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Evaluation of Air Pollution Tolerance Indices of Plant Species Growing in the Vicinity of Cement Industry and Yogi Vemana University Campus

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ABSTRACT
Plant species can be effectively used as filters for reducing air pollution and also as bio-indicators of urban air quality. Physio-biochemical parameters namely Ascorbic acid, leaf extract pH, total chlorophyll content and relative water content were measured to generate Air Pollution Tolerance Index (APTI) for seven plants each at polluted site and controlled site. All the plants were found to be sensitive to air pollution. The APTI values were in the range of 7.38 to 10.12 in the polluted site and 6.44 to 9.6 in control site. Aegle marmelos (10.12 and 9.6) and Ziziphus zizyphus (7.38 and 6.44) have recorded high and low values in both the sites respectively. In comparison between the two sites; although no significant difference between APTI values was found, all the values were slightly higher in the polluted site than the controlled for all the six plants except in Leucaeana leucocephala and a considerable variation was observed among the four parameters when their percentage variations were considered. Aegle marmelos, Cassia auriculata and Bougainvillea spectabilis were found to be tolerant towards air pollution.

Keywords: *Aeglemarmelos, Air Pollution, APTI, Bougainvillea Spectabilis, Cassia Auriculata, Cement Industry.*

1. INTRODUCTION
Air pollution is an inevitable harmful by product of rapid industrialization and urbanization that is responsible for variety of deleterious effects on both human and plant communities. Being second largest manufacturing industry in India, cement industry is a potential anthropogenic source of air pollution in the form of suspended particulate matter (SPM), SO_x, (NO_x) and carbon monoxide (CO) which may cause harm to humans as well as flora [1]. Dust deposited on leaves can affect photosynthesis, stomatal functioning and productivity [2]. As 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 [3]. It has also been reported that when exposed to air pollutants most plants experience physiological changes before exhibiting visible damage to leaves [4]. Even trees can act as biological filters that can remove large number of air borne pollutants and hence improve the quality of air in polluted environments [5]. However this function of pollution abatement can be best performed by the pollution tolerant species [6].

Thus bio-monitoring of plants can be an important tool in evaluating the sensitivity of air pollution on plants. This can be done by calculating an index known as Air Pollution Tolerance Index (APTI). A total of four factors namely ascorbic acid, total chlorophyll content, leaf extract pH and relative water content are used to calculate the index [7]. Since the tolerance and sensitivity of plants towards air pollutants varies, the categorization of plants into sensitive and tolerant groups will be helpful as the former can be used as indicators of pollutants and latter as sinks for the abatement of air pollution in the vicinity if industrial areas [8].

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 colorful flower and leaves, robustness, watering issues and space but it should also be able to help improve air quality [9]. For which the knowledge on the tolerance level of plant species is necessary [6]. Keeping in view that plants response to air pollutants vary from species to species and types of pollutants, the objective of the study is to identify specific tolerant and sensitive plants that can be used to develop green belt around the industry.

2. MATERIALS AND METHODS
Yerraguntla town, in YSR Kadapa district, Andhra Pradesh constitutes of three major cement industries namely India cements, Zuari cements and Bharathi cements in and around 15 km radius. It is located at 14^0 63'N and 78^0 53' E at an elevation of 152 m. It is one of the leading industrial towns of Rayalaseema region and is famous for limestone reserves and stones used for house flooring and construction of houses. Its economy is based on mining and transportation of these stones. The conglomeration of these many

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industries and other ancillary industries has a potential to be a source of air pollution that affects humans and flora.

The study was carried out on the seven plants collected in the areas near to the Indian Cements Ltd., and the same plants were collected in the Yogi Vemana University Campus. The seven plants include five trees namely *Aegle marmelos, Ziziphus zizyphus, Azadirachta indica* and *Leucaena leucocephala* and two shrubs namely *Cassia auriculata* and *Bougainvillea spectabilis*. The study was carried out before the onset of summer season from Febraury to March 2013. Care was taken to obtain leaf samples from the plants of same height and girth size and the samples were taken in the morning (8:30-10:00 A.M) in triplicates. The Air Pollution Tolerance Index (APTI) was determined by measuring the factors such as ascorbic acid, chlorophyll, leaf extract pH and relative water contents in leaf samples. The total chlorophyll by following the method of Arnon [11], ascorbic acid by Sadasivam and Balasubramaniam [12], relative water content by [8] and pH of leaf extract was measured by pH meter after calibrating it at pH 4 and 7.

2.1. Total Chlorophyll Content (Tch.)

TCh analysis was obtained as follows: 0.5g fresh leaves material was grounded and diluted to 10ml in distilled water. A subsample of 2.5 ml was mixed with 10ml acetone and filtered. Optical density was read at 645 nm (D645) and 663nm (D663). Optical density of TCh (CT) is the sum of chlorophyll a (D645) density and chlorophyll a (D663) density as follows:

$$CT = 20.2\ (D645) + 8.02\ (D663) \qquad (1)$$

2.2. Relative Water Content (RWC)

Leaf RWC is determined by using the method described by (Singh, 1997) and calculated with the formula

$$RWC = FW - DW / TW - DW \times 100. \qquad (2)$$

FW-Fresh weight; DW-Dry weight; TW-Turgid weight. Fresh weight is recorded by weighing the fresh leaves. To get the dry weight, the leaves are dried in an oven at 70 ^{o}C for overnight and then taken the dry weight. For obtaining the turgid weight, the leaves are immersed in water overnight, blotted dry and then weighed.

2.3. Leaf Extract pH

5 gms. of fresh leaves are homogenized in 10 ml. of deionised water. This is filtered and PH of the leaf extract determined after calibrating PH meter with buffer solution of pH-4 and 7.

2.4. Ascorbic Acid

The amount of ascorbic acid present in a solution was first determined by dissolving a known amount of ascorbic acid in distilled water (40 mg in 100ml) and titrated against 2,6dichlorophenol indophenols (DCPIP). The titer value was used as reference to find out the ascorbic acid content in an unknown leaf sample. Ascorbic acid is a strong reducing agent and it reduces the dye DCPIP into colorless leucobase, this dye is red in acid solution and becomes colorless when fully titrated with ascorbic acid. The ascorbic acid in the given sample is determined by titrating directly into a known amount of dye to colorless endpoint.
The APTI was calculated by using the following formula [7].

$$APTI= [A\ (T+P) + R]\ /10 \qquad (3)$$

Where, A= Ascorbic acid (mg/g)
T= Total Chlorophyll (mg/g)
P= pH of leaf extract.
R= Relative water content of leaf tissue (%).

3. RESULTS AND DISCUSSION

The results obtained by measuring the four physio-biochemical parameters of plants namely, ascorbic acid, total chlorophyll, leaf extract pH and relative water content and from which the Air Pollution Tolerance Index was calculated is provided in Table 1. The generated APTI index represents the parameters of seven plants each at controlled site and polluted site. The Ascorbic acid values were in the range of 0.15 to 1.58 in the controlled site; the highest value was scored by *Aegle marmelos* and the lowest score by *Azadirachta indica*. In comparison Ascorbic acid values showed an increment among all the trees in the range of 14% to 75.9% between the two sites. Highest increment was observed for *Bougainvillea spectabilis* followed by *Azadirachta indica*. With respect to total chlorophyll values, all the plants have showed lesser values in polluted site in comparison to controlled site. The ranges were 2.96 to 12.67 in the polluted site and 3.61 to 19.49 in the controlled site and *Leucaena leucocephala* and *Bougainvillea spectabilis* scored low and high values respectively in both the sites. *Cassia auriculata* showed marked difference with 45.66% followed by *Azadirachta indica* (39.64%) and *Bougainvillea spectabilis* (34.98%). Incidentally these three plants have scored high values of total chlorophyll content. In consideration of pH values, all the plants showed near neutral and slightly above neutral values in the range of 7.08 to 7.9, except for *Leucaena leucocephala* which registered slightly acidic nature 6.8 in the polluted site. High relative water content values was observed for *Azadirachta indica* (85%) followed by *Cassia auriculata* (83%) in polluted site and *Leucaena leucocephala* (82%) in the controlled site, and the lowest was recorded for *Ziziphus zizyphus* in both the sites with 58 and 55%

Table 1: Air Pollution tolerance Index of seven species at Yogi Vemana University Campus and Yerraguntla town in brackets. Tch refers to total chlorophyll content, RWC-relative water content, APTI, air pollution tolerance index.

S. No	Plant species	Ascorbic acid mg/g	TCh mg/g	pH	RWC (%)	APTI
	Aegle marmelos Corr.Serr	1.58	11.32	7.09	67	9.6
1	Rutaceae	(1.84)	(9.48)	(7.5)	(70)	(10.12)
	Ziziphus zizyphus (L.) H. Karst	0.53	10.47	7.27	55	6.44
2	Rhamnaceae	(0.9)	(10.46)	(7.2)	(58)	(7.38)
	Azadirachta indica A. Juss.	0.13	12.41	7.6	80	8.26
3	Meliaceae	(0.39)	(7.49)	(7.1)	(85)	(9.06)
	Cassia auriculata L.	0.16	28.71	7.3	76	8.17
4	Fabaceae	(0.32)	(15.60)	(7.76)	(83)	(9.04)
	Leucaena leucocephala (Lam) de wit	0.42	3.61	7.37 (6.8)	82	8.66
5	Mimosaceae	(0.86)	(2.96)		(75)	(8.33)
	Albizia lebbeck (L.) Benth	0.15	8.76	7.51	72	7.44
6	Mimosaceae	(0.18)	(2.96)	(7.9)	(80)	(8.19)
	Bougainvillea spectabilis Willd	0.2	19.49	7.08	72	7.73
7	Nyctaginaceae	(0.83)	(12.67)	(7.6)	(74)	(9.08)

respectively. *Leucaena leucocephala* recorded a decrease in relative water content while the other six plants registered an increase in the range of 2.77 to 8.11%.

The APTI values were in the range of 7.38 to 10.12 in the polluted site and 6.44 to 9.6 in the control site. *Aegle marmelos* (10.12 and 9.6) and *Ziziphus zizyphus* (7.38 and 6.44) have recorded high and low values in both the sites respectively. The values indicate that all the seven plants in both the sites are sensitive to air pollution as all of them scored near to 10 or less than 10 values. Further, in comparison, the APTI values were slightly higher in the polluted site than the controlled for all the six plants except in *Leucaeana leucocephala*. The Mann-Whitney ‘t’ test showed no significant difference in APTI values between the two sites $U_{0.05(2)}$, 7,7, = 35 (Calculated value = 41). The increment was in the range of 3.85% to 15%; the highest change was observed for *Bougainvillea spectabilis* followed by *Ziziphus zizyphus* and the lowest was for *Leucaena leucocephala*. Trees have registered high APTI values than the shrubs in both the sites. When mean and standard deviation values of all the trees were compared with their individual APTI scores; in the control site *Aegle marmelos and Leucaena leucacephala* registered high values and *Azadirachta indica* and *Albizia lebbeck* scored low values. While in polluted site only *Aegle marmelos* scored high value and the rest three trees scored low values. This indicates that *Aegle marmelos* was the tolerant tree towards air pollution. Among shrubs, in both control and polluted sites, *Cassia auriculata* and *Bougainvillea spectabilis* registered high values than the mean±standard deviation value and *Ziziphus zizyphus* scored low values reflecting their tolerance and sensitive nature towards air pollution respectively.

Cement industry forms a potential anthropogenic source of air pollution. It is a major contributor to dust, nitrogen oxides (NOx), sulfur oxides (SOx) and Carbon monoxide [13]. In comparison between plants of polluted site and control site; the increase of APTI values, decrease of total chlorophyll content indicate that these plants are under stress due to the cement industry and the associated vehicular traffic based air pollution. The Kruskall – Wallis test showed a significant difference among the plants when their percentage of difference among the four parameters between the two sites was considered (Fig. 1; $H_{0.05,7,7,7}$ = 5.819; Calculated value = 16). All the plants have registered reduction in total chlorophyll content, highest reduction of was observed in *Albizia lebbeck* (66%) and lowest in *Ziziphus zizyphys* (1%). In different to other plants *Leucaena leucocephala* which showed decrease in APTI value also registered decrease in total chlorophyll content in common to other plants. The results corroborate the studies that chlorophyll content provides information on the physiological adaptations of plants i.e. more sensitive plants show low concentration of chlorophyll amount [14-15]. All the plants showed near neutral values above 7 except in *Leucaena leucocephala* (6.8). The high pH values of leaf extract pH indicate the tolerance of pollution as also reported for the plants studied with respect to air pollution [16]. The results did not yield strong relation between pH values and ascorbic acid values and this condition contradicts with the feature that high pH may increase the efficiency of conversion from hexose sugar to ascorbic acid [17]. But a considerable increment in the range of 14.13% to 75.9% was observed in ascorbic acid values between polluted and controlled sites. At least four plants have registered more than 50% increment and the maximum increase was found for *Bougainvillea spectabilis* (75.9%)

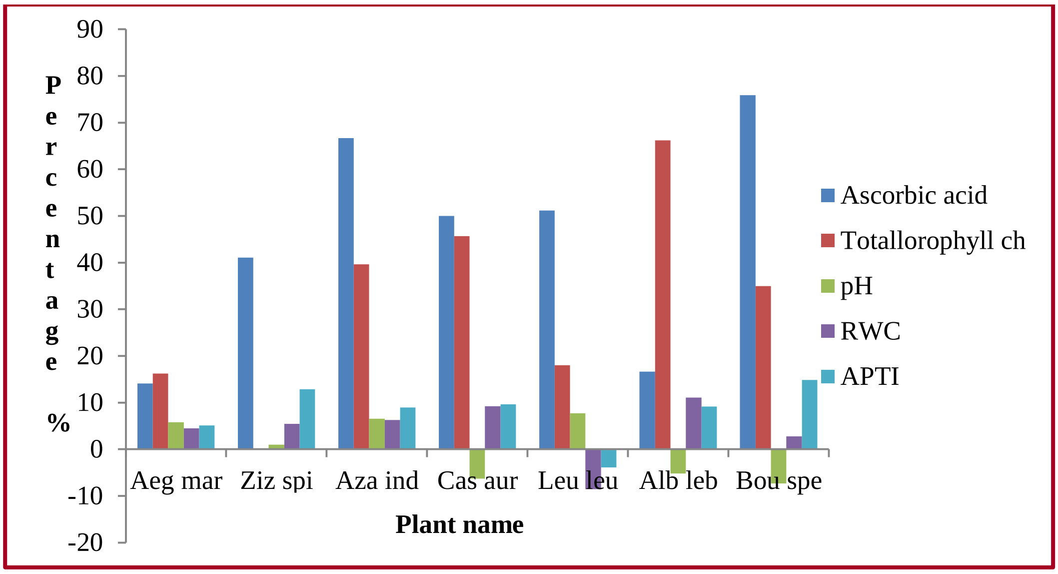

Figure 1. Percentage variations of ascorbic acid, leaf extract pH, relative water content (rwc) total chlorophyll and air pollution Tolerance Index (APTI) values for the seven species between the polluted and control sites.

followed by *Azadirachta indica* (66.6%); this indicates that plants synthesise ascorbic acid when stress tolerance is present as also suggested by[18] in their study in Anand city. High water content within a plant body will help to maintain its physiological balance under stress condition such as exposure to air pollution when the transpiration rates are high thus favouring drought resistance in plants [19]. In the study all plants have recorded an increase in relative water content values in polluted site than controlled site in the marginal range of 2.7% to 11.1%, except *Leucaena leucocephala* (decrease of 8.5%) which also registered a decrease in APTI value. This indicates that relative water content plays a considerable role in maintaining physiological balance among plants under air pollution stress and as well showed tolerance towards water stress prevailing in this semi-arid region.

Based on APTI values (6.44 to 9.6 in controlled site and 7.38 to 10.12 in polluted site) all the plants can be considered as sensitive towards air pollution according to the categorization by [20] (APTI Index <1 = very sensitive, 1-16 = sensitive, 17-29 = intermediate and 30-100 = tolerant). Among the sample of plants, trees have registered high APTI values than shrubs as in the study undertaken in Thiruvananthapuram [21], but in contradiction to the study on plants near to steel factory in Beijing, China [22]. The APTI values as a whole sample were found in the range of values of plants studied in the vicinity of Otorogan gas plant, Nigeria [23] and in urban parks of Isfahan, Iran [24] but slightly lesser values from the studies carried out in Rourkela town [6], Thiruvananthapuram [18] and Visakhapatnam [24]. The APTI values of *Azadirachta indica* and *Albizia lebbeck* were found to be less and the values of shrubs *Bougainvillea spectabilis* and *Ziziphus zizyphus*were of same range with the study undertaken in Rourkela town (Das and Prasad, 2010). The APTI values of *Azadirachta indica* was found to be higher than the value reported in the study in Anand city [18] and the values of *Albizia lebbeck*, *Bougainvillea spectabilis* and *Azadirachta indica* were found to be less than the values reported from the trees in the vicinity of cement plant in Coimbattore [1] and in Visakhapatnam industrial areas [24].

4. CONCLUSIONS

The study indicates by means of APTI index featuring the four 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 shrubs like *Cassia auriculata* and *Bougainvillea spectabilis* and trees such as *Aegle marmelos* can be used as sink towards air pollutants.

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***Bibliographic Schetch**

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