.06	0.73 ± 0.05
Dibenzo (a,b) anthracene	0.586 ± 0.06	0.47 ± 0.03	BDL	0.213 ± 0.06	BDL	0.06 ± 0.02	0.4 ± 0.04	BDL
Benzo (g,h,i) perylene	0.403 ± 0.04	0.27 ± 0.046	BDL	BDL	BDL	0.16 ± 0.044	BDL	BDL
Indeno (1,2,3- c,d) pyrene	0.046 ± 0.03	0.1 ± 0.026	BDL	BDL	BDL	BDL	BDL	0.066 ± 0.015
Total PAHs	54.78	49.816	0.193	27.24	1.51	42.82	24.976	27.056
Major PAHs	Ace	Ace	Ace	Ace	Ace	Ace	Ace	Ace

Table 4 Molecular ratios applied for diagnosing source of PAHs in ambient environment in Mahabaleshwar

BaP/BghiP	B(a)P/(BaP + Chry)	IDP/BghiP	Chyr/BaA
1.1239	0.3119	0.1157	2.2059
1.2345	0.2725	0.3704	2.67
NC	NC	NC	NC
NC	0.4082	NC	1.45
NC	NC	NC	NC
2.4791	0.3352	NC	1.9831
NC	0.3717	NC	1.6896
NC	0.4063	NC	1.4615

indicate that traffic activity is responsible for the increase in PAHs level in ambient environment.

The presence of significantly high concentration of pyrene of 10.49 at Venna lake in comparison to 0.06 at Lingmala Fall (control site) further affirms significant contribution of vehicular activity, especially gasoline-driven vehicles in degradation of air quality of the city. Yang et al. (2005) reported that gasoline-vehicle exhaust are enriched with high molecular weight PAHs such as BghiP, whereas diesel-vehicle exhaust were having the major proportion of lighter PAHs such as fluorene, fluoranthene, acenaphthylene and phenanthrene.

Khalili et al. (1995) identified Anth, Phen, Flan, Pyr, B(a)A and Chry as markers of coal combustion. As many restaurants and hotels are located in Venna lake and bus stand sites, due to high inflow of tourist. Significant amount of chrysene together with pyrene indicates that other than vehicular activity, coal combustion is also contributing to the total PAH load in the city. Khillare et al. (2008) reported that B(b)F, in addition to B(ghi)P and Pyr, are indicators of diesel-driven vehicles which seem to correlate with the present observation that the bus stand, Venna lake and Panchgani having the highest vehicular activity have exceedingly higher concentration of these PAHs in comparison to the sites having low vehicular activity.

Halek et al. (2010) reported that diesel-driven vehicles are rich in acenaphthylene, acenaphthene and fluoranthrene which seems to be consistent with the present study as concentration of low molecular weight compounds are higher at all the sites in comparison to the control site.

Heavy metals versus PAHs in the area

The air quality monitoring of Mahabaleshwar in Western Ghats using *R. awasthii* indicated that the concentrations of HM and PAHs were significantly higher at sites with more anthropogenic input, mainly vehicular activity. This fact has been further affirmed by Fig. 1 which shows the significant linear correlation ($R^2 = 0.8916$) of total metal

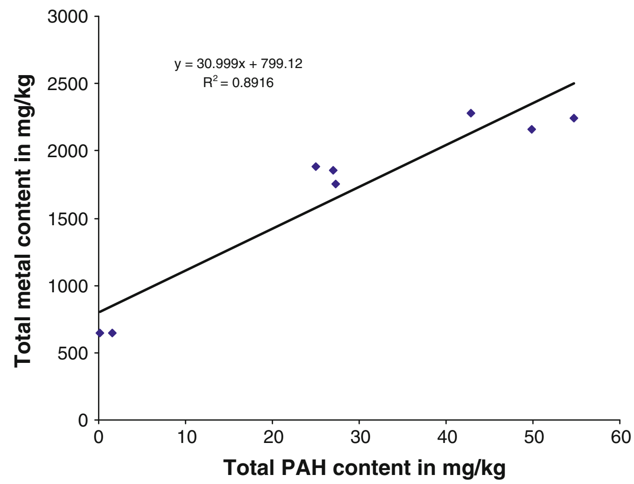


Fig. 1 *Plot* between total metal concentration and total PAHs concentration reveals significant correlation between the two parameters indication possible common source of origin

concentration with the total PAH concentration indicating common source of origin of metals and PAHs in the ambient environment.

Principal component analysis of individual PAHs and metals was carried out to observe convergence and divergence in the eight localities. PC1 explained 98.87 % of variance in the PAHs and metals profile. PC1 had high positive coefficient values for most of the PAHs, especially acenaphthene (385.1) and fluoranthene (255.0) than other metals such as, Al (0.6979) and As (1.8405). PC1 clearly indicates a single major source of pollution which is indeed the vehicular activity, and convergence and divergence of localities in the PC plot (Fig. 2) are based on the level of pollution.

It is interesting to note that the PAHs profile in lichen samples is having comparable amounts of both LMW (low molecular weight) PAHs and HMW (high molecular weight) PAHs. Among LMW PAHs, acenaphthylene is dominant where as pyrene is the dominant in HMW PAHs in the samples; the origin of both PAHs is reported to be due to high vehicular activity (CPCB 2005).

Health risk estimation

B(a)P, the classical chemical carcinogen, is considered to be the useful indicator for cancer risk assessment. The average concentration of B(a)P ranged from BDL to 1.97. According to World Health Organization (WHO), B(a)P is considered to be a reliable index for the assessment of total PAHs carcinogenicity. Since B(a)P is easily oxidized and photodegraded, therefore, the PAHs carcinogenic character could be underestimated. For better quantification of carcinogenicity related to the whole PAH factor, BaP-equivalent potency (BaPE) index after Yassaa et al. (2001),

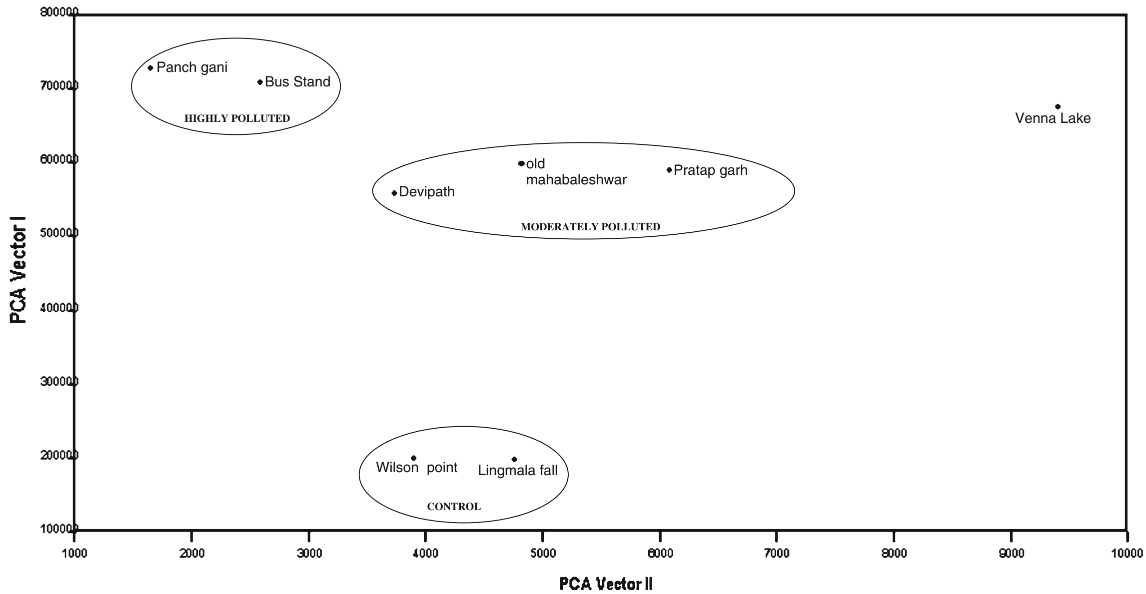
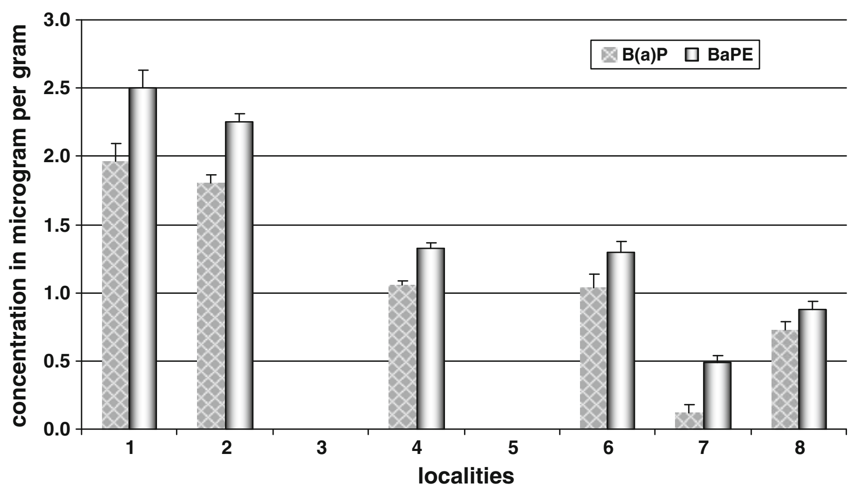


Fig. 2 Principal component analysis (PCA) applied for segregation of different sampling sites based on concentration of individual polycyclic aromatic hydrocarbons and metals

Fig. 3 Mean Benzo(a)pyrene and BaPE to assess health risk associated with PAHs in and around Mahabaleshwar city



Mastral et al. (2003), and Cheng et al. (2007) has been calculated. BaPE is quite high at Bus stand and Venna Lake where as the control sites Lingmala Fall and Wilson Point have 0 values. BaPE index (Fig. 3), thus, indicates that the cancer risk is associated with high vehicular activity. Thus, urban population appears to be exposed to significantly higher cancer risk.

Conclusion

The present lichen biomonitoring data provide preliminary evidence indicating vehicular activity resulting due to tourism having significant contribution to the total pollutants (HM as well as PAHs) profiles of the area. Therefore, more extensive studies are required to be carried out to investigate the ecotoxicological effect of pollutant on the ecosystem of Western Ghats.

Tourism industry in India is no doubt a fast-growing sector, having vast potential for generation of employment besides being a boon to the overall economic development of the country, but lot more remains to be done for planning and implementing ecotourism, in such a way that it accommodates and entertains visitors in a way that is minimally intrusive or destructive to the environment and which sustains as well as supports natural conservation in the locations it is operating in. Moreover, lichen biomonitoring in conserved areas (lichen rich areas) can play a key role in providing data on the air quality which will act as a baseline for necessary action taken up by the governments and non-governmental sectors and voluntary organisations, in an endeavour to promote ecotourism for sustainable development.

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