



AN ASSESSMENT OF AIR QUALITY USING LICHEN DIVERSITY OF DEHRADUN CITY, UTTARAKHAND, INDIA

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ABSTRACT

Lichens are the symbiotic form of two micro-organisms, viz. alga and fungus, and are excellent bioindicators of environmental conditions and climate change in an area. This is an exceptionally successful group of symbiotic organisms, exploiting various habitats and relying on nutrients accumulated from the air. Due to loss of vegetation, vehicular pollution, and other anthropogenic actions, the overall picture of lichen diversity and distribution indicates that most species are pollution tolerant taxa and show their dominance over the sensitive ones. The localities which fall within the city center showed a complete absence of lichens followed by poor growth of pollution tolerant lichens in localities situated in the middle. The peripheral borders had normal growth of both sensitive and tolerant species. This study establishes the utility of lichen diversity and their distribution in long-term monitoring studies, as an effective method for air quality assessment in an area at an almost no-cost basis. It is assumed that any changes occurring in the environment significantly affect the biota. Thus, the data collected on the distribution of lichen flora will act as reference data for conducting biomonitoring studies in the future.

Keywords: Biomonitoring, Lichen diversity, Anthropogenic activities, Air pollution.

INTRODUCTION

Air pollution is a serious global problem. In India, air quality is deteriorated mainly due to unplanned development processes such as growing urban settlements, increasing vehicular activity, and industrial development. A variety of substances, which include greenhouse gases, organic dust, and particulate matter having natural as well as anthropogenic origins are the main cause of polluted air. The two methodologies known for monitoring air pollution are to collect airborne pollutants, precipitation, and total deposits using air samples. This approach is aimed at the quantitative survey of pollutants and provides the temporal and spatial representation of the degree of pollution at different sites. Direct measurement is extremely costly. However, the second method involves employing bio-monitors (bio-accumulators) which are regarded as non-expensive and reliable means of measuring pollution levels in a country or a region. High sensitivity towards changes in climatic conditions in the environment has its utility in assessing air quality

and its impact on lichens provides useful information regarding the environment (Manning et al., 1980).

Since biomonitoring using lichens is a comparatively simple method and no expensive equipment is needed, therefore biomonitoring can be effectively utilized for air quality assessment. The earliest approach to studying the air pollution effects on lichens included plotting selected species on a distribution map. These maps indicated the presence of particular species, abundance, and other qualitative-quantitative factors. In the late '60s and early '70s of the last century, people were started to use solid dots and open circles on the base map to indicate the presence or absence of lichen species respectively.

Beschel (1958) was the first who list 42 species in 5 zones in the Austin cities. Bankman distinguished 15 epiphytic vegetation types distributed along a gradient of species richness, the poorest being connected with towns, mines, and factories of Limburg, Belgium (Barkman, 1963). Skye (1968) identified 5 zones in Stockholm and each zone has a specific level of pollution based on species

combination and distribution⁴. Some other lichen species showing the response to air pollution were taken by Rao and LeBlanc (1967), Hawksworth and Rose (1970), Will-Wolf (2002), Nash and Wirth (1988), Van Haluwyn, and Lerond (1988). Farkas et al (2001) prepared a Lichen map of Kamarom, Northwest Hungary by dividing the whole area into two zones based on lichen Flora. He collected 50 lichen taxa at 84 sites and correlates 50 sites and correlates with the dominating dust pollution.

In the Indian context, various biomonitoring studies have been carried out using higher plants. Though, such studies with lichen have been started lately. Awasthi et. al. explored the flora of lichen from Lalbagh Garden, Bangalore, and reported 22 species (Awasthi and Upreti, 1980). Initially, Das mentioned that lower and higher plants can be used as bioindicators for polluted air. He surveyed the Kolkata streets and revealed the occurrence of lichens in 25 Kolkata streets. The species and population of lichens were found to be negatively correlated to the traffic load on the street. Only the pollutant-resistant lichen, *Parmelia caperata* was found to grow on the roadside trees of Kolkata streets with a traffic load of 25 to 168 vehicles per minute and was devoid of lichens (Das et al., 1986).

Das et al (1986) studied the distribution and growth of 5 lichen species about temperature, humidity, rainfall, and pH of the bark of host trees in the Indian Botanic Garden, Howrah. The pattern of distribution of lichens in the garden was found in 3 concentric zones. The central zone of the garden enjoyed the highest Lichen coverage surrounded by a transitional zone in which lichen coverage was limited, this area may be called the 'struggle zone'. The outer peripheral area which was partly contiguous to roads with high traffic load and partly to Hoogly river with sizable pollution load from the thermal power plant, factories, steamers was devoid of lichens. This area may be called the 'lichen desert'. Mukhtar et al (2009) explored surinsar-mansar wildlife Sanctuary, Jammu, and Kashmir, and reported 30 species of lichens belonging to 18 genera from 14 families. The species belonged to different growth forms (21 crustose, 8 foliose, and 1 fruticose) and are also growing on various substrata (corticolous 17 and saxicolous-13). Nayaka et al. (2003) explored 12 localities of Bangalore city and reported the occurrence of 30 species of lichens belonging to 19 genera and 15 families. Lalbagh Garden and the Indian Institute of Science (IISc) campus, Bangalore

recorded the maximum number of 18 and 24 species of lichen respectively, which are directly attributed to the presence of high vegetation in the area providing diverse substrate for Lichen growth.

Lichen zone is a method used to indicate the severity of pollution concerning distance from sources reflected by the number of species present. The detailed physiological investigation of epiphytic vegetation of cities or larger areas around factories can be used to segregate the area into three, four, or more major lichens zones. Herzig et al (1989) classified the zones corresponding to the degree of injury to lichen flora and level of total air pollution as (Lichen desert – Critical air pollution; Inner struggle zone – Higher air pollution; Outer struggle zone – Medium air pollution; Transition zone – Lower air pollution; and normal zone – very low air pollution).

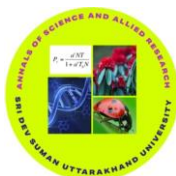
MATERIALS AND METHODS

Study area

Dehradun is bounded in the north by the higher range of lesser Himalayas and in the south, by the younger Shivalik mountain ranges, and at foothills of the Himalayas. It is one of the major halting centers of tourists to visit different holy and tourist places in the northern Himalayan belt. Being the capital city and important tourist destination of Uttarakhand, the vehicular and other human activities are quite high in the area. Hence Dehradun city is currently facing the crisis of poor air quality and related health risks due to anthropogenic activity especially traffic activity, urbanization, and status of the city, while the comparison of present data with earlier records suggests that quick and strict measures should be enforced for the restoration of the air quality.

Collection and Identification

The collection of lichens in Dehradun initiated into its four major areas, viz. northeast, northwest, southeast, and southwest, in a 1 X 1 sq. km grid more than 15 trips were undertaken and 24 localities in all the four major areas of the city were surveyed for collection of lichens. More than 400 specimens were collected and identified which revealed the presence of 23 species of lichen belonging to 17 genera and 12 families. Following Wit (1976) the distribution map for each taxon of lichens collected in the study area was plotted. The distribution of each species was plotted within 21 localities of Dehradun.

**Table 1: Description of the sites selected for the collection of lichens in Dehradun**

1.	Rajpur Road, Jakhan	Road on way to Mussoorie	Moderately polluted	Moderately polluted
2.	Dela Ram Chowk, Rajpur Road	Center of the city	Heavy vehicular activity	Critical pollution level
3.	Kuthalgate	on way to Mussoorie	Moderately polluted	Highly polluted
4.	Old Mussoorie Road, Rajpur	Near Malsi Deer Park	Moderately polluted	Moderately polluted
5.	Shanshahi Ashram	Shanshahi Ashram, Rajpur	Moderate vehicular activity	Moderately polluted
6.	Nalapani Forest, Tapovan	Sal Forest	Dense Forest	Moderate pollution
7.	FRI	Research Institute	Moderate vehicular activity	Moderate pollution
8.	Chakrata Road, Premnagar	Near IMA, periurban area	Moderate vehicular activity	Moderate pollution
9.	Hardwar Road, Mohakampur	Near Railway crossing	Highvehicular activity	Highly polluted
10.	Raipur road	Near Ordnance factory	Moderate vehicular activity	Highly polluted
11.	Saharanpur Road, Majra	Near Hilton's School, connecting road to Delhi	Highvehicular activity	Highly polluted
12.	Daat Kali Temple, Saharanpur road	Location of tunnel near the temple does allow to pollutants to escape	Highvehicular activity	Critical pollution level

Table 2: Toxitolerant species of lichens from Doon Valley

S.No.	Species	Growth form	Substratum
1.	<i>Caloplaca bassaiaea</i> (Wild ex Ach.) Zahlbr	Crustose	<i>Shorea robusta</i>
2.	<i>Dirinaria consimilis</i> (Str iton)	Foliose	<i>Albizia sp.</i> , <i>Shorea robusta</i> , <i>Melia azaderach</i> , <i>Lichi Chinensis</i> , <i>Mangifera indica</i>
3.	<i>Lecanora trop i ca</i> Zahlbr	Crustose	<i>Albizia sp.</i> , <i>Mangifera indica</i>
4.	<i>Lepraria lobificans</i> Nyl.	Leprose	<i>Mangifera indica</i> , <i>Albizia sp.</i> , <i>Shorea robusta</i> , <i>Lichi Chinensis</i> , <i>Pleiogynum Seraciferum</i> , <i>Ficus religiosa</i> , <i>Jacaranda</i> , <i>Greviella robusta</i> , <i>Locat tree</i> , <i>Pinus roxburghii</i> , <i>Cassia sp.</i> , <i>Jalneem</i>
5.	<i>Pertusaria leucostoma</i> (Bernl.)Massal	Crustose	<i>Azadirachta indica</i> , <i>Shorea robusta</i> , <i>Chorisia Speciosa</i>
6.	<i>Phaeophysia hispidula</i> (Ach.) Moberg	Foliose	<i>Albizia sp.</i> , <i>Shorea robusta</i> , <i>Mangifera Indica</i> , <i>Eucalyptus</i> , <i>Jalneem</i> , <i>Syzigium cumunii</i>
7.	<i>Pyxine cocoes</i> (Sw.) Nyl.	Foliose	<i>Shorea robusta</i> , <i>Mangifera Indica</i>
8.	<i>P. sorediata</i> (Ach.) Mont.	Foliose	<i>Mangifera indica</i>

The lichen specimens were collected from the basic requirement for collection lichen specimens is base to chest height of the tree trunks and rocks (stones) a sheath knife, geological hammer, and chisel. A hand

lens (10x) is helpful to avoid overlooking tiny crusts. specimens number date of collection, and name of the
 Collected specimens were placed in polythene bags collector.
 together with details of locality, substratum, altitude,

Table 3: Sensitive species of lichens from Doon Valley

S. No.	Species	Growth form	Substratum
1.	<i>Bacidia personata</i> Malme	Crustose	<i>Albizia sp.</i>
2.	<i>Brigantiaea leucoxantha</i> (Sprengl) R. Sant & Hof n Hof & Bellem	Crustose	<i>Albizia sp., Shorea robusta</i>
3.	<i>Caloplaca pseudosterii</i> Y. Joshi & Upreti	Crustose	<i>Shorea robusta</i>
4.	<i>Cryptothecia lunulata</i> (Zahlbr) Makhi & Patel	Crustose	<i>Shorea robusta</i>
5.	<i>Graphis atrocelata</i> (A. W. Archer) A. W. Archer	Crustose	<i>Jacaranda</i>
6.	<i>Lecanora subpraesistens</i> S. Nayaka & Upreti sp. Nova.	Crustose	<i>Melia azaderach</i>
7.	<i>Opegrapha longula</i> Ach.	Crustose	<i>Cassia sp.</i>
8.	<i>Parmotrema praesoridiatum</i> (Nyl) Hale	Foliose	<i>Albizia sp., Shorea robusta, Melia azaderach, Eucalyptus, Lichi Chinensis, Greviella robusta</i>
9.	<i>Pertusaria quassiae</i> Fee.	Crustose	<i>Jalneem tree</i>
10.	<i>Phyllospora corrolina</i> (Eschw.) Mull. Arg	Foliose	<i>Shorea robusta, Jalneem</i>
11.	<i>Phyllospora haemophaea</i> (Nyl.) Mull. Arg.	Foliose	<i>Greviella robusta, Mangifera Indica</i>
12.	<i>Physia dilatata</i> Nyl.	Foliose	<i>Mangifera Indica</i>
13.	<i>Physia dubia</i> (Hoff.) Lett.	Foliose	<i>Shorea robusta, Eucalyptus</i>
14.	<i>Physia tribacoides</i> Nyl.	Foliose	<i>Jacaranda tree</i>
15.	<i>Vainionora sp.</i>	Foliose	<i>Shorea robusta</i>

Distribution map and lichen zone

The distribution data of lichens based on the occurrence of the lichens collected from all the four areas of Dehradun city are summarized in a single map (Figure 1) clearly differentiating the city into the following three zones (Figure 2). The distribution map of epiphytic lichen vegetation in Dehradun city will act as a baseline record for carrying out future biomonitoring studies in the area. On the basis of the detailed distributional account of epiphytic lichens of the city, the area can be segregated into the following zones:

Zone A: Zone A has no lichen growth except a few samples of *Phaeophyscia hispidula*. This zone represents the center of the city up to 5 km all around with the highest level of pollution due to high vehicular and anthropogenic activities.

Zone B: Zone B represents the middle circle of Dehradun city with scattered trees that exhibits moderate lichen growth and represents an area with a moderate level of pollution.

Zone C: The areas situated on the boundary of the city with rich tree vegetation showing the normal growth of lichens on their trunk and twigs represent a pollution-free area of the city.

The distribution pattern of lichen taxa collected from four major areas of the city distinctly separated the city into three distinct zones (figure 2). The inner zone is the lichen desert having few specimens of *Phaeophyscia hispidula* and *Lepraria lobificans*. The middle zone has moderate growth of lichens and the outer zone has a good growth of lichens which is attributed to the presence of vegetation and less vehicular activity. The lichen distribution varies in all the four major areas of the city, therefore lichen



distribution in each area are discussed separately as follows:

Table 4: List of abbreviations of lichen species used in the distribution map

S.No.	Taxa	Abbreviations
1.	<i>Bacidia personata</i> Malme	B
2.	<i>Brigantiaea leucoxantha</i> (Sprengl) R. Sant & Hof n Hof & Bellem	B ₁
3.	<i>Caloplaca bassaiaea</i> (Wild ex Ach.) Zahlbr	C ₁
4.	<i>Caloplaca pseudosterii</i> Y. Joshi & Upreti	C ₂
5.	<i>Cryptothecia lunulata</i> (Zahlbr) Makhi & Patel	Cr
6.	<i>Dirinaria consimilis</i> (Str iton)	D
7.	<i>Graphis atrocelata</i> (A. W. Archer) A. W. Archer	G
8.	<i>Lecanora subpraesistens</i> S. Nayaka & Upreti sp.Nova.	L ₁
9.	<i>Lecanora tropica</i> Zahlbr	L ₂
10.	<i>Lepraria lobificans</i> Nyl.	L _p
11.	<i>Opegrapha longula</i> Ach.	O
12.	<i>Parmotrema praesorediosum</i> (Nyl.) Hale	P
13.	<i>Pertusaria leucostoma</i> (Bernl.) Massal	P ₁
14.	<i>Pertusaria quassiae</i> Fee.	P ₂
15.	<i>Phaeophyscia hispidula</i> (Ach.) Moberg	Ph
16.	<i>Phyllospora corrolina</i> (Eschw.) Mull. Arg.	Pl ₁
17.	<i>P. haemophaea</i> (Nyl.) Mull. Arg.	Pl ₂
18.	<i>Physia dilatata</i> Nyl.	Ps ₁
19.	<i>P. dubia</i> (Hoff.) Lett.	Ps ₂
20.	<i>P. tribacoides</i> Nyl.	Ps ₃
21.	<i>Pyxine cocoes</i> (Sw.) Nyl.	Py ₁
22.	<i>P. sorediata</i> (Ach.) Mont.	Py ₂
23.	<i>Vainionora</i> sp.	V

Lichen distribution in North-East Area

The northeast area (Figure 3) between the distance of 1 km north and 1 km east is completely devoid of any lichen growth, due to the fast pace of urbanization and heavy vehicular activity in the area. Tolerant lichen *Phaeophyscia hispidula* is collected from Rajpur road at 1 Km east and 1 Km north found growing on a bark of a tree near St. Joseph's Academy, Hotel Ajanta Continental, and near Kalhan Hospital. In the north direction, the grid 2 Km north and 1 Km east (Hathibarkala) is comprised of some scattered trees of *Ficus*, *Albizia*, and *Mango* which exhibit the occurrence of tolerant species *Phaeophyscia hispidula* and *Lepraria lobificans*. In the north direction, the grid 3 Km north (Garhi Cantt) has orchards of Mango and Litchi along with roadside trees of Locat and *Ficus* which exhibit the occurrence

of *Phaeophyscia hispidula*, *Lepraria lobificans*, and *Parmotrema praesorediosum*. The grid 3 km north and 2 Km east (Jakhan) comprised of scattered Mango and Litchi trees along with roadside trees of *Jacaranda*, *Albizia*, *Azadirachta*, and *Ficus* species which exhibit the presence of *Phaeophyscia hispidula*, *Lepraria lobificans*, *Pertusaria leucostoma* and *Pertusaria quassiae*.

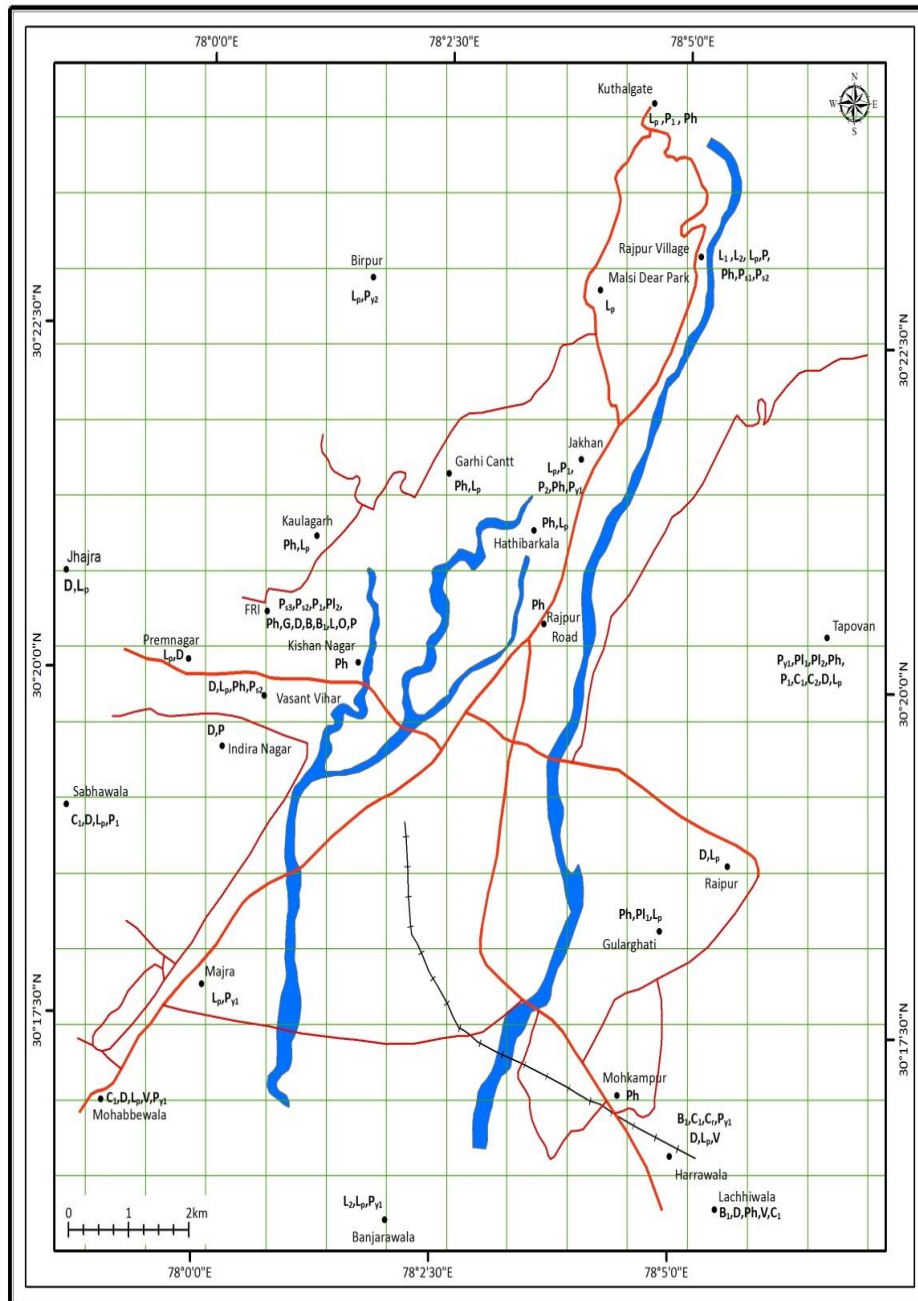
The grid 6 Km north and 3 Km east (Malsi dear park) is comprised of mixed tree vegetation which exhibits the occurrence of tolerant *Lepraria lobificans*. On the other hand, the grid 7 Km north and 4 Km east (Rajpur Village) comprised of Mango and Litchi trees along with roadside plantation of *Acacia*, *Albizia*, *Azadirachta* which exhibit the occurrence of both tolerant (*Lepraria lobificans*, *Phaeophyscia hispidula*, *Lecanora tropica*, and *Pyxine cocoes*) and

sensitive species (*Lecanora subpraesistens*, *Parmotrema praesordiosum*, *physcia dilatata*, and *P. dubia*).

The grid 9 Km north and 4 Km east (Kuthalgate) comprised of the dense forest of *Shorea robusta* along with scattered trees of mango, *Ficus*,

Azadirachta exhibit the luxuriant growth of many lichen species such as *Pyxine cocoes*, *Phyllospora corralina*, *Phyllospora haemophae*, *Phaeophyscia hispidula*, *Pertusaria leucostoma*.

Figure 1: Map showing distribution of a lichen species collected from different sites of Dehradun city



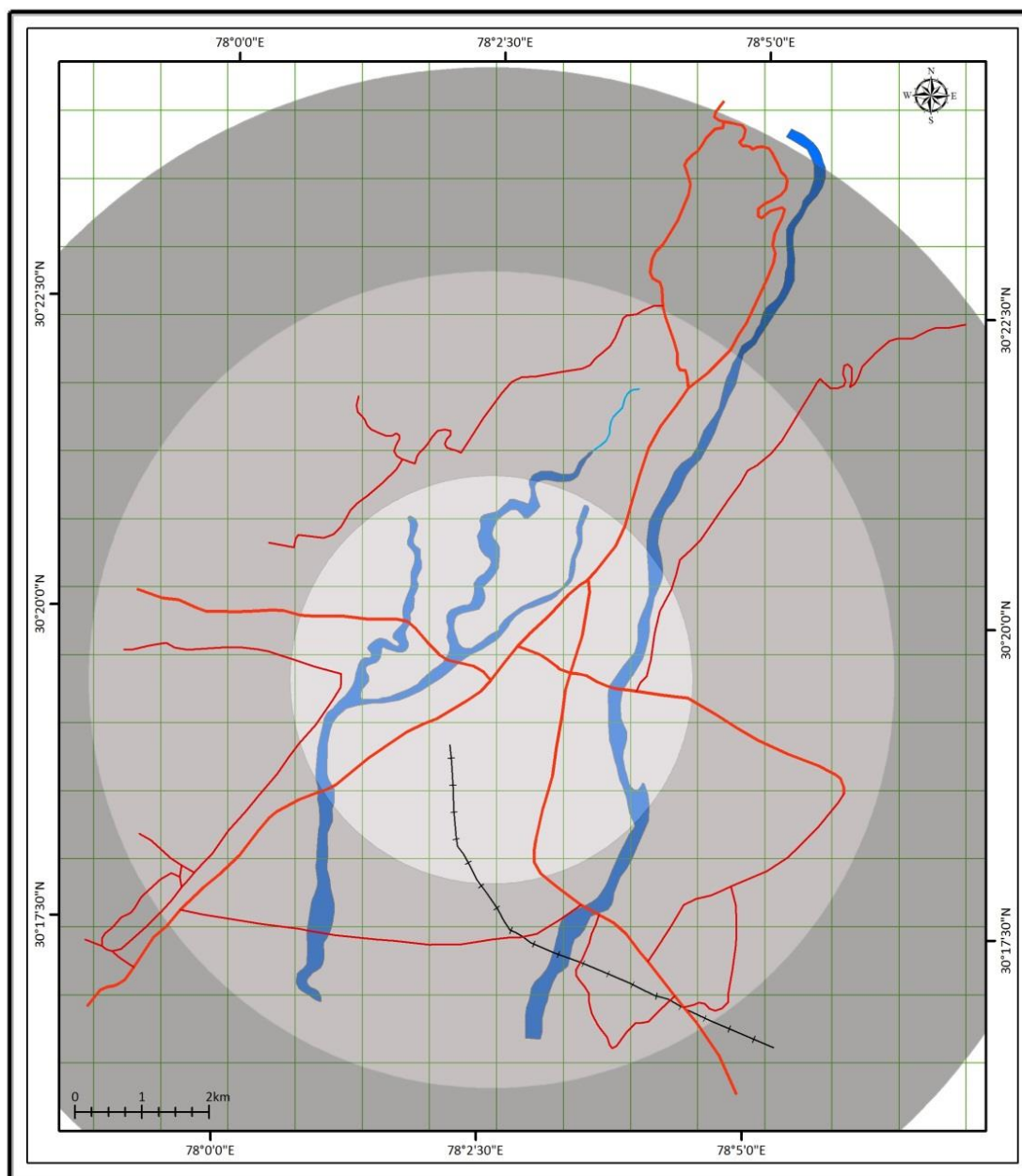


Figure 2: Map showing different lichen zones of Dehradun city

In the east direction, the grid 7 Km east and 2 Km north (Tapovan) comprised of the dense forest of *Shorea robusta* mixed with scattered trees of *Mango*, *Ficus*, *Azadirachta* which exhibit the luxuriant growth of many lichen species such as *Pyxine cocoes*, *Phyllospora corralina*, *Phyllospora haemophae*, *Phaeophyscia hispidula*, *Pertusaria leucostoma*, *Caloplaca bassiae*, *Caloplaca pseudisterii*, *Dirinaria consimilis*, and *Lepraria lobificans*.

Lichen distribution in North-West Area

In the north direction (figure 4) the grid 2 km west (Kishan Nagar) comprised of some scattered trees of *Mango* which exhibit the growth of toxitolerent species *Phaeophyscia hispidula*. The grid 3 Km. north and 2 Km. west (Kaulagarh) comprised of scattered trees of *Mangifera indica*, *Litchi chinensis*, and *Syzygium cumunii* which exhibit the growth of toxitolerent lichen

species such as *Lepraria lobificans* and *Phaeophyscia hispidula*. In the north direction the grid 7 km. north and 1 km. west (Birpur) has mixed forest shows the presence of *Lepraria lobificans* and *Pyxine sorediata*. In the west direction the grid 4 km. west (Vasant Vihar) comprised of scattered trees of Mango, Litchi along with roadside plantations of mixed trees which exhibit the presence of *Dirinaria consimilis*, *Lepraria lobificans*, *Phaeophyscia hispidula*, and *Physcia dubia*.

The grid 4 km west and 1 km north (FRI campus) comprised of plant diversity which exhibits the luxuriant growth of lichen species such as *Physcia dubia*, *P.tribacoides*, *Pertusaria leucostoma*, *Pyxine cocoes*, *Phyllospora haemophae*, *Phaeophyscia hispidula*, *Graphis atrocelata*, *Dirinaria consimilis*, *Bacidia personata*, *Brigantiaea leucoxantha*, *Lepraria lobificans*, *opographa longula*, and *Parmotrema praesoridiosum*. The grid 5 km west (Premnager) having scattered trees of *Mango*, *Ficus*, *Eucalyptus*, and *Lichi* exhibit the occurrence of *Lepraria lobificans* and *Dirinaria consimilis*. The grid 7 km west and 2 km. north (Jhajra) comprised of mixed trees of *Eucalyptus*, *Azadirachta indica*, *Mangifera indica*, and *Shorea robusta* which exhibit the presence of *Dirinaria consimilis* and *Lepraria lobificans*.

Lichen distribution in South-East Area

The southeast area (figure 5) is completely devoid of any lichen growth upto 2 km. east and 2 km. south due to heavy vehicular activity and urbanization. In the south direction the grid 5 km. south and 2 km. east (Mohakampur) has some scattered trees which exhibit the growth of highly toxitolerant *Phaeophyscia hispidula*.

The grid 6 km south and 3 km. east (Harrawala) comprised of patches of *Shorea robusta* trees along with *Eucalyptus*, *Mango*, and *Azadirachta indica* which exhibit the occurrence of *Brigantiaea leucoxantha*, *Caloplaca bassiae*, *Cryptothecia lunulata*, *Dirinaria consimilis*, *Lepraria lobificans*, *Vainionora sp.* and *Pyxine cocoes*. The grid 7 km south and 4 km east (Lachhiwala) has a dense forest of *Shorea robusta* trees along with some other trees that exhibit the occurrence of *Brigantiaea leucoxantha*, *Dirinaria consimilis*, *Phaeophyscia hispidula*, *Caloplaca bassiae*, and *Vainionora species*. In the east direction the grid 3 km. east and 3 km. south (Gularghati) has some scattered trees of *Litchi Chinensis*, *Azadirachta indica*, *Mangifera indica*, and *Syzygium cumunii* which exhibit the occurrence of *Phaeophyscia hispidula*, *Phyllospora corralina*, and *Lepraria lobificans*. The grid 6 km east

and 2 km south (Raipur) has scattered patches of *Shorea robusta* trees which exhibit the growth of *Dirinaria consimilis* and *Lepraria politicians*.

Lichen distribution in South-West Area

The grid 3 km. south and 4 km. west (Majra) has some scattered trees of *Mango*, *Lichi*, *Ficus* and *Azadirachta* which exhibit the growth of *Lepraria lobificans* and *pyxine cocoes* (figure 6). In the west direction the grid 3 km. west (Indira Nagar) comprised of patches of *Shorea robusta* trees which exhibit the occurrence of *Dirinaria consimilis* and *Parmotrema praesoridiosum*. The grid 5 km south and 6 km west (Mohabbewala) comprised of dense forest of *Shorea robusta* which shows the presence of *Caloplaca bassiae*, *Dirinaria consimilis*, *Lepraria lobificans*, *Vainionora* and *Pyxine cocoes*.

In the south direction 7 km. south and 2 km west (Banjarawala) having some scattered trees exhibit the occurrence of *Lepraria lobificans*, *Lecanora tropica* and *Pyxine cocoes*. The grid 8 km. west and 2 km. south (Sabhawala) comprised of good growth of *Shorea robusta* trees which exhibit the presence of *Dirinaria consimilis*, *Caloplaca bassiae*, *Lepraria lobificans* and *Pertusaria leucostoma*.

RESULT AND DISCUSSION

Biological monitoring can be very effective as an early warning system, to detect environmental changes. This approach is based on the assumption that any changes taking place in the environment have a significant effect on the biota. Thus, the present enumeration and distribution of lichens will act as baseline data for conducting biomonitoring studies in the valley in the future. The members of the family Physciaceae are well-known pollution tolerant lichens. The dominance of crustose lichens together with members of Physciaceae clearly indicates that the Doon valley has a polluted environment. Among the different sites of the Doon valley the Forest Research Institute (FRI) and Tapovan, Nalapani has the highest lichen diversity due to less pollution than the sites situated within the city. Distribution maps of *Lepraria lobificans*, *Phaeophyscia hispidula*, and *Dirinaria consimilis* clearly indicate their luxuriant growth within and around the city as those taxa are reported from almost all the sites surveyed for collection.

The total number of epiphytic lichens increased with increasing distance from the center of the city. *Phaeophyscia hispidula* and *Lepraria lobificans* are the species that are found to be grown on roadside trees at the city center points like Kishan Nagar Chowk, Near Ballupur Chowk, Chakrata Road,

Ashok Park, and Near Hiltons School, Majra, Saharanpur Road and near St. Josephs Academy and Ajanta Continental, Rajpur Road. These localities are situated within the city and these roads have more traffic and other anthropogenic activities. So, both species are found to be much tolerant against air pollution.

The Forest Research Institute (FRI) campus and Nalapani Sal Forest Tapovan were found to have a large number of lichen diversity. Out of 23 lichen taxa 10 lichen species were collected from FRI and 9 lichen species were collected from the reserve forest of Nalapani, Tapovan. These sites are moist and shady with dense patches of trees, providing favorable habitat for the growth of lichens. Saxicolous lichen *caloplaca bassiae* was found to be grown on stones and rock in Nalapani reserve forest, Tapovan.

The urbanization and anthropogenic activity in the study area played a vital role in the distribution of

lichen. The sites within the range of 2-5 km all-round the center of the city were devoid of epiphytic lichen growth due to a high degree of vehicular activity and lack of tree vegetation yet occurrence of *Lepraria lobificans* and *Phaeophyscia hispidula* was recorded from some city center points. Rajpur Road, Kishen Nagar Chowk, Ballapur Chowk, Chakrata Road. The maximum number of species were recorded from outskirts sites such as Tapovan, Mohabbewala, Lachhiwala, Harrawala, and Forest Research Institute Campus. The occurrence of the maximum number of species in outskirts sites of Dehradun city can be directly attributed to an abundance of reserve forests, different kinds of trees, low vehicular activity, and less anthropogenic activity. The moist and shady condition in these areas also provides suitable habitat for lichen growth.

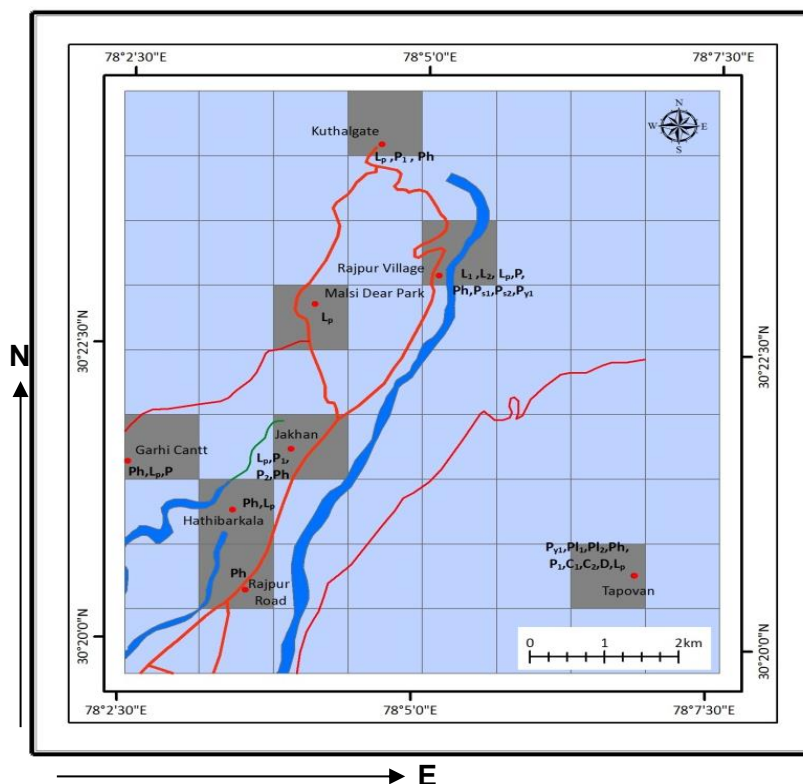


Figure 3: Map showing distribution of lichens in north-east areas of Dehradun city

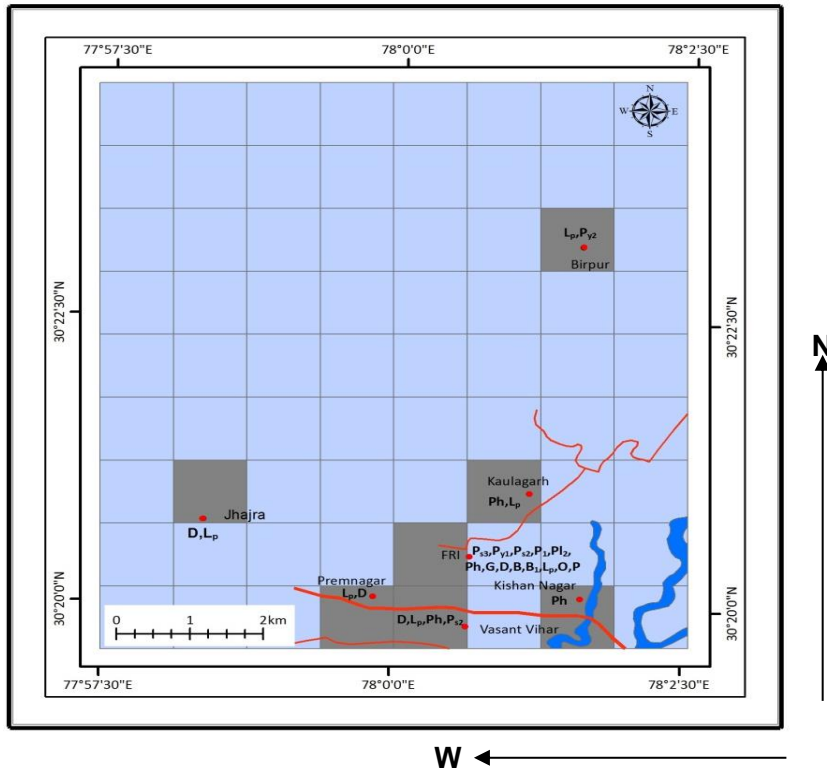


Figure 4: Map showing distribution of lichens in north-west areas of Dehradun city

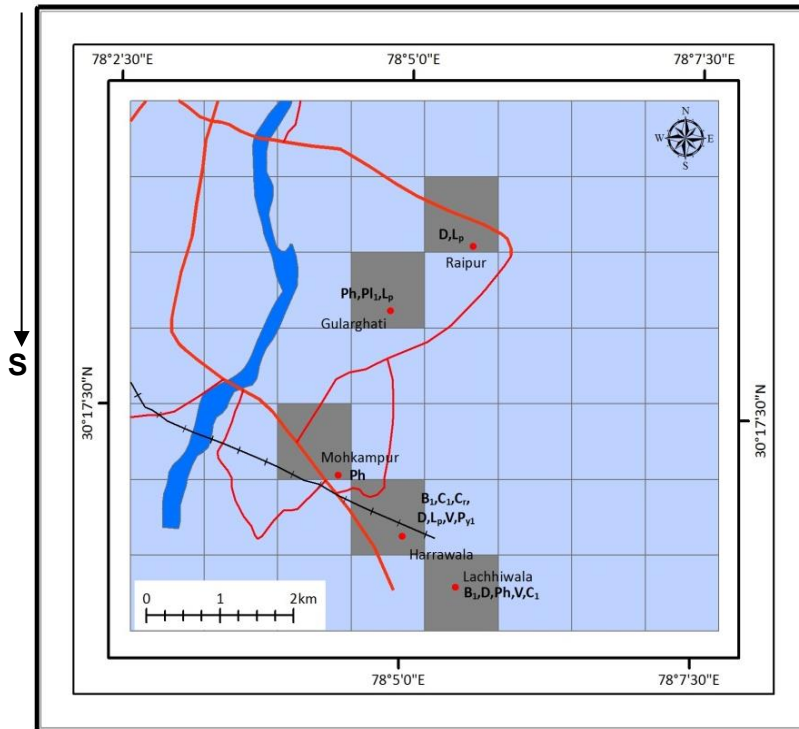


Figure 5: Map showing distribution of lichens in south-east areas of Dehradun city

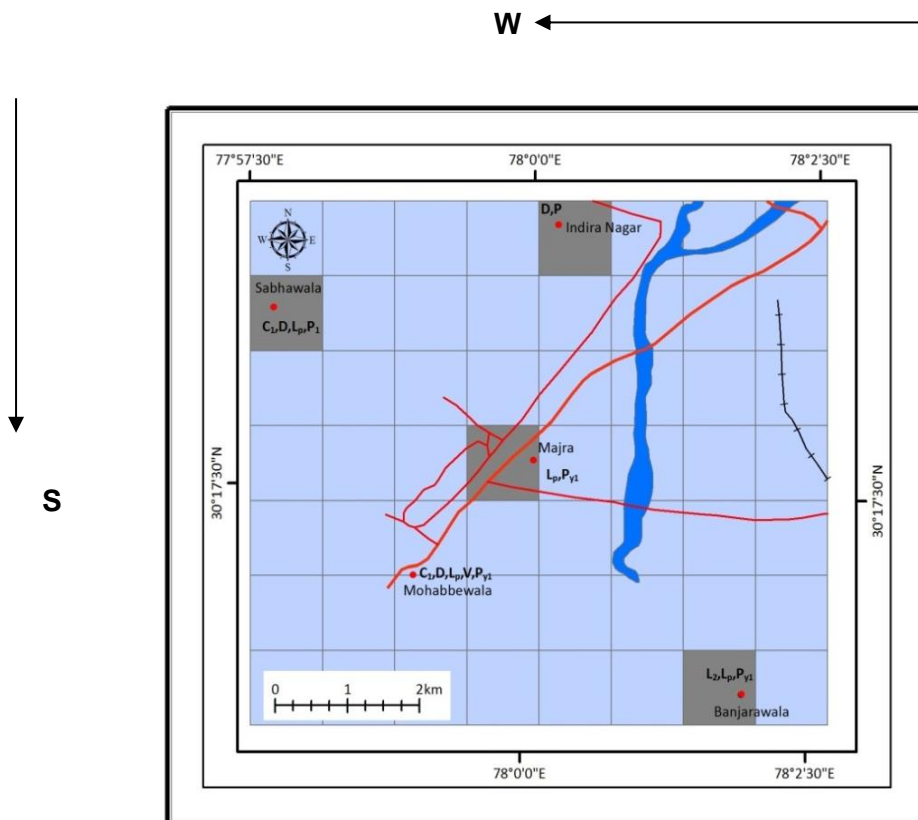


Figure 6: Map showing distribution of lichens in south-west areas of Dehradun city

The sources of air pollution within the study area varied according to sites. Vehicular activity is the main source of pollution in the area. It is clear from the study that air pollution is not equally spread throughout the city. The city center has higher vehicular activity and lack of vegetation leads to more pollution than the outskirts areas of the city. The distribution pattern of lichen taxa collected from four major areas of the city indicates the separation of the city into three distinct zones. Zone A has no lichen growth (Lichen Desert). Being the center point of the city zone A experiences heavy vehicular activity. Zone B is characterized by some pollution tolerant species like *phaeophyscia hispidula*, *Lepraria lobificans*, *Dirinaria consimilis*, etc. Zone C of the city exhibits normal growth of epiphytic lichen taxa (Crustose and foliose). Areas within Zone C are situated on the boundary of the city and experience almost low or non-polluted air. The distribution maps clearly indicate the lichen rich, moderate, and poor sites of

Dehradun. Based on the distribution map the species of the study area can be categorized into two groups; pollution tolerant species and pollution sensitive species.

Conclusion

It is clearly evident from the map that the center part of the city is entirely lacking lichen vegetation except for some samples of *Phaeophyscia hispidula* and *Lepraria lobificans*, followed by the area with moderate lichen growth on some scattered mango, lichi, and some other trees. The rich lichen vegetation occurs in the outskirt areas. The maximum number of species were recorded from outskirt sites such as Tapovan, Mohabbewala, Lachhiwala, Harrawala, and Forest Research Institute Campus. The occurrence of the maximum number of species in outskirt sites of Dehradun city can be directly attributed to the abundance of reserve forest, different kinds of trees, low vehicular activity, and less anthropogenic activity.

The moist and shady condition in these areas also provides suitable habitat for lichen growth.

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