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ANTICIPATED PERFORMANCE INDEX OF URBAN TREE SPECIES IN MAKURDI, NIGERIA

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Abstract
The study investigated the anticipated performance index of urban tree species in Makurdi, Nigeria. The objectives were to determine the air pollution tolerance and anticipated performance indices. Multistage and purposive sampling methods were used to select five (5) plots measuring 400 m × 30 m. All the individual trees within the sampled plots were identified and counted. A 30% sample intensity was purposively used to select six (6) tree species that were most frequently found. Fresh mature leaves were randomly picked in triplicates from each tree species and transported to the laboratory for analysis. The APTI and API values were calculated by the application of quantitative parameters of biochemical analysis. Descriptive statistics (percentage, frequency, bar chart) and inferential statistics (correlation) were also used to analyze the data. The results showed that *Mangifera indica* and *Anacardium occidentale* were considered to have high levels of all biochemical concentrations. Similarly, *Mangifera indica* and *Anacardium occidentale* were found to have the highest APTI and API values. This implies that these species were sensitive to air

pollution. *Mangifera indica* and *Anacardium occidentale* showed good API gradation, in contrast to poor performance recorded by *Albizia lebbeck*, *Polyalthia longifolia*, *Eleais guineensis*, and *Delonix regia*. The findings of this study conclude that *Mangifera indica* and *Anacardium occidentale* are better suited for urban settings compared to other species in the study area. Therefore, concerned stakeholders should ensure that these species are planted and managed around settlements, routes, and other urban landscapes of Makurdi city.

Keywords: Urban trees, Performance, Air pollution, Makurdi, and Biochemical parameters.

1. Introduction

Urbanization is a common phenomenon that changed the overall identity of human-altered habitats. It describes the shift of human populations migrating from rural areas, filling up cities [1]. As a result, urban habitats are characterized by many extreme anthropogenic factors, such as elevated chemical levels, transformed landscape elements, pollution patches, and disturbance sources from the enriched population [2]. Urban tree species play critical roles in providing services (heat and air pollution reduction) necessary for the well-being of human beings in cities. It is well known that plants in urban environments, particularly trees, provide several ecosystem services in different aspects of life [3]. In general, from the environmental point of view, plant benefits include climatic regulation; uptake/reduction of carbon dioxide and other greenhouse gases and pollutants [3-5].

Air pollution is caused by anthropogenic activities such as burning of solid waste (household waste), partial burning of fossil fuels and firewood [6]. It is one of the severe problems faced by the whole world in recent time. Environmental stress is increasing day by day because of air pollutants (sulphur dioxide, nitrogen dioxide, carbon dioxide, and carbon monoxide) and particulate matter, which are emitted as the smoke. The introduction of pollutants into the atmosphere by anthropogenic activities creates adverse effects on humans in urban cities [7], and there is no mechanical or chemical device that can completely check the emission of these pollutants at the source. Only plants are the hopes; these plants can completely reduce the pollution level in the air environment by actively participating in cycling nutrients and gases [7-8].

The resistance and susceptibility of plants to air pollutants can be determined by their physiological and biochemical levels. By analyzing the biochemical parameters of leaf materials, such as the potential of hydrogen ion concentration (pH), ascorbic acid, relative water content, and total chlorophyll, the 'Air Pollution Tolerance Index' (APTI) can be determined [7,9]. APTI is a tool that provides a reliable method for screening large numbers of plants with respect to their susceptibility to air pollution [10]. It is effective for evaluating the impact of pollutants on biochemical parameters, but anticipated performance index (API) is an improvement because it also considers socioeconomic and biological factors like height of plant, structure of canopy, size of plant, hardness, and texture of tree species to predict their tolerance to air pollution [11-12]. API is used to judge the capabilities of predominant species to clean up atmospheric pollutants [6]. Both APTI and API are innovative tools used in urban planning to assess and select plants that can tolerate air pollution [11]. The combination of APTI and API can be used to select plants for urban forests and green belt development [11, 13]. These indices provide a quantitative method to select suitable plant species for greening urban areas, particularly in regions with high levels of air pollution.

Therefore, the study seeks to estimate the air pollution tolerance index and anticipated performance index of tree species in Makurdi, aimed at selecting the tolerant and indicator plant species. Trees act as air pollution sinks but better performance comes from the pollution tolerant species [14]. According to Khan and Avhad [12], plants can be screened and used as biological indicators or air pollution monitors by tracking their tolerance to air pollution. This can help to develop the green and eco-friendly metropolitan environment.

2. Materials and Methods

2.1 Study area

Makurdi city lies between latitudes $7^0 44'$ and $7^0 55'$ North and longitudes 8^0 $20^{'}$ and 8^0 $40^{'}$ East of the equator. It occupies a total land mass of approximately 810 km^2 (Figure 1). According to Shabu and Tyonum [15], the city is bordered to the north by Guma Local Government Area, to the south by Gwer Local Government, to the south-west by Gwer-West Local

Government Area, and to the north-west by Doma Local Government Area of Nasarawa State. It is situated in the Benue Valley on the bank of the river Benue [15]. The river divides the city into the North and South Banks. The northern part of the city is made up of several areas, including North Bank and Federal Low Cost, while the southern part includes Old GRA, Ankpa, Wadata, High Level, Wurukum (Low Level), and New GRA. Makurdi Metropolis is characterized by two (2) seasons, warm-wet and cold-dry seasons. The warm-wet season lasts from April to October, while the dry season spans November to March. The annual rainfall ranges from 1,200mm to 1,500mm [16]. The temperature is generally high, ranging from 22^0 C to 37^0 C in the rainy season [16-17]. The 2006 National Population Census (NPC) estimated that there were 273,724 individuals living in the study area [18].

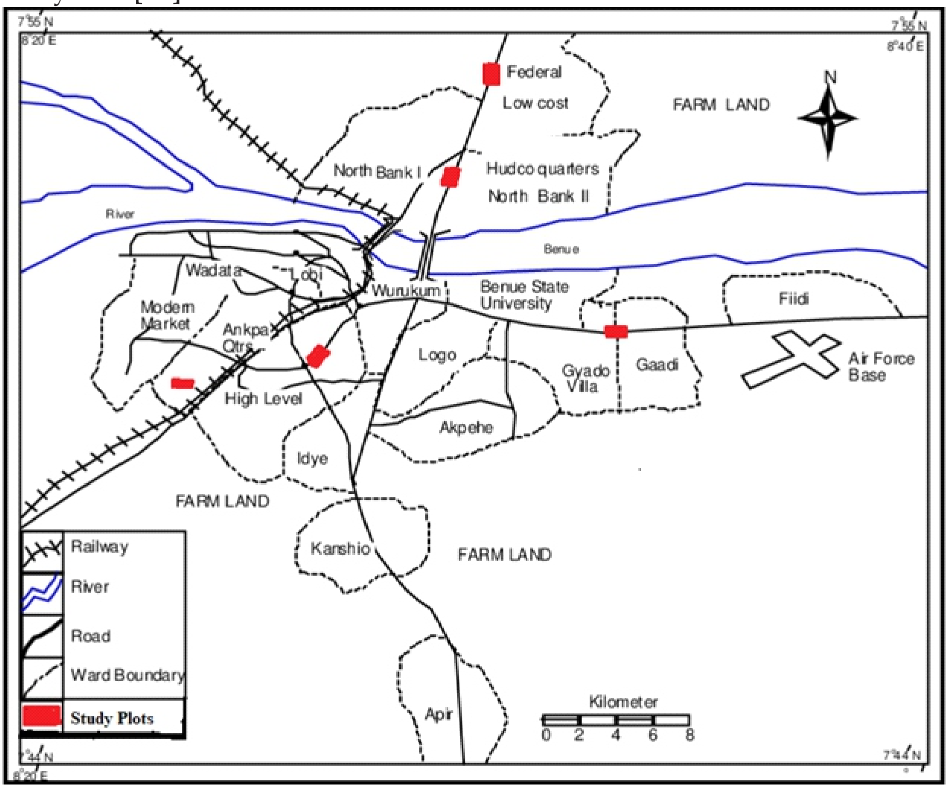

Figure 1: Map of Makurdi metropolis showing the study plots
Source: Shabu and Tyonum [15].

2.2 Data collection

Multistage sampling method was employed, with purposive sampling used in the first stage to select five plots measuring 400 m × 30 m along the major roads or streets where commercial activities are on the increase. The sampled areas of the city include High level, Industrial layout, North bank – Abuja road, Federal low cost – Abuja road and Wurkum – Gboko road. All the individual trees within the sampled plots were identified and counted. The number and scientific names of all the tree species encountered in each plot were recorded according to the International Plant Nomenclature Index [19]. When it was difficult to identify the species in the field, the common/local names were recorded and plant specimens were collected for identification at the Department of Social and Environmental Forestry herbarium, Joseph Saawuan Tarkaa University Makurdi, Nigeria.

In the second stage, six (6) most common species with the highest frequency out of the total species sampled in the first stage were selected using a sampling intensity of 30% to elicit information on air pollution tolerance and anticipated performance indices. The tree species selected include *Delonix regia*, *Polyalthia longifolia*, *Albizia lebbeck*, *Mangifera indica*, *Eleais guineensis* and *Anacardium occidentale*. The matured fresh leaves directly exposed to sun and rain were randomly collected in triplicates from each tree species. Collection was made between 7:00 am and 10:00 am. The leaves were then placed in polythene bags immediately after collection to minimize loss of moisture content, labeled with the aid of masking tape and marker pen. The leaves of same tree species obtained from different plots were bulked together to form composite sample and transported to the Department of Chemistry Laboratory, Benue State University, Makurdi, Nigeria for laboratory analysis.

2.3 Data analysis

Air pollution reduction potential depends on biochemical characteristics [20] such as Ascorbic acid, leaf pH, chlorophyll and relative water contents of leaf. According to Arndt *et al*. [21], relative water content measures the amount of water in plant tissues relative to their maximum water-holding capacity. Ascorbic acid is a powerful antioxidant that helps protect plant cells from oxidative damage caused by pollutants [21]. Chlorophyll is essential for photosynthesis, and its content can be affected by air pollutants [22]. Changes in leaf pH can affect various metabolic processes of plant [23]. The sensitivity of these biochemical parameters to air pollution formed the basis for their selection, and their analyses were performed as follows:

1.3.1 Determination of percentage relative water content (RWC)

Upon collection, the fresh leaves were immediately taken to the laboratory for the determination of the leaf fresh weight in order to minimize water loss. The fresh leaf samples were weighed on a weighing balance and recorded as fresh weight (FW). After this, the fresh leaves were floated in distilled water inside a closed Petri dish at room temperature for 24 hours. At the end of the incubation period, the leaf samples were wiped dry gently with blotted paper and reweighed to obtain the turgid weight (TW). It was then placed in a pre-heated oven at 80^0 C for 48 hours. Thereafter, the leaves were weighed to obtain the dry weight (DW). The relative water content was determined using equation 1, as adopted by Rai *et al*. [24]:

$$RWC = \frac{FW - DW}{TW - DW} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where:
FW = Fresh Weight
TW = Turgid Weight
DW = Dry Weight

1.3.1 Determination of total chlorophyll **(TCh)**

Total chlorophyll content was determined using the spectrophotometric method [25-26]. Three grams (3 g) of fresh leaves were blended and then extracted with 10 ml of 80% acetone and left for 15 minutes for thorough extraction as described by Chouhan *et al*. [26]. The liquid portion was decanted into another test tube and centrifuged at 2,500 rpm for 3 minutes using a tabletop centrifuge. The supernatant was then collected and the optical density for absorbance taken at 645 nm (D_{645}) and 663 nm (D_{663}) using a spectrophotometer. The optical density (C_T) of the total chlorophyll is the sum of the chlorophyll a (D_{645}) and chlorophyll b (D_{663}) and calculated using equation 2:

$$C_T = 20.2\,(D_{645}) + 8.07\,(D_{663}) \ldots\ldots 2$$

Where:

(C_T) = Optical density

D = Absorbance of extract at the wavelength nm

Therefore, total chlorophyll ((TCh) was calculated using equation 3:

$$TCh = 0.1C_T \frac{\text{Leaf DW}}{\text{Leaf FW}} \ldots\ldots 3$$

1.3.1 Determination of ascorbic acid content (AA)

Ascorbic acid content (AA) was measured using the spectrophotometric method [27]. EDTA (Ethylenediaminetetraacetic acid) extracting solution was added to 1 gram of the fresh leaf in a test tube, after which 1 ml of orthophosphoric acid, 1 ml of 5% tetraoxosulphate (VI) acid, 2 ml of ammonium molybdate, and 3 ml of water were added. The solution was allowed to stand for 15 minutes, after which the absorbance at 760 nm was measured with a spectrophotometer. The concentration of ascorbic acid in the sample was then extrapolated from a standard ascorbic acid curve.

1.3.2 Determination of leaf extract pH

The pH was determined according to the method of [28]. Five (5) g of the fresh leaves was homogenized in 50 ml of deionized water, and it was filtered with a Whatman 42 filter paper, and the pH of the leaf extract was determined after calibrating the pH meter with a buffer solution of pH 4 and 9.

The APTI of each tree species was determined by incorporating the values of the aforementioned biochemical parameters as adopted by Rai *et al*. [24] and Bakiyaraj and Ayyappan [29].

$$APTI = \frac{A\ \ T+P\ \ +R}{10} \ldots\ldots 4$$

Where:

A = Ascorbic Acid (mg/g)

T = Total Chlorophyll (mg/g)

P = pH of leaf extract

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The resultant values of APTI, together with relevant biological and socioeconomic characters (including plant type and habit, canopy structure, laminar size, texture and hardiness) of each tree species were combined to obtain the Anticipated Performance Index (API) for the tree species. Based on these characters, different grades (+ or -) were allotted to the tree species. These species were scored according to their grades [30-34]. API calculation for each tree species was done according to equation 5.

$$API\ (\%) = \frac{\text{Grade of tree species}}{\text{Maximum grade}} \times 100 \ldots\ldots\ldots \ldots\ldots\ldots.5$$

Where the maximum possible grade scored for any tree species is 16 [11, 30, 33]. The criteria used for calculating the API of the different the tree species are given in Table 1.

Table 1: Standard for grading character to tree species

Table 1: Standard for grading character to tree species

Grading character	Parameter	Pattern of assessment	Grading allotted
Tolerance	APTI	0.0–2.0	-
		2.1–6.0	+
		6.1-10.0	++
		10.1-14.0	++ +
		14.1-18.0	++ + +
		18.1-22.0	++ + + +
Biological	Height of tree	Short	-
		Medium	+
		Tall	+ +
	Canopy structure	Sparse/irregular/globular	-
		Spreading crown/open/semi-dense	+
		Spreading dense	+ +
	Tree type	Deciduous	-
		Evergreen	+
Laminar structure	Size	Small	-
		Medium	+
		Large	+ +
	Texture	Smooth	-
		Coriaceous	+
	Hardness	Delineate	-
		Hardy	+
Socioeconomic	Economic	<3 uses	-
		3-4 uses	+
		>4 uses	+ +

Sources: Ogunkunle *et al*. [11] (2015); Kashyap *et al*. [34].

The various categories of tree species were assigned based on their API scores (%) as follows: < 30 as not recommended, 31–40 as very poor, 41–50 as poor, 51–60 as moderate, 61–70 as good, 71–80 as very good, 81–90 as excellent, and 91–100 as best [30] with their corresponding API values from 0–7, respectively [11, 30, 34].

Data were also analyzed using descriptive statistics such as frequencies, percentages and bar charts. Biochemical, APTI, and API data were subjected to Spearman correlation to test for significant relationships among the parameters.

1. Results and Discussion

3.1 Checklist of the samples urban tree species in the study area

The checklist of urban tree species in Makurdi metropolis showed that a total of 301 individual trees belonging to 16 families and 21 species were identified and recorded. The most predominant family was Aracaceae with three (3) species, followed by Anacardiaceae, Bignoniaceae, and Leguminoceae with two (2) species each (Table 2). The checklist of tree species in the study area is lower than what has been reported by Oyebade *et al*. [35] and Agbelade *et al*. [36]. Oyebade *et al*. [35] in their study, reported 30 families and 16 species of urban trees in the commercial area of Uyo metropolis, Akwa Ibom State, Nigeria. Agbelade *et al*. [36], on the other hand, encountered 29 families of tree species in the urban centre of Abuja city, Federal Capital Territory, Nigeria. Similarly, Uddin *et al*. [37], in their investigation of urban tree species in Dhaka, Bangladesh, found 42 families of tree species. The result further shows that *Albizia lebbeck* had the highest frequency of 15.62% (47) followed by *Mangifera indica* (15.28%) (46), *Polyalthia longifolia* (12.62%) (38) and *Delonix regia* (10.96%) (33). This result led to the selection of the first six (6) species for biochemical analysis and onward computation of APTI and API. In agreement, Uddin *et al*. [37], in their study, identified *Polyalthia longifolia* as one of the most abundant and dominant tree species in the road dividers of Dhaka city, Bangladesh. *Moringa oleifera*, *Kigelia africana*, *Dacrodes edulis,* and *Calotropis gigentea* were the least tree species, with a frequency of 0.33% each (Table 2).

Table 2: Checklist of tree species in the study area

S/No	Species	Family	Frequency						Percentage (%)
			Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Total	
1.	*Albizia lebbeck*	Leguminoceae	22	9	3	5	8	47	15.62
2.	*Mangifera indica*	Anacardiaceae	8	10	11	5	12	46	15.28
3.	*Polyalthia longifolia*	Annonaceae	21	3	1	4	9	38	12.62
4.	*Delonix regia*	Leguminoceae	16	6	3	3	5	33	10.96
5.	*Anacardium occidenlate*	Anacardiaceae	7	4	6	9	2	28	9.30
6.	*Eleais quineensis*	Aracaceae	4	11	3	3	4	25	8.31
7.	*Newbouldia laevis*	Bignoniaceae	-	2	2	12	3	19	6.31
8.	*Tectona grandis*	Lamiaceae	2	5	2	4	2	15	4.98
9.	*Azadiracta indica*	Meliaceae	4	3	2	2	1	12	3.99
10.	*Coccos nucifera*	Aracaceae	-	1	2	3	2	8	2.66
11.	*Gmelina arborea*	Verbenaceae	3	1	-	1	2	7	2.33
12.	*Carica papaya*	Caricaceae	-	2	1	-	3	6	2.00

13.	*Terminalia catappa*	Combretaceae	2	2	-	-	-	4	1.33
14.	*Citrus sinensis*	Rutaceae	-	-	-	1	2	3	0.99
15.	*Casuarina equsetifolia*	Casuarinaceae	1	-	-	-	1	2	0.66
16.	*Ravenale madascariensis*	Strelitziaceae	-	-	-	-	2	2	0.66
17.	*Roystonea regia*	Aracaceae	-	-	1	-	1	2	0.66
18.	*Calotropis gigantea*	Apocynaceae	1	-	-	-	-	1	0.33
19.	*Dacrodes edulis*	Burseraceae	1	-	-	-	-	1	0.33
20.	*Kigelia Africana*	Bignoniaceae	-	-	1	-	-	1	0.33
21.	*Moringe oleifera*	Moringaceae	-	-	-	-	1	1	0.33
22.	**Total**		**92**	**59**	**38**	**52**	**60**	**301**	**100**

3.2 Biochemical parameters of the sampled urban tree species in the study area

Biochemical properties result in Figure 2 revealed that *Anacardium occidentale* had the highest content of ascorbic acid (2.36 mg/g), followed by *Delonix regia* (1.51 mg/g), against *Albizia lebbeck* having the lowest ascorbic acid content of 0.38 mg/g. The higher concentration of ascorbic acid in the sampled tree species, especially *Anacardium occidentale* and *Delonix regia,* implies that these species possessed high tolerance capacity, and the increased level of ascorbic acid may be due to the defence mechanism of the plant. This finding agrees with Khan and Avhad [12], who maintained that an increased level of ascorbic acid in leaves will increase air pollution tolerance in plants. High total chlorophyll content was observed in all the sampled species, with *Mangifera indica* (8.27 mg/g) and *Polyalthia longifolia* (3.34 mg/g) being the highest and lowest, respectively (Figure 2). High total chlorophyll content values were also reported by Nwadinigwe [38] in *Mangifera indica* (1.50 mg/g) and *Anacardium occidentale* (1.10 mg/g) from Enugu State, Nigeria. Higher chlorophyll content in plants might favour tolerance to pollutants [12].

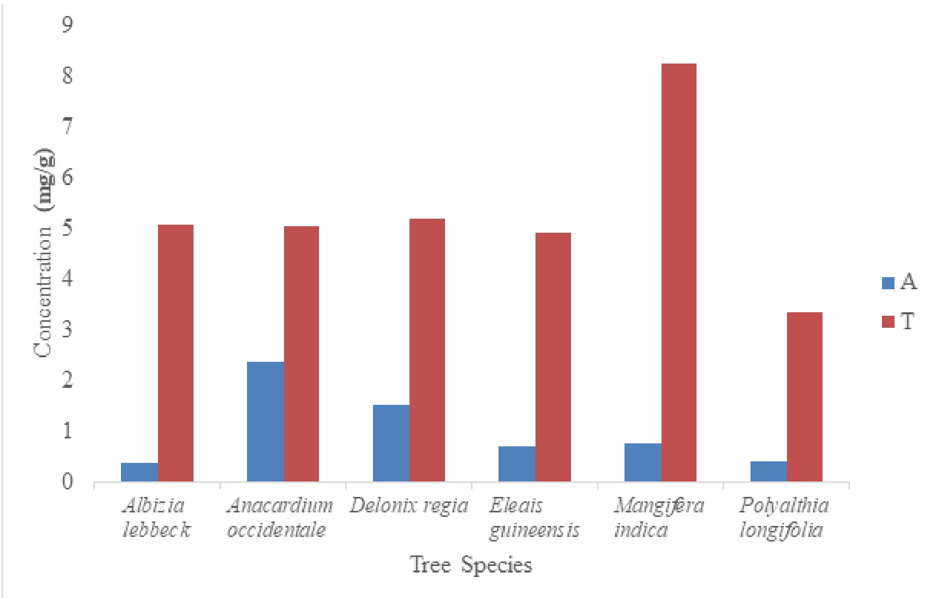

Figure 2: Ascorbic acid and total chlorophyll content of tree species in the study area
Key: A = Ascorbic acid content, T = Total chlorophyll content.

Figure 3 revealed that the pH values of the sampled tree species ranged between 4.96 and 5.64. This implies that all the sampled tree species in the study were ascertained with high leaf extract pH. This result agreed with those of Chandawat and Deepika [39] and Hari-Prasath *et al.* [40], who observed higher leaf extract pH in plants, especially in polluted conditions. A pH on the higher side improves tolerance against air pollution [12]. The high pH values in plants are recognized to develop tolerance levels against environmental pollution [41].

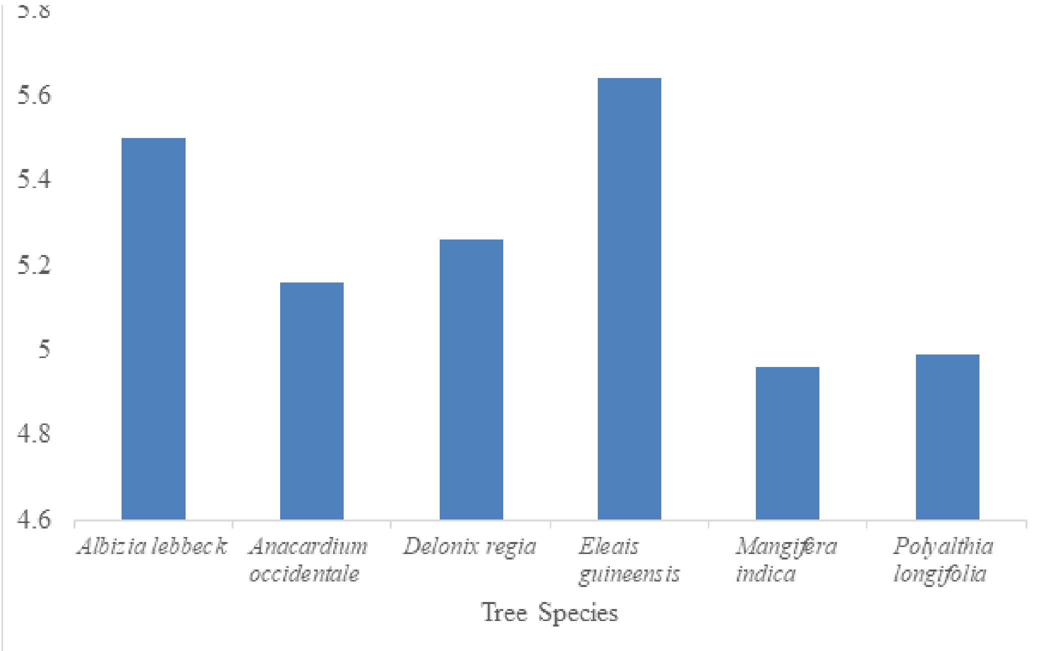

Figure 3: Values of the pH of the sampled tree species in the study area

The relative water content of the leaves of the sampled species varied from a maximum of 83.64±1.16% in *Anacardium occidentale* to a minimum of 61.53±2.34% in *Eleais guineensis* (Figure 4). This means that all the tree species in the study were found to have high percentages of water. According to Khan and Avhad [12], higher relative water content is advantageous for drought resistance in plants. The high percentage of water in the sampled species may be connected to the climate factors of the study area. This result is similar to the findings of Agbaire and Esiefarienrhe [42], who observed higher relative water content in the tree species under study around the Otorogun gas plant in Delta State, Nigeria. Similarly, *Mangifera indica* and *Polyalthia longifolia* had the greatest relative water content in the leaf samples from the study by Uka *et al*. [43] in Kumasi, Ghana, which varied from 64.42 to 93.86%. Hari-Prasath *et al.* [40] also observed higher relative water content in some tree species, including *Polyalthia longifolia* (94.19%) in Coimbatore Urban City, India.

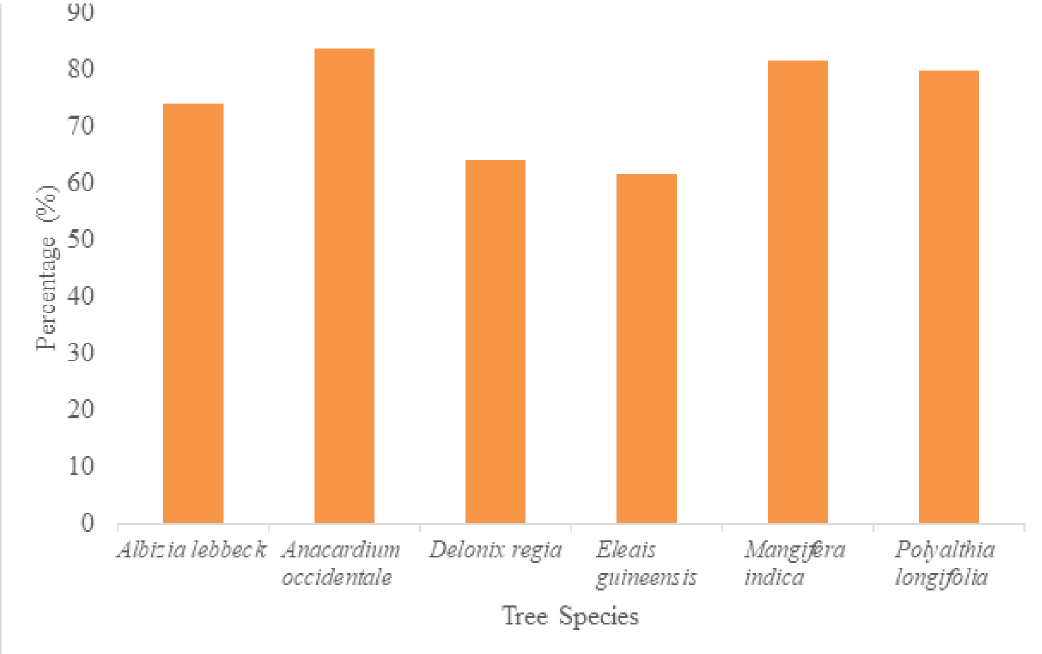

Figure 4: Tree species' relative water content in the study area

3.3 APTI of the urban tree species sampled in the study area

According to Table 3, *Anacardium occidentale* accounted for the highest APTI value (10.77), followed by *Mangifera indica* (9.17) and *Polyalthia longifolia* (8.32), respectively, with *Eleais guineensis* having the least APTI value (6.89). This result confirmed that air pollution in Makurdi metropolitan city can be mitigated by these species, most especially *Anacardium occidentale* and *Mangifera indica*. The finding of Anake *et al*. [43] is in favour of this result. They reported the higher APTI values of six common tree species, including *Mangifera indica* (10.60), growing in residential areas of the Ota industrial estate in Ota, Ogun State, Nigeria. Uka *et al*. [43] from Kumasi, Ghana, reported from their study that *Mangifera indica* is the tree species with the highest tolerance response level. Comparatively, the APTI values recorded for *Delonix regia*, *Mangifera indica,* and *Anacardium occidentale* in this study are not in agreement with the study of Nwadinigwe [38], who found lower APTI values for *Delonix regia* (5.31), *Mangifera indica* (4.18), and *Anacardium occidentale* (3.47). The rating of the species in Table 3 showed that all the tree species were sensitive to air pollution. This means that the entire tree species in the study area were found within the APTI range of 1 to 11, thus categorized as sensitive species. This conforms to the findings of Ogbonna *et* *al.* [45], who maintained that all the plants studied in the Ishiagu zinc mining area of south-eastern Nigeria were sensitive to air pollution from mining activities and therefore suggested their use as bio-indicators of air pollution.

Table 3: Biochemical parameters and air pollution tolerance indices (APTI) of tree species in the study area

S/No	Species	A (mg/g)	T (mg/g)	P	R (%)	APTI	Rating
1.	*Albizia lebbeck*	0.38	5.08	5.50	74.21±0.46	7.82	Sensitive
2.	*Anacardium occidentale*	2.36	5.03	5.16	83.64±1.16	10.77	Sensitive
3.	*Delonix regia*	1.51	5.19	5.26	63.92±0.45	7.97	Sensitive
4.	*Eleais guineensis*	0.70	4.93	5.64	61.53±2.34	6.89	Sensitive
5.	*Mangifera indica*	0.75	8.27	4.96	81.79±2.74	9.17	Sensitive
6.	*Polyalthia longifolia*	0.40	3.34	4.99	79.87±0.77	8.32	Sensitive

Key: A = Ascorbic acid content, T = Total chlorophyll content, P = pH of leaf extract, R = Relative water content.

3.4 APTI and socioeconomic/biological characteristics judgment in the study area

Table 4 showed the grades of the sampled tree species depending on the APTI and pertinent socioeconomic and biological characteristics. This revealed that *Mangifera indica* had the highest grade (68.75%) with 11 plus, followed by *Anacardium occidentale* (62.50%) with 10 plus. The lowest grade (43.75%) with 7 plus was noted in *Albizia lebbeck* and *Polyalthia longifolia* each. The classification of the tree species in the study area as good or poor performers may be linked to their socioeconomic and biological characteristics. This observation is in line with the findings reported by Rai *et al*. [24], Anake *et al*. [44] and Ganguly *et al*. [46]. They reported that *Mangifera indica* is distinguished as highly effective species because of their broader leaf size, compact crown, and greater economic importance and, therefore, is suggested as an ideal species for air pollution mitigation. They also categorized *Elaeis guineensis* as one of the poorest performing species, which cannot be recommended for air pollution mitigation programs in cities. This categorization is linked to the poor surface areas of the linear to needle leaf shape and size of the *Elaeis guineensis* species.

Table 4: APTI Values with biological and socioeconomic characters

Species	APTI	Height of Tree	Canopy Structure	Tree Type	Size	Tex ture	Hard ness	Econ omic	Total Plus (+)	% Score
Albizia lebbeck	++	+	+	-	+	-	+	+	7	43.75
Anacardium occidentale	+++	+	+	+	+	+	-	++	10	62.50
Delonix regia	++	+	+	_	+	_	+	++	8	50.00
Eleais guineensis	++	++	_	+	_	+	_	++	8	50.00
Mangifera indica	++	++	+	+	++	+	_	++	11	68.75
Polyalthia longifolia	++	++	-	+	-	+	-	+	7	43.75

3.5 Anticipated performance index of the tree species in Makurdi metropolis

As shown in Table 5, *Anacardium occidentale* and *Mangifera indica* were recorded as highly effective species with an API grade of 4. In contrast, *Mangifera indica* was reported by Pandey *et al*. [13] and Anake *et al*. [44] as a highly effective species with an API grade of 5 in their findings. In a similar development, Datta *et al*. [47] from India observed higher API rating of 5.9 for *Mangifera indica*. On the other hand, *Albizia lebbeck*, *Delonix regia*, *Eleais guineensis,* and *Polyalthia longifolia* were judged to be poor performers with an API grade of 2 (Table 5). These species were found to be poor and are not recommended for air pollution mitigation, but they are considered good bio-indicators for air pollution, as confirmed by Leghari *et al*. [6].

The API value of *Polyalthia longifolia* in this finding is lower than the value of 4.8 reported by Datta *et al*. [47] from India. In their research conducted in Kumasi, Ghana, Uka *et al*. [43] evaluated *Polyalthia longifolia* as a bad performer and *Mangifera indica* as a very good performer.Table 5: Analyses of anticipated performance index (API) of the selected tree species in the study area

S/No	Species	Grade		API Grade	Assessment
		Total Plus (+)	Percentage (%) Score		
1.	*Albizia lebbeck*	7	43.75	2	Poor
2.	*Anacardium occidentale*	10	62.50	4	Good
3.	*Delonix regia*	8	50.00	2	Poor
4.	*Eleais guineensis*	8	50.00	2	Poor
5.	*Mangifera indica*	11	68.75	4	Good
6.	*Polyalthia longifolia*	7	43.75	2	Poor

3.6 Correlation test of the relationship among biochemical parameters, APTI and API

In Table 6, APTI and API showed positive correlation with all the biochemical parameters under study. A positive correlation was also observed between APTI and API values. No inverse or negative correlation between the study parameters. This implies that the correlations between those parameters are significantly related. Tak and Kakde [48], in their study, observed a positive correlation between APTI and ascorbic acid, pH of leaf extract, and relative water content but a negative correlation with total chlorophyll. Furthermore, the findings in Table 6 revealed that total chlorophyll, pH of leaf extract, and relative water content are the most important parameters that determine the tolerance of the sampled species in the study area.

Table 6: Correlation analysis among biochemical parameters, APTI and API

Parameter	A (mg/g)	T (mg/g)	P	R (%)	APTI	API (%)
A (mg/g)	1.000					
T (mg/g)	.469**	1.000				
P	.387**	.324**	1.000			
R (%)	.376*	.357*	.046*	1.000		
APTI	.059	.327	.090**	.025	1.000	
API (%)	.160*	.029*	.177	.176	.070*	1.000

Key: A = Ascorbic acid content, T = Total chlorophyll content, P = pH of leaf extract, R = Relative water content, APTI = Air pollution tolerance index, API = Anticipated performance index, ** = Significant at 1%, * = Significant at 5%.

1. Conclusion and Recommendations

The sensitivity of tree species to air pollution of the sampled species was measured through the various biochemical parameters and finally, through APTI and API, as these parameters are significantly related. *Anacardium occidentale* and *Mangifera indica* species were more tolerant to air pollution. The high APTI and API values of *Anacardium occidentale* and *Mangifera indica* indicate their potential to act as pollution sinks in Makurdi. *Anacardium occidentale* and *Mangifera indica* tree species have proved to be the only good anticipated performance index species among the sampled tree species in the study area. The study therefore suggests *Anacardium occidentale* and *Mangifera indica* as good-performing and tolerance tree species in Makurdi metropolis. To guarantee that *Anacardium occidentale* and *Mangifera indica* species are taken into account when designing buildings, roadways, and public areas, Makurdi policymakers and urban planners should incorporate them into the entire urban planning process. These species should be used for greenbelt in polluted environments, especially the vicinity of factories and high commercial activities like motor parks, busy streets, and airports, as they proved to be highly effective species as opposed to *Albizia lebbeck, Polyalthia longifolia*, *Eleais guineensis,* and *Delonix regia,* which performed poorly. Further research on APTI and

API is also needed for other plant species in the study area. Finally, concerned stakeholders should raise awareness about the benefits of urban trees and their role in pollution mitigation.

Credit authorship contribution statement

Ikima I.D.: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review and Funding acquisition. **Meer B.B.:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review and editing. **Saka M.G.:** Conceptualization, Supervision, Resources and Validation. **Kwakwah P.G.:** Data collection and Formal analysis. **Okoye D. N.:** Data collection, Writing – review and editing.

Declaration of competing interest

The authors declared no potential conflicts of interest in the study.

Data availability

Data will be made available on request.

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