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# A COMPARATIVE STUDY OF AMBIENT AIR QUALITY UNDER TREES AND AROUND ORNAMENTAL SHRUBS AND POTTED PLANTS IN CALABAR METROPOLIS, NIGERIA

**OGAR, B.I.,[1] *IWARA, A.I.,[2] AJAKE, A.O.,[3] ABUA, M.A.,[3] UDOH, E.D.[1] AND OGAR, T.O.[4]**
[1]Forestry Research Institute of Nigeria
[2]Department of Surveying and Geoinformatics, University of Calabar
[3]Department of Geography and Environmental Science, University of Calabar
[4]Department of Geography, Cross River State College of Education
*Corresponding author: iwaradream2008@gmail.com

**Abstract**
*The study compared ambient air quality between trees and ornamental plants in Calabar Metropolis, Cross River State Nigeria. Data were gathered using primary sources (collection of air quality data: CO, $PM_{2.5}$, $PM_{10}$, $SO_2$, and $NO_2$) using Aeroqual series 200 gas samplers. Data obtained were analyzed using tables, simple percentages, and the Independent Samples Test. The results obtained showed content of CO was comparatively lower under trees (3.97ppm), but high around ornamental plants (5.03ppm) indicating that trees sequester more CO in the environment than ornamental plants. Except for $SO_2$, the levels of CO, $NO_2$, $PM_{10}$, and $PM_{2.5}$ were relatively low under tree canopies than around ornamental plants. There was a considerable variation in the concentration of pollutants at different times of the day. Based on the findings, the study recommended among several others that more trees should be planted across Calabar Metropolis mostly around areas dominated by ornamental plants to help reduce the concentration of CO and particulate matter. The planting of trees will increase the rate of carbon sequestration thereby reducing the amount of CO in the atmosphere.*

**Keywords:** *Air quality, Trees, Ornamental plants, Calabar Metropolis*

## Introduction

Across the world, the urban population and the extent of built-up areas are growing ever more with more than 4.4 billion people inhabiting the metropolitan areas (United Nations, 2022; Angel *et al*., 2021; Guastella *et al*., 2019). This steady increase has many effects on the urban environment (flooding, increase in $CO_2$, and temperature) mostly in the context of climate change. Though urban environments or areas contribute a significant fragment of the overall carbon sequence, they also have measures that deliver ecosystem services for the inhabitants. One of such ecological services or measures adopted by many cities in both developed and developing countries is the planting of trees and ornamental plants inside and outside the boundaries of cities to help in air quality improvement or the removal of pollutants, carbon sequestration, and temperature reduction among others (Vargas-Hernández and Zdunek-Wielgołaska, 2021; Ariluoma *et al*., 2021).

In this study, trees refer to woody perennial plants with single stems or trunks and branches with leaves that grow to substantial heights above the ground. At the same time, ornamentals are non-woody plants grown for their attractive appearances. These are plants outside trees used basically for decorative purposes which include pocket planters, potted and non-potted flowers, grasses, and green walls/roofs among others. Both trees and ornamental plants have been labelled as the lungs of cities because they can remove contaminants from the air (Reshma *et al.,* 2017; Xing and Brimblecombe, 2020; Colarossi, 2022). Trees take in carbon dioxide ($CO_2$), release oxygen by way of photosynthesis, and store carbon in their trunks. Forests store more carbon dioxide than they release, which is great news for us: about 30 percent of carbon emissions from burning fossil fuels are taken in by forests, an effect called the terrestrial carbon sink (Colarossi, 2022). Green components are therefore natural filters that help reduce air pollution (Reshma *et al.,* 2017).

For plants to be able to provide ecosystem services related to air pollution tolerance and cooling, they must be healthy and able to survive in such urban environments through structural, physiological, metabolic, and biochemical defence mechanisms (Oksanen and Kontunen-Soppela, 2021; Yarnvudhi *et al.,* 2022; Przybysz *et al.,* 2021). Similarly, Kumar *et al*. (2013) stated that for ornamental plants to be phytoremetioter for air pollution, they have to be evergreen, possess large-leaved, rough bark, must be Indigenous, ecologically compatible, have low water requirement, have a high absorption of pollutants, be able to resist pollutants, agro-climatic suitability, have height and spread canopy architecture among others (Kumar *et al*., 2013). In the urban environment, the presence of trees and ornamental plants can help mitigate global warming by serving as a carbon dioxide ($CO_2$) sink. In this way, urban trees and ornamental plants play a vital role in achieving net zero emissions of $CO_2$ and other greenhouse gases (Matemilola and Salami, 2020). Ambient air pollution has become a matter of great concern due to the emissions from the transport sector. The situation is alarming and gradually becoming more severe and it is expected to increase shortly. Due to the inherent impacts on humans, mitigation measures through the planting and preservation of trees and ornamental plants among other green components in urban environments are recognized in the literature as being effective in reducing the inherent effects of urban heat island (UHI) and air pollution in urban areas (Ariluoma *et al.,* 2021; Capotorti *et al.,* 2019).

Some of the studies carried out centred on the environmental benefits of ornamental plants and were purely descriptive (Reshma *et al.,* 2017; Francini *et al.,* 2022). The contributions of ornamental plants to the phytoremediation of particulate matter from indoor air have been studied (Gawrońska and Bakera, 2015). Ciftcioglu *et al.,* (2019) assessed the relationship between ornamental plants–based ecosystem services and human well-being using qualitative (semi-structured interviews) and quantitative (questionnaire) research tools. However, no assessment of ambient air quality was carried out in these studies. Similar studies (Corrocher and Solito, 2017; Ebrahimi and Mirbargkar, 2017; Xing and Brimblecombe, 2020) examined the impact of trees on ambient air quality but also failed to investigate the contributions of ornamental plants on ambient air quality. Available studies (Briantama and Basukriadi, 2022; Hopkins *et al.,* 2022; Domke *et al.,* 2020; Nowak and Crane, 2002) on air quality and carbon sequestration essentially concentrated on street trees, parks and gardens consistently ignoring the air quality improvement by ornamental plants. The present study investigated and quantified the contributions of both trees and ornamental plants on ambient air quality in Calabar Metropolis, Cross River State. The essence is to identify ambient air quality differentials of trees and ornamental plants.

***Study Area***

The study area is Calabar Metropolis in Cross River State, Nigeria which is located in the southern part of the State. It encompasses Calabar Municipality and Calabar South Local Government Areas. The Metropolis features a tropical monsoon climate. The average annual rainfall is about 1830mm with some variations within the Metropolis (Antigha *et al.,* 2014). On average, over 80% of the total annual rainfall falls over seven months (from April to October). June has an average rainfall of 530mm (Antigha *et al.,* 2014). Calabar Metropolis has experienced unprecedented urban growth that has led to the alteration of several land uses. The unprecedented urban growth and diversified land uses have modified the air quality of the area.

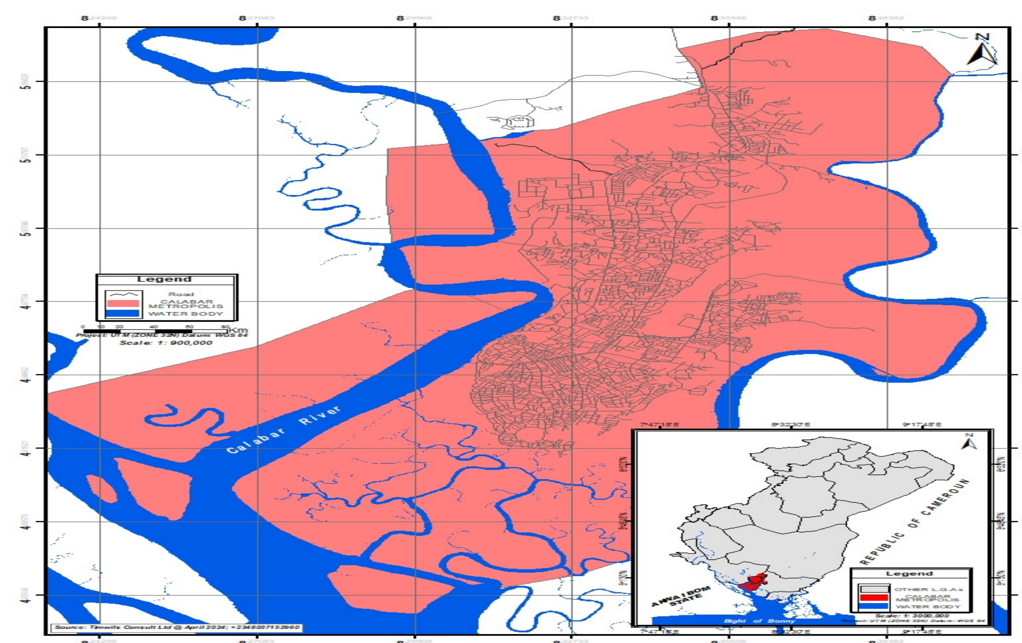


Fig. 1: Study area

## Materials and Methods

***Types and Sources of Data***

This study used primary data (continuous and discrete) to provide an answer to the research problem. Data on diurnal (daily) ambient air quality (CO, $PM_{2.5}$, $PM_{10}$, $SO_2$, and $NO_2$) across different tree species and ornamental plants found along the roads, residential areas, and commercial and institutional areas (continuous data). Data on diurnal (daily) ambient air quality (CO, $PM_{2.5}$, $PM_{10}$, $SO_2$, and $NO_2$) were collected and measured using the Aeroqual series 200 gas sampling instrument. The instrument has replaceable sensors used to measure the concentrations of CO, $NO_2$, $SO_2$, $PM_{10}$, and $PM_{2.5}$. The sensors for CO, $NO_2$, and $SO_2$, display direct real-time readings in parts per million (ppm). Aeroqual $PM_{10}$ and $PM_{2.5}$ particulate sensor samplers were used to monitor the concentrations of $PM_{10}$ and $PM_{2.5}$. The data collection period lasted for a week to enable air quality data to be collected across different tree species and ornamental plants. The gaseous samplers were switched off and on for zeroing.

***Sampling Techniques***

The purposive and random sampling techniques were employed. The purposive sampling technique was used to sample trees and ornamental plants found in public and private places (street/roads, residential areas, commercial, institutional areas, and gardens). These urban land uses have trees and ornamental plants. As such, only areas with trees and ornamental plants were sampled. In the second step, a random sampling technique was used to randomly collect air quality data from these urban land uses. Since trees and ornamental plants are found in scattered locations, they were randomly selected. Trees and ornamental plants of different species along the roads, in residential areas, institutional areas (University of Calabar), gardens, and places of work were randomly sampled because they provide ecological services. Since the exact number of trees and ornamental plants in these urban land uses is not known, the researcher randomly collected air quality data under 18 woody perennial tree species and around 18 non-woody ornamental plants. At the end of the survey, 36 trees and ornamental plants were sampled in Calabar Metropolis (Table 1).

Table 1: Common trees and ornamental plants

| **Trees species** | **Common names** | **Ornamental plants** | **Common names** |
|---|---|---|---|
| *Azadirachta indica* | Neem | *Tradescantia zebrina* | Silver inch |
| *Terminalia mantaly* | Umbrella Tree | *Rosa sinensis* | Rose of China |
| *Magifera indica* | Mango | *Bunny ear cactus* | Angel's-wings |
| *Annona muricata* | Soursop | Caesalpinia pulcherrima | Pride of barbados |
| *Hura crepitans* | Sandbox | *Allamanda cathartica* | *Golden trumpet* |
| *Persea americana* | Avocado | Rosa acicularis | Wild rose |
| *Coco nucifera* | Coconut | *Codiaeum variegatum* | Rush foil |
| *Pentaclethra macrophylla* | African oil bean | *Ixora coccinea* | Jungle flame |
| *Gmelina arborea* | Beechwood | *Acalypha wilkisiama* | *Jacob's coat* |
| *Eleais guineensis* | Oil palm | *Thevetia peruviana* | Yellow oleander |
| *Terminalia catapa* | Almond tree | *Thuja occidentalis* | Eastern white-cedar |
| *Ficus benjamina* | Weeping fig | *Polyalthia longifolia* | *Mast tree* |
| *Newbouldia laevis* | Fertility tree | *Casuarina equisetifolia* | Mile tree |
| *Dacryodes edulis* | African Pear | *Bougainvillea spectabilis* | Tree bougainvillea |
| *Spondias mombin* | Yellow mombin | *Plumeria acutifolia* | Red paucipan |
| *Moringa oleifera* | Drumstick tree | *Roystonea regia* | Royal Palm |
| *Chrysophyllum albidum* | Star apple | *Stenochlaena palustris* | Climbing Fern |
| *Citrus* | Sweet orange | *Araucaria heterophylla* | Norfolk pine |

***Data Analysis***

Descriptive statistics such as the arithmetic mean, chart, tables, and simple percentages were used to analyse the data collected, while the Independent Samples Test was the inferential statistical method used. All statistical tests were performed using the IBM-SPSS software version 21.0 and an Excel spreadsheet.

## Result and Discussion

***Pattern in Ambient Air Quality between Trees and Ornamental Plants***

The result in Table 2 and Fig. 2 shows the concentration or level of ambient air quality between trees and ornamental plants in Calabar Metropolis. The result shows clear differences in the level of air quality between the locations considered in the study. In areas with trees, the mean $SO_2$ values ranged from 0.00 to 386.10ppm, while around ornamental plants, they ranged from 0.00 to 381.90ppm (Table 2). The mean values of $SO_2$ in the in present study are above the FEPA recommended level of 0.10ppm. The mean value is also above WHO's 24-hrs allowable limit of 20ppm. The high $SO_2$ recorded under tree canopies may be attributed to the varied anthropogenic activities at the sampling points that contribute to the emission of $SO_2$. For instance, samples were collected around the Airport by IBB, Airport Roundabout/ Atimbo Roundabout, Barrack Road by Spar, and the Murtala Muhammad Highway among others. The high vehicular movements (traffic density) in these areas, along with other human activities may have contributed to the high $SO_2$ values through the combustion of fossil fuels. A similar assertion was given by Ayejuyo *et al.* (2021) when they attributed the high concentrations of $SO_2$ and $NO_2$ (335ppb and 155ppb) to high traffic density at Ojota which was higher than at other locations.

Also, Atubi (2015) stated that $SO_2$ is introduced into the environment from industrial activities that burn fossil fuels containing sulfur as well as motors. However, the content of nitrogen dioxide ($NO_2$) was low in the two locations, but with comparatively high concentration around ornamental plants (Fig. 2). A similar range of 0.000 to <0.1ppm was reported in Calabar, Nigeria by Ewona *et al*. (2013). The mean concentration of nitrogen dioxide ($NO_2$) falls below the limit of 0.06 ppm recommended by FEPA (Ebong and Mkpenie, 2016). The mean values also fall far below WHO's 1-hr mean allowable limit of 200ppm. However, the $NO_2$ range reported in the present study falls below the range of 0.14 to 1.09ppm reported in Kano metropolis, Nigeria by Okunola *et al*. (2012). The very low content of $NO_2$ implies the absence of $NO_2$ pollution in the study area. It also means that the various activities in these areas such as vehicular use, landfills, and agricultural activities among others do not elevate the content of $NO_2$ in the atmosphere.

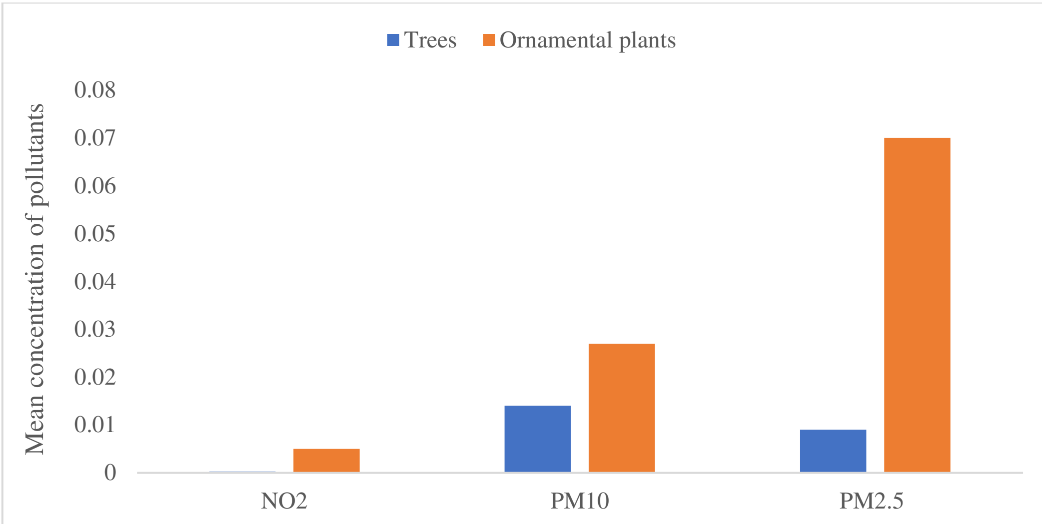


Fig. 2: Level of $NO_2$, $PM_{10}$ and $PM_{2.5}$ between trees and ornamental plants

In addition, the content of carbon monoxide (CO) also differed between trees and ornamental plants (Table 2). The comparatively low CO under tree canopies may be attributed to carbon sequestration. The trees in the sampling locations help to reduce the concentration of CO in the surrounding atmosphere. This goes to show the important role trees play in carbon reduction despite the high traffic situation in the sampling points. The high CO value recorded around ornamental plants implies poor carbon sequestration. The range of CO recorded in the present study is above that of 0.65 and 2.31ppm reported by Etim *et al.* (2022) in Calabar; it is however below the range of 10.25 – 31.67ppm reported by Attah (2015) across different land uses in Kaduna Metropolis. The concentration of CO in this study is within the 10-ppm recommended by FEPA (Atubi, 2015: Ebong and Mkpenie, 2016). It is also within WHO's 90ppm limit for 15 minutes (Balogun and Orimoogunje, 2015). Across the studied locations, a high content of CO was recorded in the ornamental garden by NAF Officer Mess MCC Road and under trees by the Stadium. These two areas usually experience high traffic which results in CO emissions. CO content is reported by Han, (2010) to be high around heavy traffic congestion, and residential and industrial activities. In a study carried out by Akpan and Ndoke (1999) in Northern Nigeria, a high concentration of CO was reported in heavily congested areas.

Furthermore, Table 2 and Fig. 2 show that the contents of $PM_{10}$ and $PM_{2.5}$ also differed between the studied locations. The range of $PM_{2.5}$ recorded in the present study is far lower than the range of 32µg/$m^3$ and 30.1µg/$m^3$ reported by Obisesan and Weli (2019) in Port Harcourt around sparse and thick vegetation respectively. However, the contents of $PM_{2.5}$ in the present study are within the threshold of 0.25µg/$m^3$ recommended by FEPA (Magaji and Hassan, 2015). The range of $PM_{2.5}$ is also within WHO's limit of 20µg/$m^3$ for 24-hrs mean concentration (WHO, 2006). The result shows that the contents of $PM_{10}$ are the same in the two locations with an insignificant increase under tree canopies.

The level of $PM_{10}$ in the present study falls within the threshold of 0.25μg/m$^3$ recommended by FEPA (Magaji and Hassan, 2015) as well as within WHO's limit of 24-hrs mean concentration of 50μg/m$^3$. The result therefore implies low concentrations of $PM_{10}$ and $PM_{2.5}$ despite the numerous anthropogenic activities in the area. This is so as a significant portion of particulate matter is generated from the combustion of wood and fossil fuels, agricultural activities, commercial and industrial activities, construction and demolition activities, and the rising of road dust into the air (Obisesan and Weli, 2019). The presence of green components may be responsible for the generally low level of particulate matter. This result and assertion agree with those of Diener and Mudu (2021) who reported that green spaces can affect air quality through particle deposition, dispersion, and modification. The study also reported that plants may also "absorb" PM through their stomata or cell membranes of their elements, particularly their leaves. This process may be responsible for the extremely low contents of $PM_{10}$ and $PM_{2.5}$ under tree canopies and ornamental plants in the present study despite the numerous human activities in the area. This result is further affirmed by the findings of Yang *et al*. (2021) who reported low $PM_{2.5}$ concentrations around vegetation areas including woodlands and grasslands. The study also reported that for different LULC types, construction lands had the highest $PM_{2.5}$ concentration, and woodlands had the lowest.

Table 2: Mean level of ambient air quality between trees and ornamental plants

| Parameters | Trees | | | Ornamental plants | | | WHO permissible limits |
|---|---|---|---|---|---|---|---|
| | Min | Max | Mean | Min | Max | Mean | |
| $SO_2$ (ppm) | 0.00 | 386.10 | 172.39 | 0.00 | 381.90 | 126.66 | 20 for 24hrs |
| $NO_2$ (ppm) | 0.000 | 0.002 | 0.0002 | 0.000 | 0.005 | 0.0003 | 200 for 1hr |
| CO (ppm) | 0.00 | 8.76 | 3.97 | 0.00 | 21.70 | 5.03 | 90 for 15mins |
| $PM_{10}$ (μg/m$^3$) | 0.004 | 0.022 | 0.014 | 0.004 | 0.027 | 0.011 | 50 for 24hrs |
| $PM_{2.5}$ (μg/m$^3$) | 0.001 | 0.017 | 0.009 | 0.001 | 0.070 | 0.011 | 20 for 24hrs |

***Spatial Differences in Ambient Air Quality between Trees and Ornamental Plants***

The result of the Independent Samples Test showed that except for $SO_2$, the contents of $NO_2$, CO, $PM_{10}$, and $PM_{2.5}$ did not differ significantly under tree canopies and around ornamental plants ($p>0.05$). This decision is consequent upon the probability values of 0.087 to 0.606 being greater than the 5% significance level or because the calculated t-values of 0.753 to 1.764 being lower than the tabulated t-value of 2.032 (Table 3). with this, the null hypothesis is accepted and the alternative hypothesis is rejected implying that there is no significant difference in ambient air quality between trees and ornamental plants in the study area. The insignificant differences in ambient air quality or pollutants between the studied locations mean that the ambient air quality or pollutants under tree canopies and around ornamental plants have the same range or concentrations of pollutants. It, however, shows that trees and ornamental plants play diverse and similar roles in purifying and reducing the high concentration of air pollutants in the atmosphere. This finding is consistent with those of Diener and

Mudu (2021) and Yang *et al*. (2021) that reported a decrease in ambient air pollutants around green spaces. In a more recent study, Meo *et al*. (2021) found that air pollutants ($PM_{2.5}$, $PM_{10}$, and CO) decreased significantly in countries with high green spaces compared to less green countries. However, a recent study by Venter *et al*. (2024) reported that urban greening may improve air quality, but the impact is moderate and may have harmful street-level effects depending on aerodynamic factors like vegetation type and urban form. The result in Table 2 therefore shows there is no significant difference in ambient air quality between trees and ornamental plants in the study area.

Table 3: Summary of Independent Samples Test results of the difference in ambient air quality between trees and ornamental plants

| Ambient air quality | t-value | p-Value |
|---|---|---|
| $SO_2$ (ppm) | 0.778 ns | 0.442 |
| $NO_2$ (ppm) | 4.205* | 0.000 |
| CO (ppm) | 0.753ns | 0.457 |
| $PM_{10}$ (μg/m$^3$) | 1.764 ns | 0.087 |
| $PM_{2.5}$ (μg/m$^3$) | 1.520 ns | 0.606 |

*Significant at 5% alpha level; ns = Not significant at 5% alpha level; df = 34; Tabulated t-value = 2.032

**Conclusion**

The study has clearly shown that the levels of air pollutants in Calabar Metropolis decrease around trees rather than around ornamental plants. Despite, the comparatively low concentration of pollutants around trees, the levels of $NO_2$, CO, $PM_{10}$, and $PM_{2.5}$ do not differ significantly between the two green areas. The differences in the level of these air pollutants go to show that trees and ornamental plants play diverse and similar roles in purifying and reducing the high concentration of air pollutants in the atmosphere. The study also reveals that the contents of $NO_2$, CO, $PM_{10}$, and $PM_{2.5}$ around trees and ornamental plants in Calabar Metropolis are not detrimental to human health, while the level of $SO_2$ is harmful to human health. Based on the research findings, the study recommended among others that more trees should be planted in the areas mostly around areas dominated by ornamental plants to help reduce the concentration of CO. Tree planting will increase the rate of carbon sequestration, thereby reducing the amount of CO in the atmosphere. Also, the study observes that the content of $SO_2$ exceeds WHO limit indicating $SO_2$ pollution in the area. It therefore means that the air quality in the area has evidence of $SO_2$ pollution from the numerous human activities carried out. On this note, government and private individuals should set up modalities to control the release of $SO_2$ substances into the atmosphere.

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