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Heavy Metal Accumulation in *Phaeophyscia hispidula* En Route to Badrinath, Uttaranchal, India

Vertika Shukla · D.K. Upreti

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Abstract *Phaeophyscia hispidula*, a common foliose lichen, growing in its natural habitat, was analysed for the concentration of six heavy metals (Fe, Ni, Zn, Cr, Cu and Pb) from five different sites of Pauri city, Garhwal Himalayas, Uttaranchal, India. The concentration of metals is correlated with the vehicular activity and urbanization. The total metal concentration is highest at Circuit House on Pauri-Devprayag Road, followed by Malli on Pauri-Srinagar Road, which experience heavy traffic throughout the year. Kiyonkaleshwar area, having less vehicular activity, had minimum accumulation of metal. The statistical parameter, coefficient of variation %, showed higher CV% for Fe and Cr but lower for Cu and Ni. The concentration of most of the metals at different sites were statistically significant (0.01 level) from their concentrations at control site. There was high spatial variability in the total metal concentrations, at different sites, that ranged from 5,087.1 to 11,500.44 μg/g, with an average concentration of 8,220.966±2,991.467 (SD).

Keywords Bioaccumulation · Lichens
Heavy metals · Pauri · Garhwal-Himalayas · India

V. Shukla · D. Upreti (✉)
Lichenology Laboratory,
National Botanical Research Institute,
Rana Pratap Marg,
Lucknow 226001, India
e-mail: upretidk@rediffmail.com

1 Introduction

Lichens have a long history of use as biological indicators of air quality (Rao & LeBlanc, 1967; Vestergaard, Stephansen, Rasmussen, & Pilegaard, 1986). Accumulation of metals by lichen thalli is one of the best studied aspects of lichen biology (Brown, 1976; Nieboer, Richardson,& Tomassini, 1978). The tolerance of lichens to most of the heavy metals and their slow growth rate, are among the main factors that make them good indicators or/and monitors of metal pollution. Lichen possess remarkable ion exchange properties and also accumulate metal rich particulate so that they collect and retain airborne metals. The levels of metals in lichens are of particular importance in environmental and geochemical studies. A close correlation is usually found between the distribution pattern of lichen species and the trace metal content of the surrounding air (Nyangababo, 1987).Metal ions can be concentrated to high level in thalli on metal rich rocks (Easton, 1994) or close to sources of pollution (Glenn, Orsi, & Hemsley, 1991; Nieboer, Ahmad, Puckett, & Richardson, 1972; Pandey, Upreti, Pathak, & Pal, 2002).

This study was undertaken to determine the degree of heavy metal contamination in the environment of the Pauri city, due to urbanisation and vehicular activity, utilizing the lichen, *Phaeophyscia hispidula* as an indicator. The study area (Figure 1) is situated *en route* to Badrinath, a holy place of Hindus in the

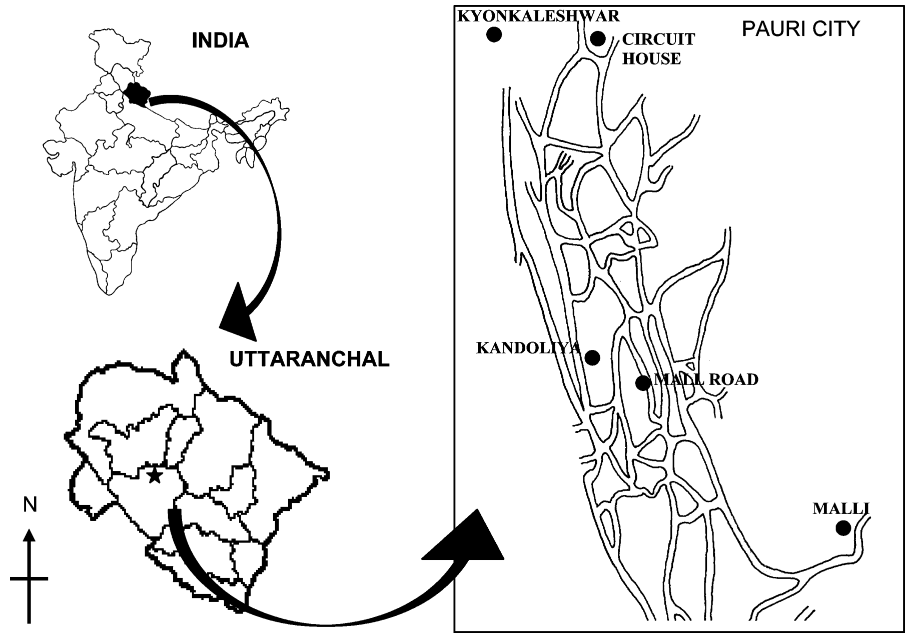

Figure 1 Map showing the location of collection sites in Pauri city, surveyed for lichen collection.

Himalayas. It experiences very high vehicular activity throughout the year except in the winters (Nov.–April).

Uttaranchal, is a newly created hilly state in Northern India, that is undergoing rapid development. Because of its location in lower Himalayas, it is pertinent to evaluate the air quality of urban centers of the Garhwal Himalayas that one undergoing urbanization and deforestation.

2 Study Area

The study area was located in the district of Pauri in the central part of Garhwal, between 29°20′N–30°15′ N latitude and 78°10′E–79°20′E longitude. The city of Pauri stands on a steep northern slope between 1,700 and 1,900 m with mountainous topography. Sampling sites were selected on the basis of the level of vehicular activity (Table I).

3 Materials and Methods

P. hispidula is the most commonly occurring foliose lichen in the region, growing on a variety of substrates in both polluted and non-polluted sites. The lichen samples were collected from 1.5 m above the ground. The concentration of six heavy metals, Fe, Ni, Cu, Cr, Zn, Pb was determined in the samples collected from five different sites in the city (Table I). The lichen samples were identified and a voucher specimen is deposited in the herbarium of National Botanical Research Institute, Lucknow (LWG).

For the analysis of the metals at road side, the lichen thalli (approximately 5 g f.wt.) were removed from the bark with sharp knife. The samples were oven dried for 12 h to a constant weight at 90°C. The dried lichen samples (three replicates) were grinded to powder (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 to 15 ml with double distilled water. Analysis was done with Flame Atomic Absorption Spectrophotometer (Perkin Elmer, model A Analyst 300). Stock standards were from Merck India and traceable to NIST (National Institute of Standards Technology). Working standards were prepared from the stock using deionised water for dilution. The results of the elemental analysis was evaluated with a one way analysis of variance (ANOVA). Results are presented as *f* values and *f* probability (Table II).

4 Result and Discussion

Since the Pauri city has no other source of pollution except heavy vehicular activity, the high levels of metal in the lichen are due to traffic activity in the

Table I Sources of lichen material of *Phaeophyscia hispidula* (Ach.) Essl., for heavy metal estimation in Pauri City

S. no.	Site	Site direction	Pollution level
1	Kiyonkaleshwar Forest	On *Pinus*, 1.5 m above ground facing road	Dense forest, no pollution
2	Kandoliya	On *Quercus*, 2 m above ground facing road	Open forest, low pollution
3	Circuit House (Pauri-Devprayag Road)	On *Pinus*, 3 m above ground facing road	Moderate vehicular activity, road was under construction, moderate pollution
4	Malli (Pauri-Srinagar Road)	On *Pinus*, 1 m above ground facing road	High vehicular activity, road was under construction, high pollution
5	Mall Road	On *Pinus*, 1.5 m above ground facing road	Market place, bus stand, maximum vehicle density, highly polluted

area. The maximum accumulation of Fe was found at Circuit House, followed by Malli. Copper and nickel showed least variation in concentration between the different sites. Lead accumulation was highest at Mall Road, and lowest at Circuit House on Pauri-Devprayag Road. Kiyonkaleshwar has minimum accumulation of chromium while Pauri-Devprayag road had the maximum concentration of chromium 9,148 μg g^{-1}.

From the Table II it is evident that the accumulation of most metals by lichens is maximum at Circuit House on Pauri-Devprayag Road followed by Malli on Pauri-Srinagar Road. The Fe content at these two sites is significantly different (1% level) from that at Kiyonkaleshwar, the control site. The maximum concentration of most of the metals at both the polluted sites can be attributed to the fact that the road at these localities was under construction for two years resulting in frequent heavy vehicular activity throughout the whole year. The low concentration of most of the metals in lichens from Kiyonkaleshwar reflects the lower traffic activity and a thick tree canopy. All the four sites exhibit high levels of lead even at Kiyonkaleshwar, a site having less vehicular activity. The Mall Road, having a Bus Stand and the market place showed maximum lead accumulation. The source of lead in this region is mainly petrol (In India, lead content is 0.15 g l^{-1} in gasoline).

In all the sites of the Pauri city, *P. hispidula* exhibited a high concentration of iron in comparison with other metals. Garty, Galun, and Kessel (1979) observed a large number of Fe containing particles associated with the mycobiont using electron microscopy and dispersive X-ray analysis. The maximum concentration of iron at Circuit House and Malli area is due to the location of these sites along dusty (gravel) road and frequent movement of vehicles.

Apart from engine emissions, some metals enter the surrounding environment due to abrasion of metallic vehicle parts. Among these, Fe, Cr and Cu are main metals. The concentration of chromium is

Table II The concentration of heavy metals in μg g l^{-1} accumulated in *Phaeophyscia hispidula* collected from various polluted sites of Pauri city along with analysis of variance (values are as mean±standard error) and coefficient of variation percent

	Iron	Chromium	Copper	Zinc	Nickel	Lead
Kiyonkaleshwar Forest	4,505±55.6	79.65±2.6	35.76±0.9	84.99±1.04	54±0.55	326.09±0.5
Kandoliya	6,937.333±4.4	151.89±0.88	26.27±0.52	102.55±0.67	56.65±0.34	407.32±0.18
Circuit House (Pauri-Devprayag Road	10,923±38.9	148.65±0.31	24.02±0.63	109.3±0.64	63.1±0.73	231.9±0.77
Malli (Pauri-Srinagar Road)	10,429±50.38	89±0.58	25±0.59	141.8±0.45	61.6±0.56	398.7±0.36
Mall Road	4,960±76.29	91.7±0.51	30.8±0.67	115.7±0.42	67.9±0.71	425.9±0.31
CV%	39.7	30.9	16.79	18.7	8.9	22.3
One way ANOVA						
f value	3,793*	700*	43*	788*	86*	32,171*
f probability	0.00	0.00	0.00	0.00	0.00	0.00

*Significantly different at 1% level

higher at Kandoliya and Pauri-Devprayag Road. Concentration of copper is more uniform ranging between 24 and 35.7 μg g^{-1}.

According to Harte, Holdren, Schneider, and Christine (1991) Zn level may be elevated near motorways due to tyrewear. The maximum concentration of Zn in the study area was recorded from Malli, a site situated on the hilly terrain with twisty road where frequent brakes are applied during driving.

The concentration of nickel is ranging from 54.0 to 67.9 μg g^{-1}. There is significant variation at 1% level between the Ni content at Kiyonkaleshwar and Mall Road (highly polluted). According to Nriagu and Pacyna (1988), the main anthropogenic emission of Ni are coal and oil combustion, copper–nickel and lead production, mining, steel and iron and cement industries. Nickel is maximum at Mall Road a place with number of vehicle-repair garages and heavy activity of automobiles.

The main source of lead is the automobile fuel, Takala and Okkonen (1981) correlated the lead content of *Hypogymnia physodes* with traffic volume and similar results have also been observed in *Dirinaria papillulifera* (Dubey, Pandey, Upreti, & Singh, 1999). In the present study highest recorded level of lead is at Mall Road and minimum at Pauri Devprayag Road.

The calculation of the coefficient of variation % (CV%) for element concentration in *P. hispidula* yields in general higher CV% for Fe and Cr and lower for Cu and Ni. It indicates (Table II) the nature of the element accumulated and entrapped by lichens (Garty, Fuchs, Zisapel, & Galun, 1977). Furthermore Garty, Kloog, Cohn, Wolfson, and Karnieli (1997) suggested that the higher CV in the case of Ni and V reflect the particulate nature of these metals, which makes for a relative low rate of dispersion. The CV is lower for Cu and it is in accordance with the findings of Olmez, Gulovali, and Gordon (1985) and Bargagli, D'Amato, and Iosco (1987) who suggest that copper is dispersed in small particles, while the higher CV% obtained for Fe represent relative low rate of dispersion.

In the present study it is interesting to note that the metal accumulation in *P. hispidula* is exceptionally higher in comparison to the similar studies conducted in Northwestern Ontario by Pfeiffer and Barclay-Estrup (1992), on *H. physodes* (L.) Nyl., which accumulated lead and iron in the ranges of 3.9–48 and 114–691 μg g^{-1}, respectively. Similarly Garty and Amman (1987) estimated Fe and Pb in *Pseudevernia furfuracea* from Switzerland in the range of 156–1,097 and 32–177 μg g^{-1} respectively. Pandey et al. (2002) affirms that *P. hispidula* is an excellent bioaccumulator of metals during a study on lichens of Hetauda Industrial area in Nepal where this species accumulated 23,035 μg g^{-1} of iron.

5 Conclusion

This study, using a single ubiquitous epiphytic lichen species, showed that a single species can be used to determine air pollution levels in Garhwal Himalayas. The present level of metallic pollutants will be useful baseline data for carrying out future studies related on ambient air quality in the area.

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