Annals of Tropical Research 46 (1):62-76(2024)
https://doi.org/10.32945/atr4616.2024

Air pollution tolerance index of selected tree species in urbanized areas of Butuan City, Philippines

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ABSTRACT

Assessing the sensitivity or tolerance of plants to air pollution is a valuable method to address the issue of air pollution in a locality. The aim of this study was to examine the Air Pollution Tolerance Index (APTI) of selected tree species in significant locations in Butuan City. This study purposively sampled 19 tree species collected from three areas in Butuan City. The trees were evaluated using APTI which consists of four parameters: leaf-extract pH, relative water content, total chlorophyll content, and ascorbic acid content. The selected tree species were categorized as tolerant, intermediately tolerant, and sensitive based on the calculated APTI. The APTI results revealed that only three species namely *Ficus elastica*, *Premna odorata*, and *Mangifera altissima* were identified to be tolerant species and could be suitable to act as sinks of air pollutants. Sensitive species were *Inocarpus fagifer* and *Terminalia catappa*. APTI can be a useful tool that can help plan and decided which tree species to plant in greenbelt areas in the city to remediate air pollutants.

Received: 28 September 2022
Accepted: 8 November 2023
Published: 29 June 2024

Keywords: Air pollution, biochemical parameters, bio-indicator, sensitive plants, tolerant plants

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INTRODUCTION

One of the major problems with urbanization and urban cities is air pollution, which contributes significantly to various health problems and has many environmental consequences (Kaushik et al 2006). Air pollution is a major problem arising mainly from urbanization and industrialization, use of automobiles, and other transportation mechanisms (Odilora et al 2006). Vehicles represent a major source of air pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matters (PMs) (Sulistijorini et al 2008). Air pollution has been found to diminish the carbon sequestration capacity of tropical forests in polluted areas (Karmakara et al 2019). However, plants still play a crucial role in maintaining ecological balance and reducing environmental pollution by capturing and storing air pollutants through their extensive leaf surfaces (Escobedo et al 2008). It is worth noting that plants' responses to air pollutants vary (Kuddus et al 2011), and often, physiological changes occur in plants before visible leaf damage becomes evident (Liu and Ding 2008). Furthermore, trees function as natural air pollutant sinks by absorbing PMs and decreasing pollutant concentrations in the atmosphere (Prajapati & Tripathi 2008).

Butuan City is no exemption to air pollution since it is urbanized and is the regional center of Caraga Region in the Philippines. A better, efficient, and natural way to combat air pollution is increasing the vegetation cover in cities by planting trees (Kapoor et al 2013). Plants are significant tool in improving air quality of urban areas and consequently the life quality of inhabitants (Beckett et al 2000). The increase of urban vegetation is significant not only for social and environmental reasons, but also for the improvement of local and regional air quality. They are the natural way to ameliorate air pollution since plants act as scavengers being the initial acceptors of air pollutants (Joshi & Swami 2009). Their leaves provide surface area for impingement, accumulation, absorption, adsorption and integration of various air pollutants (Escobedo et al 2008), thereby mitigating the problem. Biomonitoring, is a crucial tool for assessing the impact of air pollution on plants (Bakiyaraj & Ayyappan 2014). The significance of assessing plants for sensitivity and tolerance lies in their role as bioindicators. Tolerant plant species function as effective filters, absorbing and mitigating air pollution, whereas sensitive plants can be used to monitor air quality. The air pollution tolerance index (APTI), as defined by Singh et al (1991), quantifies the physiological responses of plants to air pollution. The APTI typically evaluates specific criteria air pollutants and their concentrations, including PMs, SO_2, CO, NO_2 and ozone (O_3) in the environment to assess the tolerance of various plant species to air pollution (Bakiyaraj & Ayyappan 2014, Enete et al 2013, Kuddus et al 2011, Jyothi & Jaya 2010, Agbaire 2009) The APTI relies on four biochemical parameters: leaf-extract pH, relative water content (RWC), total chlorophyll content, and ascorbic acid content. Determining these biochemical factors through APTI is crucial for assessing a plant's response to air pollution (Chauhan and Joshi et al 2010, Ogunkunle et al 2015). Furthermore, APTI provides valuable insights for landscapers and greenbelt designers. It aids in selecting plant species, both sensitive and tolerant, to serve as indicators of urban and industrial pollution levels and to mitigate the harmful effects of air pollution (Jyothi &Jaya et al 2010).

Perennial plants such as trees are commonly used as biomonitors due to its long-term existence in the area making it viable to determine the biochemical and physiological changes in the plants through time. Thus, this study aimed to evaluate the tolerance grade of selected tree species in different areas of Butuan using APTI with the four biochemical parameters (leaf-extract pH, RWC, total chlorophyll content, and ascorbic acid content).

This study can serve as preliminary information for urban planners and greenbelt designers in the city and other cities within the country. The results would also be useful to the city government, policy makers, and other decision-making bodies on creating sustainable, livable, and green cities in the region since the negative impact of air pollution would be minimized by determining first-hand the appropriate tree species that can be planted in specific locations.

MATERIALS AND METHODS

Location and Sampling Sites

Three distinct locations within the city of Butuan, which included Guingona Park, Provincial Capitol Grounds, and City Hall Circle (Figure 1) were considered in this study. The said locations are busy areas due to heavy vehicular activities especially during rush hours in the morning and afternoon.

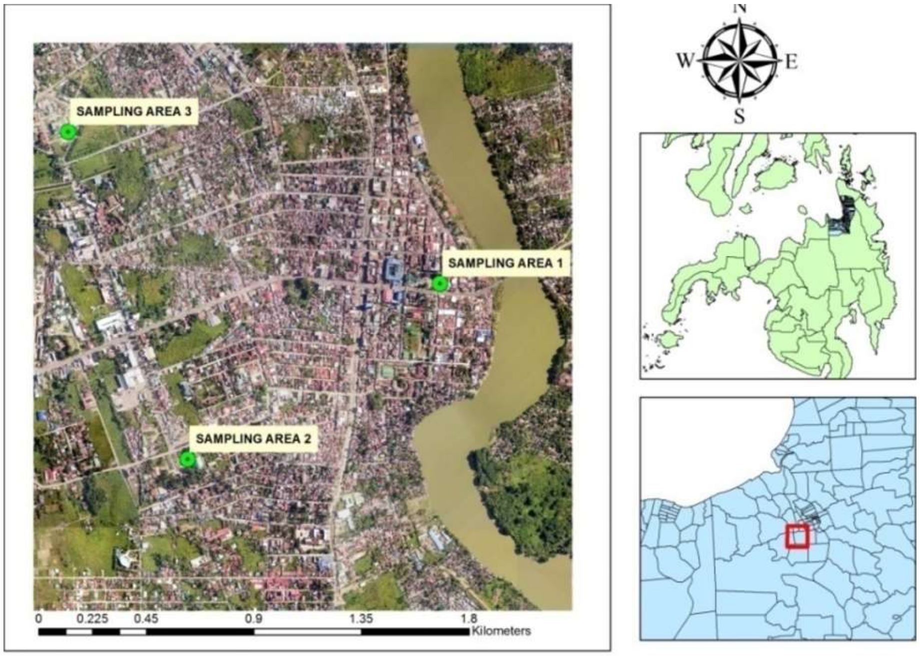

Figure 1. Map of the study area

Presence of air pollutants such as PMs, CO, and SO_2 in Butuan City are monitored by the Environmental Management Bureau (EMB) Caraga Region as indicated in Table 1. The DENR Administrative Order (DAO) No. 2000-81, stipulated the National Ambient Air Quality Guidelines the following annual average ambient values: $PM_{2.5}$ at 25µg/Nm^3, PM_{10} at 80µg/Nm^3, SO_2 at 80µg/Nm^3 and CO at 10µg/Nm^3 or equivalent to 8.75ppm. The values in Table 1 represent annual averages obtained from monitoring sites in the city. Furthermore, when comparing the annual average values of selected air quality parameters of Butuan City to the guidelines outlined in DAO 2000-81, the selected air quality parameters in Butuan has not exceeded the established limit. As per the Environmental Management Bureau's air quality index, Butuan City's air quality is rated as 'good,' indicating favorable air quality conditions.

Table 1. Annual average concentrations of particulate matters, carbon monoxide, and sulfur dioxide in Butuan city and established threshold limits of air pollutants stipulated in DAO 2000-81

Year	$PM_{2.5}$ (µg/Nm^3)	PM_{10} (µg/Nm^3)	CO (ppm)	SO_2 (µg/Nm^3)
2014	8.53	17.13	1.35	1.27
2015	4.95	9.96	0.29	7.08
2016	4.90	8.87	0.28	2.34
2017	7.50	15.24	1.74	3.85
2018	1.35	4.00	3.16	2.34
DAO 2000-81	25.00	80.00	8.75	80.00

Source: EMB Caraga Region, 2019

The study used purposive sampling of tree species present within the vicinity of the three locations identified. Trees that were located near the roads and directly exposed to traffic were identified and sampled in this study. A total of 19 tree species were identified with a few tree species that occurred more than once and sampled in each location (Table 2). An individual ascended each tree that required climbing, and manually hand-picked or cut stems using pruning shears when collecting the fully matured leaves. Four separate samples of fully matured leaves from each identified individual tree within their respective locations were collected and the leaves from each individual tree were then composited. Matured leaves were determined as having smooth and firm texture, with well-developed veins, and do not have buds at their base. The collected leaf samples were promptly transported to the Batok Hall Building Chemistry Laboratory at Caraga State University for analysis.

Table 2. Tree species and the number of individuals sampled in each study site.

Tree Species	Guingona Park	Provincial Capitol Grounds	City Hall Circle
Acacia auriculiformis Benth.		1	
Acacia mangium Willd.		1	
Bauhinia purpurea L.			1
Cassia fistula L.	3		
Chrysophylum cainito L.		1	
Crescentia cujete L.			1
Cynometra ramiflora L.	3		
Ficus elastica Roxb.	1		
Gmelina arborea Roxb.		1	
Inocarpus fagifer (Parkinson) Fosberg			1
Leucaena leucocephala (Lam.) de Wit			1
Mangifera altissima Blanco			1
Polyalthia longifolia Sonn.		1	
Premna odorata Blanco		1	
Psidium guajava L.			1
Samanea saman F. Muell.	1		
Senna siamea (Lam.) H.S. Irwin & Barneby	2		
Swietenia macrophylla King		2	1
Terminalia catappa L.		1	1

Biochemical Analysis of Leaf Samples

Singh and Rao (1983) developed the APTI by combining four biochemical parameters, composed of leaf-extract pH, RWC, total chlorophyll content, and ascorbic acid content. Leaf pH governs the efficiency of photosynthesis in plants. Leaf water content facilitates transpiration, provides a cooling effect to plants, and aids in rejuvenation during drought conditions (Swami et al 2004). Leaf water content also plays a crucial role in enabling plants to absorb minerals from the soil through their root systems (Gonzalez et al 2001). Ascorbic acid plays a central role in plant defense mechanisms because it functions by protecting plants from oxidative damage (Rautenkranz et al 1994) during water stress conditions and contributes to the synthesis of cell walls, facilitating cell division (Sahu et al 2020). Moreover, ascorbic acid has direct impact on photosynthesis and is closely linked to the chlorophyll content in leaves, thereby influencing overall plant productivity (Sahu et al 2020).

Leaf-extract pH

The preparation composed of grinding five grams of fresh leaves per individual tree per species which was homogenized in 10mL deionized water and filtered using a Whatman no. 42 filter paper (Agbaire 2009). The pH of the leaf extract was determined using Eutech pH meter that had been calibrated using buffer solutions set at pH 4, 7, and 10.

Relative Water Content (RWC)

Relative water content of leaves per individual tree per species was determined through its fresh weight obtained by weighing the fresh leaves. The leaves were immersed in distilled water over night for about 12h, blotted dry using paper towel, and weighed the following day to get the turgid weight. The leaves were oven-dried for eight hours at 70°C and reweighed to obtain the dry weight (Deepika et al 2016). The RWC was then calculated using the formula by Singh (1977) which is

$$\text{RWC (\%)} = [(\text{FW}-\text{DW})/(\text{TW}-\text{DW})] \times 100$$

Where:

FW = Fresh weight (weight of the leaf upon collection)
DW = Dry weight (weight of the leaf after oven drying)
TW = Turgid weight (weight of the leaf after blotting)

Total Chlorophyll Content (TCH)

Chlorophyll extraction and quantification followed the Arnon (1949) method. Three grams of the collected mature and fresh leaves per individual tree per species were ground and mixed with ten ml of 80% acetone, allowing it to sit for 15min. The liquid portion was separated into another test tube and centrifuged at 2,500rpm for three minutes. The resulting supernatant was collected and its absorbance was measured at 645nm and 663nm using a Biobase UV-VIS spectrophotometer. The calculations were performed using the formula below

$$\text{Chlorophyll a} = 20.2_{\text{Dx663}} - 2.69_{\text{Dx645}} \text{ x V/1000W mg g}^{-1}$$

$\text{Chlorophyll b} = 22.9_{Dx645} - 4.68_{DxA663} \times V/1000W \text{ mg g}^{-1}$

$\text{TCH} = \text{Chlorophyll a} + \text{b}$

Where:

Dx_{645} = Absorbance at 645 nm

Dx_{663} = Absorbance at 663 nm

V = Total volume of extract

W = Weight of leaf material in gram

Ascorbic Acid Content (AA)

Ascorbic acid content was determined following the methods of (Rao and Deshpande 2006). Ten grams of fresh leaves per individual tree per species was ground and added with 250mL of 0.1% oxalic acid solution then filtered into a beaker. Fifty mL of the filtrate was taken and titrated with the standard dye to a pink colored end point persisting for at least fifteen seconds. A standard dye was prepared by mixing 50mg of dichlorophenol indophenol in 250mL of distilled water containing 42mg of sodium bicarbonate. The calculations were done using the formula below:

Air Pollution Tolerance Index Determination (APTI)

The APTI gives an empirical value for tolerance of plants to air pollution (Sisodia and Dutta 2016). This assessment offers a dependable approach to evaluate whether a plant is tolerant or sensitive in outdoor settings affected by a diverse range of pollutants in the air (Singh et al 1991). The APTI was computed by the formula suggested by Singh and Rao (1983).

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

Where:

A = Ascorbic acid content (mg g^{-1})

T = total chlorophyll (mg g^{-1})

P = leaf-extract pH

R = relative water content of leaf (%)

The following shows a sample calculation of APTI value of *M. altissima*, using the values found in Table 3; leaf-extract pH=5.3, ascorbic acid=30mg g^{-1}, relative water content=86.82%, and total chlorophyll=0.31mg g^{-1}

$$\begin{aligned} \text{APTI} &= [30\,(0.31 + 5.3)] + 86.82/10 \\ &= 25.51 \end{aligned}$$

The range of values of the different biochemical parameters in the APTI can differ depending on the research methods employed and the plant species being studied. Also, according to Sahu et al (2020), changes in environmental factors such as temperature, moisture levels, relative humidity, and soil acidity have the potential to influence the tolerance response of plants. Hence, the range of values can vary from one study to another, and there is no universally standardized range applicable to all plant species. Moreover, the environmental conditions, characteristics of trees, and location of trees could affect the biochemical parameters and could be the reason why trees are inherently location-specific in terms of its response to the air quality of its environment.

Interpretation of APTI Values

According to the study of Liu et al (1983), the spectrum of APTI was classified into four grades: Tolerant (T or grade I), Moderately Tolerant (MT or grade II), Intermediate (I or grade III), and Sensitive (S).

The tolerance grades were determined as follows:

1) Tolerant: APTI > mean APTI+ SD
2) Moderately tolerant: mean APTI < APTI < mean APTI + SD
3) Intermediate: mean APTI - SD < APTI < mean APTI
4) Sensitive: APTI< mean APTI-SD

Tolerant (T or grade I) are for plant species that can withstand and thrive in areas with high levels of air pollution and exhibit a strong resistance to pollutants and remain healthy and robust even in polluted environments. Tree species classified as 'tolerant' have APTI value above the mean APTI value of all the sampled tree species plus the standard deviation (SD). Moderately tolerant (MT or grade II) are for plant species that can endure moderate levels of air pollution and are capable of surviving and growing in areas with some pollution. Trees categorized as 'moderately tolerant' have APTI value within the range that includes the mean APTI value of all the sampled tree species up to the mean APTI value plus the SD. Intermediate (I or grade III) are for plant species that can tolerate a limited degree of pollution but are sensitive to high pollution levels for an extended period. Trees that have an APTI value that falls within a range that is lower than the average APTI value minus the SD, but is approximately equal to the average APTI value of tree species, fall in the 'intermediate' category. Sensitive (S) plants are highly susceptible to air pollution and cannot thrive or survive in heavily polluted areas, and exposure to pollutants harm the plant. When the APTI value of a particular tree species is less than or lower than the average APTI value minus the SD, it is categorized as 'sensitive'.

The average and standard deviation for the biochemical parameters of the APTI across all individual tree species sampled in this study were calculated. The average APTI for all tree species sampled in this study is 16.84, with a standard deviation of 4.49. Using this data, we have established the following categories for this study: Tolerant (Tree species with an APTI value greater than 16.84); Moderately tolerant (Tree species with an APTI value within the range 12.58 to 16.84); Intermediately tolerant (Tree species with an APTI value within the range 8.09 to 12.58); and Sensitive (Tree species with an APTI value less than 8.09).

As an example, using the calculated APTI value of 25.51 for *M. altissima*, it exceeded the threshold of 16.84, thereby classifying *M. altissima* as belonging to the tolerant category.

RESULTS AND DISCUSSION

The APTI serves as the purpose of assessing or evaluating whether a plant is tolerant or sensitive to environmental conditions or stressors. In this study, parameters such as leaf-extract pH, RWC, total chlorophyll content, and ascorbic acid content of fully mature leaves of each individual tree were used to evaluate the tolerance grade of tree species sampled as indicated in Table 3.

Table 3. Biochemical parameters, Air Pollution Tolerance Index, and category of selected tree species in Butuan City.

Plant species	pH	RWC (%)	Total Chlorophyll (mg g^{-1})	Ascorbic Acid (mg g^{-1})	APTI	Category
Acacia auriculiformis Benth.	5.6	73.95	0.32	2.5	8.88	I
Acacia mangium Willd.	5.4	77.01	0.30	7.5	11.91	I
Bauhinia purpurea L.	6.4	83.38	0.36	7.5	13.41	I
Cassia fistula L.	5.5	63.07	0.31	5.0	9.21	I
Chrysophylum cainito L.	5.7	81.65	0.36	10.0	14.22	MT
Crescentia cujete L.	5.3	78.47	0.30	7.5	12.09	I
Cynometra ramiflora L.	5.6	80.41	0.30	7.5	12.44	MT
Ficus elastica Roxb.	7.3	92.14	0.33	20.0	24.28	T
Gmelina arborea Roxb.	5.1	79.21	0.35	7.5	12.62	MT
Inocarpus fagifer (Parkinson) Fosberg	6.1	53.11	0.35	2.5	6.93	S
Leucaena leucocephala (Lam.) de Wit	5.3	90.79	0.35	5.0	11.91	I
Mangifera altissima Blanco	5.3	86.82	0.31	30.0	25.51	T
Polyalthia longifolia Sonn.	5.8	62.34	0.35	7.5	10.85	I
Premna odorata Blanco	5.4	85.50	0.35	20.0	20.06	T
Psidium guajava L.	5.4	89.92	0.35	5.0	11.87	I
Samanea saman F. Muell.	5.8	65.97	0.35	2.5	8.14	I
Senna siamea (Lam.) H.S. Irwin & Barneby	4.7	58.41	0.26	11.3	11.37	I
Swietenia macrophylla King	6.1	80.47	0.35	7.5	12.90	MT
Terminalia catappa L.	4.3	58.53	0.35	2.5	7.167	S

T – Tolerant, MT – Moderately Tolerant, I – Intermediately Tolerant, S - Sensitive

Leaf-extract pH

The leaf-extract pH results of this study ranged from 4.3 to 7.3 with mean value of 5.7. *F. elastica* obtained the highest leaf-extract pH (7.3) while *T. cattappa* had the lowest value (4.3). Uka et al (2019) observed that the leaf-extract pH of their samples collected near the air-polluted road sites exhibited a more acidic range (5.08 to 5.9), whereas those from an unpolluted site showed a slightly acidic range (6.15 to 6.75). In this study, 15 species exhibited a leaf-extract pH below 6 while four displayed a pH above 6 (Table 3). The pH levels in both moderately tolerant and sensitive plant species varied from 4.4 to 8.8, as reported by Lakshmi et al (2009) which is true in 15 tree species that were sampled in this study.

According to Bakiyaraj and Ayyappan (2014), plants with lower leaf-extract pH were more prominent in sensitive plant species than among tolerant varieties. Zhen (2000) emphasized that when plants are exposed to air pollutants, especially SO_2, their cellular fluid produce a large amount of hydrogen ions (H^+) to react with SO_2 that enters through the stomata and intercellular space from air. This reaction generates H_2SO_4, leading to a reduction in leaf pH. On the other hand, plants with higher leaf-extract pH values under polluted conditions may have stronger ability to absorb SO_2 and NO_x and thus, have increased tolerance to air pollution. Rai and Panda (2014) observed a leaf-extract pH range of 4.25 to 7.23 in polluted sites and reasoned that species with high pH values suggest an increase in efficiency of the conversion of hexose sugar to ascorbic acid in foliar tissues of plants. Further, a high pH level is typically seen as beneficial for trees in terms of their tolerance against air pollution (Shannigrahi et al 2004).

Relative Water Content (RWC)

The RWC of trees of this study varied from 53.11 to 92.14 % where *I. fagifer* obtained the lowest RWC value and *F. elastica* obtained the highest. The RWC values observed in this study fall within the range of 30 to 98% RWC as stipulated by Dheeravathu et al (2018). As per the findings of Dheeravathu et al (2018), plants with RWC levels ranging from 30% to 40% are indicative of severe leaf dehydration, while RWC values of up to 98% are associated with leaves that are well-hydrated and healthy.

Asada (1999) suggested that atmospheric pollutants, such as suspended PM, $SO_{2,}$ and NO_2 may cause oxidative stress in plants, leading to significant reductions in their morphological and physiological state, which affect their turgidity. High RWC values indicate the maintenance of the physiological balance of plant leaves against environmental stressors, implying that plants with higher RWC under polluted conditions may be tolerant to air pollutants. As reported by Swami et al (2004), plants require high water content to maintain their physiological balance under stressful conditions such as exposure to air pollution especially when transpiration rates are high. Tsega and Prasad (2014) mentioned that the loss of water and nutrients in plants is due to the presence of air pollutants, which react with water at the cell surface and causes stress to the foliar surface. Moreover, they emphasized that this loss of water and nutrients is associated with protoplasmic permeability. Pollutants can cause increased cell permeability which may result in the loss of water from the guard cells, causing the plants to become flaccid and leads to closure of stomata (Verma and Chandra 2014). Decrease in photosynthetic rate mediated by water stress is the consequence of the closure of stomata, according to Hayat et al (2008). Additionally, water stress reduces chlorophyll value, photosynthetic attributes, nitrate reductase, carbonic anhydrase activities, and leaf water potential which may lead to overall decrease in plant productivity (Hayat et al 2008).

All tree species exhibited a RWC levels exceeding 50%, suggesting that the trees sampled in this study may not be experiencing significant water stress. This observation may be due to the area that still maintains a good quality air environment.

Total Chlorophyll Content

The total chlorophyll content result of this study ranged from 0.26 to 0.36mg g^{-1} with *S. siamea* having the lowest value. Most of the tree species obtained a value of 0.35mg g^{-1} and only eight tree species obtained lesser values (Table 3). The chlorophyll content findings in this study were lower compared to those reported by Uka et al (2019) and Pandey et al (2016). The air quality in Butuan City is considered good when assessed for PMs, CO, and SO_2 pollutants. However, other pollutants or environmental factors, such as high temperature and light intensity (Zhang et al 2016), which were not included in the air quality assessment, may also be affecting the plants and causing lower chlorophyll content Like the biochemical parameter RWC, atmospheric pollutants could be attributed to affect the chlorophyll content of leaves and influence biochemical changes. The chlorophyll content of plants signifies its photosynthetic activity and has been widely used as an indicator for air pollution (Ninave et al 2001). The pollution stress causes photosynthetic degradation in leaf pigmentation due to oxidation, phaeophytization, and reversible bleaching (Giri et al 2013). Hence, lower chlorophyll values indicate that a significant amount of chlorophyll is lost due to exposure to air pollutants, which damage the plant's chloroplasts. The study of Verma and Chandra (2014) found that higher pollution levels from automobile exhaust are associated with lower chlorophyll content. Moreover, they indicated that there was a decreased amount of chlorophylls a and b from plants collected in polluted sites compared to plants collected from healthy sites. Also, Zhang et al (2016) found a decreased total chlorophyll value in plant leaves found near five ring roads in Beijing which had higher concentration of SO_2 and O_3. Total chlorophyll content in *Ficus benghalensis* was measured within a range of 0.72 to 4.45mg g^{-1}, that demonstrated lower concentrations in urban and industrialized areas, while forested sites exhibited higher concentrations of chlorophyll content (Kapoor 2014). Another study conducted by Madamanchi and Alscher (1991) stipulated that pollutants like SO_2 entering the leaf are hydrated to form hydrogen sulfite (HSO_3), sulfur trioxide (SO_3), and H^+ ions and the sulfite affects the carbon fixation, ribulose biphosphate carboxylase, glycolate oxidase activity, and photophosphorylation. Additionally, the reduction in the concentration of chlorophyll might have also been caused by the increase in chlorophyllase enzyme activities, which, in turn, affects the chlorophyll concentration in plants (Mandal and Mukherji 2000).

Ascorbic Acid

The ascorbic acid content of tree species sampled in this study ranged from 2.5 to 30mg $100g^{-1}$. *M. altissima* obtained the highest value while *A. auriculiformis, I. fagifer, S. saman,* and *T. catappa* had the lowest value. The study of Uka et al (2019) found that *T. cattapa* had lower levels of ascorbic acid when sampled from areas with minimal air pollution (12.05mg g^{-1}), while higher levels were found in areas characterized by heavy vehicular air pollution (18.3mg g^{-1}). Another study by Pandey et al (2016) evaluated different species of climber plants that were exposed to air pollutants and found that the level of ascorbic acid in the plants ranged from 2.54 to 10.85mg g^{-1}. Among all the four biochemical parameters tested, ascorbic acid acts as the first line of defense against oxidative stress of pollutants (Rautenkranz et al 1994). Also, being a very important reducing agent, ascorbic acid also plays a vital role in cell wall synthesis, defense, and cell division (Conklin 2001). Therefore, reduction of ascorbic acid in the plant is directly proportionate to its sensitivity (Mazid et al 2011). The cause of low ascorbic acid content is linked to low leaf-extract pH values which indicate acidity from acidic air pollutants. In this study, *T. cattapa* generated the lowest leaf-extract pH of 4.3 and also had the lowest ascorbic acid content (2.5mg g^{-1}). Low ascorbic acid content indicates penetration of acidic air pollutants in plants. High ascorbic acid content in plants could be a sign of its tolerance against SO_2 pollution. Enete et al (2013) validated that the higher concentration of ascorbic acid in plant shows the symbol of its tolerance power against pollution. In this study, the ambient SO_2 concentration in the atmosphere of Butuan did not exceed the established limits. Our results showed different concentrations of ascorbic acid among the selected tree species. This variation could be due to natural factors such as environmental conditions. While SO_2 is an acidic pollutant, other pollutants could be present that contribute to the acidity of the air that may affect plant physiology and trigger increased ascorbic acid production. Considering that the study areas are consistently subjected to traffic, there may be localized sources of acidic pollutants, even if the overall air quality of Butuan city is indicated as not polluted.

Air Pollution Tolerance Index

The result of this study showed that out of the 19 tree species selected and sampled, only three— *M. altissima, F. elastica*, and *P. odorata—obtained* the highest APTI values of 25.15, 24.28, and 20.06, respectively, and are classified as tolerant. The study of Shannigrahi et al (2004) and Gandhi et al (2014) found a high APTI value in *M. indica,* a relative species of *M. altissima*, in urban areas in India. Mango tree species is among the recommended tree species for planting in urban greenbelts according to ERDB (2012). *C. caimito*, *S. macrophylla*, *G. arborea,* and *C. ramiflora* were moderately tolerant species while *I. fagifer* and *T. catappa* were the only species identified as sensitive. Uka et al (2019) also classified *T. cattapa* as sensitive in areas with minimal air pollution. The remaining 11 tree species were identified as intermediately tolerant species.

CONCLUSION

Each tree species has its own unique characteristics and adaptations, making them respond differently to the same pollution conditions. Although air pollution affects the biochemical synthesis of trees and influence their tolerance behaviors, the changes in biochemical synthesis due to air pollution can lead to alterations in how trees cope with and respond to pollution (Sahu et al 2020). Some trees might develop mechanisms to resist or adapt to pollution, while others may struggle to do so.

Among the identified trees, 14 tree species exhibited intermediate to moderate tolerance to air pollution. Meanwhile, three tree species—*M. altissima, F. elastica,* and *P. odorata—were* categorized as tolerant, while two other species, *I. fagifer* and *T. catappa*, were determined to be sensitive to air pollution. The tolerant tree species—*M. altissima, F. elastica,* and *P. odorata—can* be planted to help reduce the overall pollution load of the city. The study highlights the significance of assessing the APTI score of trees as a valuable tool for choosing the right tree species that can be used for greenbelt development in urbanized and industrial areas.

ACKNOWLEDGMENT

The authors would like to express their gratitude to Dr. Gerardo O. Kitche for his invaluable expertise in identifying the plant species collected for this study. Additionally, sincere thanks and appreciation is extended to the Chemistry Laboratory of Caraga State University for providing the necessary facilities and support for the laboratory analyses conducted as part of this research.

AUTHOR CONTRIBUTIONS

AMN Conceptualization, methodology, data gathering, analysis, writing-original draft.

RCS Conceptualization, methodology, data gathering, analysis, writing-original draft.

CMG Conceptualization, supervision, validation, writing, review, editing.

FUNDING SOURCE

None

AVAILABILITY OF DATA AND MATERIALS

Data are available from the corresponding author upon request.

ETHICAL CONSIDERATION

Caraga State University is still on the process of formalizing their ethics committee, the authors have taken meticulous steps to ensure the ethical conduct of the research on the air pollution tolerance index of selected tree species in urbanized areas of Butuan City. They have consulted with experts in research ethics, reviewed relevant guidelines, and implemented measures to protect the integrity of the study. These measures include obtaining informed consent from City Government of Butuan, maintaining confidentiality of data, addressing potential conflicts of interest, and minimizing any negative environmental impacts by collecting appropriate amount of leaf samples.

COMPETING INTEREST

The authors declare that they have no competing interests.

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