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LICHENS AS BIOINDICATORS OF AIR POLLUTION FROM VEHICULAR EMISSIONS IN DISTRICT POONCH, AZAD JAMMU AND KASHMIR, PAKISTAN

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Abstract

In the present study epiphytic lichen mapping was done by Index of Atmospheric Purity (IAP) for the assessment of impact of vehicular pollution on lichen diversity in the Hajira city and its north sites of District Poonch Azad Jammu and Kashmir, Pakistan. Vehicular emission is one of the sources of air pollution in the cities. Six transects and 25 sites (4 sites each 5km distance/transect with Hajira City (HC at 0km) as common site were selected for the present study. It is recorded that on increasing distance from the HC lichens diversity also increased. Lowest IAP value 38 at 0 km and highest 145 at 15 or 20 km distance was recorded. However some sites at a distance of 20 km showed decreased trend in lichen taxa because of undulating topography, change in zonation with changes in selection of trees and wind pattern. In the data higher IAP value indicated better air quality. A total of 42 lichens species were recorded from the study sites. Based on Ecological Index (Q), *Ramalina fraxinia, Flavoparmelia flavientior, Xanthoria ucrainica, X. candelaria, Parmelia minarum, Physconia grisea, Parmelina carporrhizans, Parmelia squarrosa, P. succinata P. hyperopta, Bulbothrix laevigatula, Hypogymnia physodes, Melanelixia fulginosa, Lepraria finkii, etc.,* were sensitive in response to air pollution in the study area. It is concluded that IAP is a good approach in determination of air quality using bioindicators. This method proved simple, quick and cheap and vast areas are surveyed in a relatively short time at a relatively low cost.

Key words: Air pollution, Vehicular emission, Lichens diversity and distribution, AJK.

Introduction

Lichens are symbiotic organisms that are formed by mutual relationship of algae and fungi. Mostly Ascomycota (98%) is fungal partner in lichens (Gilbert, 2000; Honegger, 1991) and the others belong to the Basidiomycota and anamorphic fungi. Approximately 21% of all fungi are able to act as a mycobiont (Honegger, 1991), thus lichens form the largest mutualistic group among fungi. In lichen formation only 40 genera are involved as photosynthetic partners: 25 from algae and 15 from cyanobacteria (Kirk *et al*., 2008). The photobionts in approximately 98% of lichens are not known at the species level (Honegger, 2001). Fungus give support and safety, fascinate moisture and assemble minerals from air. In return fungi get organic matter formed by algae through photosynthesis (Piervittori, 1999). Lichens comprise about 18, 500 species (Boustie & Grube, 2005; Feuerer & Hawksworth, 2007; Kirk *et al*., 2008). Since 1983, the name of lichen refers to its mycobiont (Voss *et al*., 1983). Lichens produce their own food by using sunlight (Henderson, 1994). Lichens are frequently found on tree stems, twigs and branches and its bark offers a suitable place to collect rainwater and materials from the air and required sunlight (Gustafsson *et al.,* 2004). However, it was reported that forest habitat affect lichens distribution (Sevgi *et al.,* 2016).

The feature of air quality is getting worse in the world. Air pollution does not mean air quality. Air pollution is concerned with pollutants while air quality states to the consequence of contaminants on a diversity of matters containing all living organisms (Nimis *et al*., 1991). Some critical pollutants are not basically measured by physical and chemical assessments because devices and laboratory equipment are used to measure inadequate pollutants for quick and cheap determination. Organisms give response to different pollution level is bioindicator. It states the ability of organism to point out the occurrence and amount of contaminants in atmosphere (Nimis *et al*., 1993). The occurrence and absence of lichens and diverse species around different pollution sources has been used for problems associated to air pollution (Jovan, 2008). Besides their biological properties (Rankovic & Kosanic, 2012), lichens are probably amongst the most suitable bioindicators to determine atmospheric quality based on physiological and morphological characters (Nimis & Mertellose, 2002). Lichens are reliable according to their morphology as lichen grow slowly, long-lasting and are not able to shed their parts during growth. They have no roots and other protected tissues for example cuticle or stomata they absorb any component passively found in atmosphere by particulate deposition or by rain (Costa *et al.,* 2002).

Atmospheric pollution is monitored by lichens and the biological effect of air pollution is determined by diversity and the mapping of lichen. Epiphytic lichen vegetation is influenced by Nitrogen (Cislaghi & Nimis, 1997). Lichen Diversity Values (LDVs) and Index of atmospheric purity (IAP) has been adopted to evaluate and monitor environmental variation in relation to the effect of atmospheric pollution in many European countries (Gombert *et al.,* 2004). IAP, a quantitative approach, employing a mathematical calculation is best known method to evaluate the effect of pollution on epiphytic lichens (Svoboda, 2007). An experiment was designed by Deruelle (1978) proved the validity of this index to monitor SO2 pollution in western France. The technique has also been utilized to monitor hydrogen fluoride around an Aluminium refinery in Arvida, Quebec (LeBlanc *et al*., 1972). IAP is frequently used for gathering information about pollution tolerance species and their spatial variation of abundance (LeBlanc & De

Sloover, 1970), and reflects a gradation of lichen species richness from "good" (high diversity) to "worst" (low diversity) (Kricke & Loppi, 2002) and sums up the effects of long term environmental conditions. LDVs have been proposed as a repeatable assessment of lichen. IAP was first proposed by Le Blanc and De Sloover which is a popular dex applied to lichens for monitoring atmospheric pollution in1970. Based on vehicular emission and their pollutants problems in the city areas of Azad Jammu and Kashmir (AJK) as well as to launch a cheap method for determining air quality the present study was designed to check the feasibility of epiphytic lichens as bioindicators and effects of vehicular emission on lichens diversity in the area. The significance of lichen as pollution indicator species, the approach used for present study was simple, fast and inexpensive. It allowed advanced sampling intensity. The overall objective of this study was to determine whether lichen flora vigour with increasing distance from the city centre of Hajira to its allied areas of District Poonch Azad Jammu and Kashmir, Pakistan.

Materials and Methods

Study area: Hajira is located in District Poonch Azad Jammu & Kashmir, Pakistan at latitude 33° 46′ 18.12″ N, longitude 73° 73° 53′ 45.96″ E and an altitude of 3168 feet. It is 142 kilometres from Islamabad, Pakistan and 27 kilometers from Rawalakot. Total area & Population of District Poonch is 855 Sq. Kms and 0.411 million. The population of Hajira is approximately 0.1 million. This town is located in a narrow valley surrounded by hills on the bank of Rangar stream. It is the closest town from the Indian occupied Kashmir, especially Poonch. For the present study Hajira city and its north sides of District Poonch were selected. There were 25 sites falling on six transects (A, B, C, D, E, F) diverging from city to its adjoining north sides. Hajira was the common site for all transects (Fig. 1). Each transect was 20 km long and separated by an angle of $30^{o.}$ Four sites (i, ii, iii, iv) were located on each transect at the distance of 5 km approximately and area of each site was 1 km^2. Methodology adopted is largely based on the German guidelines with few modifications for selection of sampling trees (Anon., 1995). These sites were selected on the basis of high, moderate and low traffic densities. City centre reflects the high traffic density.

Lichen sampling: Ten to twelve common trees in each site were randomly selected for the sampling except some variations in selection of vegetation at high altitudes (Table 1). Area of tree trunk ranging between 0.5 m from the base to 1.5 m height. A 250 cm^2 (25cm X 10cm) quadrate on the trunk of each tree was used to calculate coverage and frequency of lichens (Anon., 1995). Lichens species found within the gird, number of individuals of each species and the number of gird units in which a particular species was also recorded.

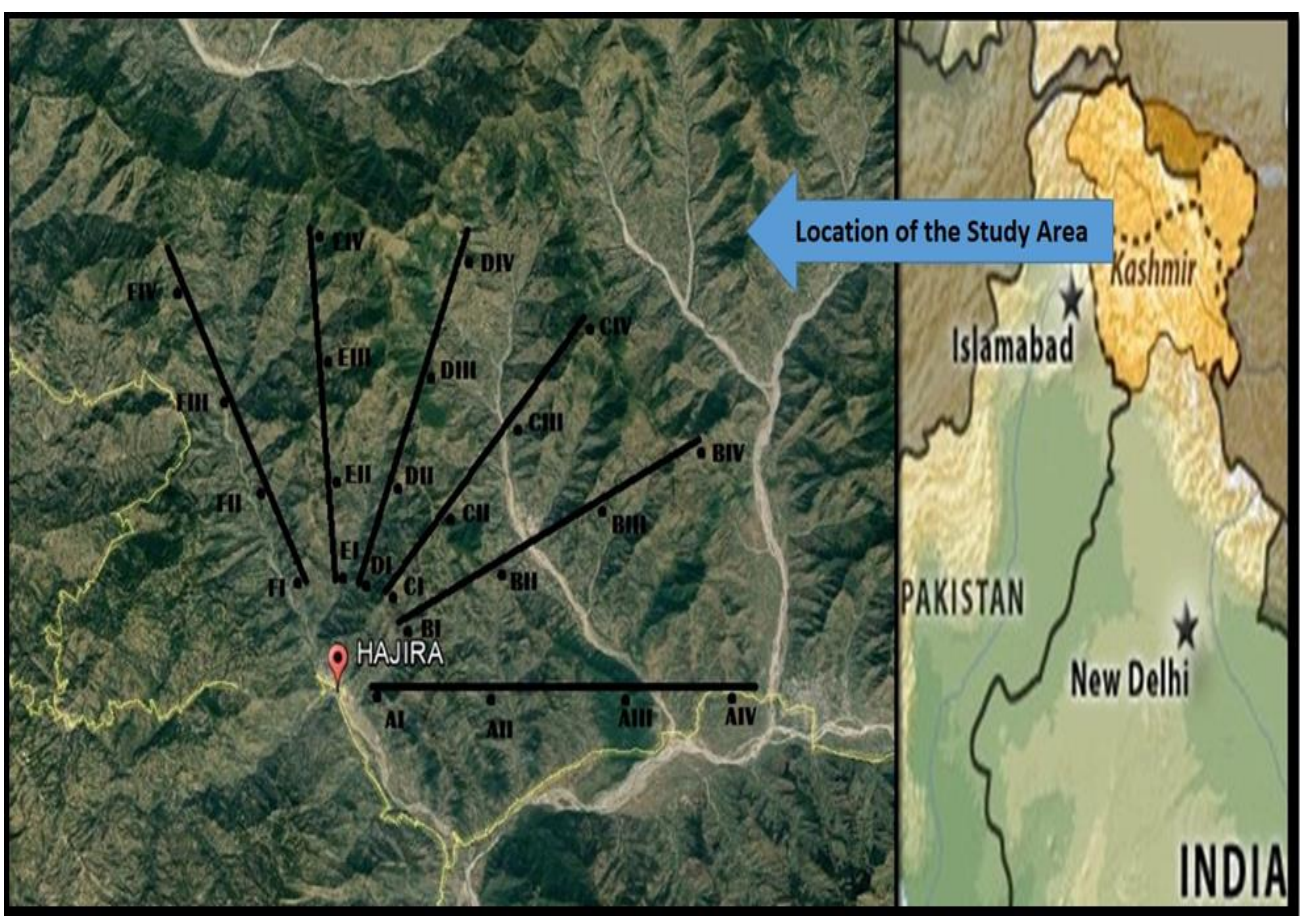

Fig. 1. Map of the surveyed area showing locations of 25 sites studied. Hajira city (HC) is located at an altitude of 1050 m above sea level at $33^0$46”21.82 North Latitudes and $73^0$53”40.54 East Longitude.

Table 1. List of tress of the studied area.

	Plants	Families	Orders
1.	*Abies pindrow* (Royle)	Pinaceae	Pinales
2.	*Ailanthus altissima* (Mill.)	Simaroubaceae	Sapindales
3.	*Cinnamomum camphora* (L.)	Lauraceae	Laurales
4.	*Aesculus indica* (Wall.)	Sapindaceae	Sapindales
5.	*Morus alba* (L.)	Moraceae	Rosales
6.	*Olea ferruginea* (Royle)	Oleaceae	Lamiales
7.	*Pinus roxburghii* (Sarg)	Pinaceae	Pinales
8.	*Pinus wallichiana*	Pinaceae	Pinales
9.	*Populus ciliate* (Wall.)	Salicaceae	Malpighiales
10.	*Prunus armaniaca* (L.)	Rosaceae	Rosales
11.	*Pyrus communis* (L.)	Rosaceae	Rosales
12.	*Pyrus pashia* (L.)	Rosaceae	Rosales
13.	*Quercus incana*	Fagaceae	Fagales
14.	*Salix tetrasperm* (Roxb.)	Salicaceae	Malpighiales
15.	*Ulmus nitida* (L.)	Ulmaceae	Rosales

Identification of lichens: All collected lichens were identified on the base of morphology and chemical test. The dissecting binocular microscope was used for the study of external morphology. The lichen substances were identified by performing color spot test standardized methodology . Identification was completed by evaluation of the morphology and biochemical test results with identification keys and published literature (Nash III, 1996; Hale, 1979; Herre, 1963; Sipman, 2005). Scientific naming and citations were further confirmed by online database Index Fungorum.

Lichen diversity index: Shannon's diversity index was adopted for determining diversity of lichen of each site (Batten, 1976).

$$H' = - \Sigma\, pi\, (\log pi)$$

where, H' = Diversity pi = the proportional abundance of the ith species. There were four lichen diversity classes such as low diversity, moderate diversity, high diversity and very high diversity.

Registration of lichens: Coverage and frequency of lichens were recorded by placing 250 cm^2quadrate randomly on boles of trees.

Index of atmospheric purity: IAP index was calculated by following equation (Le Blanc & De Sloover, 1970).

$$IAP = 1/10\sum_{i=1}^{n} (Qi \times fi)$$

where n = Number of species recorded

Q = Ecological index (i.e. the average number of species, which coexisted with each species) f = Cover and frequency of each species.

Deposition of lichen taxa: Lichens were deposited in the Herbarium of Department of Botany, Azad Jammu & Kashmir University, Muzaffarabad after assigning voucher specimen number.

Statistical analysis: Obtained data were analysed by using Microsoft Excel software. Results were statistically analysed by using multivariate ordination programs including Detrended Correspondence Analysis.

Results

Lichens taxa: The present study revealed the presence of total 41 species of epiphytic lichens representing 5 orders and 8 families at 25 sites of district Poonch Azad Jammu and Kashmir. Common orders were Lecanorales, Teloschistale, Candelariales, Capnodiales and Peltigerales (Table 2). Commonly represented families were Parmeliaceae, Teloschistaceae, Stereocaulaceae, Candelariaceae, Lobariaceae, Biatorellaceae and Ramalinaceae. Parmeliaceae was the dominated family (25 species) followed by Teloschistaceae (6 species), Stereocaulaceae (3), Physciaceae (2), Candelariaceae, Lobariaceae, Biatorellaceae, Ramalinaceae 1 species each and 1 unknown family (Fig. 2A). From 18 genera, *Parmelia* was the dominant genus with 13 species, followed by *Xanthoria* with 5 species, *Flavoparmelia* 4, *Lepraria* with 3, *Parmelinopsis, Parmotrema* with 2 each and *Biatorella, Bulbothrix, Candelaria, Cystocoleus, Hypogymnia, Melanolaxia, physia, Physconia, Parmelina, Pseudosypholaria, Xanthoparmelia, Ramalina* with 1 each respectively (Fig. 2B).

Lichens frequency: Recorded lichen can be placed into one of the three groups based on the frequencies/ coverage of their presence (Table 3).

1. Two abundant lichens such as *Parmelia saxatilis* and *P. sulcata* were found on more than 50% of tree sampled.

2. Three less common species such as *Lepraria incana, Flavoparmelia caperata* and *Candelaria concolor* on 20-50% of tree sampled.

3. A total of thirty six infrequent species, including rare species with an occurrence below 20% were recorded. There were also thirty four taxa with occurrence below 10% (Table 3). There were variations in coverage of epiphytes on different tree in different species and in different sampling plots. However, species with maximum frequency showed also maximum coverage. The most frequent recorded lichen in 25 sampling plots was *Parmelia saxatilis* with frequency (84%) had the coverage area of (784) (Table 3).

Ecological index (q) of recorded lichens species: The tolerance or sensitivity of a species was determined by ecological index (Q) ('low Q, high tolerance' and 'high Q, low tolerance'). Results showed that ecological index (Q) ranges from 2 to 42 (Table 4). *Parmelia saxatilis, P. sulcata* along with *Candelaria concolor* showed lowest Q values viz. 2, 3 and 3.5. This showed that these three lichen species were dominating the study sites. Other species such as *Lepraria incana, Parmelia omphalodes, Parmelionpsis minarum, Biatorella monasteriensis, Parmelia baltimorenses, P. hyperopta, P. squarrosa, F. flavientior, Parmelinopsis minarum, Xanthoria candelaria, X. parietina* and *X. ucrainica* showed values of Q ranges from 6 to 21. Remaining 26 lichen species had high Q value of 42 represented rare species of study sites (Table 4).

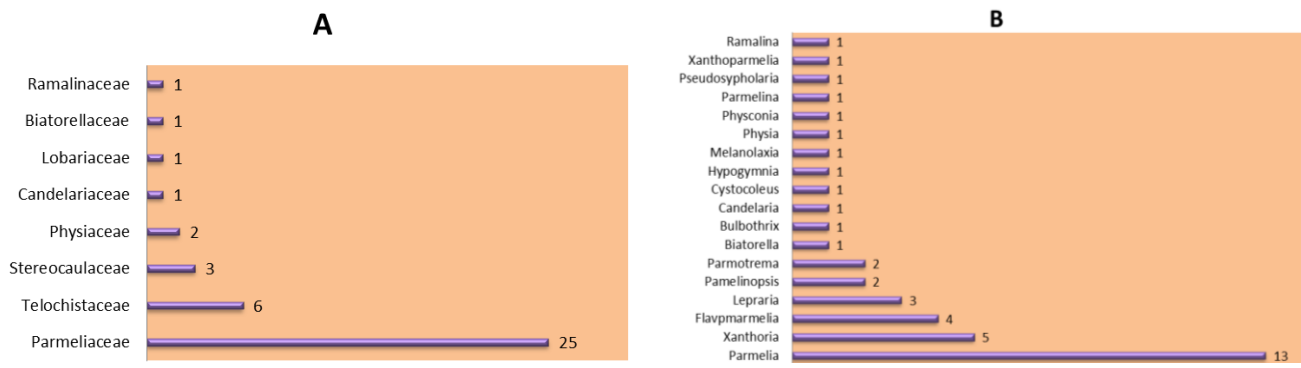

Fig. 2. Number of species of lichens in each family (A), Number of species of lichens in each genus (B) at different study sites.

Table 2. List of Epiphytic lichens with order, family and growth form of the study area.

S. No.	Lichen taxa	Voucher specimen No.	Order	Family	Growth form
1.	*Biatorella monasteriensis* (J. Lahm ex Korb.)	Naz 2000 BHUAJK	Lecanorales	Biatorellaceae	Crustose
2.	*Bulbothrix laevigatula* (Nyl.)	Naz 2001 BHUAJK	Lecanorales	Parmeliaceae	Foliose
3.	*Candelaria concolor* Dicks.	Naz 2002 BHUAJK	Candelariales	Candelariaceae	Crustose
4.	*Cystocoleus ebeneus* Dillwyn	Naz 2003 BHUAJK	*Capnodiales*	Not assigned	Filamentous
5.	*F. caperata* L.	Naz 2005 BHUAJK	Lecanorales	Parmeliaceae	Foliose
6.	*F. flavientior* Nyl.	Naz 2006 BHUAJK	Lecanorales	Parmeliaceae	Foliose
7.	*F. soredians* Nyl.	Naz 2007 BHUAJK	Lecanorales	Parmeliaceae	Foliose
8.	*F. sorians* Nyl.	Naz 2008 BHUAJK	Lecanorales	Parmeliaceae	Foliose
9.	*Hypogymnia physodes* (L.) Nyl.	Naz 2009 BHUAJK	Lecanorales	Parmeliaceae	Foliose
10.	*Lepraria finkii* (B. de Lesd.) R.C. Harris	Naz 2010 BHUAJK	Lecanorales	Stereocaulaceae	Leprose
11.	*L. incana* (L.) Ach.	Naz 2011 BHUAJK	Lecanorales	Stereocaulaceae	Leprose
12.	*L. pacifica* Lender	Naz 2012 BHUAJK	Lecanorales	Stereocaulaceae	Leprose
13.	*Melanolaxia fulginosa* (Fr. Ex Duby)	Naz 2013 BHUAJK	Lecanorales	Parmeliaceae	Foliose
14.	*Parmelia omphalodes* (L.) Ach.	Naz 2014 BHUAJK	Lecanorales	Parmeliaceae	Foliose
15.	*P. baltimorensis* Gyeln. & Fóriss	Naz 2004 BHUAJK	Lecanorales	Parmeliaceae	Foliose
16.	*P.conspersa (*Ehrh. ex Ach.) Ach.	Naz 2016 BHUAJK	Lecanorales	Parmeliaceae	Foliose
17.	*P. glabratula* ((Lamy) Nyl.	Naz 2017 BHUAJK	Lecanorales	Parmeliaceae	Foliose
18.	*P. hyperopta* Ach.	Naz 2018 BHUAJK	Lecanorales	Parmeliaceae	Foliose
19.	*P. minarum* Vain.	Naz 2019 BHUAJK	Lecanorales	Parmeliaceae	Foliose
20.	*P. parlatum* L.	Naz 2020 BHUAJK	Lecanorales	Parmeliaceae	Foliose
21.	*P. perlata* (Huds.) Ach.	Naz 2021 BHUAJK	Lecanorales	Parmeliaceae	Foliose
22.	*P. physoides* L.	Naz 2022 BHUAJK	Lecanorales	Parmeliaceae	Foliose
23.	*P. saxatilis* (L.) Ach.	Naz 2023 BHUAJK	Lecanorales	Parmeliaceae	Foliose
24.	*P. squarrosa* Hale	Naz 2024 BHUAJK	Lecanorales	Parmeliaceae	Foliose
25.	*P. succinata* (L.) Ach.	Naz 2025 BHUAJK	Lecanorales	Parmeliaceae	Foliose
26.	*P. sulcata* Taylor	Naz 2026 BHUAJK	Lecanorales	Parmeliaceae	Foliose
27.	P. hyperopta Ach.	Naz 2029 BHUAJK	Lecanorales	Parmeliaceae	Foliose
28.	*Parmelina carporrhizans (*Taylor) Hale	Naz 2027 BHUAJK	Lecanorales	Parmeliaceae	Foliose
29.	*Parmelinopsis minarum* (Vain.) Elix & Hale	Naz 2028 BHUAJK	Lecanorales	Parmeliaceae	Foliose
30.	*Parmotrema carnitum* (Ach.)	Naz 2030 BHUAJK	Lecanorales	Parmeliaceae	Foliose
31.	*P. praesorediosum* Nyl.	Naz 2031 BHUAJK	Lecanorales	Parmeliaceae	Foliose
32.	*Physconia grisea* (Lam.) Poelt.	Naz 2032 BHUAJK	Teloschistales	Physciaceae	Foliose
33.	*Physcia* sp.	Naz 2033 BHUAJK	Teloschistales	Physciaceae	Foliose
34.	*Pseudosypholaria arota* (Ach.)	Naz 2034 BHUAJK	Peltigerales	Lobariaceae	Foliose
35.	*Ramalina fraxinea* (L.) Ach.	Naz 2035 BHUAJK	Lecanorales	Ramalinaceae	Fruticose
36.	*Xanthoparmelia conspersa* (Ehrh. ex Ach.) Hale	Naz 2036 BHUAJK	Teloschistales	Teloschistaceae	Foliose
37.	*Xanthoria aureola* (Ach.) Erichsen	Naz 2037 BHUAJK	Teloschistales	Teloschistaceae	Foliose
38.	*X. candelaria* (L.) Th. Fr.	Naz 2038 BHUAJK	Teloschistales	Teloschistaceae	Foliose
39.	*X. parietina* (L.) Th. Fr	Naz 2039 BHUAJK	Teloschistales	Teloschistaceae	Foliose
40.	*X. polycarpa* (Hoffm.) Rieber	Naz 2040 BHUAJK	Teloschistales	Teloschistaceae	Foliose
41.	*X. ucrainica* S.Y. Kondr.	Naz 2041 BHUAJK	Teloschistales	Teloschistaceae	Foliose

BHUAJK: Botany Herbarium University of Azad Jammu and Kashmir

Table 3. Frequency of occurrence of recorded lichens. Values are percentage of 200 trees on which the species occurred.

S.No.	Lichen species	Fr. (%)	Coverage	S. No.	Lichen species	Fr. (%)	Coverage
1.	*Bulbothrix laevigatula*	4	20	21.	*Parmelia succinata*	4	40
2.	*Cystocoleus ebeneus*	4	10	22.	*Physcia* sp.	4	40
3.	*Flavoparmelia soredians*	4	23	23.	*Xanthoria polycarpa*	4	20
4.	*F. sorians*	4	23	24.	*Physconia grisea*	4	30
5.	*Hypogymnia physodes*	4	40	25.	*Biatorella monasteriensis*	8	63
6.	*Lepraria finkii*	4	20	26.	*Parmelia baltimorensis*	8	20
7.	*Melanolaxia fulginosa*	4		27.	*Lepraria pacifica*	8	10
8.	*Parmelia conspersa*	4	30	28.	*Parmelia squarrosa*	8	80
9.	*P. glabratula*	4	30	29.	*Parmelinopsis minarum*	8	85
10.	*P. hyperopta*	4	35	30.	*Xanthoria candelaria*	8	20
11.	*P. parlatum*	4	20	31.	*X. ucrainica*	8	35
12.	*P. perlata*	4	80	32.	*Flavoparmelia flavientior*	8	15
13.	*P. physoides*	4	40	33.	*Ramalina fraxinia*	4	30
14.	*Parmelina carporrhizans*	4	50	34.	*X. parietina*	12	132
15.	*P. hyperopta*	4	25	35.	*Parmelia omphalodes*	16	150
16.	*Parmotrema carnitum*	4	10	36.	*Parmelinopsis minarum*	16	114
17.	*P. praesorediosum*	4	50	37.	*Lepraria incana*	36	224
18.	*Pseudosypholaria arota*	4	5	38.	*Flavoparmelia caperata*	40	284
19.	*Xanthoparmelia conspersa*	4	40	39.	*Candelaria concolor*	48	437
20.	*X. aureola*	4	20	40.	*Parmelia sulcata*	56	500
-	-	-	-	41.	*P. saxatilis*	84	784

Table 4. Lichen taxa found in the study area and Ecological index).

S. No.	Lichen species	Ecological index (Q)	S. No.	Lichen species	Ecological index (Q)
1.	*Parmelia saxatilis*	2	21.	*Lepraria finkii*	42
2.	*P. sulcata*	3	22.	*L. pacifica*	42
3.	*Candelaria cocolor*	3.5	23.	*Melanelixia fulginosa*	42
4.	*Lepraria incana*	6	24.	*Flavoparmelia caperata*	42
5.	*Parmelia omphalodes*	10.5	25.	*Xanthoparmelia conspersa*	42
6.	*Parmelinopsis minarum*	14.3	26.	*Parmelia glabratula*	42
7.	*Xanthoria parietina*	14.3	27.	*P. parlatum*	42
8.	*Parmelia baltimorenses*	21	28.	*P. perlata*	42
9.	*P. hyperopta*	21	29.	*Hypogymna physodes*	42
10.	*Flavoparmelia flavientior*	21	30.	*Parmelia succinata*	42
11.	*Parmelia squarrosa*	21	31.	*Parmelina arporrhizans*	42
12.	*Parmelinopsis minarum*	21	32.	*Parmelia hyperopta*	42
13.	*Xanthoria candelaria*	21	33.	*Parmotrema carnitum*	42
14.	Biatorella monasteriensis	21	34.	*P.praesorediosm*	42
15.	*Xanthoria ucrainica*	21	35.	*Physconia grisea*	42
16.	*Bulbothrix laevigatula*	42	36.	*physcia* sp.	42
17.	*Cystocoleus ebeneus*	42	37.	*Pseudosypholaria arota*	42
18.	*Flavoparmelia soredians*	42	38.	*Ramalina fraxinia*	42
19.	*F. sorians*	42	39.	*Xanthoparmelia conspersa*	42
20.	*Hypogymnia physodes*	42	40.	*Xanthoria aureola*	42
	-	-	41.	*X. polycarpa*	42

Lichen diversity index and IAP value: Results showed lichen diversity in terms of number of lichen species gradually increased along transects when moving away from the city (Table 5), however some variation were also there due to variation in zonation along with plants communities. In city area there were only 2 lichen species that was the site of Hajira at a distance of 0 km. It is noted that there was gradual increased in number of species from 0 km to 10 km and decreasing trend was noted in number of lichen species at distance of 15 and 20 km. Those were the sites of Chatra and Abbaspur in transect A (Table 5). In transect B and F there was increased in number of lichen species with the increased in distance and ranges from 3 to 6 and 5 to 7 respectively at a distance from 5 to 20 km. Other transect such as C, D and E showed increased trend in number of lichen species with distance from the centre, however in transect C, a decreased number of lichen species was noted at a distance of 20 km from the centre that was the site of Las Dana. In transect D and E similar trend was noted as in C (Table 5). In general the lichen diversity indices showed an increase trend when moving from the city centre to a distance of 20 km (Table 5) except some variation were noted as stated in frequency distribution results. The diversity index of the site located in city centre was 0.81 (LLD) and was different from the rest of sites. Highest diversity indices of 1.84 (VHLD) was recorded for the site located at 15 km away from city (Bunbake) in transect E (Table 5).

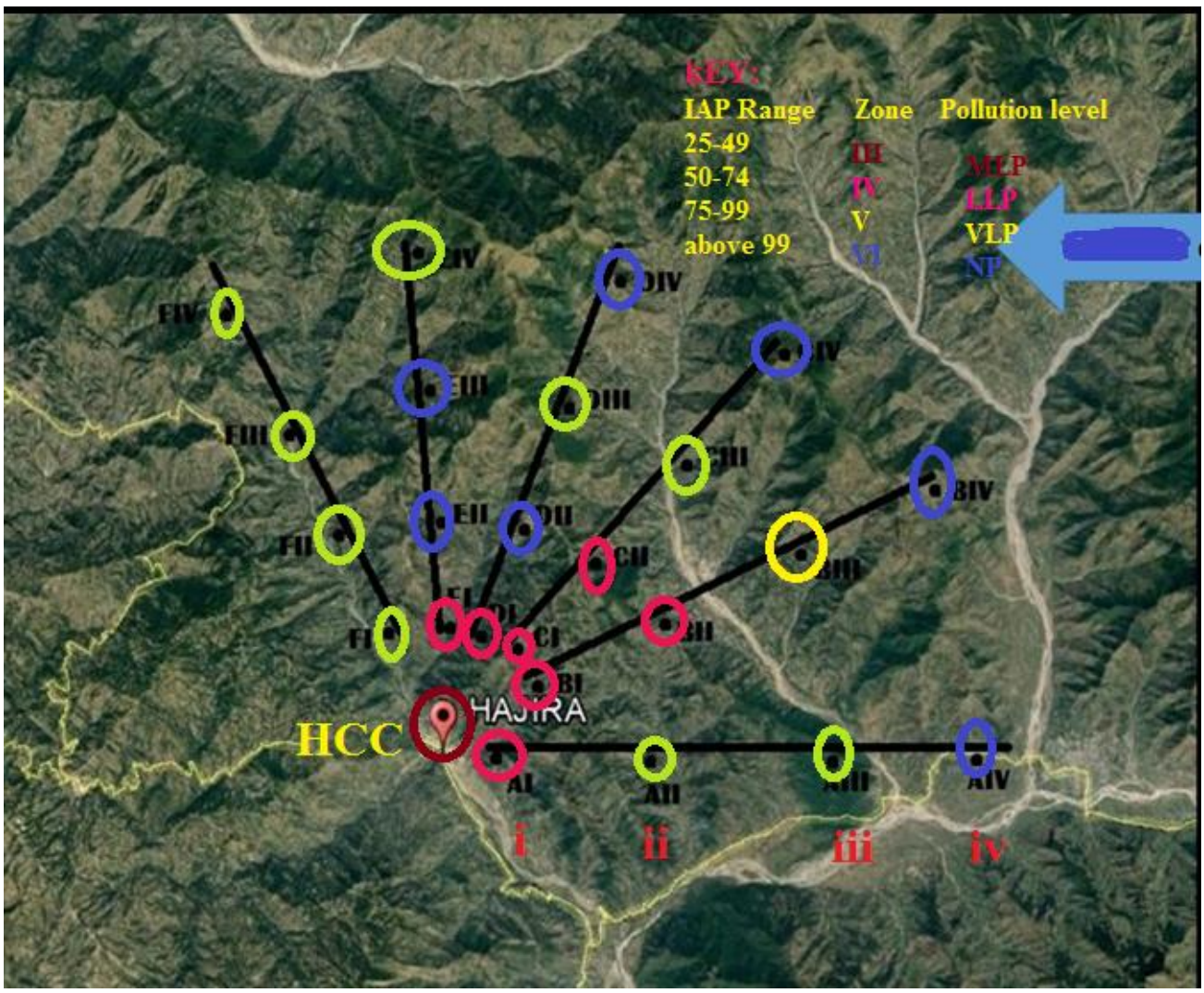

Fig. 3. Pollution zone map of Hajira city and its north sites of district Poonch according to IAP Protocol.

The IAP value 38 recorded for the site in city centre was different to the values obtained for the rest of sites in all transect (Table 5, Fig. 3). Data indicated that IAP values gradually increased when the distance increased from the city; however there was a slight variation. Highest IAP value was 145 at the sites 15 or 20km (Table 5). IAP values are categorized as 1-24, 25-49, 50-74, 75-99 and >99 (Table 5). These ranges are designated as different IAP or polluted zones from II to VI. In the present study no site was found with IAP Value 0 (no lichen; Zone I) and IAP less than 24 (Zone; II), hence sites have started from zone-III (IAP range: 25-49). The first zone (designated as zone-III) with lowest IAP values of 38 moderate level of pollution (MLP) category at site 1 (CC) and last zone (designated as zone-VI) with highest IAP value of 145 and no pollution category corresponding with the minimum and maximum number of lichen species present at that sites. All other sites along this transect A showed increased IAP values (56, 90, 84 and 38). Similarly all sites along transect B showed same increased trend (55, 72, 75 and 98) in IAP values (Table 5, Fig. 3). All sites along transect C showed increased IAP values (55, 67, 77 and 50). Similar observation was found in transect D and E. The IAP value was (67, 76, 88 and 56) and along the transect E showed increased IAP values (67, 135, 145, 139). All sites along transect and F showed increased IAP values (84, 88, 76, 109) except (Namnota) Fiii (Table 5, Fig. 3).

Pollution monitor species of the study area: Lichen taxa *Parmelia saxatilis P. omphalodes, P. sulcata, Candelaria cocolor, Flavoparmelia caperata, Lepraria incana,* and *P. minarum* existing in maximum sites along each transect indicating the ability towards adapting in environment from high pollution level to low pollution level (Table 6). The Q value of all the species was less than 15. This showed that these species were tolerant in response to effect of pollutants from vehicular emission of study area. *Biatorella monasteriensis, Parmelia baltimorensis, Parmelia hyperopta, Flavoparmelia flavientior, Parmelia squarrosa, Parmelinopsis minarum, Xanthoria candelaria, X. parietina* and *X. ucrainica* existing in only two sites indicated sensitivity in response to pollution in the study area. Interestingly all these species had Q value of 21. Remaining species of lichens existing one site either at a distance of 15 km or 20 km showed more sensitivite species of the area with Q value of 42 (Table 6). At a distance of 20 km majority of species were absent but present at 15 km. This is because due to change in zonation and selected plants.

Table 5. Lichen number, Diversity indices and IAP classes and pollution level in the study area.

Sites	Distance (km)	Height (m)	Latitude North	Longitude East	No of species	Diversity index	Diversity index classes	IAP values	IAP range	IAP zones	Pollution level
Hajira City (HC)	0	1050	33.771429	73.895830	2	0.81	LLD	38	25-49	III	MLP
Naker (Ai)	5	1250	33.761883	73.910956	3	1.02	HLD	56	50-74	IV	LLP
Tanda (Aii)	10	1375	33.745823	73.931107	7	1.23	VHLD	90	75-99	V	VLP
Chatra Aiii)	15	1200	33.738483	73.960652	5	1.20	VHLD	84	75-99	V	VLP
Abbaspur (Aiv)	20	1200	33.755215	74.000316	2	0.82	LLD	38	25-49	III	MLP
Narian (Bi)	5	1175	33.768648	73.925003	3	0.83	LLD	55	50-74	IV	LLP
Gala peer (Bii)	10	1625	33.783103	73.973473	4	1.01	HLD	72	50-74	IV	LLP
Thandikussi(Biii)	15	1850	33.806219	74.009531	4	1.03	HLD	75	75-99	V	VLP
Mehmood gali Biv)	20	2300	33.837716	74.051931	6	1.56	VHLD	98	75-99	V	VLP
kathyara (Ci)	5	1380	33.784612	73.915924	3	1.16	VHLD	55	50-74	IV	LLP
Khalidaramen (Cii)	10	1510	33.813480	73.954045	4	1.43	VHLD	67	50-74	IV	LLP
Murchkot (Ciii)	15	1820	33.843759	74.002352	4	1.46	VHLD	77	75-99	V	VLP
Lus dana (Civ)	20	2300	33.870535	74.040651	3	0.98	MLD	50	50-74	IV	LLP
Sarari (Di)	5	1325	33.786497	73.909686	4	0.90	MLD	67	50-74	IV	LLP
Gorimar (Dii)	10	2300	33.819344	73.936776	4	1.12	VHLD	76	75-99	V	VLP
Dana N0. 4 (Diii)	15	2225	33.863607	73.950006	7	1.50	VHLD	88	75-99	V	VLP
Tolipeer (Div)	20	2500	33.903625	73.963929	3	0.84	LLD	56	50-74	IV	LLP
Pothichaprian (Ei)	5	1290	33.787444	73.898503	5	1.35	VHLD	67	50-74	IV	LLP
Pirkot (Eii)	10	1380	33.812813	73.892073	8	1.52	VHLD	135	>99	VI	NP
Bunbake (Eiii)	15	2140	33.849582	73.886266	9	1.84	VHLD	145	>99	VI	NP
Alisojel (Eiv)	20	1720	33.890310	73.870333	7	1.35	VHLD	139	>99	VI	NP
Kaloot (Fi)	5	1500	33.787863	73.886719	5	1.52	VHLD	84	75-99	V	VLP
(Fii)	10	1770	33.813529	73.869258	5	1.37	VHLD	88	75-99	V	VLP
Namnota (Fiii)	15	2350	33.832742	73.856583	5	0.97	MLD	76	75-99	V	VLP
Pukhur (Fiv)	20	1610	33.861493	73.841476	7	1.39	VHLD	109	>99	VI	NP
Average	-	-	-	-	4.76	1.27	-	79.4	-	-	-

: 0.80-0.89 → low lichen diversity (LLD), 0.90-0.99 → Moderate lichen diversity (MLD), 1.00-1.09 → High lichen diversity (HLD), > 1.10 → Very high lichen diversity (VHLD) class.

Table 6. Lichen sensitive and tolerance species of 6 transects at each distance.

S. No	0 km	5 km	10 km	15 km	20 km
	Lichen species				
1.	×	*Parmelia saxatilis*	*P. saxatilis*	*P. saxatilis*	*P. saxatilis*
2.	*Parmelia sulcata*	*P. sulcata*	*P. sulcata*	*P. sulcata*	*P. sulcata*
3.	×	*Candelaria concolor*	*C. concolor*	*C. concolor*	*C. concolor*
4.	*Flavoparmelia caperata*	*F.caperata*	*F. caperata*	*F. caperata*	*F. caperata*
5.	×	*Lepraria incana*	*L. incana*	*L.incana*	*L. incana*
6.	×	*Parmelia minarum*	*P. minarum*	*P. minarum*	*P. minarum*
7.		*Parmelia omphalodes*	*P. omphalodes*	*P.omphalodes*	×
8.	×	*Xanthoria parietina*	*X. parietina*	*X. parietina*	*X. parietina*
9.	×	×	×	*Ramalina frexinia*	×
10.	×	×	×	*Flavoparmelia flavientior*	×
11.	×	×	×	*Xanthoria ucrainica*	×
12.	×	×	×	*Xanthoria candelaria*	×
13.	×	×	*Parmelinopsis minarum*	*P.minarum*	×
14.	×	×	×	*Parmelia squarrosa*	*P. squarrosa*
15.	×	×	×	*Lepraria pacifica*	×
16.	×	×	*Flavoparmelia baltimorenses*	*F. baltimorenses*	×
17.	×	×	*Biatorella monasteriensis*	*B. monasteriensis*	×
18.	×	×	×	×	*Physconia grisea*
19.	×	×	×	*Xanthoria polycarpa*	×
20.	×	×	×	*Physia* sp.	×
21.	×	×	×	×	*Parmelia succinata*
22.	×	×	×	*Xanthoria aureola*	×
23.	×	×	×	*Xanthoparmelia conspersa*	×
24.	×	×	×	*Pseudosypholaria arota*	×
25.	×	×	×	*Parmotrema praesorediosum*	×
26.	×	×	×	*Parmotrema carnitum*	×
27.	×	×	×		
28.	×	×	×	×	*Parmelina carporrhizans*
29.	×	*Parmelia physoides*	×	×	×
30.	×	×	*Parmelia perlatum*	×	×
31.	×	*Parmelia parlatum*	×	×	×
32.	×	×	×	×	*Parmelia hyperopta*
33.	×	*Parmelia glabratula*	×	×	×
34.	×	*Parmelia conspersa*	×	×	×
35.	×	×	×	*Melanolaxia fulginosa*	×
36.	×	×	×	*Lepraria finkii*	×
37.	×	×	×	*Hypogymnia physodes*	×
38.	×	×	*Flavoparmelia sorians*	×	×
39.	×	×	*F. soredians*	×	×
40.	×	×	*Cystocoleus ebeneus*	×	x
41.	×	×	×	×	*Bulbothrix laevigatula*

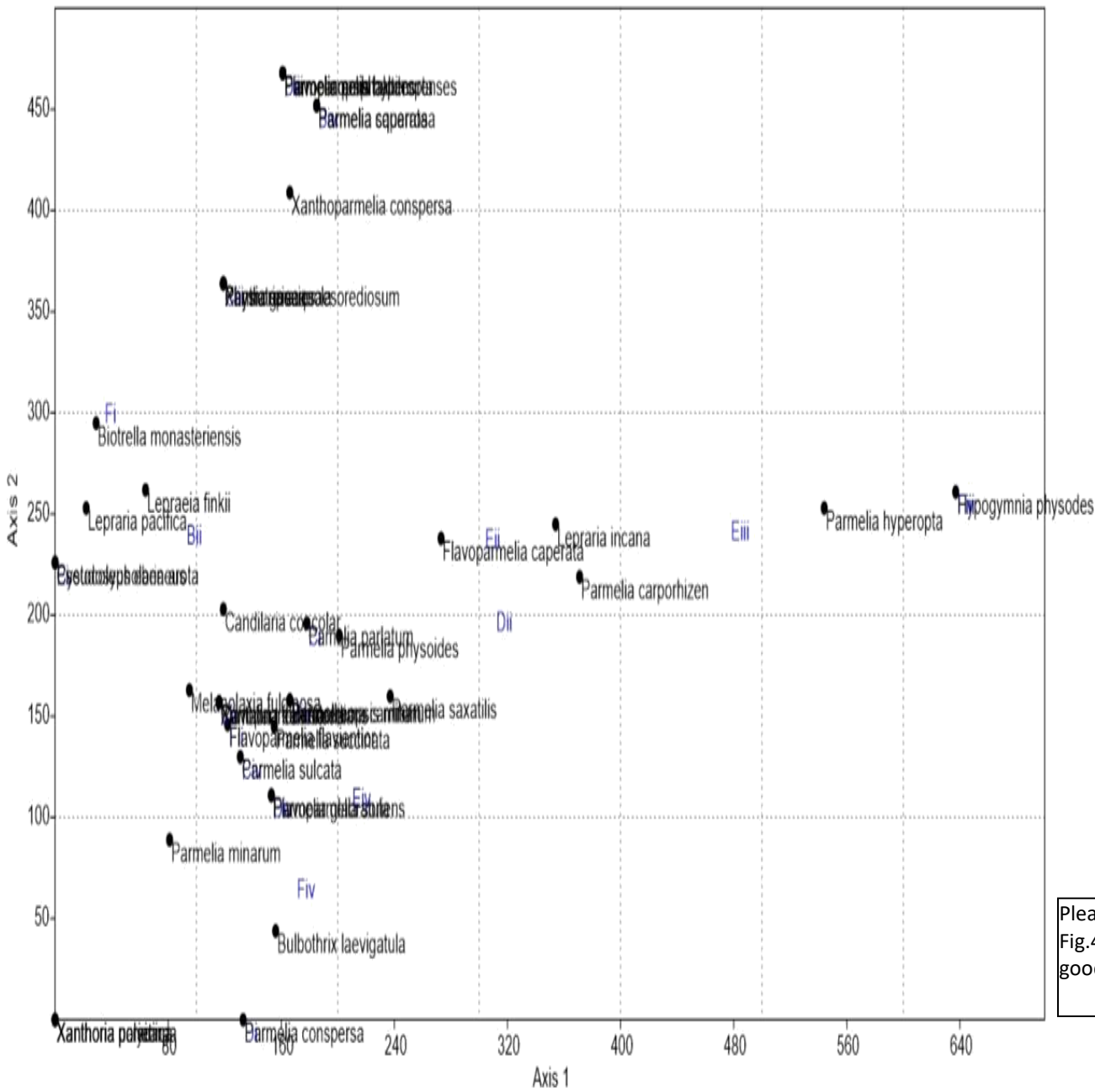

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Fig. 4. DCA diagram of species distribution pattern in different study sites.

Deterented correspondence analysis: The result of DCA showed that *Parmelia hyperopta* and *Hypogymnia physodes* were strongly correlated with Eiii (Bunbake). *Hypogymnia physodes* was also strongly correlated with Div (Tolipeer). *Flavoparmelia caperata, Lepraria incana* and *Parmelia carporrhizen* showed correlation Dii (Gorimar) and Fii (Dothan). *Parmelia baltimorensis* and *F. caperata* are strongly correlated with Biii (Thandikussi) and Fiii (Namnota). *Bulbothrix laevigatula* related with Fiv (Pukhur). *Biotrella monastrensis* correlated with Fi (Kaloot). Whereas other species did not showed any significant correlation with specific site and clusterized in center (Fig. 4).

Discussion

Air pollution with respect to SO_2 and NO_2 is mainly due to emission from the transport and anthropogenic factors throughout the world. Many researchers followed the Index of Atmospheric Purity (IAP) to determine the effects of atmospheric pollutants especially (SO_2 and NO_2) on living organisms (De Sloover & Le Blanc, 1968; Kricke & Loppi, 2002; Loppi, 1996). In the present study a total of 41 species of lichens having 8 families at the 25 sites of the study area were recorded. During the study it was found that lichen taxa increased with increasing distance from the city centre (0 km) and reached maximum at 15 km however, a distance of 20 km lichen taxa showed decreased trend. Possible factors for this may be undulating topography, change in zonation with changes in selection of trees and wind pattern. Present study revealed that ecological index (Q) range from 2 to 42. Results are in accordance with Le Blance and De Sloover (1970) that showed Q ranges from 8 to 38 in different species. In the present study lower Q value were found in *Parmelia saxatilis, P. sulcata, Candelaria*

concolor, *Flavoparmelia caperata, Lepraria incana* and *Parmelia omphalodes.* It shows these have the ability towards adapting in environment from high to low pollution level. Loppi *et al.* (2002) reported the genus *Parmelia* was most abundant with highest number of species in natural zone. Similar findings are found in literature that *Flavoparmelia caperata* and *Parmotrema chinense* were present in all sites where *F. caperata* was very common in Portugal (Godinho *et al*., 2008). All other species present in one or two sites showed more sensitive species of the area with Q value of 42. At a distance of 20 km majority of species were absent but present at 15 km in the present study. This was due to change in zonation and some variation in vegetation type. In area where heavy traffic rate, lichens and bryophytes present on tree are highly polluted with dust (Fudali, 2006; Davies *et al*., 2007). *Xanthoria parietina* was more sensitive to transport emissions and nitrogen oxide unlike the more sensitive *Ramalina duriaei,* which showed extensive functional variations (Cuny *et al*., 2002).

Results of diversity indices (DI) of the present study showed that DI range from 0.81 Hajira City (HC) at 0 km to 1.84 Bunbake (Eiii) at 15 km from HC. It is noted that with increasing the distance from the city center the diversity indices increased. However, transects E & F showed unexpected results along each transect. According to categorization of lichen diversity level based on diversity indices (Batten, 1976), Hajira city site with diversity index of 0.81 falls into class I (range from 0.80-0.89) which mean a low lichen diversity level. Transect A at site Aiv (Abbas pur) at a distance of 20 km from Hajira city showed same diversity index of 0.82. The reason behind is maximum traffic in Abbas pur city and maximum vehicular emission in the city centre. All other transects along their sites showed increased diversity indices values and fall into class III (high lichen diversity) and IV (very high lichen diversity class) on increasing distance. In transect E all the sites with diversity indices 1.35, 1.52, 1.84, 1.35 fall in class V (very high lichen diversity). Along transect F similar increasing trend is observed except sites present 15 km away from city centre with diversity index 0.97 falls in class II (moderate lichen diversity). This is because there is no traffic density; roads are non metallic as well as change in vegetation structure. Increased trend in DI was also observed in Sri Lanka and it was found that diversity index value is low at city center and high away from Colombo city (Attanayaka and Wijeyaratne, 2013). Same observations were reported in London where high pollution decreases lichen diversity when moving away from polluted site lichen flora increases (Larsen *et al*., 2007).

Results obtained for IAP in this study are similar to the previous work reported by Le Blanc *et al.* (1974) that reported highly disturbed (city centre) sites showed lower IAP values whereas the undisturbed sites (rural areas) showed high IAP values. According to air quality level based on IAP value (Conti & Cecchetti, 2001), Hajira site with IAP value 38 falls into level C with Zone III, which means a moderate level of pollution. Same transect at site Aiv (Abaspur) at a distance of 20 km from Hajira city showed IAP value 38 that also fall into level C with Zone III. The reason behind this was impact of vehicular emission. All other transect showed changed level from MLP to NP on increasing distance. Lichens were also used to monitor pollution caused by geothermic emission, IAP values [low (>25) around geothermal power plant and high (<45) away from power plant] had been reported (Loppi, 1996). It reflected a high IAP value indicated a better air quality. In the present results high IAP value in sites away from the city and low IAP value in the site closer to city on most transects showed that IAP values indicate the air quality of the area. Similar findings were observed in all Europe where due to Sulphur dioxide and Nitrogen oxide lichen flora becomes low (Skye, 1968; Hawksworth & Rose, 1970). Similarly it is reported that nitrogen oxide minimize lichen flora expressed as AP in Seville, Spain (Fuentes & Rowe, 1998) and in Tuscany, Italy (Lorenzini *et al*., 2003). The lichens and bryophytes growing on trees along the streets and the roads with heavy traffic in Kyiv may indicate that tree bark was heavily polluted by dust (Fudali, 2006; Davies *et al.* 2007). It explains the occurrence of some epilithic lichens (*Caloplaca decipiens* and *Physcia caesia*). The conclusion is that tree bark and the atmospheric air in Kyiv are evidently strongly dusted because of the increasing number of vehicles. To assess the air pollution in Pakistan, we recommend using the index of atmospheric purity (IAP).

Conclusions and Recommendations

The present study revealed that air pollution in the city area of Hajira and its allied sites is primarily due to pollutants emitted from vehicles which have an impact on diversity of lichens and their distribution in area. It is concluded that IAP is a reliable method to monitors air pollution. This method can be applied on vast area in a relatively short at very low cost for future studies on this area**.** To estimate the air pollution in Pakistan we recommend using only the corticolous lichens and the method of index of atmospheric purity (IAP). Indicator species of epiphytic lichens for zones with different air quality were proposed and can be used for further monitoring. It was established that air pollution in Hajira was influenced by exhaust fumes of vehicles.

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