Mycosphere 5 (5): 681–687 (2014)
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Article

ISSN 2077 7019
Mycosphere
Online Edition

Doi 10.5943/mycosphere/5/5/9

Lichen as indicator of metal pollution in the vicinity of SIPCOT industries in Cuddalore, southeast coast of India

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Logesh AR, Upadhyay AK, Joshi S, Kalaiselvam M, Upreti DK, Shukla AC. 2014 – Lichen as indicator of metal pollution in the vicinity of SIPCOT industries in Cuddalore, southeast coast of India. Mycosphere 5(5), 681–688, Doi 10.5943/mycosphere/5/5/9

Abstract

Lichens are useful biological indicators of environmental contamination for a variety of metals and radionuclide of both natural and artificial origin. In present study, an active biomonitoring study was carried out with a commonly growing foliose species of *Dirinaria applanata* (Fée) D.D. Awasthi, collected from Pichavaram mangroves of Tamil Nadu. A total of twelve metal (Al, Cd, Cr, Co, Cu, Fe, Hg, Mg, Mn, Ni, Pb and Zn) accumulated in the transplanted lichen thalli of *Dirinaria applanata* at four sites (Parangipettai, SIPCOT, Cuddalore OT and NT) were targeted. The transplantation site near SIPCOT, being an industrial area exhibited highest concentration of Al, Cd, Co, Cu, Fe, Hg, Mg and Mn than the other sites. Cr (1009.98±µg/g dw) and Ni (7.35± µg/g dw) were found to be more at Cuddalore OT having higher anthropogenic activities while Pb and Zn were recorded maximum at Cuddalore NT with more vehicular activity. The level of most of the metals reached above the EPA standard. The accumulation of metals in different transplanted sites clearly indicates a particular type of metal accumulation with an anthropogenic activity in that area.

Key words – *Dirinaria applanata* – heavy Metal – monitoring Transplantation

Introduction

Lichens are being used as bioindicators since the mid half of twentieth century and quite a number of studies have been carried throughout the world (Brodo 1961, Le Blanc & Rao 1973, Upreti & Pandey 1994, 2000). In India, accounts of lichen biomonitoring studies with lichens are initiated in the last decade and detailed studies on both organic and inorganic metals are available from few regions of the country (Bajpai et al. 2004, 2009, 2010, 2010a, 2010b, Bajpai & Upreti 2012, Saxena et al. 2007, Shukla & Upreti 2007, 2011, Shukla et al. 2010). Few passive monitoring studies with lichens in Southern Indian region are available (Nayaka et al. 2003); however, no records of active monitoring in the area are so far available. Thus, in the present investigation, an attempt have been

Submitted 1 September 2014, Accepted 10 October 2014-, Published online 23 October 2014
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made to assess the status of metal pollution in and around industrial and traffic rich areas in Coastal Cuddalore district, with the help of a foliose lichen; which grows abundantly in mangroves.

Active monitoring employs the transplantation of lichens from healthy site to polluted site, for determining the level of pollution or accumulation. However, passive monitoring is a method where lichens are directly collected from the study sites to analyze the level of bioaccumulation. Since, the transplanted sites are mostly devoid of foliose lichen, as only few crustose forms were recorded on avenue trees, therefore the foliose lichens was used for the current investigation.

Literature reveals that among the different lichen species; members of lichen family Physciaceae (*Pyxine* sp., *Dirinaria* sp., *Phaeophyscia* sp.) were used frequently for biomonitoring (Bajpai et al. 2004, Shukla & Upreti 2007, Satya et al. 2009, Bajpai et al. 2010a, 2011); therefore, in the present study, we have also used *Dirinaria applanata* for transplantation.

Materials & Methods

Study Area

The study area, Pichavaram mangroves (coordinates between 11° 23' N to 11° 30' N latitude and 79° 45' E to 79° 50' E longitude) is situated 15 km northeast to Chidambaram, Cuddalore district of Tamil Nadu in South India.

The mangrove covers the area of about 1100 ha of which 50% is covered with forest, 40% by waterways and the remaining filled by sand-flats and mud-flats. It is an estuarine type mangrove biotope, located at the Vellar-Coleroon estuarine complex.

The fresh lichens were collected along with the substrate to prevent the damage of the thallus. Further, the collected lichen specimens were identified and authenticated following Awasthi (2007) and Singh & Sinha (2010).

Transplantation

The lichen thalli were fixed on the hardboard with the help of glue along with the substratum. The boards containing lichen thalli were tied on building and trees at 5 meters and 10 meters height, respectively. The lichens were transplanted in 4 different sites right from Parangipettai (Site 1), SIPCOT (Site 2), Cuddalore OT (Site 3), and Cuddalore NT (Site 4) (Fig. 1, Table 1).

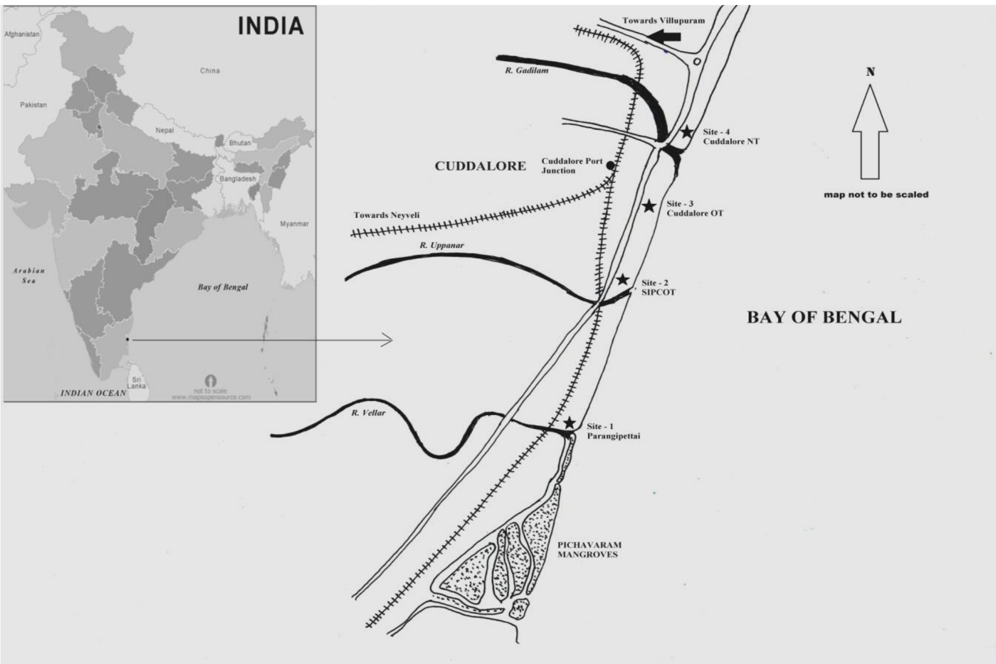

Fig. 1 – Transplanted sites

Table 1 Description of the sites where the experiment conducted

Site	Site Description Locations	Height from ground	Remarks
Site 1	Parangipettai	5 mts	Residential area
Site 2	SIPCOT Industrial estate	5 mts	Purely industrial area with 53 small industries
Site 3	Cuddalore Old Town	5 mts	Area with traffic and more commercial activities
Site 4	Cuddalore NT	5 mts	Area with more traffic than site-3

mts = meters

Heavy metal analysis

The transplanted lichen thalli were exposed for 30 days. After 30 days, the lichen boards were collected and lichen thalli were cleaned, oven-dried for 24 h at 60^0C temperature. The dried lichen samples were ground to powder; 0.5 g of sample was digested in a mixture of $HNO_3/HClO_4$ (*v/v* 9:1). Residues were filtered through Whatmann filter paper no. 42 and diluted to 20 mL with double-distilled water. Heavy metals in lichens, were determined by the method of Walting & Walting (1982), and subsequently quantified by Inductively Coupled Plasma – Optical Emission Spectrophotometer (ICP-OES) (Perkin Elmer, USA).

Statistical analysis

The experiment was carried out in triplicates. The standard deviation in each case was, n=3. Further, to confirm the validity and significance of the data, an analysis of variance (ANOVA< 0.01) was also performed.

Results and Discussion

The level of accumulation of heavy metals from the study sites were illustrated in Fig 1. Among the four different areas studied, site-1 was residential area, site-2 was industrial area, site-3 and site-4 were the areas of heavy traffic and exposed for commercial exploitation. The lichens collected from the Pichavaram mangroves were initially estimated for the accumulation of heavy metals and observed that it was below the threshold level (Table 2).

After the transplantation of 30 days, it was observed that accumulations of heavy metals were increased in all the four sites in comparison to first day of transplantation (Table 3 & Fig. 2). Lichen transplant laid at site-2, SIPCOT, an industrial area of Cuddalore; exhibit higher accumulation of all the metals (Al, Cd, Cr, Cu, Fe, Hg, Mg and Mn) except Co, Ni, Pb and Zn. The probable reason for higher concentration of different metals in the area may be due to the presence of cluster of industries;plastic, fertilizer and aluminium manufacturing. The similar findings have already been reported by Dubey et al. (1999), Upreti & Bajpai (2001), Bajpai et al. (2010a).

Aluminium (Al) is the third most abundant element found on the earth's crust (Lide 2005). Moreover, in the present investigation, accumulation of aluminium was higher at site 2 (443.2±12.85 µg g^{-1}) followed by site 1 (239.45±21 µg g^{-1}). The main anthropogenic emission of aluminium was reported by weathering of rocks, industrial process such as aluminium manufacturing and air emission (Lantzy & MacKenzie 1979). Since, aluminium is not that much harmful to living beings, therefore the effect and accumulation of aluminium was least concerned. Cadmium is one of the most hazardous elements and it released into the environment by fossil fuel combustion, production of phosphate fertilizers and municipal solid waste incineration (Morrow 2010). Further, Rani et al. (2011) reported that *Phaeophyscia hispidula* accumulates **Cadmium** (Cd) ranging from 532 µg g^{-1} to 875 µg g^{-1}. However, in the present investigation (*Dirinaria applanata*), Cadmium level was recorded higher at site 2 (17.74±1.64 µg g^{-1}) followed by site 4 (11.2±1.26 µg g^{-1}).

Table 2 Heavy metal concentration in the thalli of lichen *D. applanata* collected from unpolluted site of Pichavaram Mangroves, Tamil nadu, India. All Values are mean ±S.D. (n=3)

Metal	Accumulation (μg g^{-1} dw)
Cadmium	N.D.
Copper	N.D.
Lead	N.D.
Nickel	0.0033±.0002
Mercury	0.003±.0001
Manganese	0.396±0.06
Zinc	1.08±0.076
Chromium	5.83±0.31
Cobalt	10.13±0.52
Aluminum	9.06±1.89
Magnesium	20.72±0.34
Iron	106.01±0.172

The presence of **Chromium** (Cr) in lichen thallus exhibits its airborne origin, and it is emitted in the atmosphere by different sources like coal and oil combustion, steel manufacturing and cement production (Schutte 1977, Shtiza et al. 2008).

In the present investigation, concentration of Cr and **Nickel** (Ni) was ranging from 5.83±0.31 to 1009.89±87.64 μg g^{-1} dw and 0.003±0.0001 to 7.36±0.87 μg g^{-1} dw, respectively, at site 3; the commercial area having railway junction, harbor and fishing industries. Chromium level was found higher at site-3 (1009.89±12 μg g^{-1}) followed by site 2 (979.92±14.56 μg g^{-1}). Similarly, literature also reveals that *Dirinaria consimilis* accumulated 61.80-1920 μg g^{-1} and *Phaeophyscia hispidula* accumulated 103.79-1189.56 μg g^{-1} of chromium (Mishra et al. 2003, Bajpai et al. 2004).

As per the literature, **Lead** (Pb) content with traffic volume is directly proportional to Pb accumulation in lichen thallus (Takala & Okkonen 1981). *Phaeophyscia hispidula* accumulates higher amount of Pb ranging from 8600±395 to 12433±185 μg g^{-1} (Rani et al. 2011). However, the tyre activity and application of brake pads release **Zinc** (Zn) in the environment (Bajpai et al. 2011). Further, it was also reported that *Phaeophyscia hispidula* and *Pyxine cocoes* accumulates higher concentration of zinc than the other lichens (Bajpai et al. 2011).

Similarly, in the present findings, maximum accumulation of Pb (11.25±0.15 μg g^{-1} dw) and Zn (145.17±7.7 μg g^{-1} dw) were found at site-4 (Fig 1), as these sites showed heavy vehicular activity/ emissions. Site 4 with higher vehicular activities exhibit maximum concentration of Zinc (145.17±7.7 μg g^{-1}) followed by site 3 (118.8±16.98 μg g^{-1}) which also have vehicular activities. Zinc chloride is a chemical which used in the manufacturing of tyres of motor vehicles, and this may be the reason for accumulation of zinc in the lichens as site 4 and site-3 are the traffic rich areas than the other two sites.

According to Baptista et al. (2008), **Iron** (Fe) content in lichens is evidently affected by iron originating from fuel and soil dust. Lichens have special affinity with iron, and most of the lichens accumulate the metal in higher concentration than other metals. Majority of the previous findings carried out in Indian lichens, regarding metal accumulation, exhibited higher concentration of Fe (Nayaka et al. 2003, Shukla et al. 2007). *Pyxine cocoes* accumulates higher amount of iron ranging from 1573.0-19374.0 μg g^{-1} (Saxena et al. 2007). Similarly, in the present study, iron was accumulated in higher concentrations at all the sites especially at site 2, it was 1018.46±65.23 μg g^{-1} dw.

Furthermore, the concentration of Al, Cd, Co, Cu, Fe, Hg, Mg and Mn was recorded maximum at the site 2 in comparison to the other three sites. Higher accumulation of most of the metals may be because of the presence of more than fifty industries; emitting various types of contaminants into the atmosphere. Moreover, the metals in lichens exhibit a sequence of Fe>Cr>Al>Mg>Zn>Mn>Cu>Cd>Ni>Pb.

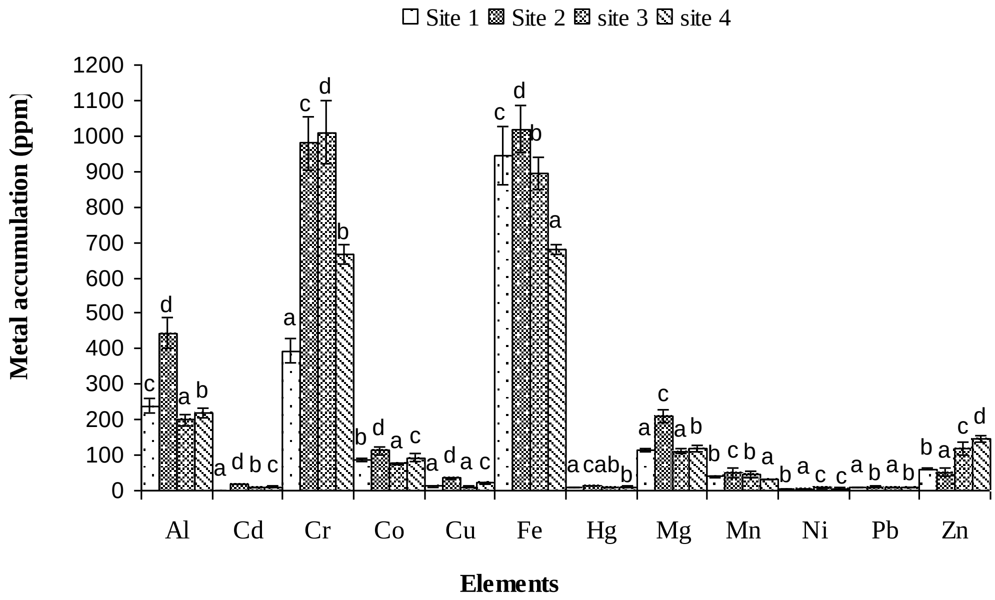

Fig. 2 – Metal accumulation at different sites

Table 3 Metal accumulation at different sites

S. No.	Metals	Values (PPM)			
		Site 1	**Site 2**	**Site 3**	**Site 4**
1	Al	239.45±21 c	443.2±12.85 d	198.98±10.64 a	219.76±7.25 b
2	Cd	1.14±0.08 a	17.74±1.64 b	7.63±0.74 d	11.2±1.26 c
3	Cr	392.82±3.58 a	979.92±14.56 c	1009.89±12.64 d	668.27±7.4 b
4	Co	87.78±5.4 b	112.53±11.24 d	76.66±7.17 a	93.47±9.37 c
5	Cu	11.8±0.85 a	34.84±2.5 d	11.2±2.4 a	21.65±1.49 c
6	Fe	944.47±8.12 c	1018.46±16.23 d	895.17±11.21 b	678.54±14.55 a
7	Hg	8.29±0.95 a	14.08±1.54 c	9.43±0.91 ab	10.96±1.2 b
8	Mg	113.19±5.74 a	210.36±19 c	110.96±8.21 a	119.5±9.1 b
9	Mn	40.11±3.1 b	49.99±12.4 c	44.52±10 b	32.6±0.05 a
10	Ni	4.68±0.54 b	3.31±0.061 a	7.36±0.87 c	6.64±0.5 c
11	Pb	8.4±0.45 a	10.55±0.92 b	8.5±0.6 a	11.25±0.15 b
12	Zn	60.5±2.1 b	50.88±11.5 a	118.8±16.98 c	145.17±7.7 d

One Way ANOVA
$p \leq 0.05$

Conclusion

Since the lichens are excellent bioaccumulators of heavy metals, it is used in the biomonitoring studies as well as to detect the metallic and organic pollutants from the environment. Active monitoring studies have been carried out with different lichen species till date, but this is first study with *Dirinaria applanata*. Also clearly proved that *D. applanata* is a good accumulator compare with the other lichen species. Hence from the present study, it was concluded that the accumulation of heavy metals in the transplanted lichen thallus indicates that Cuddalore city has been highly contaminated with the heavy metals and the levels were above the EPA standards. The higher accumulation of Cr, Cd, Ni and Pb indicates the hazardous status of the study area. Moreover, it is an alarming situation that warrants the need for some safety measures to avoid the environmental pollution.

Acknowledgements

The authors are thankful to Prof. K. Kathiresan, Dean & Director, CAS in Marine Biology, Annamalai University for the help during sample collection in Pichavaram mangroves and Centralized Instrumentation Facility, CASMB, AU for the analyses of heavy metals. Besides, Dr. R. Anburaj & Mr. A. Sathishkumar, CASMB, AU are deeply acknowledged for rendering help during the collection and transplantation of lichens.

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