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Research Paper

Biomonitoring of Air Pollution with Trees Grown Along the Highway in Calabar, Cross River State, Nigeria

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Abstract
Urban air pollution is one of the major atmospheric pollution issues that is getting worse with the growing urban population, increasing traffic density and industrialization. Green plants have proven to be better indicators of air pollution. Biomonitoring of air pollution with trees in Calabar was carried out from August to October, 2019. Five trees species; Terminalia mantaly, Huracrepitans, Polylathialongifolia, cassia fistula and Delonixregiawere analyzed for four biochemical parameters;, Ascorbic Acid, Total Chlorophyll, Relative Water Content and leaf extract pH to determine the air pollution tolerance ability of the trees.The investigated trees fell within the sensitive range of air pollution tolerance index of trees with Terminalia mantaly, Huracrepitans having the highest values of 9.76 and 9.28 respectively. All the investigated trees were recommended for planting as avenue trees to serve as air purifiers and bioindicators of air pollution in Calabar metropolis. The study suggested that further studies should be carried out in the state with other categories of green plants.
Key word: ***Biomonitoring; Air pollution;Trees;APTI; Calabar.***

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I. INTRODUCTION

Air pollution is one of the greatest challenges ravaging the world. It has become a major environmental risk as far as public health is concerned;the World Health Organization (WHO) has estimated that approximately 2 million and 1.3 million deaths worldwide mostly in developing countries have occurred due to indoor and outdoor air pollution respectively (Ram *et al*., 2015). Hence, reducing levels of air pollution may also reduce the global burden of disease, and this can be partly achieved using plants. Planting of trees on street canyons can reduce about 40% for NO_2 and 60% for particulate matter (PM) (Pugh *et al*., 2012).

Different plants respond to air pollutants in varying ways depending on thespecies, type of pollutant, its reacting mechanisms, concentration and duration of exposure.The measurable/observable effects of air pollution on plants are wide ranging. Acid rain and vehicular pollution for instance, causes foliar injury to plants (Ramlall*et al.*, 2015) and brings about biochemicalchangesand physiological changes in roadside plants (Sharma *et al.*, 2017a).

Although green plants are well known for their abilities to reduce air and noise pollution, but it is important that plants used for the purpose of urban greeningbe tolerant to air pollutants (Pandey *et al*., 2015).

Several studies have been carried out the world over including Nigeria, on the use of trees for monitoring of air pollutants; Li *et al*., 2016; Ibironke*et al*., 2016; Nwaogwugwu*et al*., 2017;Rathore*et al*., 2018; Sahu*et al*., 2020;Anake*et al*., 2022. In Cross River State, there is dearth of studies on the use of trees as air pollution biomonitors. If tolerant tree species are planted, they may have a significant effect on the quality of the urban environment and the cleanliness of life in the city. Hence, the current study was conducted to findout the pollution tolerance level of trees species grown along the highway in Calabar Metropolis.

This will assist government, researchers, foresters, horticulturists, landscapers, environmental scientists and industrialists in the identification and selection of air pollution tolerant tree species that can act as sinks as well as screen air pollution.

II. MATERIALS AND METHODS

Study area

The research will be carried out in, Cross River State, Nigeria. Calabar is located between latitudes 4°50'00" and 5°10'00"N at the Southern part of Cross River State and longitudes 8°17'00" and 8°20' 00" E. The temperature ranges between 22 – 32°C. Rainfall ranges between 26mm and 613mm monthly. Height above sea level is 99m. Calabar Metropolis comprising of Calabar Municipality and Calabar South Local Government Area covers an area of approximately1480sqkms (Atuand Bisong, 2013). Calabar is sandwiched between the Great Kwa River to the East and the Calabar River to the West(Figure 2). The state derived its name from the Cross River that naturally demarcates the state and the nation from the Federal Republic of Cameroon on the Southeast. The state is bounded to the North by Benue State, to the west by Ebonyi and AkwaIbom States. The Atlantic coastline provides the Southern boundary. It is the administrative headquarters of Cross River State, Nigeria.

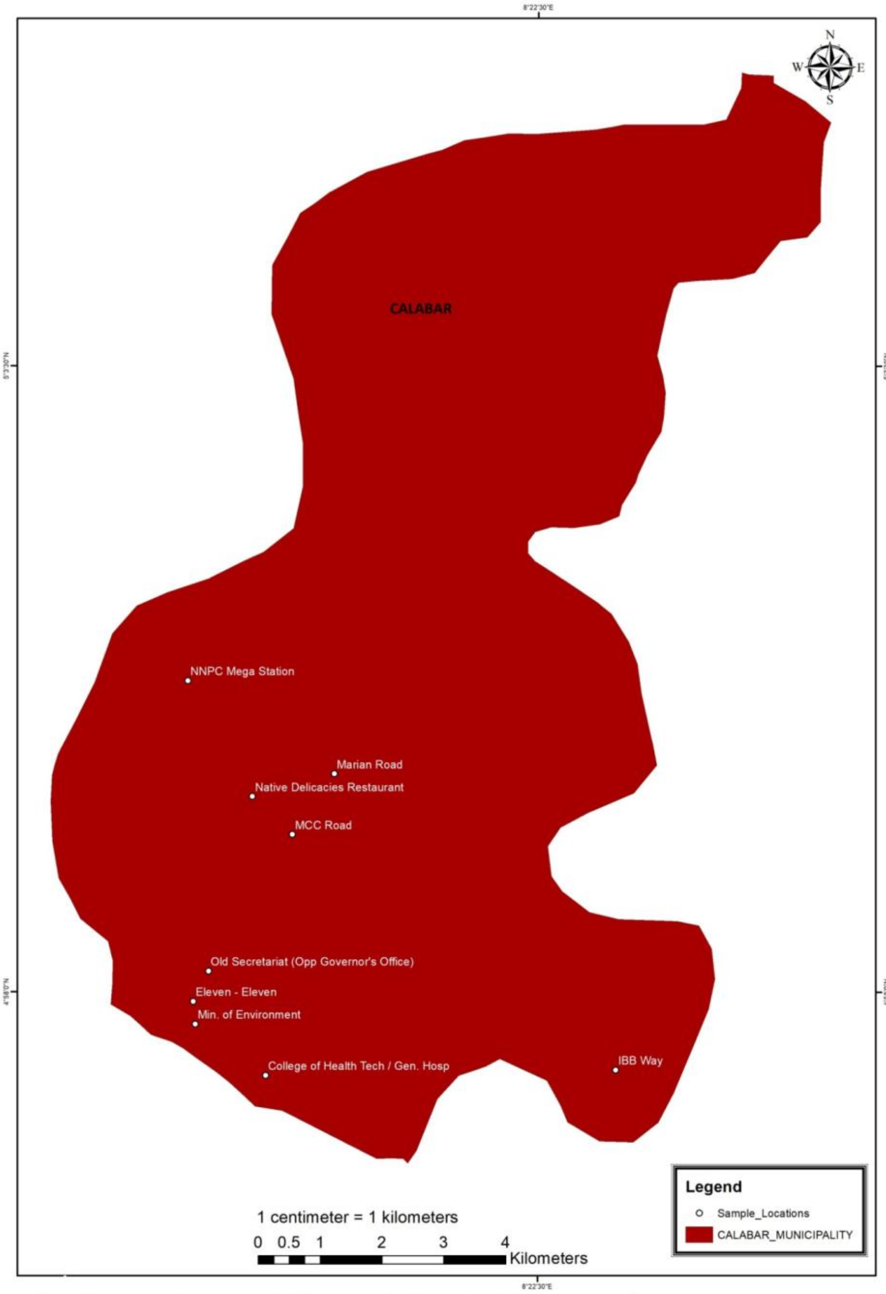

FIG.1: MAP OF CALABAR MUNICIPALITY SHOWING SAMPLED AREAS

Sampling Technique

The study was carried out in Calabar, the Cross River State capital. Purposive sampling was used in selecting tree species based on their occurrence; systematic random sampling was thereafter employed in selecting tree stands along the highway for sample collection. Samples were collected from five mature trees of specific diameterfor three months (August – October) along the Murtala Muhammed Highway. Both deciduous and evergreen trees wereselected. The leaves obtained from each site were mixed to form composite samples and put in labeled polythene bags and taken to the laboratory for analysis. The collected samples were then oven dried and crushed for analysis of biochemical properties such as Relative Water Content (RWC) using standard methods.

Relative Water Content

The per cent of leaf relative water content was calculated using the initial, turgid and final weight of leaf material as shown in the following equation (Singh, 1977). Fresh weight was obtained by weighing the fresh leaves. The leaves were then immersed in water over night, blotted dry and then weighed to get the turgid weight. Next, the leaves were dried over-night in an oven at 70° C and reweighed to obtain the dry weight.

$$RWC = \left(\frac{FM - DM}{TM - DM} \right) x\ 100$$

s

Where; FM= Fresh mass, DM=Dry mass and TM= Turgid mass

Determination of Total Chlorophyll

Total Chlorophyll was determined according to the method described by Arnon (1949). It was extracted with 80% acetone and determined spectrophotometrically. The total chlorophyll of the sampled leaves was then calculated using the following equations;

Chlorophyll a = 12.7DX663 – 2.69DX645 x V/1000W mg/g

Chlorophyll b = 22.9DX645 – 4.68DX663 x V/1000W mg/g

T. chl. = 20.2 DX 645 + 8.02 DX 663 X vmg mg/g

Where: TCh = chlorophyll a + b; mg/Dx = Absorbance of the extract at thewavelength Xnm; V = total volume of the chlorophyll solution (ml), and W = weight of the tissue extract (g).

Determination of Ascorbic Acid Content

Ascorbic acid content (expressed as mg/g) was determined using the method described by (Bajaj and Kaur, 1981) with a JENWAY 7305 spectrophotometer at 760nm.

Determination of leaf extract pH

This was determined using a JENWAY pH meter (model 3505). The leaf extract pH was obtained by homogenizing 0.2g of the pulverized leaf samples in 10mls of distilled water.

Determination of Air Pollution Tolerance Index (APTI) of Plants

The values of all the above parameters will be incorporated in the equation as suggested by Singh and Rao (1983) and the Air Pollution Tolerance Index for plants will be calculated using the formula:

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

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

The APTI index range was categorized viz; (Table 1) (Choudhury and Barnerjee 2009)

Table 1: Air pollution Tolerance Index (APTI) Range for Plants

APTI value	Response
1 – 11	Sensitive
12 – 16	Intermediate
17 and above	Tolerant

Shreshta*et al*. (2021)

Statistical analysis

A two-way analysis of variancewas used to analyze the results obtained. Where statistical differences were observed, Duncan multiple Range Test (DMRT), was used to separate mean values at $P \leq 0.05$.

III. RESULTS

The study investigated the tolerance of trees to air pollution in Calabar Metropolis. All the Biochemical parameters such as Ascorbic Acid (AA), Total Chlorophyll (TChl), pH and Relative Water Content (RWC) played significant roles in determining the tolerance of trees in the study area. Results are shown below;

Ascorbic Acid Content

The ascorbic acid content of the investigated trees species was highest in *Terminalia mantaly*(0.17mg/g¹ dw) followed by *Delonixregia* (0.15mg/g¹ *dw*), while the lowest was recorded by *Polyalthialongifolia*(0.08mg/g¹*dw*). ANOVA revealed marked significant differences in ascorbic acid content of trees used in urban greening in the study ($p \leq 0.05$).

Total Chlorophyll

*Huracrepitans*recorded the highest total chlorophyll content with a mean value of 28.77mg/g¹ dw, followed by *Cassia fistula*with a mean value of 20.86mg/g¹ dw. The lowest value was recorded in *Polyalthialongifolia*(13.44mg/g¹ dw) (Table 1). ANOVA indicated significant variations ($p \leq 0.05$)in the total chlorophyll content of trees grown along the highway in Calabar.

Table 2: Mean values of biochemical properties of trees grown along the highway in Calabar Metropolis, Cross River State, Nigeria

Taxon	AA (Mg/g^1)	TCl (Mg/g^1)	pH	RWC (%)
Cassia fistula	0.11	20.86	7.48	88.52
Delonix regia	0.15	17.12	7.95	81.39
Huracrepitans	0.10	28.77	7.68	88.75
Polyalthialongifolia	0.08	13.44	7.67	88.53
Terminalia mantaly	0.17	18.09	7.18	93.27
P.V	0.00**	0.00**	0.00**	0.00**

pH

In the study area, *Delonixregia* recorded the highest leaf extract pH value of 7.95, followed by *Huracrepitans* with a mean pH value of 7.68. The lowest valuewas observed in *Terminalia mantaly* (7.18) (Table 1). ANOVA showed significant variations in the pH levels of trees grown along the highway in Calabar ($p \leq 0.05$).

Relative Water Content (RWC)

Terminalia mantaly recorded the highest leaf Relative Water Content with a mean value of 93.27%in the study area, followed by *Huracrepitans* (88.75%) and then the lowest in *Delonixregia* with a mean value of 81.39% (Table 1).ANOVA revealed that differences existed in the Leaf Relative water content of trees grown along the highwayin Calabar ($P \leq 0.05$).

Table 3: Mean values (DW) of APTI of Trees grownalong the highway in Calabar, Cross River State, Nigeria

Taxon	AA (Mg/g^1)	TCl (Mg/g^1)	pH	RWC (%)	APTI
Cassia fistula	0.11	20.86	7.48	88.52	9.15
Delonix regia	0.15	17.12	7.95	81.39	8.52
Hura crepitans	0.10	28.77	7.68	88.75	9.28
Polyalthialongifolia	0.08	13.44	7.67	88.53	9.02
Terminalia mantaly	0.17	18.09	7.18	93.27	9.76
P.V	0.00**	0.00**	0.00**	0.00**	0.00**

The highest APTI value was recorded in *Terminalia mantaly (9.76)* followed by *Huracrepitans (*9.28) and the lowest was observed in *Delonixregia* (8.52)(Table 2).
Analysis of variance (ANOVA) showed that there were marked significant variations in the APTI of trees across the study period, season of samples collection and locations of samples collection.

The order of tolerance of the investigated trees was; *T. Mantaly*(9.76) >*H. crepitans*(9.28) >*C. fistula*(9.15>*P. longifolia* (9.02) >*D. regia* (8.52).

IV. DISCUSSION

Many authors have documented the importance of APTI in determining plants tolerance to air pollution. (Radhi and Reddy 2016, Kaler*et. al.*, 2017;Wadlow*etal*., 2019; Han *et al*., 2020; Bui *et al.*, 2021; Mukhopadhyah*et al*., 2021; Anake*et al.*, 2022).

In the present study, the high APTI values obtained could be due to the high Ascorbic acid content and Relative water content recorded in trees during the study period. This agrees with the findings of Ogbonna*et al.* (2015) who studied the biochemical properties of trees alongUmuahia-Aba road and observed that *Mangiferaindica* recorded the highest air pollution tolerance index and relative water content.Ogunrotimi*et al*. (2017) in their investigation on the sensitivity and Tolerance levels of 12 trees using Air pollution tolerance indexestablished that high values of (12.7)in *Polyalthialongifolia, Mangiferaindica, Gmelinaarborea, Tectonagrandis*and *Terminalia catapa* were the most tolerant of all the trees species studied.

Trees that recorded low APTIcould be attributed to the reduction in leaf Relative water and ascorbic acid contents in the tree. This agrees with the result of Seyyednjad*et al*. (2011) who worked on air pollution tolerance indices of some plants around industrial zones South Iran and observed *Eucalyptus camadulensis* had an APTI value of 8.5. All the trees investigated in this study fell within the sensitive range of tolerance (1 – 11). They can therefore be used as bio-indicators of air pollutionand hence suitable for urban greening.

Ascorbic acid content

Ascorbic acid, also known as ‘Vitamin C’ plays a vital role in cell wall synthesis, photosynthesis, cell wall division and carbon fixation.The low ascorbic acid content agrees with the findings of Khan and Avhad (2016)who reported means values of ascorbic acid in *Terminalia catapa* (0.0498), *Polyalthialongifolia* (0.0191) in Ghatkopar.

Total chlorophyll

Chlorophyll is an essential tool in evaluating the effect of air pollutants on plants; It plays an important role in plant metabolism. The high values of total chlorophyll content of the studied trees indicate a low level of air pollution in Calabar Metropolis. This is in consonance with works of Allen *et al.* (1987) and Patel and Kumar (2018) who opined that certain pollutants diminishes the total chlorophyll content of plants, hence the morethe pollutants, the lower the total chlorophyll and vice versa.

Relative Water Content

Leaf relative water content refers to the balance between water supply to the leaf tissue and transpiration rate. It is an important indicator of water status in plants.Relative water content can be as high as 98% in fully turgid transpiring tissues, and as low as 30 – 40% in severely drying leaves depending on the plant species (Zhang *et al.*, 2015).The variations in the values are an indication that the trees responded well to air pollutants.

pH

This study revealed that the pH values obtained in all the trees tilted towards the alkaline pH range and were all sensitive to air pollution.The relatively higher pH values maybe as a result of the deposition of dust and vehicular particles on leaves' surfaces. Rathore*et al*. (2018) recorded higher pH values in *Mangiferaindica* (9.2), *Azadirachtaindica* (8.9) amongst other plants in Udaipur City.

V. CONCLUSION

Trees are excellent indicators of air pollution and the tolerance of plants to air pollution may be site specific depending on the level of pollution. *Terminalia mantaly* and *Huracrepitans* had the highest air pollution tolerance index and can be used as bio-sink, while the rest can be used as bioindicators of air pollution. All the trees investigated fell within the sensitive category of APTI grades. Cultivation of these tree species may have a marked effect on varied aspectsof the quality of the urban environment and the cleanliness of life in the city.

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