Continental J. Applied Sciences
Gana et al. (2026) 21 (3): 89 – 98 Doi: 10.5281/zenodo.20521738

Short Communication

# Geo-Spatial Assessment of Vehicular Air Pollution Across Different Times of the Day in Minna Town, Niger State, Nigeria

**David Ndalati Gana[1], Solomon Ndace Jiya[1], Hadiza Mohammed Liman[1], John Tsado Mathew[2]***
**[1]Department of Geography, Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria**
**[2]Department of Chemistry, Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria**
Corresponding author: jmathew@ibbu.edu.ng

## Abstract

*Air pollution in vehicles is one of the emerging problems of environmental concern and general health issues in fast urbanizing cities in Nigeria, but its spatial and temporal patterns are still not well understood within secondary urban centers like Minna, Niger State. The paper used a geo-spatial analysis of vehicular air pollution in Minna Town at various times of the day by using ground-level air quality measurements that had been georeferenced with GPS and analyzed using Geographic Information Systems (GIS) to graphically depict the patterns of pollutant distribution across the urban road network. The primary pollutants that were monitored were carbon monoxide, nitrogen dioxide, particulate matter, and sulphur dioxide at the chosen traffic hotspots at different times of the day, in the morning, midday, and evening. During the afternoon period (1:002:00 pm), the pollution became worse in most of the parameters. $PM_{2.5}$ existed at its highest level of 710 μg/m$^3$ on Minna -Bida Road and 443 μg/m$^3$ on Top Medical Road, with $PM_{10}$ at 623 μg/m$^3$ in Eastern Bypass. Later (1:00 2:00 pm), the pollution increased in a range of parameters. $PM_{2.5}$ was highest at 710 μg/m$^3$ at Minna-Bida Road and 443 μg/m$^3$ at Top Medical Road, with $PM_{10}$ at 623 μg/m$^3$ at Eastern Bypass. In the evening (5:006:00 pm), a lot of pollutants were even higher. The maximum $PM_{2.5}$ of 410 μg/m$^3$, $PM_{10}$ of 451 μg/m$^3$, and the highest score of $CO_2$ of 9999 μg/m$^3$ at Chanchaga Mekunkele Road. Findings indicated that there existed a considerable amount of spatial and temporal variation in pollution levels, with the highest levels being observed in the large intersections and motor parks during the rush hours. The paper suggests specific traffic control measures, stiffer emission policies, and ongoing geo-spatial surveillance as the means of ensuring public health in Minna and other similar cities in Nigeria.*

**Keywords:** Air, Environmental, Health, Monitor, Pollution, Vehicular

**Received: 25 March 2025** **Accepted: 30 May 2025**

Citation: Gana, N.D., Jiya, S.N., Liman, H.N., Mathew, J.T. (2026). Geo-Spatial Assessment of Vehicular Air Pollution Across Different Times of the Day in Minna Town, Niger State, Nigeria. Continental J. Applied Sciences, 21(3), 89-98. Doi: 10.5281/zenodo.20521738

## Introduction

The rapid urbanization and the subsequent increase in motorized transport have risen to take centre stage as contributors to worsening air quality in cities in sub-Saharan Africa. Nigeria, as the most populous country on the African continent, is experiencing a form of urban mobility crisis, and the secondary cities in the country have never recorded a higher number of vehicles per square kilometer than they are currently. The example of Minna, the capital of the Niger State, is no exception, which is a mid-sized administrative and commercial centre that has been characterized by a significant population increase over the last 20 years, and a significant increase in the number of motor vehicles, motorcycles, and tricycles operating on its streets (Ofoezie et al., 2022). The increase in transportation activity is also associated with the increase in the release of harmful pollutants, such as carbon monoxide (CO), nitrogen dioxide ($NO_2$), particulate matter ($PM_{2.5}$ and $PM_{10}$), sulphur dioxide ($SO_2$), and volatile organic compounds (VOCs) that endanger the respiratory condition and well-being of urban residents. The spatial pattern of such emissions and the temporal change are thus of immediate societal health and environmental concern (Meo et al., 2024; Feyisetan et al., 2025).

The emissions produced by vehicles are not evenly spread both spatially and through time. The density of traffic varies significantly during the day, with the most common peak times being the morning and evening traffic, the commercial activities in the middle of the day, and school transportation, with the low numbers representing the early morning and the late-night hours (Ezeigwe et al., 2024). These oscillations have a direct impact on the concentration and the spatial distribution of air pollutants of various places in the urban landscape. Hotspots with high levels of pollutants are associated with congested intersections, motor parks, central markets, and arterial roads, unlike residential areas and areas with minimal traffic, which are likely to record relatively low levels of emissions (Zefreh, & Torok, 2021). In the absence of a spatially resolved notion of where and when they are highest, environmental managers and urban planners are poorly placed to invoke specific action to reduce the pollution or guard vulnerable groups in the population like street vendors, traffic wardens, school children, and pedestrians (Whelan et al., 2024).

Through the incorporation of geospatial tools, such as Geographic Information systems (GIS), Global Positioning systems (GPS), and remote sensing, the assessment of urban air pollution has been enhanced including high-resolution spatial mapping of hotspots of emissions and depiction of the spread of pollution at city scales. Geospatial tools offer a potent platform for the integration of the dynamic interaction of traffic flow, road infrastructure, land use, and pollutant concentrations at different times of the day when coupled with ground-level air quality monitoring equipment (Dong et al., 2025). Although the use of such methodologies has been on the increase in the largest cities of Nigeria, including Lagos, Kano, and Ibadan, the use of geo-spatial tools to evaluate the air quality of vehicles is of crucial importance in small administrative capitals, including Minna, where the rapid intensification of urban growth persistently changes the transport environment (Chukwu et al., 2022).

This paper thus aims to carry out a geo-spatial analysis of air pollution by vehicular traffic in various time spans of the day in Minna Town, Niger state, based on field measurements of pollutant levels georelated to particular road sections and crossroads in the town. The research will be used to identify the hotspots of emissions, diurnal pollution profiles, and offer evidence-based advice on air quality control and urban transportation planning in Minna and other similar secondary cities in Nigeria by studying the spatial and temporal variation of pollutant concentrations.

**Materials and Methods**

## Study Area

## Location

Minna is the capital City of Niger State. It is located within Latitude 9°32′0′′N to 9°42′0′′N and longitudes Longitude 6°26′0′′E to 6°28′0′′E of the Greenwich Meridian. Minna has two Local Governments namely; Chanchaga and Bosso Local Government Areas (Figures 1).

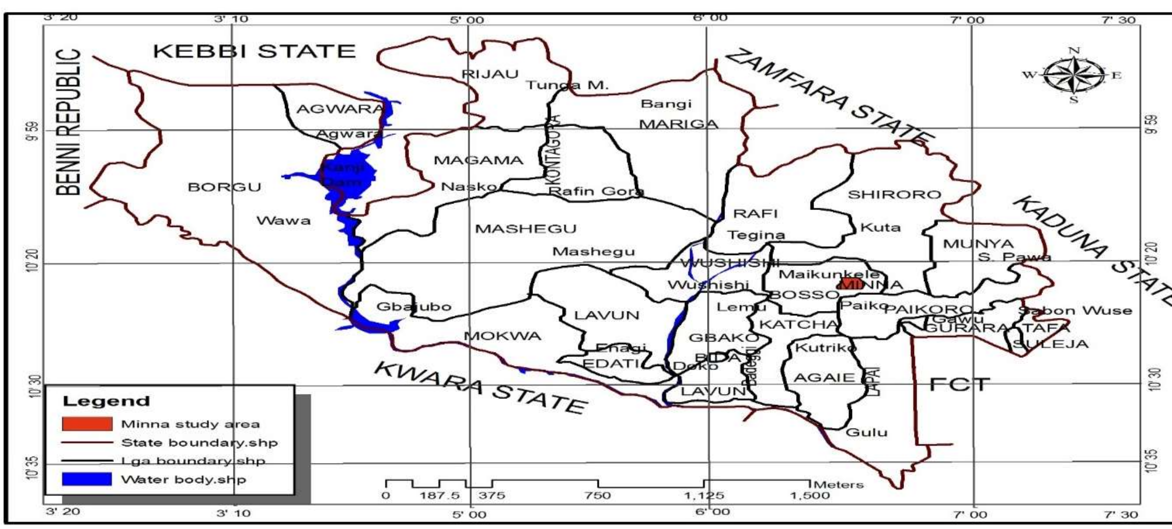


Figure 1: Locational Map of Niger State showing Minna
Source: Niger State Ministry of Land and Housing Minna (2023)

**Methodology**
The nature and sources of data for this study was basically primary origin. The samples were collected for a month and average data was obtained. The primary source of data was the detection and collection of air quality parameters. The air quality parameters collected were Particulate Matter ($PM_{2.5}$), Particulate Matter ($PM_{10}$), Nitrogen Oxide ($NO_x$) and Carbon Oxide ($CO_x$), Carbon Dioxide ($CO_2$) Total Volatile Organic Compound (TVOC), and formaldehyde (HCHO) respectively. This study used 5 in 1 multiple portable precision digital air quality detector (HB-90A) of Bosean Electronic Technology. The instrument was devoid of mistakes in the reading as it carried out in weather free from extreme wind and rainfall. The Geographical Positioning Systems (GPS) was used to generate the locational coordinates of the purposively selected junctions and roundabouts in Minna metropolis.

This study applied stratified and purposive sampling technique to select spatial locations and intersections of the roads such as junctions and roundabouts in Minna metropolis (total of 9 roads and 5 sample points of junctions and roundabouts per road summing it to 45 sample points). Selecting of 45 sample points in Minna Metropolis ensures comprehensive spatial coverage of the city's major traffic corridors and intersections. This approach captures the variability of vehicular emissions across different road types and traffic intensities, especially at critical junctions and roundabouts where pollutant concentrations tend to peak. It also provides a robust dataset for analyzing pollution patterns and identifying hotspots, which supports more accurate and representative air quality assessments necessary for effective urban environmental management.

**Results and Discussion**

Table 1: The State of Vehicular Air Pollution across different Time of the Day in Minna Town

| Parameter | Morning (8:00 - 9:00am) | Afternoon (13:00-14:00pm) | Evening (17:00-18:0pm) |
|---|---|---|---|
| **Chanchaga - Mekunkele Road** | | | |
| $PM_{2.5}$ (μg/m$^3$) | 313 | 389 | 410 |
| $PM_{10}$ (μg/m$^3$ | 420 | 515 | 451 |
| $NO_x$ (μg/m$^3$) | 0.44 | 0.67 | 0.77 |
| $CO_x$ (μg/m$^3$) | 1.15 | 2.29 | 2.29 |
| $CO_2$ (μg/m$^3$) | 1029 | 8070 | 9999 |
| TVOC (μg/m$^3$) | 0.014 | 0.012 | 0.013 |
| HCHO (μg/m$^3$) | 0.007 | 0.008 | 0.009 |
| **Maitunbi Road** | | | |


ISSN: 3043-6087. Science and Education Development Inst., Nigeria

| | | | |
|---|---|---|---|
| $PM_{2.5}$ (µg/m$^3$) | 221 | 310 | 391 |
| $PM_{10}$ (µg/m$^3$ | 281 | 340 | 410 |
| $NO_x$ (µg/m$^3$) | 0.24 | 0.45 | 0.48 |
| $CO_x$ (µg/m$^3$) | 1.13 | 2.17 | 2.20 |
| $CO_2$ (µg/m$^3$) | 897 | 1023 | 1520 |
| TVOC (µg/m$^3$) | 0.011 | 0.012 | 0.014 |
| HCHO (µg/m$^3$) | 0.006 | 0.007 | 0.008 |
| **Minna – Bida Road** | | | |
| $PM_{2.5}$ (µg/m$^3$) | 677 | 710 | 680 |
| $PM_{10}$ (µg/m$^3$ | 871 | 715 | 783 |
| $NO_x$ (µg/m$^3$) | 0.97 | 0.88 | 0.91 |
| $CO_x$ (µg/m$^3$) | 1.15 | 1.15 | 1.15 |
| $CO_2$ (µg/m$^3$) | 1988.2 | 2501.2 | 2352.2 |
| TVOC (µg/m$^3$) | 0.013 | 0.014 | 0.016 |
| HCHO (µg/m$^3$) | 0.0012 | 0.006 | 0.007 |
| **Western Bypass** | | | |
| $PM_{2.5}$ (µg/m$^3$) | 222 | 229 | 273 |
| $PM_{10}$ (µg/m$^3$ | 286 | 201 | 349 |
| $NO_x$ (µg/m$^3$) | 0.53 | 0.62 | 032 |
| $CO_x$ (µg/m$^3$) | 1.15 | 2.29 | 1.15 |
| $CO_2$ (µg/m$^3$) | 1220.2 | 1053 | 961.2 |
| TVOC (µg/m$^3$) | 0.016 | 0.015 | 0.018 |
| HCHO (µg/m$^3$) | 0.006 | 0.008 | 0.007 |
| **Eastern Bypass** | | | |
| $PM_{2.5}$ (µg/m$^3$) | 398 | 297 | 406 |
| $PM_{10}$ (µg/m$^3$ | 544 | 623 | 527 |
| $NO_x$ (µg/m$^3$) | 0.38 | 0.20 | 0.17 |
| $CO_x$ (µg/m$^3$) | 2.30 | 1.19 | 2.28 |
| $CO_2$ (µg/m$^3$) | 917.2 | 1296.2 | 1370 |
| TVOC (µg/m$^3$) | 0.016 | 0.014 | 0.015 |
| HCHO (µg/m$^3$) | 0.008 | 0.008 | 0.007 |
| **Government House Road** | | | |
| $PM_{2.5}$ (µg/m$^3$) | 224 | 226 | 217 |
| $PM_{10}$ (µg/m$^3$ | 293 | 378 | 297 |
| $NO_x$ (µg/m$^3$) | 0.19 | 0.23 | 0.19 |
| $CO_x$ (µg/m$^3$) | 1.15 | 2.29 | 1.15 |
| $CO_2$ (µg/m$^3$) | 760.2 | 819.4 | 860.4 |
| TVOC (µg/m$^3$) | 0.012 | 0.014 | 0.018 |
| HCHO (µg/m$^3$) | 0.007 | 0.009 | 0.008 |
| **Mechanic Road** | | | |
| $PM_{2.5}$ (µg/m$^3$) | 239 | 233 | 265 |
| $PM_{10}$ (µg/m$^3$ | 312 | 303 | 349 |
| $NO_x$ (µg/m$^3$) | 0.25 | 0.27 | 0.33 |


**ISSN: 3043-6087. Science and Education Development Inst., Nigeria**

| | | | |
|---|---|---|---|
| $CO_x$ (µg/m³) | 1.15 | 2.29 | 3.44 |
| $CO_2$ (µg/m³) | 768.6 | 853.2 | 999 |
| TVOC (µg/m³) | 0.018 | 0.012 | 0.013 |
| HCHO (µg/m³) | 0.009 | 0.007 | 0.009 |
| **Brighter Road** | | | |
| $PM_{2.5}$ (µg/m³) | 221 | 230 | 251 |
| $PM_{10}$ (µg/m³ | 290 | 320 | 301 |
| $NO_x$ (µg/m³) | 0.29 | 0.32 | 0.28 |
| $CO_x$ (µg/m³) | 1.15 | 2.29 | 1.15 |
| $CO_2$ (µg/m³) | 806.4 | 957.6 | 822.8 |
| TVOC (µg/m³) | 0.012 | 0.016 | 0.014 |
| HCHO (µg/m³) | 0.004 | 0.008 | 0.004 |
| **Top Medical Road** | | | |
| $PM_{2.5}$ (µg/m³) | 273 | 443 | 276 |
| $PM_{10}$ (µg/m³ | 355 | 546 | 368 |
| $NO_x$ (µg/m³) | 0.23 | 0.28 | 0.19 |
| $CO_x$ (µg/m³) | 1.25 | 2.29 | 2.29 |
| $CO_2$ (µg/m³) | 865.2 | 1919 | 1171.6 |
| TVOC (µg/m³) | 0.012 | 0.015 | 0.012 |
| HCHO (µg/m³) | 0.005 | 0.006 | 0.007 |

Table 1 showed the state of vehicular air pollution across different time of the day in Minna Town and metropolis. The elevated $PM_{2.5}$ and $PM_{10}$ concentrations recorded during the morning peak hours, particularly at Minna-Bida Road (677 µg/m³ and 871 µg/m³ respectively), far exceed the WHO air quality guideline limits of 15 µg/m³ for $PM_{2.5}$ and 45 µg/m³ for $PM_{10}$, indicating serious public health risks for commuters and roadside residents. These findings are consistent with Abulude et al. (2021), who reported preliminary assessment of air pollution quality levels of Lagos, Nigeria. The high CO levels at Minna-Bida Road (1988.2 µg/m³) suggest incomplete combustion from aging vehicle fleets, corroborating Milku et al. (2024), who linked vehicular CO emissions in Nigerian cities to poorly maintained engines. The relatively low NO2, TVOC, and HCHO values may reflect the predominance of petrol-driven vehicles over diesel-heavy fleets. Similar patterns were documented by Ezeigwe et al. (2024) in Abuja, reinforcing that rapid urbanisation without emission controls intensifies roadside pollution across Nigerian metropolitan areas.

The afternoon peak-hour concentrations reveal a marked deterioration in air quality compared to morning levels, reflecting intensified vehicular activity during midday traffic surges. PM2.5 values of 710 µg/m³ at Minna–Bida Road and 443 µg/m³ at Top Medical Road far exceed the WHO 24-hour guideline of 15 µg/m³, posing acute respiratory and cardiovascular risks to exposed populations. The dramatic surge in CO to 8070 µg/m³ at Chanchaga–Mekunkele Road is particularly alarming, indicative of severe incomplete combustion from congested, poorly maintained vehicles, consistent


ISSN: 3043-6087. Science and Education Development Inst., Nigeria

with findings by Ezeigwe et al. (2024), who associated elevated CO levels in Nigerian urban corridors with aging vehicle fleets operating under stop-and-go traffic conditions. The rise in $NO_2$ corroborates observations by Mmom, and Essiet (2014), who linked afternoon $NO_2$ peaks in Nigerian cities to increased fuel combustion under higher ambient temperatures. Similar afternoon pollution intensification was documented by Ihedike et al. (2023) in Abuja, attributing the pattern to thermally driven photochemical reactions and peak commercial activity, underscoring the urgent need for emission control policies along high-traffic corridors in Minna.

The evening peak-hour readings reveal a continued and, in some cases, worsening deterioration of air quality, consistent with heightened return-journey traffic volumes. The extraordinary CO level of 9999 $\mu g/m^3$ recorded at Chanchaga–Mekunkele Road represents a critical public health threshold, far exceeding NESREA's permissible limit of 10 ppm, and is indicative of severe vehicular congestion compounded by reduced atmospheric dispersion as wind speeds typically decline in the evening hours. These findings align with Mmom and Essiet (2014), who documented pronounced evening pollution peaks at traffic intersections in Uyo, attributing them to cumulative daytime emissions and reduced photochemical breakdown under diminishing solar radiation. The persistent TVOC and HCHO concentrations across all evening locations corroborate findings by Abulude et al. (2021), who linked stable volatile organic compound levels along Nigerian urban corridors to continuous combustion from idling vehicles. The slight CO decline at Western Bypass suggests localised dispersion effects from relatively open road geometry, consistent with observations by Kanee et al. (2020), who noted topography-driven variability in roadside pollutant concentrations across Nigerian metropolitan corridors, reinforcing the need for targeted traffic management interventions at high-density intersections.

## Conclusion

This paper has given a thorough geo-spatial evaluation of air pollution on vehicles in various periods of the day in Minna Town, Niger State and it has established that the concentration of the pollutants is neither homogenous nor consistent across the urban environment over time. These findings indicate that major traffic routes, motor parks, and commercial crossroads are the long-term sources of emissions and the level of pollutants is at its highest point in the morning and evening rush hours when the concentration of vehicles is maximum. The combination of the air quality measurements performed on the ground with the GIS-based spatial analysis has been effective in the characterization of the dynamical patterns of the air quality and the diversity of the emissions produced by vehicles in the city. The findings emphasize the need to implement specific policies of traffic control, the standards of car emissions, and urban planning interventions that should be specific to the pollution hotspots noticed across Minna. Finally, the findings of this study will provide useful baseline information that will be used to promote evidence-based environmental management and health protection of the population in fast-spreading Nigerian secondary cities.

Relying on the results of this investigation, it is suggested that the Niger State Environmental Protection Agency and other urban officials should introduce the traffic decongestion measures in the identified pollution hotspots, impose the high standards of vehicle emission, and encourage people to use cleaner fuels and alternative means of transportation. The planners must consider air quality in the planning of land use and the road network and the continuity of geo-spatial air quality monitoring systems should be developed to evaluate the pattern of pollution in Minna Town in the long run.

**Disclaimer (Artificial Intelligence)**
Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**Acknowledgement**
We would like to acknowledge all the staff of Geography Department, and the Postgraduate School, Ibrahim Badamasi Babaginda University, Lapai, Niger State, Nigeria for their unwavering support towards the success of this programme and to my supervisors, I said a big thank you, sirs.

**Competing Interests**
Authors have declared that no competing interests exist.

## References

Abulude, F. O., Damodharan, U., Acha, S., et al. (2021). Preliminary assessment of air pollution quality levels of Lagos, Nigeria. *Aerosol Science and Engineering*, *5*, 275–284. https://doi.org/10.1007/s41810-021-00099-1

Chukwu, T. M., Morse, S., & Murphy, R. J. (2022). Spatial Analysis of Air Quality Assessment in Two Cities in Nigeria: A Comparison of Perceptions with Instrument-Based Methods. *Sustainability*, *14*(9), 5403. https://doi.org/10.3390/su14095403

Dong, J., Liang, X., Du, B., Ju, Y., Wang, Y., & Guo, H. (2025). Applications of Geographic Information Systems in Ecological Impact Assessment: A Methods Landscape, Practical Bottlenecks, and Future Pathways. *Sustainability*, *17*(22), 10358. https://doi.org/10.3390/su172210358

Ezeigwe, N. M., Adinma, E. D., Okobia, E. L., & Schwander, S. (2024). Characterization and Quantification of Vehicular Emissions in Abuja Municipality: Implications for Public Health. *Nigerian Medical Journal : Journal of the Nigeria Medical Association*, *65*(3), 276–291. https://doi.org/10.60787/nmj-v65i3-383

Feyisetan, O. A., Ndamitso, M. M., Salau, R. B., Salihu, S. O., Mustapha, S., Abulude, F. O., & Mathew, J. T. (2025). Spatio-seasonal variability and source inference of $PM_{2.5}$ in Abuja, Nigeria: Implications for urban air quality policy. Journal of Chemical and Allied Science, 1(2), 23-35. DOI: https://doi.org/10.60787/jcas.vol1no2.58

Ihedike, C., Mooney, J. D., Fulton, J., & Ling, J. (2023). Evaluation of real-time monitored ozone concentration from Abuja, Nigeria. *BMC Public Health*, *23*(1), 496. https://doi.org/10.1186/s12889-023-15327-1

Kanee, R. B., Adeyemi, A., Edokpa, D. O., & Ede, P. N. (2020). Particulate matter-based air quality index estimates for Abuja, Nigeria: Health implications. *Journal of Geoscience and Environment Protection*, *8*(5), 313–321. https://doi.org/10.4236/gep.2020.85019

Meo, S. A., Salih, M. A., Alkhalifah, J. M., Alsomali, A. H., & Almushawah, A. A. (2024). Effect of Air Pollutants Particulate Matter $PM_{2.5}$, $PM_{10}$, Carbon Monoxide (CO), Nitrogen Dioxide ($NO_2$), Sulfur Dioxide ($SO_2$), and Ozone ($O_3$) on Fractional Exhaled Nitric Oxide (FeNO). *Pakistan Journal of Medical Sciences*, *40*(8), 1719–1723. https://doi.org/10.12669/pjms.40.8.9630

Milku, A. K., Atombo, C., Derkyi, N. S. A., Attiogbe, F., & Asuako, E. L. (2024). Nonlinear interaction and compounding factors of vehicle parameters influencing exhaust pollution. *PloS one*, *19*(12), e0314894. https://doi.org/10.1371/journal.pone.0314894

Mmom, P. C., & Essiet, U. (2014). Spatio-temporal variations in urban vehicular emissions in Uyo City, Akwa Ibom State, Nigeria. *Journal of Sustainable Development*, *7*(4), 272–283. https://doi.org/10.5539/jsd.v7n4p272

Ofoezie, E. I., Eludoyin, A. O., Udeh, E. B., Onanuga, M. Y., Salami, O. O., & Adebayo, A. A. (2022). Climate, Urbanization and Environmental Pollution in West Africa. *Sustainability*, *14*(23), 15602. https://doi.org/10.3390/su142315602

Whelan, I., Luiu, C., & Pope, F. D. (2024). Assessing the Polarising Impacts of Low-Traffic Neighbourhoods: A Community Perspective from Birmingham, UK. *International Journal of Environmental Research and Public Health*, *21*(12), 1638. https://doi.org/10.3390/ijerph21121638

Zefreh, M. M., & Torok, A. (2021). Theoretical Comparison of the Effects of Different Traffic Conditions on Urban Road Environmental External Costs. *Sustainability*, *13*(6), 3541. https://doi.org/10.3390/su13063541


**ISSN: 3043-6087. Science and Education Development Inst., Nigeria**