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Evaluation of air pollution tolerance and performance index of plants growing in industrial areas

Aasawari A Tak[1], Umesh B Kakde[2*]
[1, 2] Department of Botany, The Institute of Science, 15, Madame Cama Road, Maharashtra, India

Abstract
Evaluation of plants for their accumulation and absorbing capacity of air pollutants is essential for the greenbelt development in urban areas. To screen the plant's tolerance and sensitivity biochemical parameters *viz*., pH of leaf extract, total chlorophyll content, ascorbic acid, relative water content, air pollution tolerance index (APTI) and air pollution performance index (API) was analyzed. Commonly available twelve plant species selected from three different industrial sites. The results of (API) and (APTI) demonstrated that *Azadirachta indica, Cassia siamea, Ficus benghalensis* as most tolerant plant species. As plants play an essential role in mitigating air pollution, the present study focuses on selecting the appropriate plant species for the reduction of air pollution at three industrial sites.

Keywords: anticipated performance index (API); air pollution tolerance index (APTI); chlorophyll; ascorbic acid; air pollutants

Introduction

In the recent era, modern civilization and industrialization gave rise to many revolutionary developments as well as improved automobiles. Leading to combine effects of industrialization and vehicular emission triggered the environment concerning atmospheric air pollution. We all need clean atmosphere for the sustenance of living organisms for growth and development. Primary air pollutants like SO_2, NO_2, CO_2 and soot particles crossed its limiting capacity in many other countries and India. Agricultural waste and domestic sewage are other contributors causing environmental pollution. All such anthropogenic emissions are reacting together and creating trouble for human and animal health. Addition of some automobiles, two wheelers, four wheelers are responsible for the combustion process, which releases particulate matter and gases into the air. The deprivation of air quality is becoming a serious ecological issue worldwide [1]. Plants are known as the most important source of all metabolic activities affected by the majority of the air pollutants, which are results of ambient air born pollution. Leaves are known as the primary receptors of air pollutants as they provide large surface areas and abundant in number. When leaves exposed to specific major air pollutants like sulphur dioxide, nitrogen dioxide, fluorides, ammonia, chlorine, ethylene many visible changes could be seen such as pigmentation on leaf surfaces, chlorosis, necrosis, abscission, premature defoliation, dwarfing, inter venial necrotic blotches on leaf surfaces which can be identified easily. Analysis of air pollution tolerance index along with air pollution performance index of plants acts as the ecofriendly tool for the analysis of air pollution the impact and other environmental issues. Therefore, in recent epoch vegetation in urban areas becoming necessary not only for socio–economic characters but mostly for its effects on local and provincial ambient air quality.

Air pollution is a mixture of gases, pollutants, chemicals waste released from industrial areas, particulate matter, vehicular emissions released from automobiles, agricultural residues which damage other living metabolisms. The leading cause behind the air pollution is industrialization and transportations. It was also observed that some of heavy metals along with particulate matter also affects plants life cycle adversely [2]. Depending upon the intensity level of air pollutant on plants variation is recorded in biochemical parameters such as total photosynthetic pigment content, pH, ascorbic acid, the relative water content in leaves [3]-[5]. Air pollutants adversely affect plant growth, and plants known as natural filters for air pollution [6]. By selection of tolerant and better performance species, abatement of air pollution is possible [7]. Screening of plants tolerance on any single parameter may not provide a clear picture of pollution damage. The evaluation of air pollution tolerance index and air pollution performance index determines the suitable tolerant and sensitive plants by calculating specific biochemical parameters *viz*., pH of leaf extract, total chlorophyll content, relative water content, ascorbic acid. All biochemical parameters then combine to give one formula, which determines tolerance and sensitivity of plants.

Thane is the metropolitan city of Mumbai, Maharastra, India with three major industrial zones *viz*. Balkum, Kolshet and Wagle estate. Type of industries in these industrial zones includes cement, steel plants, underground coal mining industries, glass, distillery etc. The traffic density and vehicular emission of the locations are moderate to high. Primary air pollutants concentration at three major industrial sites in Thane city presented in (Table 1)

Table 1: Air pollution concentration at industrial sites

Industrial site	NOx	SO_2	RSPM (PM_{10})	Air Pollution Index	Air quality
	µg/m3	µg/m3	µg/m3	%	
ES–1: Balkum	61.00	22.00	271.00	125.00	Extremely Polluted
ES–2: Kolshet	53.00	16.00	176.00	88.00	Extremely Polluted
ES–3: Wagle estate	66.00	9.00	67.00	50.00	Medium Polluted
Max. limit of pollutants	< 80.00	< 80.00	< 100.00		

* Central pollution control board of India sets limit for pollutants

† Air pollution index, measure of air quality

Average data for air pollutants (*viz*. nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and respirable suspended particulate matter (RSPM), collected from Thane Municipal Corporation (TMC) for the current study. Data indicates maximum RSPM, SO_2, and NO_2 at Balkum industrial area followed by Kolshet industrial zone. Emissions of air pollutants are comparatively small at Wagle Industrial area. Average values of RSPM for Balkum and Kolshet industrial zones are higher than threshold limit (100 µg/m3) specified by central pollution control board (CPCB), while SO_2 and NO_2 are within specified limit (less than 80 µg/m3) for all three sites. A higher level of RSPM in the ambient air at Balkum and Kolshet industrial areas attributes to heavy vehicular traffic and automobile exhaust, mainly from diesel vehicles. At all three industrial locations, a concentration of NO_2 found higher than SO_2. High level of NO_2 in ambient air is primarily due to exhaust from diesel vehicles. The present study focuses on evaluating biochemical parameters and performance index of plants in three industrial zones and a control site in Thane city to identify their tolerance, sensitivity levels and their resistance towards air pollution. Lack of knowledge about tolerance and sensitivity levels of plants species in this area has triggered the field study. The study will be helpful in selecting appropriate plant species to perform well for the Greenbelt development.

2. Materials and methods

2.1 Study area

Thane geographically located in Maharashtra State and covered under Mumbai metropolitan region. Latitude and Longitude lie in between 19° 12' N and 73° 02' E with the total area of 128.23 square km. Climatic conditions of the study area range from 35–40°C temperature for summer and between 25–35°C during the winter months of November–January. The average rainfall is about 2500 mm. The weather of the region is coastal, hot and humid.

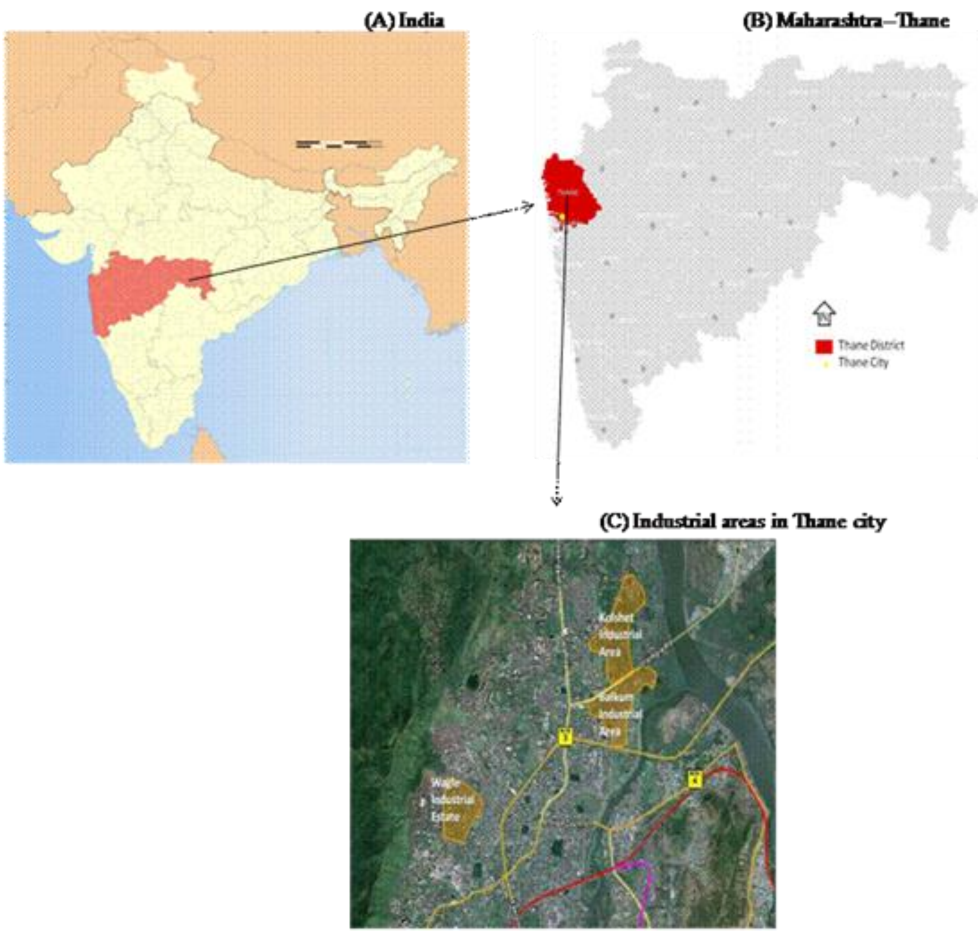


Fig 1: Location of study site

2.2 Sampling sites

The experimental sites in the present study were three industrial areas *viz*. Balkum industrial area (ES–1), Kolshet industrial area (ES–2) and Wagle Industrial area (ES–3) of Thane city. The traffic density and vehicular emission of the locations are moderate to high with peak periods found during morning and evening hours. Primary air pollutants concentration at industrial sites presented in Table 1. The trees in the Yeoor hill area considered as the control site (CS).

The investigation period for sampling the tree species was in summer from 10th January to 10th March 2017. Three replicates of fully matured leaves samples were collected randomly from selected tree species growing in the industrial conditions as well as at the control site. The samples were collected in the early morning from the lower branches (at the height of 2–4 m) for determining ATPI index in the leaves. Twelve plant species selected for the study *viz.* –, *Moringa pterygosperma, Tamarindus indica, Tectona grandis, Annona squamosa, Azadirachta indica, Acacia nilotica, Mangifera indica, Cassia siamea, Alstonia scholaris, Bahunia variegate, Ficus benghalensis, Ficus religiosa.*

2.3 Total chlorophyll

One gram of the greenest leaves of the plants selected and washed with water and dried at room temperature for a while. Then leaf samples macerated in a pestle with mortar adding 20–25 mL of 80% acetone. A pinch of magnesium carbonate added to the leaf material while grinding. Centrifuged the content at 2000 r.p.m. for 15 minutes. The extract transferred to a volumetric flask and made up to the volume of 50 mL using 80% acetone. The optical density of this green solution read at 645 nm (D645), and 663 nm (D663) using a spectrophotometer and the total chlorophyll calculated with the Equation 1 by Arnon, (1949)[8].

$$CT = 20.2 \times (D645) + 8.02 \times (D663) \quad \text{(Equation 1)}$$

2.4 pH of leaf extract

Five grams of the fresh leaves crushed in mortal, pestle with ten mL of distilled water, and filtered. The pH meter calibrated with the buffer solution of pH 4, 7 and 9 and pH was determined.

2.5 Relative water content (RWC)

Fresh weight of leaves was measured. The leaves were kept overnight deep in the water bottle. Leaves were dried and then weighed to get the turgid weight. Again, the same leaves were dried overnight in an oven at 70°C and reweighed to obtain the dry weight. RWC was determined and calculated as per Equation 2 as per method of Barr and Weatherley, (1962) [9].

$$RWC\ (\%) = \frac{(FW - DW)}{(TW - DW)} \times 100 \quad \text{(Equation 2)}$$

Where,
FW is fresh weight,
DW is dry weight, and
TW is turgid weight.

2.6 Ascorbic acid

One gram of fresh foliage homogenized in 4 mL oxalic acid – EDTA extracting solution for 30 seconds. 0.5 mL of metaphosphoric acid–acetic acid and one mL 5% V/V sulphuric acid followed by two mL of ammonium molybdate. Dilute to volume with distilled water. The solution kept to stand for about 15 min. The absorbance measured with a digital spectrophotometer at a wavelength of 760 nm. The concentration of the ascorbic acid was determined from a standard ascorbic acid regression curve as per by Bajaj and Kaur, (1981). [10].

2.7 Air pollution tolerance index (APTI)

The air pollution tolerance indices of twelve commonly available plants determined as per Equation 3. Determination of the APTI helps to identify the tolerant and sensitive plant species.

$$APTI = \frac{[(A \times (T + P) + R)]}{10} \quad \text{(Equation 3)}$$

Where, A – Ascorbic acid (mg/gm fr.wt),
T – Total chlorophyll (mg/gm fr.wt),
P – Leaf extracts pH and
R – Relative water content (RWC) [(%) of the leaves]

2.8 Anticipated performance index (API)

By combining the results of APTI values with important biological and socio-economic characters (*viz*. plant habitat, type of plant, laminar structure, canopy structure & economic values), the API calculated for different plant species. Different grades (+ or -) allotted to these plants based on these characters. Various plants scored as per their grades given by Mondal *et al*. (2011) [12]. The criteria used for determining the API of different plant species presented in Table 2 and 3.

Table 2: Gradation of plant species based on APTI and other biological and socio–economic characters

Sr. No.	Grading	Character	Pattern of assessment	Grade allotted
A	Tolerance	Air pollution tolerance index (APTI)	12.0–16.0	+
			16.1–20.0	++
			20.1–24.0	+++
			24.1–28.0	++++
			28.1–32.0	+++++
			32.1–36.0	++++++
B	Biological & Socio–Economic	(i) Plant habitat	Small	-
			Medium	+
			Large	++
		(ii) Canopy structure	Sparse/irregular globular	-
			Spreading crown/ open semi dense	+

			Spreading dense	++
		(iii) Type of plant	Deciduous	-
			Evergreen	+
		(iv) Laminar structure: size	Small	-
			Medium	+
			Large	++
		: Texture	Smooth	-
			Coriaceous	+
		: Hardiness	Delineate	-
			Hardy	+
		(v) Economic value	Less than three uses	-
			Three or four uses	+
			Five or more uses	++

Table 3: Anticipated Performance Index (API) of plant species

Grade	Score (%)	Assessment category
0	Up to 30	Not recommended
1	31–40	Very poor
2	41–50	Poor
3	51–60	Moderate
4	61–70	Good
5	71–80	Very good
6	81–90	Excellent
7	91–100	Best

2.9 Statistical analysis

Correlation coefficient calculated between independent variable *viz*. total chlorophyll, pH, ascorbic acid, RWC and dependent variable such as APTI to determine the degree of correlation between dependent and independent variables by using Analysis ToolPack in Excel. For all primary data, $n = 12$ and significance was tested at 1% and 5% level of significance (i.e. $p = 0.01$ & 0.05).

3. Results and Discussion

3.1 Change in total photosynthetic pigment

All selected plant species considered for the evaluation found intermediately tolerant against vehicular and industrial pollution emissions. Reduction in chlorophyll was found the less in *Tectona grandis* (0.90 ± 0.01) while, increased in *Mangifera indica* (6.90 ± 0.07) at three of the industrial sites as given in (Table 4 and Fig. 2). Increased level of chlorophyll considered as tolerant in nature [13]. Many factors that control resistance level in plants affect tolerance in plants. It is well evident fact that plants show variation in chlorophyll content depending upon climatic conditions, the age of leaf and with the pollutants [14]. The photosynthetic rate decreased in plants at Site 1 (ES–1), as compared to site 2 (ES–2) & 3 (ES–3) than of the control site. The plants with photosynthetic pigment content in the range of 4 9.38 mg/gm are classified as intermediately tolerant and sensitive plant species respectively. The chloroplast damaged because of the pollutant attacks; there is a reduction in chlorophyll content at polluted site leaves [15, 16] or enhanced chlorophyll degradation [17], inhibition chlorophyll biosynthesis.

3.2 Change in ascorbic acid (AA)

Ascorbic acid plays a major role in resistance to air pollution as it acts as an antioxidant generally found in growing parts of plants [18, 19]. The increased concentration of ascorbic acid in plants helps to fight against air pollution tolerance [20]. It is revealed from the study that lower level of ascorbic acid content was found at Site 1 and 2, in *Acacia nilotica*, followed by *Moringa pterigosperma*, *Ficus religiosa*, *Mangifera indica*, *Tectona grandis.* A Higher level of ascorbic acid was found in *Azadirachata indica* (6.50 ± 0.48 mg/gm) and *Cassia siamea* (6.34 ± 0.26 mg/gm) at experimental site–1 (ES–1). It is clear from (Table 4), that plants responded differently, as the highest amount of ascorbic acid seen at most polluted sites than with control site. Previous researchers recorded similar findings for different plant species [21, 22]. However, some researchers had also reported opposite trend [23]. i. e. higher amount of ascorbic acid in a plant at the control site while, less amount of ascorbic acid was present in plants at highly polluted sites.

3.3 Change in leaf extract pH

The leaf extract pH of selected plant species ranged from (3.10 ± 0.0) in *Tamarindus indica* to (7.70 ± 0.0) in *Ficus benghalensis* at three of the experimental and control site as shown in Table 4. Some scholars have proved that in polluted sites plants show higher level of leaf extract pH of plant species was responsible for tolerance factor to air pollutants [24, 25]. Also from previous records, leaf extract pH of plants found lesser when comes in contact with an acidic pollutant [26].

3.4 Change in relative water content analysis (RWC)

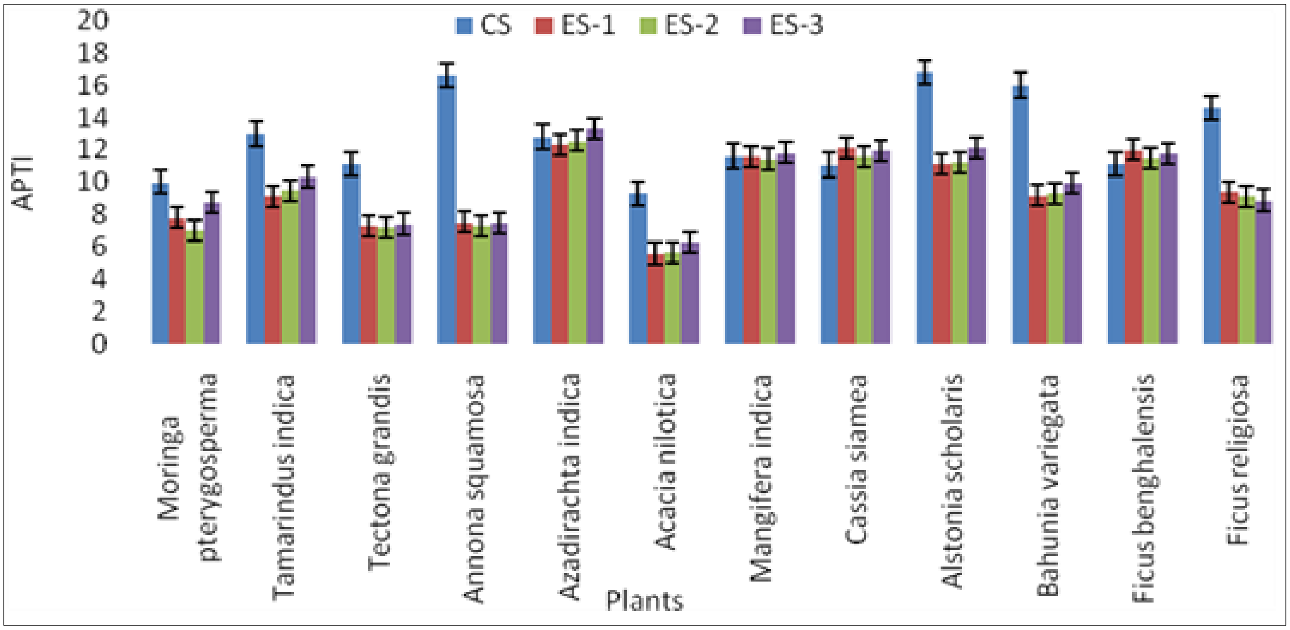
The large quantity of water (RWC) in plant helps in maintaining its wáter level balance under stressful conditions of pollution [27]. The RWC at three of the experimental sites ranged in between 37.70 ± 2.46% in *Annona squamosa* to 94.40 ± 2.95% in *Alstonia schlolaris* than control site as shown in (Table 4). RWC in the leaf is the water present in it upto its full turgidity. Water is the crucial prerequisite for plant life [28]. Vehicular and industrial air pollution affects on the photosynthetic and transpiration metabolism. Decreased wáter levels plant species is due to impact of gaseous pollutants [29, 30].

Table: 4 Analysis of APTI index of three industrial areas with control site

Sr. No.	Botanical name	Site	Total chlorophyll, mg/gm	pH of leaf extract	Relative water content, %	Ascorbic acid, mg/gm	APTI
1	*Acacia nilotica*	*CS*	7.80 ± 0.02	5.20 ± 0.00	81.30 ± 8.17	1.50 ± 0.17	10.0 ± 0.69
		ES–1	4.93 ± 0.03	5.55 ± 0.00	45.89 ± 2.03	0.96 ± 0.02	5.60 ± 0.22
		ES–2	4.99 ± 0.10	5.37 ± 0.00	46.50 ± 0.50	0.98 ± 0.03	5.67 ± 0.04
		ES–3	5.49 ± 0.14	5.25 ± 0.00	51.59 ± 3.40	1.03 ± 0.03	6.26 ± 0.33
2	*Alstonia scholaris*	*CS*	4.40 ± 0.13	6.00 ± 0.00	92.20 ± 3.48	3.70 ± 0.10	13.0 ± 0.26
		ES–1	2.37 ± 0.10	5.87 ± 0.00	83.98 ± 1.97	3.28 ± 0.07	11.10 ± 0.19
		ES–2	2.40 ± 0.10	5.91 ± 0.00	85.10 ± 3.44	3.25 ± 0.10	11.21 ± 0.41
		ES–3	2.64 ± 0.13	5.93 ± 0.00	94.40 ± 2.95	3.11 ± 0.04	12.11 ± 0.28
3	*Annona squamosa*	*CS*	1.80 ± 0.02	6.00 ± 0.00	49.90 ± 4.94	7.80 ± 0.56	11.1 ± 0.18
		ES–1	4.30 ± 0.07	6.40 ± 0.00	37.70 ± 2.46	3.51 ± 0.08	7.53 ± 0.23
		ES–2	4.42 ± 0.13	6.35 ± 0.00	38.20 ± 2.31	3.20 ± 0.08	7.26 ± 0.12
		ES–3	4.67 ± 0.38	6.15 ± 0.00	42.38 ± 3.38	3.00 ± 0.10	7.49 ± 0.54
4	*Azadirachta indica*	*CS*	3.70 ± 0.02	6.30 ± 0.00	74.20 ± 5.57	9.10 ± 0.36	16.6 ± 0.18
		ES–1	3.45 ± 0.09	5.80 ± 0.00	62.90 ± 3.57	6.50 ± 0.48	12.30± 0.73
		ES–2	3.65 ± 0.05	5.85 ± 0.00	66.64 ± 2.51	6.20 ± 0.36	12.55 ± 0.27
		ES–3	3.89 ± 0.06	6.12 ± 0.00	73.92 ± 2.90	5.92 ± 0.34	13.32 ± 0.61
5	*Bahunia variegate*	*CS*	3.40 ± 0.17	6.70 ± 0.00	74.40 ± 4.58	5.30 ± 0.10	12.8 ± 0.35
		ES–1	2.88 ± 0.04	6.68 ± 0.00	62.09 ± 3.54	3.10 ± 0.14	9.17 ± 0.23
		ES–2	3.42 ± 0.30	6.69 ± 0.00	62.92 ± 0.55	2.95 ± 0.10	9.27 ± 0.08
		ES–3	3.80 ± 0.07	6.70 ± 0.00	69.80 ± 1.30	2.80 ± 0.13	9.92 ± 0.25
6	*Cassia siamea*	*CS*	4.60 ± 0.10	5.80 ± 0.00	55.3 ± 1.10	3.60 ± 0.10	9.28 ± 0.22
		ES–1	3.94 ± 0.15	6.49 ± 0.00	55.11 ± 3.02	6.34 ± 0.26	12.13 ± 0.22
		ES–2	3.99 ± 0.11	6.38 ± 0.00	55.84 ± 3.83	5.80 ± 0.13	11.60 ± 0.24
		ES–3	4.39 ± 0.04	6.27 ± 0.00	61.95 ± 1.74	5.40 ± 0.09	11.95 ± 0.25
7	*Ficus benghalensis*	*CS*	4.30 ± 0.10	6.30 ± 0.00	80.30 ± 4.45	3.40 ± 0.10	11.64 ± 0.53
		ES–1	4.43 ± 0.11	7.70 ± 0.00	72.50 ± 3.32	3.92 ± 0.08	12.01 ± 0.31
		ES–2	4.20 ± 0.08	7.20 ± 0.00	74.80 ± 1.78	3.50 ± 0.13	11.50 ± 0.35
		ES–3	4.25 ± 0.05	7.30 ± 0.00	78.50 ± 1.56	3.40 ± 0.22	11.48 ± 0.43
8	*Ficus religiosa*	*CS*	4.10 ± 0.27	6.10 ± 0.00	56.70 ± 1.54	5.30 ± 0.10	11.08 ± 0.28
		ES–1	4.55 ± 0.05	7.40 ± 0.00	56.50 ± 5.20	3.14 ± 0.17	9.40 ± 0.68
		ES–2	4.35 ± 0.04	7.00 ± 0.00	58.20 ± 2.72	2.89 ± 0.15	9.10 ± 0.40
		ES–3	4.56 ± 0.09	7.20 ± 0.00	55.20 ± 3.01	2.86 ± 0.04	8.88 ± 0.34
9	*Mangifera indica*	*CS*	3.30 ± 0.10	6.20 ± 0.00	92.90 ± 6.78	7.90 ± 0.66	16.8 ± 0.25
		ES–1	6.20 ± 0.09	6.20 ± 0.00	72.80 ± 4.46	3.45 ± 0.05	11.56± 0.50
		ES–2	6.50 ± 0.18	6.21 ± 0.00	73.50 ± 3.44	3.22 ± 0.03	11.45 ± 0.41
		ES–3	6.90 ± 0.07	6.23 ± 0.00	82.50 ± 3.70	2.72 ± 0.02	11.82 ± 0.41
10	*Moringa pterygosperma*	*CS*	3.20 ± 0.02	5.40 ± 0.00	69.20 ± 0.17	10.60 ± 0.40	16.00 ± 0.34
		ES–1	2.60 ± 0.02	5.90 ± 0.00	53.50 ± 2.91	2.89 ± 0.04	7.81 ± 0.33
		ES–2	2.65 ± 0.02	5.80 ± 0.00	55.10 ± 2.81	2.76 ± 0.23	7.84 ± 0.44
		ES–3	2.94 ± 0.01	5.55 ± 0.00	65.30 ± 2.95	2.65 ± 0.06	8.74 ± 0.34
11	*Tamarindus indica*	*CS*	5.90 ± 0.03	3.10 ± 0.00	70.40 ± 1.02	4.50 ± 0.32	11.1 ± 0.31
		ES–1	4.65 ± 0.04	3.10 ± 0.00	60.10 ± 4.25	4.05 ± 0.15	9.15 ± 0.37
		ES–2	4.82 ± 0.04	3.00 ± 0.00	65.20 ± 2.36	3.80 ± 0.09	9.49 ± 0.29
		ES–3	5.27 ± 0.14	2.90 ± 0.00	73.20 ± 2.96	3.70 ± 0.10	10.35 ± 0.34
12	*Tectona grandis*	*CS*	4.70 ± 0.02	5.30 ± 0.00	44.10 ± 4.06	10.20 ± 0.70	14.6 ± 0.30
		ES–1	0.90 ± 0.01	6.10 ± 0.00	49.50 ± 1.65	3.32 ± 0.08	7.27 ± 0.12
		ES–2	1.20 ± 0.02	6.00 ± 0.00	50.40 ± 1.74	3.00 ± 0.18	7.20 ± 0.25
		ES–3	1.50 ± 0.10	5.65 ± 0.00	54.30 ± 4.62	2.78 ± 0.03	7.42 ± 0.46

* Mean ± SEM for triplicates values of plants showing thereadings for the biochemical parameters

† ES – 1: Experimental site at Balkum, ES – 2: Experimental site at Kolshet, ES – 3: Experimental site at Wagle estate, CS: Control site at Yeoor hill



* ES – 1: Experimental site at Balkum, ES – 2: Experimental site at Kolshet, ES – 3: Experimental site at Wagle estate, CS: Control site at Yeoor hill

Fig 2: Comparison of APTI for industrial sites

Table 5: Correlation matrix between biochemical parameters and APTI values for Balkum Industrial area (ES–1)

	APTI	Total chlorophyll	pH of leaf extract	RWC	Ascorbic acid
APTI	1.00				
Total chlorophyll	0.19	1.00			
pH of leaf extract	0.24	-0.03	1.00		
RWC	0.72	0.05	0.07	1.00	
Ascorbic acid	0.76	-0.05	0.01	0.18	1.00

Table 6: Correlation matrix between biochemical parameters and APTI values for Kolshet Industrial area (ES–2)

	APTI	Total chlorophyll	pH of leaf extract	RWC	Ascorbic acid
APTI	1.00				
Total chlorophyll	0.19	1.00			
pH of leaf extract	0.34	0.10	1.00		
RWC	0.76	0.05	0.10	1.00	
Ascorbic acid	0.76	-0.06	0.11	0.25	1.00

Table 7: Correlation matrix between biochemical parameters and APTI values for Wagle Industrial area (ES–3)

	APTI	Total chlorophyll	pH of leaf extract	RWC	Ascorbic acid
APTI	1.00				
Total chlorophyll	0.10	1.00			
pH of leaf extract	0.18	-0.09	1.00		
RWC	0.79	0.01	-0.01	1.00	
Ascorbic acid	0.74	-0.10	0.06	0.24	1.00

Table 8: Correlation matrix between major air pollutants and APTI values

	APTI	NOx (µg/m3)	SO2 (µg/m3)	RSPM (µg/m3)
APTI	1.00			
NOx (µg/m3)	0.63	1.00		
SO2 (µg/m3)	-0.97	-0.42	1.00	
RSPM (µg/m3)	-0.97	-0.49	1.00	1.00

Table 9: Evaluation of plant species based on APTI and biochemical factors

Scientific name	Assessment parameters				Laminar structure			Assessment parameters			
	1	2	3	4	5	6	7	APTI	Tree habitat	Canopy structure	Tree type
Acacia nilotica	+	++	++	+	++	+	+	++	12.0	75.0	V.Good

Alstonia scholaris	+	++	++	+	++	+	+	++	12.0	75.0	V.Good
Annona squamosa	+	++	++	-	++	+	+	++	11.0	68.0	Good
Azadirachta indica	+	++	++	+	++	+	+	++	12.0	75.0	V.Good
Bahunia variegate	+	++	++	-	++	+	+	++	11.0	68.0	Good
Cassia siamea	+	++	++	+	++	+	+	++	12.0	75.0	V.Good
Ficus benghalensis	+	++	++	+	++	+	+	++	12.0	75.0	V.Good
Ficus religiosa	+	++	++	+	++	+	+	++	12.0	75.0	V.Good
Mangifera indica	+	++	++	+	++	+	+	++	12.0	75.0	V.Good
Moringa pterygosperma	+	++	++	-	++	+	+	++	11.0	68.0	Good
Tamarindus indica	+	++	++	+	++	+	+	++	12.0	75.0	V.Good
Tectona grandis	+	++	++	-	++	+	+	++	11.0	68.0	Good

* Where 1 – APTI; 2 – Tree habitat; 3–Canopy structure; 4– Tree type; 5–Size; 6–Texture; 7– Hardiness.

Table 10: Anticipated performance index of plant species

Sr. No.	Scientific name	Grade allotted			Assessment
		Total	%	API value	
1	*Acacia nilotica*	12	75	5	V. Good
2	*Alstonia scholaris*	12	75	5	V. Good
3	*Annona squamosa*	11	68	4	Good
4	*Azadirachta indica*	12	75	5	V. Good
5	*Bahunia variegate*	11	68	4	Good
6	*Cassia siamea*	12	75	5	V. Good
7	*Ficus benghalensis*	12	75	5	V. Good
8	*Ficus religiosa*	12	75	5	V. Good
9	*Mangifera indica*	12	75	5	V. Good
10	*Moringa pterygosperma*	11	68	4	Good
11	*Tamarindus indica*	12	75	5	V. Good
12	*Tectona grandis*	11	68	4	Good

3.5 Change in air pollution tolerance index analysis (APTI)

The study observed that the increased air pollution tolerance of plant species found in *Azadirachta indica* (13.32 ± 0.61) followed by *Ficus benghalensis* (12.01 ± 0.31) than control site as shown in (Table 4). The decreased APTI was recorded in *Acacia nilotica* (5.55 ± 0.00) at experimental site 1 (ES–1), and the lowest reduction was found in *Azadirachta indica* (13.32 ± 0.61). It is evident from (Table 4), that variation in biochemical and physiological parameters (ascorbic acid, relative wáter content, total chlorophyll content, and pH) of the selected plant species showed change in APTI values. APTI valuesrecorded increased in the highly polluted site which are Balkum (ES–1) and Kolshet (ES–2) industrial area than polluted which Wagle (ES–3) industrial area. Increased values of air pollution tolerance index shows greater tolerance of plant species to air pollutants.

3.6 Correlation matrix interpretation for biochemical parameters with APTI

The correlation coefficient values of anticipated performance index and biochemical parameters *viz*., total chlorophyll, pH of leaf extract, ascorbic acid and relative water content with APTI of different tree species (Table 5, 6 & 7). It revels from the results that there is a significant positive correlation between RWC, ascorbic acid, and APTI. Negative correlation observed for total chlorophyll, while pH shows insignificant correlation. It is clear from the observation that total chlorophyll content and ascorbic acid of the selected plant species are the most significant factors for tolerancein plants. Plants may respond differently under different pollution stress [31].

3.7 Correlation matrix interpretation for air pollutants with APTI

The correlation coefficient values of air pollutants reveled from the (Table 8) that APTI found to be positively correlated with NOx. A negative correlation was observed between SOx and RSPM with APTI values. It was clear from the recorded results that major air pollutants emissions effects on plant's biochemistry. The SOx and RSPM affecting on ascorbic acid and the total chlorophyll content of all selected plant species situated in three of the industrial sites (Table 10). It is evident (Table 1) that air pollution index of all pollutants at three of the experimental sites was greater than maximum limiting value of pollutants, given by central pollution control board of India.

3.8 Anticipated performance index (API)

All selected plant species assessed for various biochemical characteristics, socioeconomic parameters (*viz*., laminar structure, canopy structure, type of plant, plant habitat, APTI and economic values) (Table 9). The parameters were categorized for a grading scale (Table 2) to evaluate the anticipated performance index (API) of plant species. The classification pattern of twelve plant species evaluated in (Table 9) for their API values. The (Table 10) showed that all species are the tolerant and good performer. Among which *Azadirachta indica, Tamarindus indica, Acacia nilotica, Cassia siamea, Mangifera indica, Ficus religiosa, Alstonia scholaris, Ficus benghalensis* were categorized as the very good performer. To avoid pollution stress, these plants are classified to spread a dense canopy of evergreen foliage. These plants are also having some medicinal as well as

Economic values and can be planted along the roadside. Thus, anticipated performance index can be a helpful ecofreindly tool in the selecting appropriate plant species for Greenbelt zones in view of abating the urban air pollution.

4. Conclusion

The experimental evaluation of both parameters, air pollution tolerance index (APTI) and air pollution performance index (API) of plants reveled that plants gets affected by continous attack of major air pollutants. The chemicals released from industrial waste and some vehicular emissions directly shows the effects on plants metabolism. The outcome of result suggests plants with both higher APTI and very good API index *viz*., *Azadirachta indica, Mangifera indica, Cassia siamea, Ficus benghalensis*, which is useful as a bio–monitoring tool for the betterment of the environment. Air pollution in the urban areas abetted partially by planting tolerant plant species. Determination of APTI and API helps in identifying tolerant plant species.

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6. Conflict of Interest

The author declares that there is no conflict of interests regarding the publication of this manuscript.

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