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Air Pollution Tolerance Index and Biochemical constituents of some plants growing in Neyveli Lignite Corporation (NLC), Tamil Nadu, India

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Abstract

Plant species can be effectively used as filters to reduce air pollution and also as bio-indicators of urban air quality. Screening of plants for their sensitivity/tolerance level to air pollutants is important because the sensitive plants can serve as bio-indicator and the tolerant plants as sink for controlling air pollution in urban and industrial areas. Biochemical parameters namely Relative Water Content, leaf extract pH, ascorbic acid, chlorophyll, starch, protein, amino acid, reducing and total sugar were estimated to generate Air Pollution Tolerance Index (APTI) for ten plants each at polluted site and control site. The results showed that *Terminalia catappa* (18.16 and 16.19) and *Mangifera indica* (16.01 and 15.98) have recorded high and low values in both the sites respectively. In comparison between the two sites, all the values were slightly higher in the polluted site than the control for all the ten plants and a considerable variation was observed among the four parameters where their percentage variations were considered. *Terminalia catappa*, *Mangifera indica* and *Calotropis gigantea* were found to be tolerant towards air pollution.

Key words: Air pollution, relative water content, pH, APTI, biochemical parameters.

1 Introduction

Plants are an integral basis for all ecosystems and also most likely to be affected by airborne pollution which are identified as the organisms with most potential to receive impacts from ambient air pollution. Also the effects are most often apparent on the leaves which are usually the most abundant and most obvious primary receptors of large number of air pollutants. Biomonitoring of plants is an important tool to evaluate the impact of air pollution. Hence in the latest years urban vegetation became increasingly important not only for social reasons but mostly for affecting local and regional air quality. The usefulness of evaluating APTI for the determination of tolerance as well as sensitiveness of plant species were followed by several authors (1, 2, 3, 4, 5). Air Pollution can be defined as the human introduction into the atmosphere of chemicals, particulate matter or biological materials that cause harm or discomfort to humans, or other living organism or damage the environment (6). Air pollution is a major problem arising mainly from industrialization (7).

Tree act as a sink of air pollutants and thus reduce their concentration in the air (8). However, this function of pollution abatement is best performed by the pollution- tolerant species. It appears that tree plantation in industrial areas is a site- specific activity and knowledge of tolerance level of plant species to air pollution is necessary. Plants growing in polluted environment often responded and showed significant changes in their morphology, physiology and biochemistry. The response of plants towards air was assessed by air pollution tolerance index. Planting of trees and shrubs forms one of the best way to mitigate air pollution in urban areas and plant selection criteria should not only be limited to colourful flower and leaves, robustness, watering issues and space but it should also be able to help improve air quality (9).

The aim of this study is therefore to determine the Air Pollution Tolerance Index (APTI) values of ten plant species within the Neyveli Lignite Corporation, Neyveli and the study was carried out with a view to find out the tolerance as well as sensitivity of the common plant species subjected to industrial pollution.

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2. Materials and Methods

2.1 Study area

Neyveli Lignite Corporation Limited (NLC) is a Mini- ratna, Government of India enterprise registered under Indian Companies Act 1956, engaged in commercial exploitation of the lignite deposit available at Neyveli region. It is located at 11.30^{o} N - 79.29^{o} E. It is 52 km inland from Bay of Bengal, 197 km South of Chennai. Neyveli is a mining and power generation township in Cuddalore District in the Indian state of Tamil Nadu. The present study was conducted during the period of six months (January to June-2012).

2.2 Sampling

Plants were randomly selected from the immediate vicinity of the station. This is designated as polluted site

(PS). Leaf Samples of the various plants were then collected. Three replicates of fully matured leaves were taken and immediately taken to the laboratory for analysis. A composite sample of each plant species was obtained before analysis. A site nearby with similar ecological conditions was selected as the control site (CS). Samples were preserved in refrigerator for further analysis.

2.3 Relative Water Content (RWC) – [Liu and Ding, 2008 (10)]

$$RWC\ (\%) = \frac{FW - DW}{TW - DW} \times 100$$

where FW is Fresh weight, DW is Dry weight, and TW is Turgid weight.

Fresh water was obtained by weighing the fresh leaves. The leaves were then immersed overnight in water, blotted dry and then dried overnight in an oven at 70°C and reweighed to obtain the dry weight.

2.4 Air Pollution Tolerance Index (APTI) Determination – [Singh and Rao, 1983 (11)]

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

where, A is ascorbic acid (mg/g. fr. wt), T is total chlorophyll (mg/g. fr. wt), P is leaf extracts pH and R is relative Water Content [(%) of the leave's].

2.5 Leaf extract pH – [Singh and Rao, 1983 (11)]

Five g of the fresh leaves was homogenized in 10 ml demonized water. This was filtered and the pH of the leaf extract determined after calibrating pH water with buffer solution of pH 4 and 9.

2.6 Ascorbic Acid (AA) – [Abida and Harikrishna, 2010 (12)]

One g of ground fresh leaves was homogenized in 4 ml oxalic acid - EDTA extracting solution for 30 sec., 1 ml of orthophosphate acid and 1 ml 5% tetraoxosulphate (vi) acid were added. 2 ml of ammonium molybdate and 3 ml of water were also added. The solution was left to stand for 15 min. The absorbance was read off with a digital spectrophotometer at 760 nm. The concentration of the ascorbic acid was determined from a standard ascorbic acid regression curve.

2.7 Biochemical Analysis

The Biochemical analysis was carried out by the following methods viz., Chlorophyll- Arnon [13], Starch- [Lugol`s Iodine Method], Amino acid- Moore and Stein [14], Protein- Lowry *et al*. [15], Reducing Sugar- Nelson [16] and Total Sugar- Nelson, [16].

3 Results

3.1 Relative Water Content (RWC) and Leaf Extract pH

Relative water content (RWC) and leaf extract pH of control and polluted site plants are presented in table 1. The highest relative water content was achieved in polluted site (94.1±0.07 mg/g fr. wt) and control site (93.5±0.05 mg/g fr. wt) in *Terminalia catappa*. Similarly, the lower relative water content in polluted site (36.9±0.07 mg/g fr. wt) and control site (36.07±0.05 mg/g fr. wt) was recorded in *Murrya koenigii* plants. Similarly in *Terminalia catappa* plants, the leaf extract pH was higher in polluted site (8.08±0.031 mg/g fr. wt) and control site (8.01±0.029 mg/g fr. wt) and lowest leaf extract pH was observed in polluted site (3.98±0.032 mg/g fr. wt) and control site (3.87±0.028 mg/g fr. wt) in *Murraya koenigii* plants.

Table 1: Effect of Air pollution on Leaf extract pH (mg/g fr. wt) and Relative Water Content (%) of certain Plants around Neyveli town

S. No	Name of the plants	Leaf extract pH		Relative water content	
		Control site	Polluted site	Control site	Polluted site
1.	*Terminalia catappa* L.	8.01 ±0.029	8.08 ±0.031	93.5±0.05	94.1±0.07
2.	*Mangifera indica* L.	7.88 ±0.034	7.92 ±0.039	91.1 ±0.07	92.5 ±0.08
3.	*Ficus religiosa* L.	6.98 ±0.038	7.01 ±0.041	90.1 ±0.06	83.5 ±0.06
4.	*Polyalthia longifolia.*L.	6.96 ±0.012	7.00 ±0.018	80.4 ±0.08	82.7 ±0.08
5.	*Sesbania grandiflora* L.	5.32 ±0.062	5.76 ±0.069	70.8 ±0.08	75.1 ±0.09
6.	*Punica granatum* L.	5.10 ±0.054	5.20 ±0.059	84.2 ±0.02	85.3 ±0.05
7.	*Murraya koenigii* L.	3.87 ±0.028	3.98 ±0.032	36.7 ±0.05	36.9 ±0.07
8.	*Nerium oleandrum* L.	3.98 ±0.031	3.99 ±0.023	86.4 ±0.04	87.2 ±0.06
9.	*Calotropis gigantea* L.	7.80 ±0.079	7.86 ±0.081	93.4 ±0.06	90.4 ±0.08
10.	*Artocarpus heterophyllus* L.	7.52 ±0.078	7.63 ±0.081	90.22 ±0.07	90.21 ±0.09

3.2 Ascorbic Acid and Air Pollution Tolerance Index (APTI)

Table 2 shows Ascorbic acid and the APTI content of control site and polluted site plants. The higher Ascorbic acid content was observed in polluted site (20.9±0.11 mg/g fr. wt) and control site (20.5±0.09 mg/g fr. wt) of *Terminalia catappa* plants. Similarly, the lower ascorbic acid content was observed in polluted site (4.09±0.12 mg/g fr. wt) and control site (3.07±0.07 mg/g fr. wt) was recorded in *Murraya koenigii* plants. The highest APTI content was observed in *Terminalia catappa* (18.16±0.19 mg/g fr. wt) in polluted site and 16.19±0.12 mg/g fr. wt) in control site. Similarly, the lower APTI content was observed in experimental site (5.00±0.24 mg/g fr. wt) and control site (4.80±0.15 mg/g fr. wt) was recorded in *Nerium oleantrum*.

3.3 Total chlorophyll and Starch

Table 3 represents the total chlorophyll and starch content of control site and polluted site plants. The higher Total chlorophyll and starch content was recorded in polluted site (14.90±0.095; 14.13±0.012 mg/g fr. wt) and control site (14.60±0.068; 13.10±0.099 mg/g fr. wt) of *Terminalia catappa* plants. Similarly, the lower chlorophyll and starch content in polluted site (6.92±0.034; 5.05±0.034 mg/g fr. wt) and control site (6.40±0.028; 5.00±0.032 mg/g fr. wt) was recorded in *Murrya koenigii* plants.

3.4 Protein and Amino acid

Protein and amino acid content of polluted site plants were higher in control and the results are presented in table 4. The higher protein and amino acid content was

observed in polluted site (32.41±0.156; 10.93±0.085 mg/g fr. wt) and control site (32.38±0.149; 10.20±0.013 mg/g fr. wt) of *Terminalia catappa* plants. Similarly, the lower protein and amino acid content in polluted site (10.80±0.031; 4.80±0.056 mg/g fr. wt) and control site (10.01±0.021; 4.09±0.040 mg/g fr. wt) was recorded in *Murrya koenigii* plants.

3.5. Reducing and Total sugar

The sugar content of polluted and control site plants are presented in the table.5. The higher reducing and total sugar content was recorded in polluted site (16.24±0.105; 18.64±0.202 mg/g fr. wt) and control site (14.82±0.099; 18.60±0.197 mg/g fr. wt) of *Terminalia catappa* plants. Similarly, the lower reducing and total sugar content was recorded in polluted site (4.68±0.021; 8.98±0.041 mg/g fr. wt) and control site (4.55±0.020; 8.80±0.038 mg/g fr. wt) in *Murrya koenigii* plants.

Table 2: Effect of Air pollution on Ascorbic acid and APTI (mg/g fr. wt) content of certain plants around Neyveli town

S. No	Name of the plants	Ascorbic acid		APTI	
		Control site	Polluted site	Control site	Polluted site
1.	*Terminalia catappa* L.	20.5 ±0.09	20.9 ±0.11	16.19±0.12	18.16 ±0.19
2.	*Mangifera indica* L.	18.5 ±0.06	18.97 ±0.12	15.98 ±0.16	16.01 ±0.19
3.	*Ficus religiosa* L.	12.9 ±0.07	13.5 ±0.10	13.0 ±0.13	13.9 ±0.20
4.	*Polyalthia longifolia.*L.	9.98 ±0.08	9.99 ±0.13	13.03 ±0.09	14.17 ±0.14
5.	*Sesbania grandiflora* L.	3.07 ±0.07	4.51 ±0.12	8.0 ±0.09	8.20 ±0.15
6.	*Punica granatum* L.	5.8 ± 0.06	6.90 ±0.09	9.0 ±0.08	9.82 ±0.10
7.	*Murraya koenigii* L.	3.07 ±0.07	4.09 ±0.12	7.5 ±0.16	7.89 ±0.20
8.	*Nerium oleandrum* L.	6.98 ±0.08	7.00 ±0.15	4.8 ± 0.15	5.0 ±0.24
9.	*Calotropis gigantea* L.	16.5 ±1.20	16.9 ±1.40	14.9 ±0.99	15.1 ±1.23
10.	*Artocarpus heterophyllus* L.	15.1 ±1.00	15.99 ±1.28	14.0 ±0.78	14.09 ±0.88

Table 3: Effect of Air pollution on Chlorophyll and Starch content (mg/g fr. wt) of certain plants around Neyveli town

S. No	Name of the plants	Chlorophyll		Starch	
		Control site	Polluted site	Control Site	Polluted site
1.	*Terminalia catappa* L.	14.6 ±0.079	14.9 ±0.095	13.10 ±0.009	14.13±0.012
2.	*Mangifera indica* L.	14.00 ±0.068	14.12 ±0.063	13.00 ±0.019	13.12 ±0.022
3.	*Ficus religiosa* L.	11.97 ±0.046	12.29 ±0.049	10.09 ±0.032	10.12 ±0.040
4.	*Polyalthia longifolia.*L.	10.18 ±0.020	10.29±0.021	11.59 ±0.027	11.68 ±0.027
5.	*Sesbania grandiflora* L.	9.52 ±0.040	9.69 ±0.021	9.78 ±0.009	9.79 ±0.010
6.	*Punica granatum* L.	9.24 ±0.009	9.69 ±0.011	5.76 ±0.007	5.82 ±0.011
7.	*Murraya koenigii* L.	6.40 ±0.028	6.92 ±0.034	5.0 ±0.032	5.05 ±0.034
8.	*Nerium oleandrum* L.	11.29±0.597	11.34 ±0.605	9.73 ±0.042	9.82 ±0.049
9.	*Calotropis gigantea* L.	12.59 ±0.080	12.62±0.071	12.87 ±0.032	12.90 ±0.040
10.	*Artocarpus heterophyllus* L.	12.50±0.037	12.60 ±0.049	12.80 ±0.019	12.90±0.022

Table 4: Effect of Air pollution on Protein and Amino acid (mg/g fr. wt) content of certain plants around Neyveli town

S. No	Name of the plants	Protein		Amino acid	
		Control Site	Polluted site	Control Site	Polluted site
1.	*Terminalia catappa* L.	32.38±0.149	32.41 ±0.156	10.20±0.13	10.93 ±0.085
2.	*Mangifera indica* L.	30.10±0.100	30.14 ±0.106	10.0 ±0.07	10.29 ±0.1465
3.	*Ficus religiosa* L.	28.00±0.052	28.96 ±0.056	8.20±0.07	8.43 ±0.061
4.	*Polyalthia longifolia.*L.	28.11±0.049	28.12 ±0.056	9.62±0.05	9.64 ±0.055
5.	*Sesbania grandiflora* L.	18.38 ±0.041	18.41 ±0.049	4.92±0.04	4.98 ±0.048
6.	*Punica granatum* L.	20.38±0.019	20.40 ±0.026	7.82±0.04	7.86 ±0.005
7.	*Murraya koenigii* L.	10..01±0.021	10.80 ±0.031	4.09±O.04	4.80 ±0.056
8.	*Nerium oleandrum* L.	24.58±0.079	24.68 ±0.109	8.62 ±0.06	8.67 ±0.072
9.	*Calotropis gigantea* L.	30.10±0.130	30.11 ±0.149	9.99 ±0.08	10.11 ±0.090
10.	*Artocarpus heterophyllus* L.	29.64±0.052	29.90 ±0.061	9.97±0.05	10.00 ±0.060

Table 5: Effect of Air pollution on Reducing and total sugar content of certain (mg/g fr. wt) plants around Neyveli town

S No	Name of the plants	Reducing sugar		Total sugar	
		Control Site	Polluted Site	Control site	Polluted site
1.	*Terminalia catappa* L.	14.82±0.099	16.24±0.105	18.60±0.197	18.64±0.202
2.	*Mangifera indica* L.	14.78 ±0.042	14.82±0.046	18.52±0.072	18.60±0.088
3.	*Ficus religiosa* L.	13.19 ±0.017	13.21±0.021	16.40±0.040	16.42±0.043
4.	*Polyalthia longifolia.*L.	6.84 ±0.011	6.98±0.017	9.60± 0.030	9.62±0.034
5.	*Sesbania grandiflora* L.	5.23 ±0.007	5.42±0.007	9.90 ±0.014	9.98±0.018
6.	*Punica granatum* L.	10.10 ±0.006	10.24±0.006	15.62±0.010	15.69±0.011
7.	*Murraya koenigii* L.	4.55 ±0.020	4.68±0.021	8.80 ±0.038	8.98±0.041
8.	*Nerium oleandrum* L.	10.86 ±0.040	10.99±0.046	14.82±0.078	14.86±0.082
9.	*Calotropis gigantea* L.	14.68 ±0.083	14.79±0.096	18.43±0.142	18.42±0.158
10.	*Artocarpus heterophyllus* L.	13.64 ±0.017	13.71±0.021	17.81±0.040	17.86±0.049

4 Discussion

Most of the urban areas of the world today have high concentration of air pollutants emanating from different sources viz., motor vehicle, traffic, power generation, residential heating and industry of adjoining areas (17). The plants being constantly exposed to the environment absorb, accumulate and integrate pollutants impinging on their foliar surfaces. Consequently, they show visible or subtle changes depending on their sensitivity level (18).

In the present investigation, the relative water content of the leaves from the polluted area was higher than those from the control plants. It is similar to the report of Gharge and Menon (3); Rai *et al*. (19), who found higher relative water content in the experimental plants than in the control plants. This indicates that relative water content plays a considerable role in maintaining physiological balance among plants under air pollution stress and as well as showed tolerance

towards water stress prevailing in this semi-arid region (4). The plants with high relative water content under polluted conditions may be tolerant to pollutants (1). High water content within plant body helps to maintain its physiological balance under stress conditions such as exposure to air pollution when the transpiration rates are usually high. It also serves as an indicator of drought resistance in plants. Sensitive plants had lower leaf-extract pH than tolerant plants. Similar result was obtained in the present investigation. High pH may increase the efficiency of conversion from hexose sugar to Ascorbic acid, while low leaf extract pH showed good correlation with sensitivity to air pollution (20). pH of the leaf extract plays an important role in deciding the tolerance level of the plants against the pollution. Higher the pH provides better tolerance in plants against pollutants (3). Rai *et al*. (19) found that plants from industrial site had a pH towards the acidic site, whereas those from the non industrial site showed neutral to slightly alkaline range. The ascorbic acid from plants in the polluted site was higher than that from the control plants, in this present work. This agrees with the reports of Chandawat *et al*. (21), Meerabai *et al*. (22) and Rai *et al*. (19) who found higher levels of Ascorbic acid in the leaves of the most tolerant plants and those at the polluted sites and this suggests their tolerance to the air pollutants. For the Air Pollution Tolerance Index study, ascorbic acid concentration is estimated. Reducing power of ascorbic acid is directly proportional to its concentration. Tripathi and Gautam (23) also reported increase in the concentration of ascorbic acid in the leaves of *Mangifera indica* L., near roadsides due to enhanced pollution loads of automobiles. The increase level of ascorbic acid reported may be due to the defence mechanism of the respective plants (24). Photosynthetic rate was reduced in plants at low leaf pH. High pH may increase the efficiency of conversion of hexose sugar to ascorbic acid and it is related to the tolerance to pollution (20). The present study revealed that chlorophyll content in all the plants varied with the pollution status of the area. A considerable loss in total chlorophyll in the leaves of plants exposed to air pollution stress supports the argument that the chloroplast is the primary site of attack by air pollutants. Jyothi and Jaya (1) observed higher levels of total chlorophyll in *Ficus benghalensis* and this may be due to the tolerance nature of the plant. On the other hand, Gharge and Menon (3) and Rai *et al*. (19) reported that lower chlorophyll while other decreases it (25). Chandawat *et al*. (21) observed that the chlorophyll content of all plants they tested varied with the pollution status of the area, as well as the tolerance and sensitivity of the plant species. The total chlorophyll is related to ascorbic acid productivity since the ascorbic acid is concerned mainly in the chloroplasts (10). Certain air pollutant have been reported to reduce chlorophyll content (26, 27) while others increase it (23, 28). In the present study the air pollution tolerance index of polluted site plants was high when compared to control site. Similar study of air pollution tolerance index was also conducted by Tanee and Albert (29) and Nwadinigwe (5). An increase of APTI values of plants at the polluted site compared with those at the control site may be due to constant exposure of these plants to emissions of gaseous and particulate matter from industries operating where they were collected, as well as emissions from vehicle exhausts (19). In certain plants higher accumulation of starch was observed in polluted region than the control plants. According to Tripathi *et al*. (30) higher accumulation of starch is due to higher resistance of their photosynthetic apparatus and low starch export from the Mesophyll. Reduction in starch content in polluted stations can be attributed to increased respiration and decreased CO_2 fixation because of chlorophyll deterioration. It has been mentioned that pollutants like SO_2, NO_2 and H_2S under hardening conditions can cause more depletion of soluble sugars in the leaves of plants grown in polluted area. Similar result was obtained by Tzvetkova and Kolarov (31) in *Tilia argentea* and *Quercus cerris*.

In the resent study protein and Amino acid content of the control site plants was lower than that of the polluted site plants.

5 Conclusion

APTI determination is of importance because with increased industrialization, there is increasing danger of deforestation due to air pollution. The results of such studies are therefore handy for future planning and may be helpful to bring out possible control measures. The study indicates by means of APTI index featuring the five biochemical parameters, that the air pollutants are the chief factors responsible to alterations in plant attributes in the polluted areas in addition to natural soil and climatic conditions. Thus the basic information on APTI values for various plants will be of important value, as with increase in air pollution there will be an increase in damage to flora. The present study indicates that trees such as *Terminalia catappa* and *Mangifera indica* shrubs like *Calotropis gigantea* can be used as sink towards air pollutants. Therefore, more work should be carried out on the APTI determination of many more plants globally, since air pollution is a global menace.

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