EVALUATION OF AIR POLLUTION TOLERANCE INDEX OF TREE SPECIES OF BIKANER CITY (RAJASTHAN)

Leela Kaur*, Prabhu Dan Charan*, Rajaram Choyal

* Maharaja Ganga Singh University, Department of Environmental Science, Bikaner, Rajasthan, India

corresponding author: Prabhu Dan Charan, e-mail: prabhueniro@gmail.com

ABSTRACT

The air pollution tolerance index (APTI) is one of the modern tools for assessing the impacts of air pollutants on plant physiology. The value of APTI is different for different plant species. Plants with higher values of APTI are tolerant and act as a sink due to their bioaccumulation ability for air pollutants. Hence, they can be planted to establish green belts in areas with severe air pollution, especially in industrial zones. The present investigation was carried out to assess the APTI values of top twenty urban tree species of the Bikaner city of North-Western Rajasthan. The leaf samples were taken from selected roadside trees distributed in the residential, commercial and industrial zones of the city. On the basis of APTI values, it was observed that Leucaena leucocephala (23.41), Eucalyptus camaldulensis (21.87) and Cassia siamea (21.39) had an APTI value above 20 and they are therefore classified as tolerant species. Similarly, Pongamia pinnata (9.48) showed APTI under 10, therefore it falls into the sensitive category. 80% of the total species in the studied area are categorized as a moderately sensitive category. There were no plant species in very sensitive (APTI < 1) and very tolerant (APTI > 30) category.

Keywords: air pollution tolerance index (APTI), bio-indicator species, tolerant species, roadside trees, green belts

INTRODUCTION

Air pollution has emerged as a global public health problem. It has been identified as a major environmental health hazard. There are many causes of air pollution, including industrialization [1, 2], urbanization [3, 4], vehicle exhaust, deforestation, mining etc. [5]. The number of vehicles is increasing day by day. It was observed that India became the fourth largest automobile market in 2017 [6]. India was the fourth largest emitter of greenhouse gases (GHGs) and accounts for about 5% of total GHG emission at the global level [7]. The total number of registered cars and motorized two wheelers in India was 137 million in 2012 [8]. Vehicle exhaust emission depends on various factors, including fuel quality, maintenance and servicing of vehicles, quality of roads etc. It has been observed that the diesel vehicles emit more particulate matter and oxides of nitrogen compared to petrol vehicles; therefore, diesel is less eco-friendly fuel than petrol [9]. Due to
the government subsidy for diesel, the share of diesel cars was reached 58% in 2012-13 [10] from 27% in 2006 [11].

The multiple pressures on the environment lead to the release of various pollutants into the atmosphere, resulting in drastic environmental and ecological impacts. The calculation of detrimental effects of pollution in terms of monetary value is very difficult, but an estimate from OECD (Organization for Economic Co-operation and Development) suggest that ambient air pollution alone may cost India more than 0.5 trillion dollars per year [12]. About 80% of cities violate air pollution regulation standards in India [13]. The plants are very sensitive to such pollutants and therefore respond accordingly. Such plant species are considered bioindicators of air pollution. They are used as a tool for prediction and recognition of various environmental stresses [14, 15]. Various pollutants can enter into the plant tissues through opening of stomata [16], cuticle [17], cell walls and membranes [18].

Several studies have been carried out on the physiological and biochemical responses of plants to various pollutants [19 - 22]. The plants exposed to air pollutants show physiological changes prior to the visible damage to leaves [23]. These physiological changes include pH of leaf extract [24], relative water content [25], chlorophyll content [26 - 28] and ascorbic acid content [26, 29 - 31]. The response of plants to various pollutants is different for different species. The analysis of individual physiological parameter is not enough to describe cumulative impact of air pollution. Therefore, an air pollution tolerance index (APTI) serves as powerful tool for assessing overall impact of pollution on plant species. APTI is a realistic method which evaluates the tolerance level of plant species towards air pollution by assessing biochemical parameters of its leaves. APTI provides reliable information for establishing green belts in industrial area and selection plant species with regard to their sensitivity to pollution [32]. After reviewing the researches carried out by different researchers [33 - 37], the sensitivity of various plants to different air pollutants can be classified as shown in Table 1.

<table>
<thead>
<tr>
<th>APTI value</th>
<th>Sensitivity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>Very sensitive</td>
</tr>
<tr>
<td>1 - 10</td>
<td>Sensitive</td>
</tr>
<tr>
<td>11 - 20</td>
<td>Moderately sensitive</td>
</tr>
<tr>
<td>21 - 30</td>
<td>Tolerant</td>
</tr>
<tr>
<td>31 - 100</td>
<td>Very tolerant</td>
</tr>
</tbody>
</table>

The sensitive species can be used as bioindicators, while tolerant species can be used as a sink for air pollution. Several studies have been carried out on APTI at national and international levels [38 - 42], but vegetation of the city of Bikaner in North-Western Rajasthan has not been investigated from their air pollution tolerance perspective. Therefore, the present study was carried out to assess the APTI of selected plant species commonly found along the roadsides of the residential, commercial and industrial area of the Bikaner city.

**EXPERIMENTAL**

**Study area**

The city of Bikaner is located in the North-Western part of Rajasthan between 28.02°N and 73.3°E (Figure 1). According to the 2011 census, the city had 644,406 inhabitants. The region has an arid type of climate with an average annual rainfall of 277.55 mm in the district (1991 - 2010), while the normal rainfall (1901 - 1971) is lower than average rainfall and amounts to 257.8 mm [43]. Almost 90% of the total annual rainfall falls during the south-west monsoon, which enters the district in the first week of July and withdraws in the middle of September. The study area is located in the central area of the Thar Desert, which measures extreme values of heat in the summer and cold in the winter. The temperature varies from about 1 °C in the winter to 48 °C in the summer. Atmosphere is
generally dry, except for the monsoon period. The humidity is highest in August with average daily relative humidity of 71% in the morning and 52% in the evening.

In this research, trees planted along the city roads were observed. All 11 major roads in the Bikaner city (Station Road, Poogal Road, Jaipur Road, Jodhpur Road, Jaisalmer Road, Ganganagar Road, Rani Bazar Road, Dauji Road, KEM Road, Udasar Road, and Nagnechi Road) were included in the study. Dauji Road, Station Road and KEM Road pass through major commercial areas of the city. Poogal Road, Rani Bazar Road and Ganganagar Road pass through three major industrial areas of the city: Beechhwal industrial area, Rani Bazar industrial area and Karni Nagar industrial area. The remaining roads pass through or nearby major residential colonies. Therefore, this research was focused on the commercial, industrial and residential areas of the city.

Sampling and analyses

The assessment of air pollution tolerance index (APTI) of vegetation of the city started with selection of tree flora. The study was carried out in the period from January to June 2018. After conducting a random survey, top twenty tree species were selected for the present investigation. The selection of these plants was based on their common presence at road sides of the residential, commercial, and industrial area of the Bikaner city. The top twenty tree species commonly found in the city are: *Acacia nilotica, Acacia senegal, Ailanthus excelsa, Albizia lebbeck, Alstonia scholaris, Azadirachta indica, Cassia siamea, Colophospermum mopane, Dalbergia sissoo, Delonix regia, Eucalyptus camaldulensis, Ficus benghalensis, Ficus religiosa, Leucaena leucocephala, Moringa oleifera, Pongamia pinnata, Prosopis cineraria, Salvadora oleoides, Salvadora persica and Tecoma undulata*. Three specimens of fully matured leaves of selected trees (having girth at breast height (GBH) > 20 cm) were collected in polythene bags, labelled and immediately brought to the laboratory for analysis. Standard methods were adopted for analysis of total chlorophyll [44], pH of leaf extract [33], relative moisture content [45] and ascorbic acid content [31]. The previously mentioned parameters were used for analysis of air pollution tolerance index (APTI). The APTI values for different plant species were computed by following formula proposed by Singh and Rao [33]:

\[
\text{APTI} = \frac{A(T+P) + R}{10}
\]

where is: A - ascorbic acid (mg/g), T - total chlorophyll (mg/g), P - pH of the leaf extract, R - relative water content of a leaf (%).

RESULTS AND DISCUSSION

The average values of different parameters and APTI are shown in Table 2. The sensitivity and response of plants was different for different species, which is represented as different APTI values. It was observed that the APTI values of top twenty tree species of the Bikaner city vary from 9.48 to 23.41. The plant species that have lower APTI act as bioindicators of air pollution, while those that have higher values and are tolerant to air pollution are used for development of green belts in the urban area [41]. Based on sensitivity, it was observed that most of the studied plants can be classified into the moderately sensitive
category (Table 1). Only *Pongamia pinnata* (9.48) showed APTI under 10 (therefore it belongs to the sensitive category), while *Leucaena leucocephala* (23.41), *Eucalyptus camaldulensis* (21.87) and *Cassia siamea* (21.39) were had APTI more than 20 and therefore classified as tolerant species. The rest of the plants are categorized as moderately sensitive, accounting for 80% of the studied species (Figure 2). It was observed that the plants with higher pH values of the leaf extract are more tolerant to air pollutants. Three species, *Leucaena leucocephala* (pH = 8.95), *Eucalyptus camaldulensis* (pH = 9.45) and *Cassia siamea* (pH = 8.93) showed highest pH values and are also tolerant to the air pollution. These findings correspond to the findings of Ogunkunle et al. [46] who worked on the air pollution tolerance index and anticipated the performance index of some tree species for biomonitoring environmental health.

Table 2. Average values of different physiological parameters and APTI of top 20 tree species of the Bikaner city

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Leaf extract pH</th>
<th>Relative moisture (%)</th>
<th>Total chlorophyll (mg/g)</th>
<th>Ascorbic acid (mg/g)</th>
<th>APTI value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Acacia nilotica</em></td>
<td>5.72</td>
<td>73.06</td>
<td>8.52</td>
<td>5.43</td>
<td>15.04</td>
</tr>
<tr>
<td>2. <em>Acacia senegal</em></td>
<td>6.64</td>
<td>72.11</td>
<td>7.55</td>
<td>4.88</td>
<td>14.14</td>
</tr>
<tr>
<td>3. <em>Ailanthus excelsa</em></td>
<td>8.54</td>
<td>80.56</td>
<td>11.54</td>
<td>3.54</td>
<td>15.16</td>
</tr>
<tr>
<td>4. <em>Albizia lebbeck</em></td>
<td>8.32</td>
<td>79.54</td>
<td>12.8</td>
<td>4.5</td>
<td>17.46</td>
</tr>
<tr>
<td>5. <em>Alstonia scholaris</em></td>
<td>8.73</td>
<td>79.54</td>
<td>6.84</td>
<td>4.87</td>
<td>15.54</td>
</tr>
<tr>
<td>6. <em>Azadirachta indica</em></td>
<td>7.87</td>
<td>78.33</td>
<td>11.55</td>
<td>4.47</td>
<td>16.51</td>
</tr>
<tr>
<td>7. <em>Cassia siamea</em></td>
<td>8.93</td>
<td>82.54</td>
<td>13.66</td>
<td>5.84</td>
<td>21.39</td>
</tr>
<tr>
<td>8. <em>Colophospermum mopane</em></td>
<td>8.76</td>
<td>74.8</td>
<td>8.47</td>
<td>4.56</td>
<td>15.34</td>
</tr>
<tr>
<td>9. <em>Dalbergia sissoo</em></td>
<td>6.24</td>
<td>76.51</td>
<td>7.74</td>
<td>3.94</td>
<td>13.16</td>
</tr>
<tr>
<td>10. <em>Delonix regia</em></td>
<td>8.73</td>
<td>76.58</td>
<td>12.53</td>
<td>1.35</td>
<td>10.53</td>
</tr>
<tr>
<td>12. <em>Ficus benghalensis</em></td>
<td>7.66</td>
<td>75.94</td>
<td>10.43</td>
<td>2.41</td>
<td>11.95</td>
</tr>
<tr>
<td>13. <em>Ficus religiosa</em></td>
<td>6.92</td>
<td>73.5</td>
<td>9.37</td>
<td>1.82</td>
<td>10.31</td>
</tr>
<tr>
<td>14. <em>Leucaena leucocephala</em></td>
<td>8.95</td>
<td>82.41</td>
<td>14.12</td>
<td>6.73</td>
<td>23.41</td>
</tr>
<tr>
<td>15. <em>Moringa oleifera</em></td>
<td>7.92</td>
<td>73.51</td>
<td>13.86</td>
<td>2.44</td>
<td>12.67</td>
</tr>
<tr>
<td>16. <em>Pongamia pinnata</em></td>
<td>6.37</td>
<td>64.87</td>
<td>6.43</td>
<td>2.34</td>
<td>9.48</td>
</tr>
<tr>
<td>17. <em>Prosopis cineraria</em></td>
<td>8.34</td>
<td>68.23</td>
<td>8.79</td>
<td>6.22</td>
<td>17.48</td>
</tr>
<tr>
<td>18. <em>Salvadora oleoides</em></td>
<td>8.92</td>
<td>79.25</td>
<td>13.54</td>
<td>3.75</td>
<td>16.35</td>
</tr>
<tr>
<td>20. <em>Tecomella undulata</em></td>
<td>6.85</td>
<td>73.64</td>
<td>7.88</td>
<td>3.76</td>
<td>12.90</td>
</tr>
</tbody>
</table>
The moisture content of the plant maintains the turgidity of the leaves and supports the vital physiological balance under stress conditions. Any environmental stress, such as air pollutants, can increase the water content in leaves to reduce the stress. Accordingly, a higher relative water content in the leaves of a plant is directly proportional to tolerance of that plant species to the stress caused by emission of pollutants. The results of the present investigation are positively correlated with earlier findings [47 - 49]. Dhankar et al. [48] have found that the relative water content is an indicator of stress and that its concentration increases with the induction of stress in the form of air pollutants. Sharma et al. [49] showed that *Grevillea robusta* had higher relative water content with increasing air pollution.

The results of the analysis of the total chlorophyll content have shown that tolerant plant species, i.e., *Leucaena leucocephala* (14.12 mg/g), *Eucalyptus camaldulensis* (13.42 mg/g) and *Cassia siamea* (13.66 mg/g) have a higher chlorophyll content, while sensitive plant species (*Pongamia pinnata*) have the lowest chlorophyll content (6.43 mg/g). The results of the study are in accordance with research carried out by Joshi et al. [50] who worked on air quality monitoring of Indore city. The content of ascorbic acid in the samples was ranged from 1.35 mg/g (*Delonix regia*) to 6.73 mg/g (*Leucaena leucocephala*). Ascorbic acid is a natural detoxicant, so it helps plants to withstand injuries caused by air pollution and also prevents the harmful effect of toxic emissions [34]. This study revealed that plants have ascorbic acid content in the following order: tolerant plants > moderately sensitive plants > sensitive plants. This proves the fact that level of ascorbic acid improves the tolerance of plants to the negative impacts of air pollutants. These results are supported by earlier findings [51 - 53]. Zhang et al. [51] showed ozone tolerance of plants with a high content of ascorbic acid, while Ghosh et al. [52] and Cheng et al. [53] found that the ascorbic acid content promotes plant growth as well as the resistance level of plants to air pollutants.

**CONCLUSION**

In this study, APTI values of top twenty species of trees along the major roadsides of different residential, commercial and industrial zones of Bikaner city were determined. It was observed that only three species showed APTI values above 20: *Leucaena leucocephala* (23.41), *Eucalyptus camaldulensis* (21.87) and *Cassia siamea* (21.39). *Pongamia pinnata* (9.48) showed APTI lesser than 10, therefore it belongs to the sensitive category. The remaining 16 species had the APTI values from 10 to 20, which is why they are categorized as moderately sensitive species. No tree species were found in very sensitive (APTI < 1) and very tolerant category (APTI > 30). Since roads and highways are one of the important line sources of air pollution, suitable plant species must be planted along major roadsides of the city to fight air pollution. It will not only increase the greenery, but it will also help to reduce air pollution and ultimately improve the social as well as environmental health.
REFERENCES


[17] M. Krywult, J. Hom, A. Bytnerowicz, K.E. Percy, Deposition of gaseous nitric acid and its effects on foliage of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) seedlings, Proceedings of the 16th international meeting for specialists in air pollution effects on forest ecosystems, Air Pollution and Multiple Stress, Fredericton, Canada, IUFRO, 7-9 September, 1994.


Y. Murata, Exogenous proline and glycinebetaine increase NaCl-induced ascorbate-glutathione cycle enzyme activities, and proline improves salt tolerance more than glycinebetaine in tobacco bright yellow-2 suspension-cultured cells, Journal of Plant Physiology 164(2007) 11, 1457-1468. https://doi.org/10.1016/j.jplph.2006.10.004


Acknowledgements

Authors are grateful to the National Remote Sensing Centre, Hyderabad (India) for providing financial support under IGBP-NCP-VPA project.