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Assessment of Daytime Air Quality with Respect to NOx, COx and SOx in Template Urban and Sub-Urban Settlements in Central Nigeria

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Abstract

Clean air is critical, not only to human health but also to a wholesome and sustainable environment. It is now understood that climate change can affect air quality at the local and regional levels, just as the concentrations of some air pollutants contribute to climate change. In Nigeria, the effects of climate change are becoming increasingly obvious. Considering that climate change action requires a conscious and continual monitoring of the environmental elements critical to the phenomenon, we investigated the daytime levels of CO and CO_2, SO_2 and NO_2 in parts of Central Nigeria known for its extensive and intensive agriculture and yearly bush burning practices; these areas represent template settlements in Nigeria's Savannah belt. Data were subjected to Statistical Analysis using Pearson Moment Correlation Coefficient and compared to regulatory standards. The mean concentrations of these air pollutants were in the following ranges: CO (0.37 - 39.4 ppm) and CO_2 (37.0 - 380 ppm) with the highest concentrations at major road intersections with heavy vehicular traffic, during the rainy season. However, the SO_2 levels were generally lower, ranging from below detection limit (BDL) to 0.14 ppm. Again, the highest concentrations were recorded at major road junctions in the cities and more so during dry season. Similarly, the NO_2 concentrations were lower than the CO and CO_2 levels but comparable to the SO_2 levels (BDL-0.13 ppm) with the highest concentrations also at road junctions during the dry season. The study revealed that the levels of these air pollutants measured are obviously due more to vehicular traffic emissions than any other source. Except for CO_2, these levels are of no immediate threat to the human population or the environment in the study area, as they are generally below regulatory permissible levels for the protection of human health, flora and fauna (WHO, NESREA and, DPR). Still, if unregulated, the levels could rise to concentrations that might be of concern in the long term, especially for residents where traffic congestion is common in the daytime. This requires green transportation initiatives and public health campaigns on the importance of sustainable air quality management.

Keywords

Air Quality, Carbon Dioxide, Nigeria, Sulphur Dioxide, Nitrogen Dioxide, Urban Area

1. Introduction

Air pollution is a threat to human and animal health in all countries, but especially in low and middle income countries. The World Health Organization (WHO) estimates that the majority of the world's population is living in places where its air quality guidelines levels were not met. This situation has worsened in most large cities in these low- and middle-income countries, a situation driven by population growth, industrialization and increased motor vehicular use. Despite pollution control efforts, air quality has approached dangerous levels as recorded in most of these cities, where pollutant levels sometimes exceed World Health Organization (WHO) air quality standards (Wark et al., 1998). Of emerging concern is the observation that elevated carbon dioxide levels could be a risk factor in the transmission of air-borne diseases such as SARS-CoV-2 and COVID-19 (Haddrell et al., 2024).

Studies in other parts of the world have revealed that exposure to automobile air pollution may lead to a variety of health effects. For example, studies in Canada found increased risk of mortality from heart and lung disease in people living within 100 meters of a roadway. New York City studies demonstrated that diesel trucks create air toxics hot-spots at crossings, urban areas, bus stops, and bus depots (Kinney et al., 2000; Lena et al., 2002; Jerrett et al., 2009; Spengler et al., 2011; Eisinger et al. 2021).

A typical refuse dump in Nigeria comprises plastics, garbage, tins, motor machine parts, rags and textiles, wood, dry cell batteries, papers, raw sewage (including urine and excreta), ash etc. (Sha'Ato et al., 2007). Emissions from the deliberate or inadvertent burning of the garbage at the dump sites tend to increase the atmospheric levels of the gases of interest in this paper (Musa et al., 2021; Sonibare, et al., 2020; Oguntoke, et al., 2019; Bray et al., 2021; Daffi, et al., 2021) adding to the pool associated with vehicular traffic as reported in studies elsewhere. This is a common feature in most cities and surrounding settlements in Nigeria. Added to these sources, in Nigeria's Savannah belt, the so called "bush burning" is an annual certainty, as a way of clearing land in the dry season, preparatory to farming activities when the raining season sets in or hunting; this practice also contributes to the levels of greenhouse gases (GHGs) in the Nigerian environment (Hamid et al., 2010; Otitoju et al., 2019). Poor air quality in Nigeria could have profound implications for respiratory health; inhalation of polluted air, especially particulate matter and harmful gases, can lead to respiratory health complications such as asthma, bronchitis, and other chronic obstructive pulmonary diseases (COPD). Children, the elderly, and individuals with pre-existing respiratory conditions are particularly vulnerable. Air pollution not only affects the respiratory system but also poses significant risks to cardiovascular health. Studies have shown that long-term exposure to air pollutants increases the incidence of heart attacks, strokes, and other cardiovascular diseases (Tran et al., 2023).

Since there is a paucity of information and data on the levels of GHGs in cities and towns around Central Nigeria and in view of the foregoing, we set out to determine the baseline levels of COx, NOx and SOx in template urban and sub-urban settlements in the region as an indicator of the air quality in the area in the wet and dry seasons, the climatic regime in the area (The World Bank Group, 2021). The specific study area is rapidly undergoing physical development with influx of new inhabitants with different socio-economic backgrounds and activities that could generate these pollutants. The overall objective is to contribute baseline data that could guide regulatory authorities and grow the global database on GHGs, especially in countries in transition, like Nigeria.

2. Materials and Methods

2.1. Sampling Locations

Seven (7) sampling sites were purposively chosen across the study area to reflect a wide socio-economic setting, including their demographics and infrastructural character. These are indicated in **Figure 1**. In Makurdi, the major and largest city in the study area is located at approximately 7˚44'N latitude and 8˚30'E longitude. This city is situated on the south bank of the Benue River, which is a major tributary of the Niger River. The city is a transit linking the northern part of Nigeria to the eastern region; thus, it experiences heavy motor vehicular traffic especially during festive periods. Here sampling stations were established at Wurukum Roundabout, WR and Lafia Junction, LJ – 2 points. In Gboko (Latitude: 7.3214˚N; Longitude: 9.0018˚E) a city comparable to Makurdi, stations were set at Bristow Roundabout, BR, Abagu Roundabout, AR and Gboko Central Open Market, GM – 3 points. In Adikpo (Latitude: 7.09318˚N; Longitude: 9.08869˚E), which has more of a rural setting, we set stations at the City Center, AT – one point; and on Otukpo (Latitude: 7.1904˚N; Longitude: 8.1306˚E), a town comparable to Gboko in demographics and physical setting: a sampling station was set at the Community Bank Junction, OT– one point). These sites are located at the city centres.

2.2. Determination of Air Pollutants

Measurements were taken between 7.00-9.00 am in the morning and between 4.00-6.00 pm in the evening at each sampling point, every sampling day (Ayodele and Emmanuel, 2007). This was done during the dry and rainy seasons, respectively. At every station, the hand-held Gasman instrument employed was switched on and the display unit adjusted to zero reading and held at two meters above the ground level until the free Light Emitting Diode (LED) and the sounder which produces an audible alarm in every ten seconds was heard. The gas concentration displayed on the screen was then recorded. The instrument was reset for another measurement. Readings were taken at 5 minutes, 10 minutes, 15 minutes, 20 minutes and 25 minutes to ensure a steady concentration of the gas. The following gases were determined: CO, CO_2, NO_2 and SO_2.

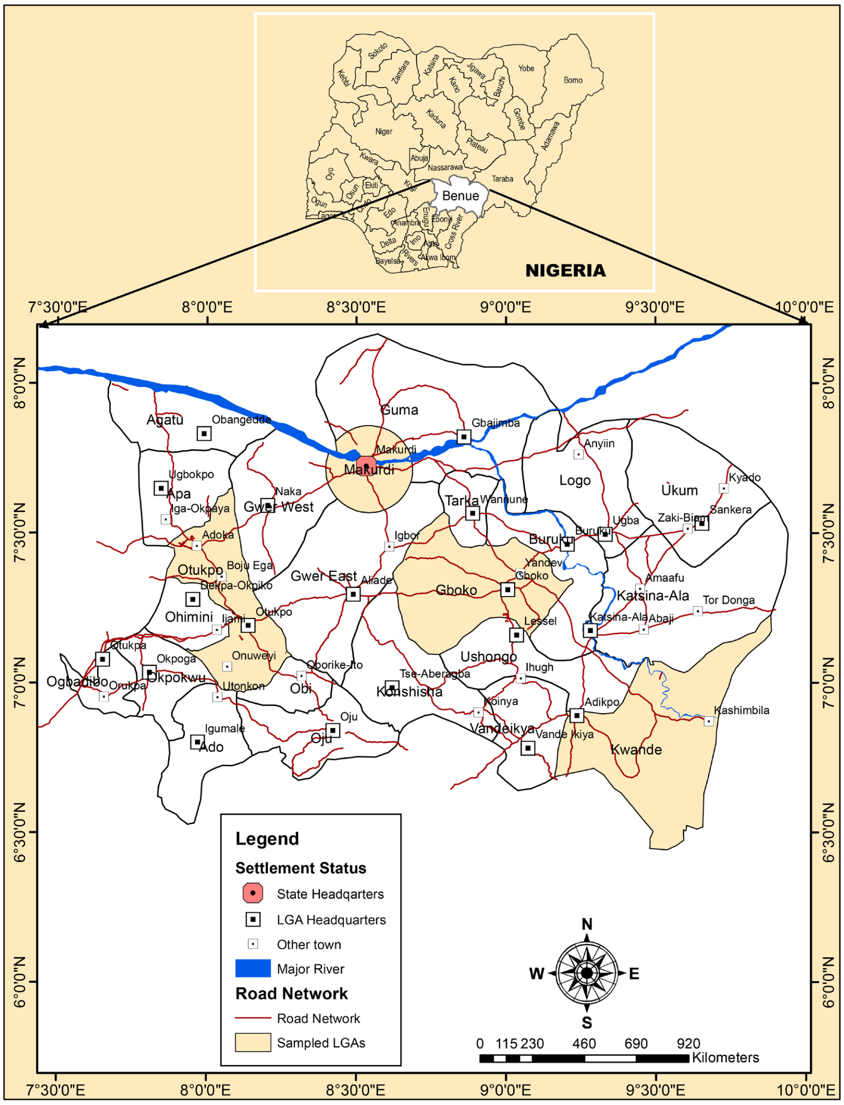

Figure 1. Map of Nigeria and Benue State showing the general sampling areas (Source: Map prepared by Williams Hundu of GIS Laboratory, Department of Geography, Benue State University, Makurdi, Nigeria).

3. Results

The results of air pollutants analysis during the dry and wet seasons are presented in Figures 2-4. The number of sample (n) for each case is five. Taken holistically, CO levels (ppm) ranged from 3.70 on day 11 at Gboko market to 30.6 on day 5 at Wurukum roundabout (major road intersection) in Makurdi during dry season and 0.80 on day 5 at Adikpo town to 39.4 on day 1 at Wurukum roundabout in Makurdi. The CO_2 level (ppm) ranged from 37.4 on day 11 at Gboko market to 309 on day 6 at Abagu roundabout in Gboko during dry season and 38.0 at various sampling sites and days to 390 on day 3 at Wurukum roundabout in Makurdi during wet season, while the SO_2 levels (ppm) ranged from 0.05, on average, at various sampling sites and days to 0.14 on day 9 at Wurukum roundabout in Makurdi and day 17 at OCB junction in Otukpo town during dry season and below detection limit on day 15 at Bristow roundabout in Gboko to 0.10 at various sampling sites and days during wet season. On the other hand NO_2 levels (ppm) ranged from 0.03 on day 3 at Gboko market and day 1 at Lafia junction in Makurdi to 0.13 on day 2 at Lafia junction in Makurdi during dry season and 0below detection limit on day 18 at Gboko market and day 9 at Lafia junction in Makurdi to 0.12 on day 12 at Bristow roundabout in Gboko during wet season. These data as summarized in Figure 2 and Figure 3 show that the levels of the major health damaging pollutants (NOx and SOx) cluster mostly below human safety guideline levels (Table 1).

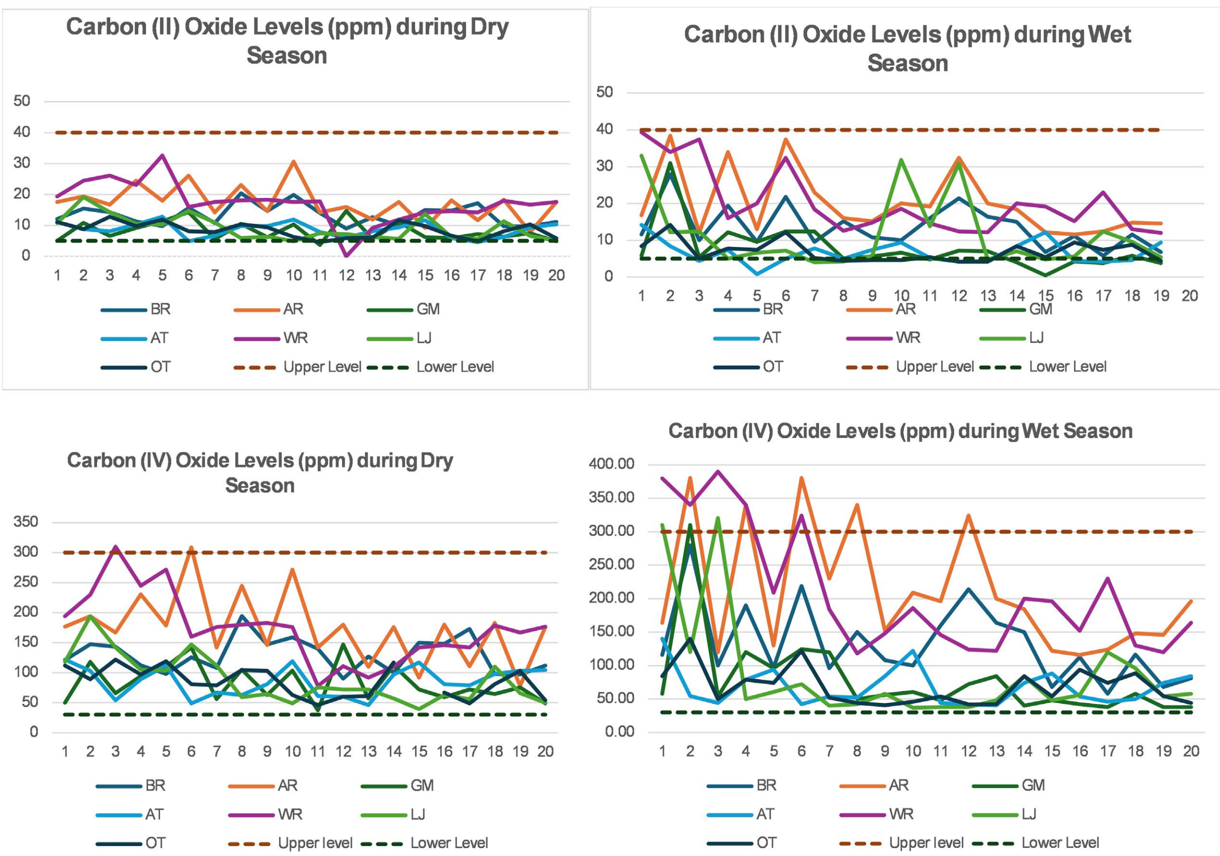

Figure 2. Day time levels of carbon (II) and carbon (IV) oxides (ppm) measured at seven locations in template urban and semi urban areas in Benue State, Nigeria in the dry and wet seasons.

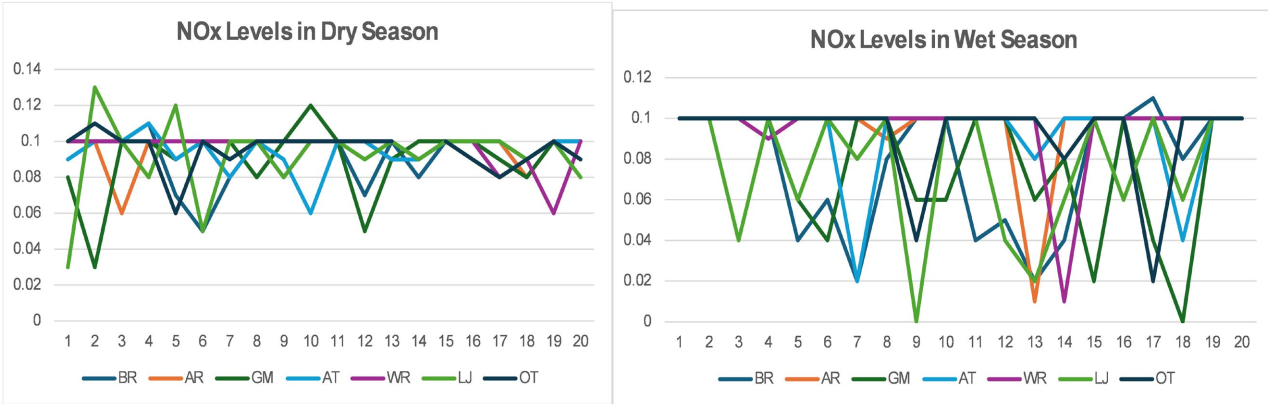

Figure 3. Day time levels of NOx (ppm) measured at seven locations in template urban and semi urban areas in Benue State, Nigeria in the dry and wet seasons.

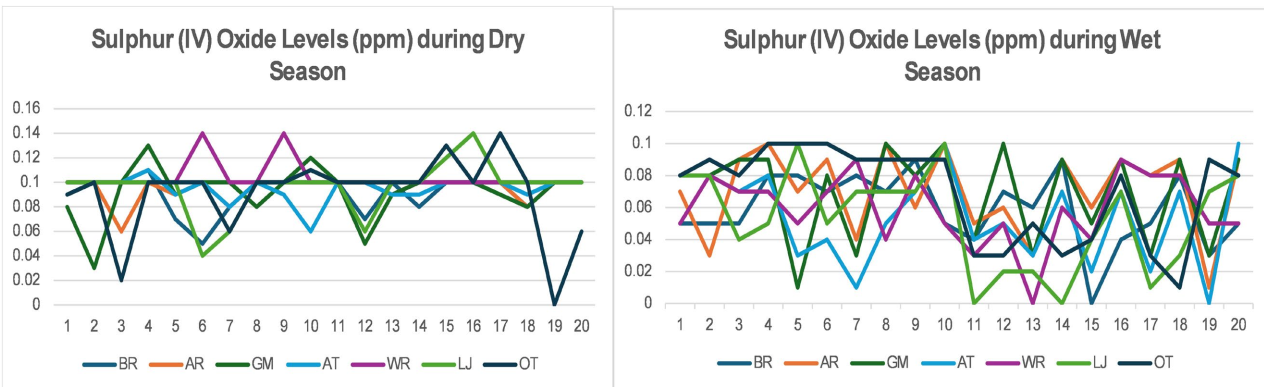

Figure 4. Day time levels of sulphur (IV) oxide (ppm) measured at seven locations in template urban and semi urban areas in Benue State, Nigeria in the dry and wet seasons.

Table 1. Some ambient air quality guidelines.

Pollutant	FMEnv (long-term Limits, 24 hrs)	DPR	NESREA	WHO
		mg/m^3		
CO	1.00	10.0^a	5.00^b	0.001^b
NO_2	0.085	0.15^a	0.12^a	0.08–0.11
SO_2	0.05	0.10-0.15^a	0.12^a	0.10–0.15

a = daily average; b = 8-hr average. (DPR: Department of Petroleum Resources (DPR, 2002). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) (p. 279). Department of Petroleum Resources; NESREA: National Environmental Standards and Regulations Enforcement Agency (NESREA) & National Environmental (Air Quality Control) Regulations (2021). Federal Republic of Nigeria Official Gazette, No. 161, Vol. 108, Government Notice No. 43, Schedule XIII. Federal Government Printer; WHO: World Health Organization (2021). WHO Global Air Quality Guidelines. Particulate Matter (PM2.5 and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. Executive Summary).

The values measured here are, understandably, far lower than reported by Sonibare et al. (2020) in an air quality survey around some major solid waste dumpsites in Lagos State in Nigeria's southwest region and fall below Nigeria's Federal Ministry of Environment's (FMENV's) set limits (Sonibare, et al., 2020). The Lagos area is more industrialized than the Central Nigeria where our study was conducted. Similarly, Benibo et al. (2020) found SO_2 and NO_2 were below detection limits during the dry seasons, but with mean levels above daily average limits of Department of Petroleum Resources (DPR), National Environmental Regulations and Standards Enforcement Agency (NESREA), and WHO, due to their high levels during the rainy seasons. They attributed their findings to mining activities which attracted related heavy traffic in the study area. Gav et al. (2024) have reported levels of COx, NOx, and SOx in ranges like the results presented here for several cities across Nigeria. Taken together and apart from the hotspots which municipal solid waste dumpsites and congested traffic areas represent, levels of these gaseous pollutants do not pose the hazard of acid deposition for now including in Central Nigeria. Still, it is probable that if unregulated emissions are allowed, their levels could rise as the population grows and urbanization increases, with more anthropogenic activities serving as point-sources. As stated by Eisinger et al. (2021) many factors govern the formation of near-road air pollution hot spots: traffic volumes and speeds, the number and ages of cars and trucks on the road, roadway design, topography, and local meteorology all play a role in determining whether near-road air pollution is worse than in surrounding neighbourhoods. In Nigeria, generally, old vehicles dominate the roads, therefore it is no surprise that our study indicates an intuitive correlation between traffic and the concentrations on the polluting gases investigated. This should be a health risk concern to the authorities and bears close monitoring.

4. Conclusion

The study revealed that the daytime levels of COx, NOx, and SOx in the ambient air in the part of Central Nigeria studied levels are of no immediate threat to the human population or the environment in the study area, as they are generally below regulatory permissible levels for the protection of human health, flora and fauna (WHO, NESREA and, DPR). These air pollutants measured are obviously due more to vehicular traffic emissions than any other source. Still, if no regulatory measures are in place, the levels could rise to concentrations that might be of concern, in the long term, especially for residents where traffic congestion is common in the daytime. This requires green transportation initiatives and public health campaigns on the importance of a sustainable air quality management culture. Furthermore, as old vehicles dominate the roads, our study highlights the importance of paying attention to monitoring emissions from vehicular traffic as a public health concern by the authorities, with the recommendation that further investigations be carried out and the appropriate regulations crafted towards green transportation and urban settlement patterns.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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