Sensitivity of Lichens to Air Pollution around the Industrial Area of Bhadravathi Town, India

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ABSTRACT

Ambient air quality monitoring was carried out for two consecutive years (2006-2008) to assess the concentration of suspended particular matter (SPM), sulfur dioxide (SO2) and nitrogen oxides (NOx) at an industrial area of Bhadravathi town and at Kuvempu University campus (15 km away from Bhadravathi town). Epiphytic lichens were monitored according to EU guidelines. The concentration of SPM (232.30-236.56 /g/m3) was highest of the three analyzed air pollutants, although all three were well within the threshold limit at both sites. Lichen species belonging to 9 genera were identified on the tree barks of Mangifera indica and Pongamia pinnata in the control area while sensitive lichen species were absent in the industrial area. The varied response of lichen species may be directly attributed to air pollution in Bhadravathi town.

Keywords: air quality, air pollutants, epiphytic lichen, lichens diversity value, Ramalina, Teloschistes

INTRODUCTION

Ambient air quality monitoring was carried out for two consecutive years (2006-2008) to assess the concentration of suspended particular matter (SPM), sulfur dioxide (SO2) and nitrogen oxides (NOx) at an industrial area of Bhadravathi town and at Kuvempu University campus (15 km away from Bhadravathi town). Epiphytic lichens were monitored according to EU guidelines. The concentration of SPM (232.30-236.56 /g/m3) was highest of the three analyzed air pollutants, although all three were well within the threshold limit at both sites. Lichen species belonging to 9 genera were identified on the tree barks of Mangifera indica and Pongamia pinnata in the control area while sensitive lichen species were absent in the industrial area. The varied response of lichen species may be directly attributed to air pollution in Bhadravathi town.

MATERIALS AND METHODS

Description of study area

Bhadravathi is an industrial town situated at 13°49′46″ N to 75°42′22″ E in the Shimoga District of Karnataka state, India. It is situated at a distance of about 255 km from the state capital Bangalore. The study area is notorious for its emissions from two large-scale industries (Visveswaraya Iron and Steel Plant and Mysore Paper Mills Ltd.) in addition to numerous small-scale industries of the town. Air quality and lichen diversity of Bhadravathi town were compared with that of a control area (Kuvempu University campus) 15 km away from Bhadravathi town. Epiphytic lichens were monitored according to EU guidelines. The concentration of SPM was the mass/quantity of SPM. In each case it was determined by weighing the filter paper before and after sampling with proper equilibrium each time. The monthly mean of SPM for each of the sampling sites was obtained separately using the values of all the consecutive samplings of the respective month.

Sampling

Ambient air quality monitoring to determine air quality

Ambient air quality monitoring followed standard methods of the National Ambient Air Quality Monitoring (NAAQM). Air sampling was carried out using APM-410 and APM-411 high volume air samplers. The sampling frequency was 24 h, twice a week at uniform intervals and for a period of 2 consecutive years (July 2006 to June 2008). The specifications of the high volume air sampler used for air monitoring are: Flow rate, 0.9-1.2 m3/min; Recommended filter, Whatman filter paper No. 41 (25 cm diameter); Sampling time, normally 8 h, 24 h (max); Power requirement, 220 V, single phase, 50 Hz, A.C. built in voltage stabilizer with automatic shut off.

Determination of suspended particulate matter

1. Filter inspection

The light table surface was cleaned with a methanol-soaked wiper and allowed to dry. The filter was handed with sterile gloves to prevent contamination. Before placing each filter in the filter chamber of the instrument it was examined for damage.

Suspended particulate matter (SPM) was measured (w/v) as was the mass/quantity of SPM. In each case it was determined by weighing the filter paper before and after sampling with proper equilibrium each time. The monthly mean of SPM for each of the sampling sites was obtained separately using the values of all the samplings of the respective month.

SPM in ambient air (IS 5182-Part IV) was calculated as:

\[
SPM = \frac{(W_f - W_i \times 10^6)}{V}
\]

where, SPM = in \(\mu g/m^3\), \(W_f\) = final weight of the filter in g, \(W_i\) = initial weight of the filter in g, \(V\) = volume of air sampled in m\(^3\), \(10^6\) = conversion of g to \(\mu g\).
Determination of sulphur dioxide

A modified West and Gaeke (1956) method was used. The ambient air was bubbled through the aqueous solution of potassium tetra-chloromercurate (TCM) and the SO$_2$ in air forms a dichlorosulphonmercurate complex, which resists oxidation by the oxygen in the air. This complex is stable to strong oxidants such as ozone and nitrogen oxides (NO$_x$) and therefore, the absorber solution is stored for a couple of hours prior to analysis. This complex was made to react with pararosaniline and formaldehyde to form the intensely colored pararosaniline methylsulphonic acid. The absorbance of the solution was measured by means of a spectrophotometer (Systronics 367). The concentration of SO$_2$ in the sample was expressed in µg/m$^3$ and was calculated as follows:

$$C (SO_2 \text{ µg/m}^3) = \frac{(A - A_0) \times 1000 \times V_s}{V_t \times V_i}$$

where $A =$ sample absorbance, $A_0 =$ reagent blank absorbance, $B =$ calibration factor (µg/absorbance), $V_t =$ volume of air sampled (l), $V_i =$ final volume of sampling solution, $V_s =$ aliquot taken for analysis, 1000 = conversion factor from l to m$^3$.

Determination of nitrogen oxides

The gas was collected in the absorber of the air sampler and the mixture was analyzed with the sodium arsenite method (Jacob and Hochheiser 1958).

Ambient NO$_x$ was collected by bubbling air through a solution of sodium hydroxide and sodium arsenite. The concentration of nitrite ion (NO$_2^-$) produced during sampling was determined colorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide and $N$-(1-naphthyl)-ethylenediamine di-hydrochloride (NEDA) and measuring the absorbance of highly colored azodye at 540 nm using a spectrophotometer (Systronics 367). The concentration of the NO$_x$ in the sample was expressed in µg/m$^3$ and was calculated as follows:

$$C (NO_x \text{ µg/m}^3) = \frac{(S \text{ NO}_2^-) \times V_s}{V_t \times 0.82 \times V_i}$$

where $S =$ NO$_2$ = NO$_x$ concentration in analyzed sample, 0.82 = sampling efficiency, $V_t =$ volume of air sampled (l), $V_i =$ final volume of sampling solution, $V_s =$ aliquot taken for analysis.

Epiphytic lichen diversity monitoring

European guidelines (Asta 2002) were adopted. These are based on the on the fact that epiphytic lichen diversity is impaired by air pollution and environmental stress. The frequency of occurrence of lichen species on a defined portion of tree bark can be used as an estimate of diversity and as a parameter to estimate the degree of air pollution. Sampling Design: Each sampling unit was selected to represent a certain portion of the survey area and it received equal attention.

The size of sampling units depends on the grid size and hence on the geographical scale of the study. With sampling units of 0.25 × 0.25 km, 0.25 km is the maximum grid density. For the same reason, a 1 × 1 unit can be sampled every 1, 2, 3, ... $n$ km according to the survey requirements. Sampling units larger than 1 × 1 are not recommended, as they can cause a number of practical problems. Hence, in the present study, the 0.25 × 0.25 km grid density was selected. Identification of distinct perturbation occurrences at point sources were given attention while in control areas, general investigations were adopted. The number of trees per sampling unit was dependent on its dominance.

Selection of tree species

Tree species must be selected, after reconnaissance of the study area, in order to verify the frequency/distribution of suitable trees. Free-standing trees were selected, i.e. those whose trunks received direct solar radiation for at least part of the day. However, the use of both free-standing trees and of those in closed-canopied stands must be avoided in a single survey. After reconnaissance of the study area, on the basis of dominance, two tree species were selected namely, Mangifera indica and Pongamia pinnata. Sample trees were selected to ensure that they were free standing and also received direct solar radiation at least part of the day.

A monitoring quadrate consisting of four independent quadrant segments of five 10 × 10 cm$^2$ each (Fig. 1) was attached vertically to the tree trunk in such a manner that the lower edge of each segment was 1 m above the ground. This was adopted as in urban centers where lichen cover is often restricted at the base of trees (Asta 2002).

All lichen species present within each quadrant segment were recorded using a form and the frequency of occurrence of each species in the 5 squares of each quadrant segment noted. The list of species with their frequency values in one segment constitutes a relevé of lichen vegetation.

Table 1 Annual concentrations of SPM, SO$_2$ and NO$_x$ (µg/m$^3$) showing significant differences among the industrial area and control site.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Control</th>
<th>Around industrial area</th>
<th>$F$-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006-07</td>
<td>20.08 ± 11.91</td>
<td>236.56 ± 83.22</td>
<td>122.16</td>
<td>0.0001</td>
</tr>
<tr>
<td>2007-08</td>
<td>20.15 ± 16.14</td>
<td>232.30 ± 81.63</td>
<td>115.85</td>
<td>0.0001</td>
</tr>
<tr>
<td>2006-07</td>
<td>0.07 ± 0.09</td>
<td>13.23 ± 4.75</td>
<td>134.56</td>
<td>0.0001</td>
</tr>
<tr>
<td>2007-08</td>
<td>0.033 ± 0.06</td>
<td>13.62 ± 6.09</td>
<td>133.87</td>
<td>0.0001</td>
</tr>
<tr>
<td>2006-07</td>
<td>0.35 ± 0.36</td>
<td>19.69 ± 7.88</td>
<td>136.21</td>
<td>0.0001</td>
</tr>
<tr>
<td>2007-08</td>
<td>0.28 ± 0.31</td>
<td>19.15 ± 6.88</td>
<td>126.01</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

All values = standard deviation

RESULTS

The concentration of air pollutants was within the threshold limit prescribed by the Central Pollution Control Board (CPCB 2000), but in comparison with control sites, air pollution was very high in the study area. Among air pollutants,
Air pollution affects epiphytic lichen diversity in India. Naveen et al.

SPM concentration was comparatively higher than the concentrations of NOx and SO2 (Table 1).

In all, a total of 9 genera of epiphytic lichens were identified: Pyxine, Chrysothrix, Parmotrema, Teloschistes, Dirinaria, Graphis, Ramalina, Lecanora, and Heterodermia (Fig. 2). Their occurrence is listed in Tables 2 and 3. In comparison, all 9 genera of epiphytic lichens were present in the control site, but lichens belonging to the genera Ramalina and Teloschistes were absent on M. indica in the industrial area. Species of genera Teloschistes, Ramalina, Parmotrema, Lecanora, and Heterodermia were present in the industrial area, but the frequencies were lower than those in the control site (Tables 2 and 3).
rina and Heteroderma were absent on the bark of P. pin-nata while only six genera were found. These results suggest that the control site had high diversity of lichens with frequencies of 118 ± 7.23 and 132 ± 5.12 on the barns of M. indica and P. pinatta, respectively. The genus Pyxine (29 ± 5.8) dominated while Parmotrema (5 ± 0) showed the least diversity on M. indica. Dirinaria sp. (21 ± 2.8) was dominant on P. pinatta.

At the industrial site Pyxine sp. (21 ± 4.4) was most common on the bark of M. indica. The total sum of frequency of lichen genera was 42 ± 3.5, indicating lichen diversity. Pyxine sp. (15 ± 3.1) dominated on P. pinatta. The industrial area had and LDV of 41.7, about three times less than the control site (122).

All values of air pollutants were expressed as the mean of 96 trials for each year and lichen species were expressed as the mean of 12 trials for each year. Data pertaining to the air pollutants were subjected to one-way multifactorial analysis of variance (ANOVA) in order to determine significant differences between means (P < 0.001).

**DISCUSSION**

From the present study it is evident that the diversity of lichens differed between the industrial area and the control site. The variation in response could be directly attributed to the emissions from two large industries and from a number of small-scale industries in the study area. This observation supports what was noted in earlier studies on lichens at Pauri City, Uttarakhand, India by Vertica Shukla and Upreti (2007). A qualitative survey of the epiphytic lichens in the surroundings of Ulan Bator in October 2007 also showed similar trends (Hauck 2008). Gombert et al. (2006) found lichens and tobacco plants as complementary biomonitors of air pollution in the Grenoble area (Isere, southeast France).

**Findings**

The present work on the use of lichens as a litmus for air pollution reveals that air pollution is the main factor affecting lichen distribution in the study area. Lichen communities change as air quality and environmental conditions change. So, by examining the types of lichens on trees in a neighborhood and the amount of bark that they cover, one can obtain a relative measure of local air quality (Enviro-Zine 2004) and lichens, therefore, are excellent bioindicators and biomonitors. Some species appear to have different tolerance in different geographical regions and so scales of tolerance must be determined in the area to be surveyed. A scale drawn up in one region can not consequently be reliably applied to another without prior study. Karunarathna (2008) noticed lichens as biomonitors of SO2 and NO2 pollution in Colombo and suburbs, further the lowest lichen diversity (0.8374) was recorded from the site located in Colombo Fort. He identified 47 genera of lichens, out of which 10 were sensitive to air pollutants. Dolney et al. (2009) found more than 20 lichen species among all sample plots with the two (A. palmulata and P. squarrosa) in southwestern Pennsylvania, USA being sensitive to air pollution. These results suggest that urban and rural regions show contrasting communities of epiphytic lichen corresponding to air pollution and habitat alteration.

Since the LDV varies from site to site it is clear that air pollution has not equally spread throughout the study area. Nayaka et al. (2003) reported a similar correlation between air pollution and lichen diversity in Bangalore.

**CONCLUSION**

In most studies crustaceous lichens are most tolerant, foliose lichens less tolerant, and fruticose lichens least tolerant. It does not follow that all crustaceous lichens are more tolerant than all foliose and fruticose species: In the present study, sensitivity had the following order: Pyxine (foliose) < Graphis (crustose) < Parmotrema (foliose) < Dirinaria (foliose) < Chrysothrix (crustose) < Lecanora (crustose) < Heteroderma (foliose) < Teloschistes (fruticos) < Rama-lina (fruticose).

The present investigation gives strong evidence that lichen growth in the study area was affected by air pollution. Moreover, a relationship existed been between the lichen community existing at sampling sites and the degree of air pollution. The absence of naturally appearing lichens in severely polluted areas limits the spatial differences of polluted areas. Zones based on epiphytic lichen vegetation provide a better indication of air pollution intensity than distribution maps of particular species. Hence, documentation of the lichen species at the study area will be of greater importance in the future.

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