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Accumulation of heavy metals in foliose lichens growing in industrial area of Udham Singh Nagar, Uttarakhand, India

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A B S T R A C T

The purpose of this study was to assess the level and possible sources of organic and inorganic pollutants in Udham Singh Nagar (USN) and their effect on naturally growing foliose lichen *Pyxine cocoes* (Sw.) Nyl. The lichen samples were collected from three different sites on the basis of anthropogenic activities detected in the area. The high metal content was found at Bajpaur and Tanda forest which experiences heavy traffic activity.

Introduction

Lichens are one of the most valuable biomonitor of atmospheric pollution and used as sensitive indicators to estimate the biological effects of pollutants by measuring changes at community or population level and as accumulative monitors of persistent pollutants Loppi and Bonini, 2000. Lichens have a wide variety of growth forms but foliose lichens are better accumulators in comparison with fruticose ones Swinscow and Krog, 1988.

In general foliose lichens are employed in the biomonitoring studies which may be due to the morphology of the foliose lichens that provides larger surface area for the absorption/ adsorption of the pollutants and have certain characteristics that make them ideal biomonitoring organisms; the perennial nature, absence of root or other special organs for uptake of nutrients and lack of cuticles which enable them to absorb pollutants directly from the atmosphere. Al in the present study *P. cocoes* the widespread and dominant occurrence of members of Physciaceae family at places with maximum vehicular activity and human interference. The high capacity of lichens to accumulate air pollutants, resistance to environmental stress and longevity are the other features that make them most suitable organisms for biomonitoring studies (Garty, 2001).

The aim of the present study is to use a naturally growing foliose lichen *Pyxine* *cocoes* in biomonitoring and to determine the air pollution levels in different regions of the city in the district.

Materials and methods

Study area

Udham Singh Nagar district popularly known as "Gateway of Kumaun Himalayas" is situated in the Terai region of Uttarakhand. The district covers an area of about 3000 km^2 between 28° and 30° N latitude and 78° and 81° E longitude (Fig. 1). The district has large industrial areas basically of textile, paper and sugar mills, PVC pipe, polyester film and pharmaceutical units. Being situated in the Terai region of Western Himalaya, the district has fertile soil and from the past many years the forest areas have been removed for agriculture cultivation. The fast pace of industrialization together with the destruction of forest resulted in few scattered, open canopy deciduous forests in the district. The Tanda forest near Rudrapur, the forest near Bajpur and Khatima forest are the three main forest of the district.

Urban and periurban area of USN were surveyed for collection of lichen in October 2009. Lichen samples were collected from three sampling sites of USN area among these Tanda observed as control site with respect to frequency of vehicles passing there (Table 1). In each site, the samples were taken from 5 isolated trees (*Boehmeria rugulosa*, *Shorea robusta*, *Dalbergia sisso*, *Ficus bengalensis* and *Mangifera indica*). Lichen specimens were collected from trees which were fulfilling standard criteria such as (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 (Pino *et al.*, 2004). From each tree 4–5 whole thalli of *P. cocoes* were collected. The laboratory samples from each site were removed from the bark with sharp knife and sorted to remove extraneous material. Composite samples were prepared by mixing all lichens samples for each site. Separate packets were made for heavy metals.

Heavy metal analysis

The dried lichen samples (n=3 from composite samples) were ground to powder (1.0 g) and digested in mixture of concentrated HNO_3 and $HClO_4$ (v/v 9:1) for 1 hour. 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.

Results and discussion

Distribution of heavy metals in the area

Lichen thallus showed maximum accumulation of all the heavy metal and it ranges from 3.36 to 503.39 μg g^{-1} dry weights as total metal contents in the study area. Among these Fe is the major element distributed in the surveyed area followed by Al, Zn, Cu, Cr, Ni, Pb and Cd as 503.39, 297.75, 172.99, 25.43, 22.16, 16.56, 10.77 and 3.36 μg g^{-1} dry weights (total metal) respectively. Among the three sites Bajpur area showed the maximum concentration of total metals 472.67 followed by Khatima and Tanda as 443.81 and 134.92 μg g^{-1} dry weights respectively. Lead, Cr, Cd and Ni showed a clear trend of increasing concentrations in areas associated with vehicular emission as well as coal burning. Compared to other metals Cu (metalloid) also accumulated in lichen and showed an increasing concentration not only in high traffic areas but also in the control area as well. The lowest concentration of metals in the area of Khatima is due to lowest anthropogenic activity in the area (Table 1).

The distribution of heavy metals allowed the detection of their emission sources and their range of dispersion within the study area. The level of Fe noted in this study showed the higher concentrations were observed in the area and it ranges from 108.00±1.47 µg g^{-1}DW to 234.13±3.93µg g^{-1}DW. Some studies concentrations of 50–1600 ppm Fe in lichens at non-polluted areas and 400–16000 ppm in highly polluted ones (Nieboer *et al.*, 1978). Some authors have suggested that the occurrence and distribution of Fe as pollutants in the environment originate mainly from soil particles (Baptista *et al.*, 2008). In the present study maximum concentration was observed near Bajpur area having open canopy of trees with horse riding areas it may be a reason for higher Fe in the lichen thallus. However, the increased concentrations noted from the high traffic areas which resulted in variations as to the level of Fe from the different areas may suggest the effect of anthropogenic sources on the level of this element. The Al metal exhibit also higher concentration in the areas within the range of 12.03±1.53 to 188.06±4.93µg g^{-1} dry weights. It represents second most abundant element found in the area having mixed pollution source like automobile exhausts, paper industries and electroplating along with higher traffic load areas such as Bajpur and Tanda. According to Garty (2001) this metal is widely spread through air dust and deposits over lichens substratum/thallus. In the present study it was reported that the control areas (Khatima) have minimum concentration of this metal in the lichen.

The high concentrations of Al and Fe indicate that a certain proportion of the lichen elemental composition may have been derived from soil particulates (Guevara *et al.*, 1995). In fact, the occurrence of metals in particulate forms explains the huge accumulation of toxic elements in lichens growing in polluted environments (Garty *et al.*, 1979).

Lead is known to accumulate in the thallus according to the environmental availability of particles and exposure time (Brown, 1987; Loppi *et al.*, 1997). Different biomonitoring studies have been carried out using lichen have shown that the Pb is a widespread pollutant and one of the most important emission sources. In the present study Bajpur forest had very high concentration of Pb (5.86±0.20 µg g^{-1}DW) whereas Tanda forest had very less concentration of Pb.

The burning of fossil fuel, incineration of solid waste, Ni and Cd batteries and paint phosphate fertilizers are the main sources of Cd in air (Nimis *et al.*, 1990). The maximum cadmium content ranged between 1.63±0.32 µg g^{-1}DW at Tanda forest and 1.73±0.12 µg g^{-1}DW at Bajpur forest. Cd is considered to be particularly toxic for various lichen species (Nieboer *et al.*, 1978). Cd also has a high negative correlation with protein and reducing sugar content (Riga-Karandinos and Karandinos, 1998). The mycobiont hyphae, especially those forming the upper cortex of lichen thalli, are the main site of Cd accumulation (Sanità di Toppi *et al.*, 2005). The Cd had been traced to urban metal smelting companies, burning of household wastes, battery and paint manufacturing industries and in most cases enhanced by vehicle emissions. The Diethyl cadmium is used in the production of tetraethyl lead it may be a reason for higher concentration in the atmosphere (Lee, 1972).

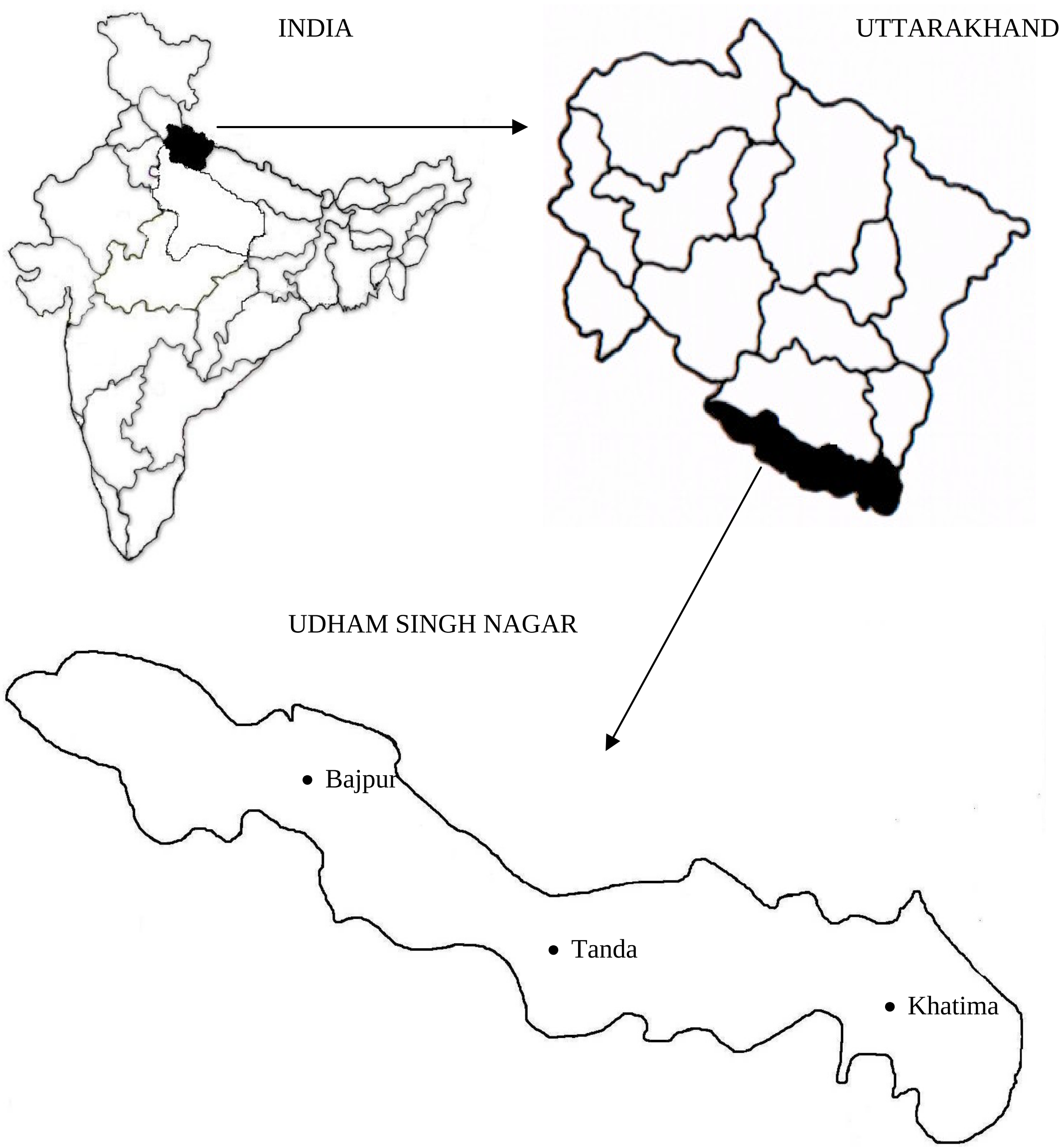

Fig.1 Udham Singh Nagar district map showing localities surveyed for lichen collection

Table.1 Mean and standard deviation of heavy-metal concentration in *Pyxine cocoes* in Udham Singh Nagar

LOCALITIES	Al	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Total metal
Tanda forest	97.66± 4.10	1.63±0.32	9.6±0.37	9.9±0.25	234.13±3.93	9.03±0.23	4.90±0.17	76.96±0.76	443.81
Khatima	12.03±1.53	BDL	1.36±0.24	4.2±0.45	108.00±1.47	1.03±0.24	BDL	8.30±0.45	134.92
Bajpur forest	188.06±4.93	1.73±0.12	11.2±0.36	11.33±0.77	160.26±4.78	6.50±0.40	5.86±0.20	87.73±1.33	472.67
	297.75	3.36	22.16	25.43	503.39	16.56	10.77	172.99	

Mean± S.E., n=3, BDL= below detection limit

The higher Zn concentration in the environment may be associated with automobile tire and incomplete combustion of fossil fuel (Ward and Sampson, 1989). Several sources of anthropogenic atmospheric Zn emission have been reported in the literature (Bargagli, 1998; Nimis *et al.*, 1999). Vehicular traffic and industrial emissions are supposed to be the main sources of Zn alteration in the study sites of Bajpur and Tanda forests, the Zn content varied from 8.30±0.45 μg g^{-1}DW to 87.73±1.33 μg g^{-1}DW.

The concentration recorded for lead and elements such as Cd, Cr, Pb 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. Lead is still the main trace element in the urban environment due to its long residence time in urban soil.

In the present study areas that are associated with high traffic density witnessed a high concentration of element. The finding of the present study is also in agreement with the findings of, where it was suggested that Pb alone is not only the pollutants associated with vehicular emissions.

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