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BIOMONITORING OF AIR QUALITY WITH BRYOPHYTES USING DIVERSITY AND FREQUENCY AS AN INDICATOR

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Eleven sites of Kumaon hills (northwest Himalaya) were selected for air quality monitoring. At each selected site, the bryophyte population growing on rocks, soil and bark were studied for their micro-climate and frequency coverage analysis. Frequency coverage data of bryophytes from all the undertaken localities were used to calculate the index of atmospheric purity (IAP). The IAP value of various study sites was plotted on an out line map of study area to detect the pollution gradients and to relate it with the known sources of contamination. A destructive influence of air pollution mainly caused by vehicular movement is evident by the fact that even the common weeds like *Bryum argenteum*, *Funaria hygrometrica*, *Hylocomium splendens*, *Frullania squarrosum* and *Lejunea sp.*, which were earlier growing luxuriantly, now have restricted distribution. The study explores the application of community structure analysis for regional monitoring of air quality.

Key words: Biomonitoring, Bryophytes, IAP, Kumaon hills

Population pressure (approximate population of Kumaon was 2943199 in 2000, out of which 80% is rural), deforestation, landslide, water scarcity, automobile exhaust, poverty, unplanned construction and many other such phenomenon have been identified as a threat to the equilibrium of Kumaon ecosystem (Annon 1991; Rajput and Agarwal 2004). The destruction of natural forest cover owing to population explosion has caused the disappearance of innumerable species and has helped in making the system imbalance. In addition to this, tons of toxic and otherwise hazardous and unwanted substances are polluting the environment. Wood, coal and other cellulosic materials are used as conventional fuel on hills. In Nainital and Almora about eight thousand vehicles are running round the clock. Automobiles utilize diesel and petrol as fuel, which on combustion spew out high doses of CO, CO_2, SO_2, NO_x, and metals present as mining contaminants or from wear and tear of vehicle (Huang *et al.*1994). In absence of effective antipollution measures and poor enforcement the particulate and gaseous pollutants spewed out in air have deleterious effect on biota (Pearson *et al.* 2000).

Industrial revolution and man made activities have led to high anthropogenic emission of heavy metals in the biosphere (Lombi *et al.* 2000; Riget *et al.* 2000). There is a real danger of large-scale disturbances of natural flora and fauna due to pollution over years. Control of atmospheric pollution requires an adequate eco-friendly program for the monitoring of air quality, which should be cost-effective, self sustained, rapid, reliable and safe (Ernst *et al.* 2000).

Plants occupy an important position in the ecosystem being directly in contact with substratum, water and air. Various biological materials have been used as biomonitor in past few years throughout the globe *e.g.* lichens (Pfiffer and Barclay 1992, Jeran *et al.* 2002) and bryophytes (Louis *et al.* 2001 Ruhling and Tyler 2004, Saleman *et al.* 2004).

Bryophytes are ecologically important diversified plant community; differ morphologically and physiologically from

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higher plants. Bryophytes can influence a diverse range of ecological processes (Wieder 1990) and might have significant effect on carbon, water, mineral and energy budget of ecosystem (Miller *et al* 1978), even when they occur at low biomass within the community (Longton 1992). They impart lush greenery and a verdant cover in every possible shade of green tinged with hues of brown, red and yellow to almost all kind of habitat like rocks, boulders, stones, hillsides, tree trunk, forest cover and various artificial substrates in and around Kumaon hills (Pant and Tiwari 1989). Moreover, many of them are known to grow at proximity to point source (Glime and Saxena 1991). The Kumaon ecosystem is an evolving ecosystem and still it has to stabilize the resources that are in fact crucial for the survival of humanity. Little has been attempted to mitigate the man-made pollution and its influence on Kumaon ecosystem.

Pollutants through changing physiological processes in individual plants affect growth, development, reproduction and also the tolerance to environmental and competitive stresses (Wu *et al.* 2002). The physiological and biological changes manifested at individual level, influence the biological processes at the supra-individual level also (*e.g.* succession and degradation in communities). In fact, it is the supra-individual level that provides reliable information about pollution (Csintalan and Tuba 1992). Present study is an attempt to use bryophyte community structure as a passive biomonitoring agent for environmental quality.

MATERIALS AND METHODS

(a) Calculation of IAP: For study of IAP, regular and extensive surveys were made to the undertaken sites of Kumaon hills *i.e.* Kainchi, Kosi, Golf ground, Naukuchia Tal, Kathpuria, GBPIHED, Chitai temple, Nainital, Mukteswar, Bhowali and Artola. During each survey the distribution pattern and abundance of undertaken species of bryophytes *viz. Marchantia, Bryum, Ceratodon, Funaria, Polytrichum, Astrella, Hypnum, Frullania, Hydrogonium, Plagiochasma, Hylocomium, Anthoceros* and *Lejunia* were studied. IAP was computed in accordance to Mikhailova and Vorobeichik (1995).

$$IAP = \Sigma f \times Q / 10$$

Where, IAP = Index of Atmospheric Purity, Q = Ecological Index of the species (calculated as an average number of neighboring species) and f = Frequency of species.

(b) Preparation of IAP map: The IAP values were plotted on an outline map prepared for the study area. The sites having low IAP values in the range of 0-8 represented the most polluted area and marked as zone I. Area having the IAP value of 9-16 was marked as zone II representing the moderate pollution level. The sites having the IAP value in between 17-24 represents the almost clean status and thus classified as zone III. The areas having the IAP value more than 24 (*i.e.* pure habitat) were designated as zone IV.

The field study was conducted thrice in a year, each time in triplicate sets. The data presented herein are the average of all the experiments.

RESULTS

Amongst all the undertaken sites, the maximum IAP value (41) was calculated for Mukteswar, representing the zone IV (Table 1, Figure 1). The minimum IAP value (6) was calculated for Bhowali and Nainital representing most polluted (seven and four times more polluted from Mukteswar and Artola respectively) amongst all the sites studied (Figure 1). Only a few well-known tolerant species like *Plagiochasma appendiculatum*, *Polytrichum commune* and *Astrella wallichiana* were present in low abundance. These both the

Table 1: Distribution of bryophytes and computation of IAP at eleven different sites of Kumaon hills

Species	Frequency of bryophytes studied at different sites										
	1	2	3	4	5	6	7	8	9	10	11
Marchantia	3	5	-	3	5	3	-	2	4	3	4
Bryum	-	-	2	4	3	1	5	-	5	2	-
Ceratodon	-	-	1	3	-	2	3	1	-	-	2
Funaria	2	2	3	-	2	3	4	-	1	-	-
Polytrichum	3	-	2	4	-	-	3	-	2	2	-
Astrella	2	3	3	-	3	4	-	2	1	3	3
Hypnum	-	-	-	-	5	-	-	-	2	-	3
Frullania	-	-	-	-	-	-	-	-	1	-	-
Hydrogonium	3	4	3	3	-	2	4	-	3	-	2
Plagiochasma	-	4	5	1	5	4	-	3	5	2	5
Hylocomium	-	2	-	2	-	-	2	1	4	-	2
Anthoceros	2	2	3	-	3	1	-	1	4	-	1
Lejunia	-	-	-	4	-	2	-	-	2	-	3
No of bryophytes											
sp. (n)	6	7	8	8	7	9	7	6	12	5	9
Σf	15	22	22	24	26	23	26	10	34	12	25
IAP value	9	15	17	19	18	21	18	6	41	6	23
IAP zone	II	II	III	III	III	III	III	I	IV	I	III

Study sites 1. Kainchi, 2. Kosi, 3. Golf ground, 4. Naukuchia Tal, 5. Kathpuria, 6. GBPIHED, 7. Chitai temple, 8. Nainital, 9.Mukteswar, 10. Bhowali, 11. Artola (Jageswar Dham)
Frequency classes: 1. Few minute colonies 2. Many small (>50 cm^2) colonies 3.Scattered medium (<50 cm^2) and small colonies, 4. Scattered large colonies, 5. Continuous cover.

stations represent the zone I. Chitai temple, Naukuchia Tal, Golf ground and Kathpuria having almost similar IAP values represented a similar status of air quality constituting the zone III (Table 1).

DISCUSSION

Although several diversity indices based on species richness have been prepared and used for pollution monitoring studies (Sinha *et al.* 1993) but the calculation of IAP value using distribution and relative abundance of the species is vital and of wider application for pollution monitoring studies (Burton 1990 Palmieri *et al.* 1997, Manuel *et al.* 2000).

Field observations revealed that at most of the sites studied, the IAP was more closely associated with species diversity and abundance. But this equation did not hold true in all the cases as micro-environment also influences the bryophyte diversity and abundance (Vitt and Slack 1984 Rice *et al.*, 2001 Gombert *et al.*, 2004). This may be the reason for low IAP value of Naukuchia Tal, in spite of rich bryo-wealth, but with less diversification. The least affected site was the Mukteswar (IAP = 41) which has limited automobile movement and dense forest cover.

The study revealed that *Plagiochasma* and *Hydrogonium* were frequently distributed along the road sides which reflect to their ecotypic adaptation. It was also very interesting to note that in spite of high abundance of *Hydrogonium* along the road; only a few plants were observed at Nainital. This suggests the restricted distribution of *Hydrogonium*, which could be due to its peculiar niche or microclimate requirement.

A very low IAP value was calculated for Nainital and Bhowali representing the worse

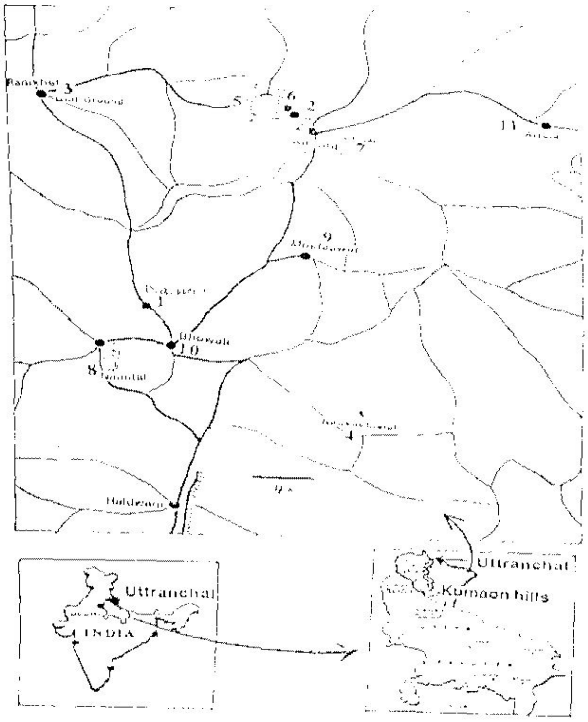

Figure 1: Map of Kumaon hills showing IAP monitoring sites.

environmental conditions. Some of the *Marchantia* and *Plagiochasma* thalli were growing nearby the heavy traffic at Nainital and Bhowali in isolated patches with poor growth. Toxic particulate and gases spewed out in automobile exhaust may have deleterious effect on physiological and metabolic processes of plant and may be responsible for disappearance or migration of species from polluted areas. Kainchi (IAP = 9) and Naukuchia Tal (IAP = 15) represented the IAP zone II. The individual species appear to interact independently to different gradients and accordingly bryophytes are classified in to equilibrium species having well defined niches distinct from close competitor and fugitive species having overlapping niche with similar species (Vitt and Slack 1984). The low bryo-diversity at Naukuchia Tal could be due to a narrow micro-climatic range that results in to low IAP value. Further, most of the bryophyte species observed at Naukuchia Tal were of equilibrium type, which leads to low bryo-diversity. At Naukuchia Tal several sensitive lichen species were also observed which suggests the relative healthy status of air quality in spite of its low IAP (Table 1). During surveys it was also found that at heavy to moderately polluted sites sensitive species like *Marchantia, Frullania, Lejunia* and *Anthoceros* were scarcely available.

It was concluded that habitat of Kosi, Kathpuria, Golf ground, Artola and Chitai were moderately polluted, grouped under IAP zone III (Table 1) and stable community was observed with diversified resources shared by the component species.

Rich bryoflora both in variety and frequency at Muketswar (IAP = 45) supports the minimum pollution load. Very low vehicular movement and high humidity with low temperature represent an ideal niche for luxuriant growth of bryophytes at Mukteshwar. Beside test species, high abundance of other sensitive bryophytes like *Taxiphyllum taxirameum, Conocephalum conicum, Anemobryum sp., Pholia fontana, Aneura pinguis, Hyophila involuta* and *Brachythecium buchananii* amply documented its clean and healthy environmental status. Almost a clean ecological status at Muketswar was evident by thick forest cover *i.e.* high abundance of perennial macrophyte flora. as *Woodfordia fruticosa* (L) Kurz, *Macaranga pustulata* King ex HK. f., *Mallotus philippensis* (Lamk.) Muell., *Rhododendron arboreum* Sm and *Murica esculanta* Buch Ham. ex. Dum. were growing luxuriantly alongwith the leafy liverworts *Frullania squarrosa, Ptychanthus sp.* Pleurocarpus mosses like *Porella densifolia, Aerobryidium sp., Anomodon minor, Anomodon rugelii, Cryptoleptodon sp., Thudium sp.* and *Trachypodopsis sp.* were also growing abundantly in the dense forest cover. However, *Pinus roxburghi* Sarg. and *Quercus glauca* were more or less uniformly distributed throughout the range. Sensitive lichen species like *Pyrenula* and *Ramalina* were also evenly distributed at Muketswar. A similar pattern of metallic pollutants on Kumaon range was reported by Saxena and Saxena (2000) through

Plagiochasma bag transplant. Results suggest that computation of IAP value serve as a reliable, simple and quick method for detection of pollution gradients, especially covering large area.

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