Original Article

POLLUTION STANDARD INDEX-BASED ANALYSIS OF AIR QUALITY IN UDEAGBALA INDUSTRIAL REGION, ABIA STATE

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Abstract: This study assessed the air quality status of the Udeagbala Industrial Area in Aba, Abia State, Nigeria, using the Pollution Standard Index (PSI) and Air Pollution Tolerance Index (APTI) of selected plant species. The objective was to evaluate ambient air quality and the physiological response of vegetation to industrial air pollution. Air samples were collected from two industrial zones and one non-industrial (control) area to measure the concentrations of key pollutants, including carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM_{10}). Results revealed significantly higher concentrations ($p < 0.05$) of all pollutants in the industrial zones compared to the non-industrial area, indicating poor air quality in the vicinity of industrial activities.

In addition to air monitoring, four plant species—Sida acuta, Xanthosoma sagittifolium, Ipomoea batatas, and Panicum maximum—were evaluated for their biochemical responses to pollution stress. The Air Pollution Tolerance Index was calculated using four parameters: relative water content (RWC), leaf pH, ascorbic acid (AA) content, and total chlorophyll (TCH). Findings showed that ascorbic acid and relative water content were elevated in plants from the industrial area, suggesting a physiological adaptation to air pollution stress. Conversely, total chlorophyll content was lower in plants from the same zones, indicating potential damage or inhibited photosynthetic efficiency due to pollutant exposure.

All four species demonstrated intermediate tolerance to pollution based on their APTI scores, highlighting their potential use as bioindicators in environmental monitoring. The study concludes that industrial emissions have a measurable negative impact on ambient air quality and vegetation health in Udeagbala, emphasizing the need for stricter pollution control and monitoring efforts in the region.

Keywords: Air Quality, Pollution Standard Index (PSI), Air Pollution Tolerance Index (APTI)

Introduction

Air pollution is one of the severe problems the world is facing today. It deteriorates ecological condition and can be defined as fluctuation in any atmospheric constituent from the value that would have existed without human activity (Tripathi and Gautam, 2007). Over the years, there has been a continuous growth in human population, road transportation, vehicular traffic and industries which increases the concentration of gaseous and particulate pollutants (Joshi et al., 2009). The problem of air pollution is a serious threat to environmental health in many cities of the world (McCarth et al., 2007; Wong et al, 2008; Kan et al., 2009). High concentration levels of air pollutants have been shown to have general adverse effects on human health (Hulguin et al, 2007; Allen et al., 2009). Ambient air pollution has been particularly associated with health problems (Miller et al., 2007; Borm et al., 2007; Slama et al., 2008). . Pollution is mainly caused due to human, especially transportation and industrialization (Odilara et al., 2006). All combustion releases gases and particles into the air. These can include sulphur and nitrogen oxides, carbon monoxide and soot particles, as well as smaller quantities of toxic metals, organic molecules and radioactive isotopes (Rai, 2013). Trees experience the greatest exposure and are influenced greatly by pollutant concentration due to their perennial habit (Chauhan, 2010). Regional impact of air pollution on local plant species is one of the major ecological issues. The climate condition, the physical-chemical properties of air pollutants and their residence time in the atmosphere have impact on surrounding plants (Wagh et al., 2006).Various studies on air pollution have been done (Khanna et al., 2013; Khanna et al., 2014).

Plants are an integral basis for all ecosystems and also most likely to be affected by air borne pollution which are identified as the organisms with most potential to receive impacts from ambient air pollution. Since plants are stationary and continuously exposed to chemical pollutants from the surrounding atmosphere, air pollution injury to plants is proportional to the intensity of the pollution (Nwakanma et al., 2016). 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 (Agbaire et al., 2009). Various strategies exist for controlling atmospheric pollution, but vegetation provides one of the best natural ways of cleaning the atmosphere by providing an enormous leaf area for impingement, absorption and accumulation of air pollutants level in the environment with a various extent (Das and Prasad, 2010). Plants act as the scavengers for air pollution as they are the initial acceptors (Joshi and Swami, 2009; Kumar, and Nandini, 2013).

Green plants are known for their role in attenuation of certain air pollutants and are widely recommended in the form of green belts and urban green spaces for air pollution mitigation (DeRidder, 2004; Lee, A. and Maheswaran, 2011). Air Pollution Tolerance Index (APTI) is used to evaluate the susceptibility or resistance level of plants for air pollutants (Chauhan, 2010; Chandawat et al, 2011; Chouhan et al., 2012; Bhattacharya et al., 2013; Lohe et al., 2015). They use four parameters, namely ascorbic acid content, total chlorophyll content, relative water content, and leaf-extract pH. These parameters are determined and computed together to obtain the APTI of the plant (Singh et al.,1991). The objective of the research is to determine the atmospheric compositions and the air pollution tolerance index of some plant species so as to identify those that can be planted around industrial areas in order to attenuate the adverse effects on man and his environment.

Materials and Methods

Study Area

This study was conducted in the city of Aba, Abia state in Nigeria which lies between Latitude $05^0 07´$ North and $7^0 22´$ East of the Greenwich Meridian. Aba is a city in the Southeast of Nigeria and the commercial nerve center of the entire state. Aba is a major urban settlement and commercial center in a region that is surrounded by small villages and towns, as of 2006 a census carried out by the (NPC, 2006), showed that the city had a population of 534,265. The city is surrounded by oil wells, which separate it from the city of Port-Harcourt, a 30km pipeline powers Aba with gas from the Imo state river natural gas repository. Its major economic contributions are textile and palm oil along with pharmaceuticals, plastics, cement and cosmetics. There is also a brewery, glass company and distillery within the city. Ugeagbala industrial layout has a lot of industries that produce different products including soap cosmetics and vegetable oils. Consequently, many noxious gases and particulate matter are produced from fumes and exhausts of these industrial plants and these, coupled with emissions from vehicles and refuse dumps, pollute the air around the area (Nwadinigwe, 2009).

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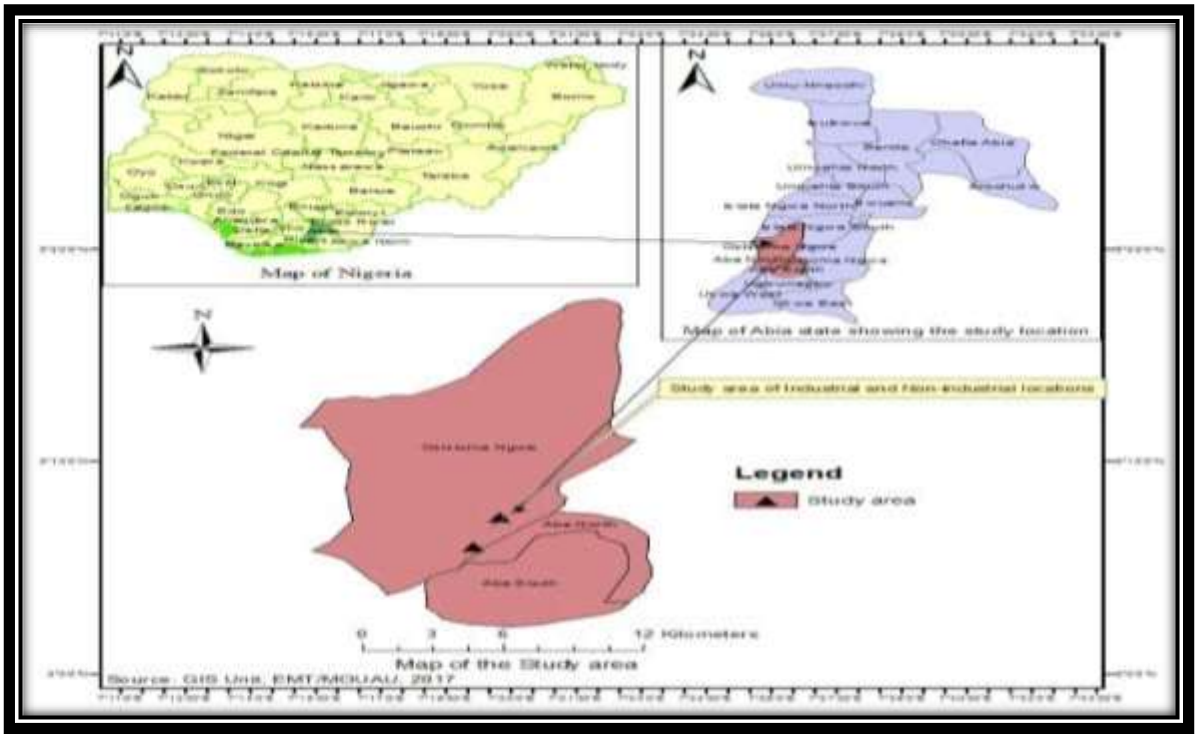

Figure1: Map of Abia State showing the study Location.

Sample Location

Plants species sampled for research were collected from Udeagbala Industrial area of Osisioma Local Government of Abia State, Nigeria. Plant species sampled included *Sida acuta*, *Xanthosima sagittifolium, Ipomea batata and Panicum maximum* from industrial locations and non-industrial location as control from botanical garden from Michael Okpara University of Agriculture, Umudike, Abia State.

Sampling Technique

Plants were randomly selected from the study locations (Fig.1) designated as Industrial areas and Non-Industrial area. Leaf samples of the selected plant species were collected. Three replicates of fully matured leaves were collected and immediately taken to the laboratory for analysis. A composite sample of each plant species was obtained before analysis. The leaf fresh weight was taken immediately upon getting to the laboratory and sample was preserved in the refrigerator for other analysis.

Analysis of Biochemical Parameters

Relative Leaf Water Content (RWC)

With the method as described by (Singh, 1991), leaf relative water content (RWC) was determined and calculated with the formula:

$$\mathbf{RWC} = \frac{FW - DW}{TW - DW} \times 100 \qquad \textbf{Equation 1.}$$

Where: FW = Fresh weight

DW = Dry weight

TW = Turbidity weight

Fresh weight was obtained by weighing the fresh leaves. The leaves were immersed in water overnight, blotted dry and weighed to get the turgid weight. The leaves were dried overnight in an oven at $70^{0}C$ and reweighed to obtain the dry weight.

Total chlorine content (TCH)

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This was carried out according to the method described by (Arnon, 1949). 3gram of fresh leaves was blended and extracted with 10ml of 80% acetone and left for 15minutes for thorough extraction. The liquid portion was decanted into another test-tube and centrifuge at 2,500rpm for three minutes. The supernatant was collected and absorbance taken at 645nm and 663nm using a spectrophotometer**.**

Calculations were done using the formula:

Chlorophyll a= $\frac{12.7Dx663 - 2.69Dx645 \times Vmg\ mg/g}{1000w}$ **Equation 2.**

Chlorophyll b = $\frac{22.9Dx645 - 4.68Dx663 \times Vmg\ mg/g}{1000w}$ **Equation 3**.

TCH =$Chlorophyll\ a + b\ mg/g$

Dx = *Asorbance of the extract at the wavelength Xnm*

V = *Total volume of the chlorophyll solution (ml)*

W = *weight of the tissue extracted (g)*

Leaf extracts pH

5gram of fresh leave was homogenized in 10ml deionized water. This was filtered and the pH of the leaf extract was determined after calibrating pH meter with buffer solution of pH 4 and 9.

Ascorbic acid content (AAC)

Ascorbic acid content (expressed in mg/g) was measured using spectrophotometric method (Bajaj and Kaur, 1981). 1gram of the fresh foliage was put in a test-tube, 4ml oxalic acid – EDTA extracting solution was added, then 1ml of orthophosphoric acid and 1ml 5% tetraoxosulphate (vi) acid was added to the mixture. 2ml of ammonium molybdate was added and then 3ml of water. The solution was allowed to stand for 15minutes after which the absorbance was measured at 760nm with a spectrophotometer. The concentration of ascorbic acid in the sample was extrapolated from a standard ascorbic acid curve.

Air pollution tolerance index (APTI) determination

Air pollution tolerance index was done following the method of Singh and Rao (Singh and Rao, (1983). given as:

$APTI = \frac{A(T+P) + R}{10}$ **Equation 4**

A = Ascorbic acid content (mg/g)

T = Total chlorophyll mg/g

P = pH of leaf extract

R = Relative water content of leaf

Tolerance Class: On the basis of indices, different plants were categorized into tolerance, intermediate, sensitive and very sensitive (Table 1).

Table 1: Air Pollution Tolerance Index (APTI)

Range of APTI	Tolerance
30-100	Tolerant
17-29	Intermediate
1-16	Sensitive
<1	Very sensitive

Source: Lohe et al. (2015)

Statistical Analysis

The data collected from this study was subjected to one way Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS). Means were calculated and compared to find the levels of significance of the plant parameters. Mean values of the parameters over the different locations was differentiated using Fisher's Least Significant Difference (F-LSD) at P-value less than 0.05 ($P<0.05$) as statistically significant.

Results

The results are presented in Tables 2 to 6. Table 2 shows air quality concentrations and meteorological variables, Table 3 shows biochemical Parameters of plant leaves of the selected species in industrial area 1, biochemical Parameters of plant leaves of the selected species in industrial area II (Table 4), Table 5 shows Mean±SD result of biochemical parameters of plant leaves of the selected species in non-industrial Areas and Table 6 indicated various categories of tree species based on APTI.

Table 2: Statistical Summary of Air Quality concentrations and Meteorological Parameters in Industrial and Non Industrial Areas

LOCATION	CO2 (ppm)	CO (ppm)	SO2 (ppm)	NO2 (ppm)	PM10 (ug/m^3)	TEMP. (^{0}C)	RH (%)	WINDSPEED (m/s)
Ind. Area I	99.45±0.78	27.19±5.23	0.04±0.01	2.03±0.04	1.31±0.01	32.50±0.71	54.50±0.71	0.55±0.35
Ind. Area II	65.71±21.57	31.26±7.99	0.26±0.19	0.90±1.22	0.92±0.43	32.50±0.71	77.50±13.44	1.75±0.49
NonInd. Area	57.13±6.55	22.84±0.54	0.36±0.31	0.05±0.00	0.54±0.37	32.00±0.00	65.50±27.58	1.60±0.42

Source: Authors' Fieldwork, 2017.

Table 2 shows the mean air quality concentrations and meteorological parameters obtained from the study locations. Results shown that the average concentration ($P<0.05$) of carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter (PM_{10}) of industrial area I and II have significant high values to the nonindustrial layout of the study area in Aba metropolis. This could be seen that at RH (77.50 and 54.50%), Temp (32.5^0C) and wind speed (0.55 and 1.75 m/s) respectively for the industrial axis recorded the highest mean value of CO_2 (99.45 ppm), CO (27.19 ppm), SO_2 (0.04 ppm), NO_2 (2.03 ppm) and PM_{10} (1.31ug/m^3) for Industrial Area I and CO_2 (65.71 ppm), CO (31.26 ppm), SO_2 (0.26 ppm), NO_2 (0.90 µg/m^3) and PM_{10} (0.92 µg/m^3) for Industrial Area II respectively. The Non-Industrial layout showed lowest level of CO_2 (57.13 ppm), CO (22.84 ppm), SO_2 (0.36 ppm), NO_2 (0.05 µg/m^3) and PM_{10} (0.54 µg/m^3) at RH (65.50%), Temp. (32^0C) and Wind speed (1.60m/s). The Non-industrial layout showed relatively fair levels of CO_2, CO, SO_2, NO_2 and PM_{10} in terms of good air quality as it can be seen that the lowest concentration levels of the air quality parameters were observed around the area. According to (Mishra, et al, 2012). , impact of air pollution on local plants are the major ecological issues, as plants are very efficient in trapping atmospheric particles and leaves have been used as monitors of air pollution. Sulphur dioxide (SO_2) at lower concentrations fulfils the essential nutrient sulphur requirement of plants but if SO_2 is present in excess quantities, it may become a toxic to the plant, which leads to injury of the chloroplast membranes and breaking down the chlorophyll which will eventually cause the plant to exhibit visual damage on the leaves. High concentrations of SO_2 also damage the plasmalemma, other important membranes and disrupt enzyme activity of plants (Hopkins and Hűner, 2003).

Table 3: Statistical Summary of Biochemical Parameters of plant leaves of the selected species in Industrial Area I

Plant species	pH	RWC(%)	TCH(Mg/g)	Ascorbic acid	APTI
Sida acuta	6.60±0.27	93.02±0.29	0.77±0.04	0.63±0.02	9.77
Xanthosima sagittifolium	6.09±0.16	91.72±0.86	0.46±0.02	0.49±0.02	9.49

Ipomea batata	6.43±0.29	84.83±0.86	0.39±0.01	0.56±0.05	8.86
Panicum maximum	6.29±0.13	91.83±0.38	0.23±0.04	0.71±0.01	9.65

RWC = Relative water content, AA = Ascorbic acid content, and TCH= Total chlorophyll content

Table 3 shows the parameters analysed with significant difference (P<0.05) in the different plant leaves of *Sida acuta*, *Xanthosima sagittifolium*, *Ipomea batata* and *Panicum maximum* with its mean values ranging from 6.09 to 6.60 for pH, 84.83 to 93.03% for RWC, 0.23mg/g to 0.77mg/g for TCH and 0.49 mg/g to 0.71mg/g AA for the Industrial Area I.

Table 4: Statistical Summary of Biochemical Parameters of plant leaves of the selected species in Industrial Area II

Plant species	**pH**	**RWC%**	**TCH(mg/g)**	**Ascorbic acid(mg/g)**	**APTI**
Sida acuta	6.58±0.17	90.66 ±0.79	0.67±0.04	0.59 ± 0.01	9.49
Xanthosima sagittifolium	6.21±0.29	75.41 ±22.36	0.51±0.01	0.47 ± 0.04	7.86
Ipomea batata	6.05±0.37	81.24±1.07	0.45±0.02	0.54 ± 0.05	8.48
Panicum maximum	6.04±0.09	90.12±0.79	0.36±0.06	0.82 ± 0.02	9.54

RWC = Relative water content, AA = Ascorbic acid content, and TCH = Total chlorophyll content

Table 4 shows that the plant species collected from Industrial Area II vary significantly (P<0.05) for *Sida acuta*, *Xanthosima sagittifolium, Ipomea batata* and *Panicum maximum* with its mean values ranging from 6.04 to 6.58 pH, 75.41 to 90.66% RWC, 0.36mg/g to 0.67mg/g TCH and 0.47 mg/g to 0.82mg/g AA.

Table 5: Mean±SD result of biochemical parameters of plant leaves of the selected species in non-industrial Areas

Plant species	pH	RWC (%)	TCH (mg/g)	Ascorbic acid(mg/g)	APTI
Sida acuta	6.64±0.08	83.84±1.01	0.89±0.04	0.49±0.02	8.75
Xanthosima sagittifolium	5.95±0.08	74.84±0.27	0.96±0.11	0.27±0.01	7.67
Ipomea batata	5.88±0.31	71.65±1.08	1.02±0.13	0.38±0.01	7.43
Panicum maximum	5.96±0.16	86.11±2.39	1.06±0.14	0.39±0.02	8.88

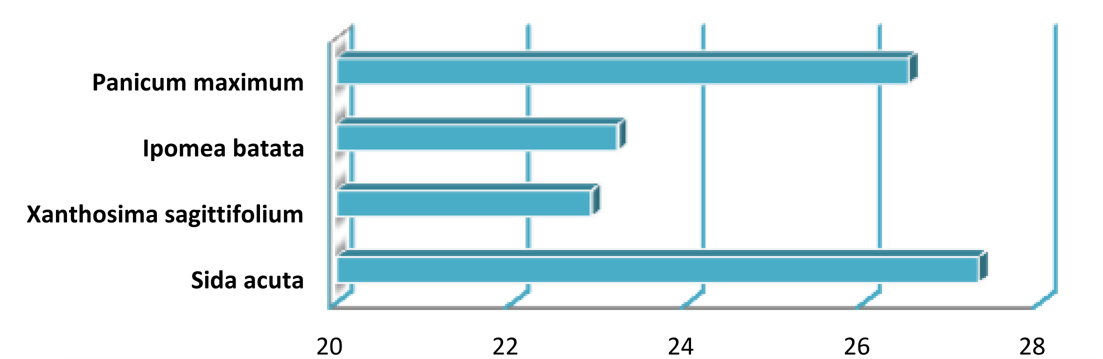
RWC = Relative water content, AA = Ascorbic acid content, and TCH = Total chlorophyll content

Table 5 shows that the plant species collected from the Non-industrial Area which was considered as the control site vary significantly (P<0.05) for *Sida acuta*, *Xanthosima sagittifolium*, *Ipomea batata* and *Panicum maximum* with its mean values ranging from 5.88 to 6.64 pH, 71.65 to 86.11% RWC, 0.89 mg/g to 1.06 mg/g TCH and 0.27 mg/g to 0.49 mg/g AA.

Table 6: Various categories of tree species based on APTI

Plant species	**APTI (mean value)**	**%**	**Tolerance**
Sida acuta	22.17	27.3	**Intermediate**
Xanthosima sagittifolium	18.69	22.9	**Intermediate**
Ipomea batata	18.86	23.2	**Intermediate**
Panicum maximum	21.64	26.5	**intermediate**
Total	**81.36**	**100**	

In the present study, out of 4 species sampled from the industrial and non-industrial environment , 4 species showed APTI mean values that ranged between 18.69-22.17 were found between the classification ranges of 17-29 signifying intermediate tolerance species , with *Sida acuta* contributing 27.3%, *Xanthosima sagittifolium* 22.9%, *ipomea batata* 23.3% and *Panicum maximum* 26.5% respectively (Fig. 2) (Table 6).



	Sida acuta	Xanthosima sagittifolium	Ipomea batata	Panicum maximum
%	27.3	22.9	23.2	26.5

Fig.2: Percentage Contribution of Plants as tolerance species in the Udeagbala Inustrial Area

Discussion

Table 3 - 5 shows the biochemical characteristics and Air Pollution Tolerance Index (APTI) for selected plant species from the Industrial layout and non-industrial axis of Osisioma Local Government Area, Abia state. It was observed that all the plant samples collected from both the industrial and non-industrial sites showed a pH ranging from 6.04 to 6.60 and 5.88 to 6.64 for Industrial and non- industrial areas respectively. The acidic nature may be due to the presence of SOx, NOx, or other acidic pollutants from the industrial emission in the ambient air causing a change in pH of the leaf sap towards acidic (Swami et al. , 2004). Low leaf pH extract showed good correlation with sensitivity to air pollution and also reduce photosynthetic process in plants (Thaka and Mishra, 2010). Plants with lower pH are more susceptible while those with pH around 7 are tolerant (Kumar. and Nandini, 2013). pH helps plant physiology responds to stress (Miria and Anisa, 2013). The cells system functions well at optimum pH but being exposed to acidic pollutants over a long period will reduce pH levels in fewer tolerant species thus interrupt the biological activities of the plants (Saxena and Ghosh, 2013). High pH level will increase the efficiency for the conversion of hexose sugar into ascorbic acid and upgrade the reducing power of ascorbic acid thus providing a better resistance in plants against pollutants (Yan-Ju and Hui, 2008).. Relative water content (RWC) of all the plant sampled from the industrial areas and non-industrial area recorded highest at the industrial area I and II than the non-industrial area. High water content within a plant body helps to maintain its physiological balance under stress condition such as exposure to air pollution when the transpiration rates are usually high which may lead to desiccation. Therefore, maintenance of RWC by the plant may decide the relative tolerance of plants towards air pollution (Verma, 2003). The higher the RWC in a particular species, the greater is its drought tolerance capacity (Dedio, 1975). Thus, the higher RWC in industrial site sample may be responsible for normal functioning of biological processes in plants (Meerabai et al., 2012).

Chlorophyll is the principal photoreceptor in photosynthesis (Tanee and Albert, 2013).Chlorophyll of plant was found to be low in the leaf sampled from the industrial areas I and II as compared to the non-industrial area. According to Singh (1991), the determination of total chlorophyll level could be a good indicator of chronic sulphate condition. The study showed that chlorophyll content in all the plants varied with the pollution status of the area. The higher the levels of pollutants, the lower the chlorophyll content as certain pollutants in totality reduce the total chlorophyll content. Accordingly, certain air pollutants have been reported to reduce chlorophyll content (Joshi and Swami, 2009), while others increase it (Tripathi and Gautam , 2007; Agbaire and Esiefarienrhe, 2009). It is evident that chlorophyll content of plants varies from species to species; age of leaf and also with the pollution level as well as with other biotic and abiotic conditions (Abida and Harikrishna, 2010). The ascorbic acid content (Vitamin C) increased in the leaves of plants at industrial areas I and II than the samples of the non-industrial area as seen in the Table 2-4. This is in agreement with the finding of (Gallie Chen, 2004). Who observed increase in industrial area than control. Increase in ascorbic acid content of all the plant species might be due to the increased rate of production of reactive oxygen species (ROS) during photo-oxidation process (Tripathi and Gautam, 2007). Based on the APTI values calculated for each plant species at all the samples locations, the APTI of plant species from the industrial areas ranged from 8.86 to 9.77 and 7.86 to 9.54 for Industry I and II respectively. The maximum value was observed in *Sida acuta* and minimum value was in *Ipomea batata* in Industrial area I while the APTI value for Industrial area II was highest in *Panicum maximum* and lowest in *Xanthosima sagittifolium*. The APTI value estimated using the four biochemical parameters in plant leaves namely pH, RWC, TCH and AA value can be used as a predictor of air quality. Plants having higher index value are tolerant to air pollution while plants with lower index value show less tolerance (Singh and Rao, 1983).. All the plants found in industrial areas (I and II) are indicative of higher pollution exposure as compared to non-industrial area. A plant species known to be sensitive or tolerant in one geographical area may behave differently in another area (Raza *et al.*, 1988). Dust pollution and chronic concentration of gaseous pollutants may affect the biochemical make up and tolerance capacity of plants to the air pollution. Industrial areas are in the grip of more serious air pollution problem due to heavy industrial emission as compared to non- industrial area. It could be deduced from the result obtained from the study that different plant responds differently to air pollution which then indicates that the different APTI values obtained for all areas suggested that plants growing in industrial layout have higher APTI than those in non-industrial area.

Conclusion

Air pollution tolerance index (APTI) of plants is becoming a vital environmental tool because it assists the assessment of plant's tolerability to air pollution since the eventual increase of air pollution levels will be detrimental to the health of the existing vegetation. The results from this study provide information for the selection of tolerant species for future planning of an industrial area in order to mitigate air pollution and even ultimately reduce pollution.

Species in sensitive groups is best to be used as bio-indicators for monitoring air quality and species ranked as tolerant is best to be planted around industrial areas to reduce the effect of air pollution, since the tolerant species have the ability to absorb air pollutants.

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