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Assessment of Health Consequences of Prolonged Ozone Pollution as a Disaster on Urban Communities in Central-Western Part of Kano State, Nigeria

[1*]MUSA, YF; [2]SULAIMAN, F; [3]USMAN, AB

[1]Department of Geography, Usmanu Danfodiyo University, Sokoto, Nigeria*
[2]Department of Environmental Resource Management, Usmanu Danfodiyo University, Sokoto, Nigeria
[3]Department of Geography, Shehu Shagari College of Education, Sokoto, Nigeria

**Corresponding Author Email: musa.yakubu@udusok.edu.ng*
[*]ORCID ID: https://orcid.org/0000-0002-8443-4513
**Tel: +2348060219302*

Co-Authors Email: faizasulaiman50@gmail.com; au_budah2000@yahoo.com

ABSTRACT: Prolonged ozone (O_3) pollution at high levels poses a significant threat to both human health and the sustainability of livelihoods. Hence, the objective of this paper is to assess the health consequences of prolonged ozone (O_3) pollution as a disaster on urban communities in the Central-Western part of Kano State, Nigeria. The concentrations of O_3 were monitored and analysed using various standard methods. Results revealed that O_3 levels were consistently high throughout all seasons, with the highest concentrations observed in the commercial and industrial areas. The concentrations of the pollutant are not significantly different and exceed the permissible standards (0.06 ppm) set by the National Environmental Standards and Regulations Enforcement Agency (NESREA). It is concluded that prolonged exposure to O_3 threatens human health. It was recommended that there should be enforcement of minimum permissible emission of the pollutant by industries, motorist among others. Also, the public should be enlightened on the consequences of exposure to the pollutant.

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Ozone (O_3), a highly reactive form of oxygen, is commonly associated with the upper atmosphere (referred to as stratospheric O_3), where it forms a protective layer against ultraviolet radiation (Donzelli and Suarez-Varela, 2024; Madronich *et al.*, 2024). However, when present at ground level (known as tropospheric or ground-level O_3), is a secondary air pollutant that is not emitted directly into the atmosphere but rather formed through reactions between volatile organic compounds (VOCs) and nitrogen oxides (NO_x) under sunlight (Antanasijević *et al.*, 2019). In humans, exposure to O_3 primarily occurs through inhalation. Due to its high reactivity and low water solubility, the upper respiratory tract is ineffective at filtering out the pollutants from inhaled air, unlike more water-soluble contaminants like sulphur dioxide (SO_2) (WHO, 2006). As a result, most inhaled ozone bypasses the upper airways and reaches the lower respiratory tract (Akbar *et al.*, 2023). Here, it dissolves in the thin layer of epithelial

**Corresponding Author Email: musa.yakubu@udusok.edu.ng*
[*]ORCID ID: https://orcid.org/0000-0002-8443-4513
**Tel: +2348060219302*

lining fluid (ELF) throughout the lung's conducting airways (USEPA, 2019a). Additionally, ozone absorption is influenced by age and gender, as structural differences in airway passages and tissue membranes lead to higher uptake in children and females (Nuvolone *et al*., 2018; Gong *et al*., 2017).

Prolonged exposure to ground-level O_3 is a pressing public health concern, as numerous studies reveal that inhaling it can damage the lining of the respiratory tract (Li *et al*., 2024), leading to inflammation and significant impacts on respiratory health (Li *et al*., 2024). Emerging evidence suggests it may also contribute to cardiovascular and neurological conditions (Xu *et al*., 2023), raising concerns for vulnerable populations, including children, the elderly, and individuals with pre-existing health conditions. This research aims to address the critical and systemic effects of long-term O_3 exposure and its broader implications for public health. Hence, the objective of this paper is to assess the health consequences of prolonged ozone (O3) pollution as a disaster on urban communities in Central-Western Part of Kano State, Nigeria

MATERIALS AND METHODS

The study area: Kano Metropolis is located in the central-western part of Kano State between latitude 11059´59.57´´ – 12002´39.57´´N and longitudes 8033´19.69´´ – 8031´59.69´´E (Fig. 1). It lies in the northwestern boundary of Nigeria and is some 840km away from the edge of the Sahara Desert and 1,140km from the Atlantic Ocean. According to the 2006 census, its population is 2,828,861 (NPC, 2006). Using the Malthusian population projection growth model, the metropolis's population as of 2023 will be 4,541,802.

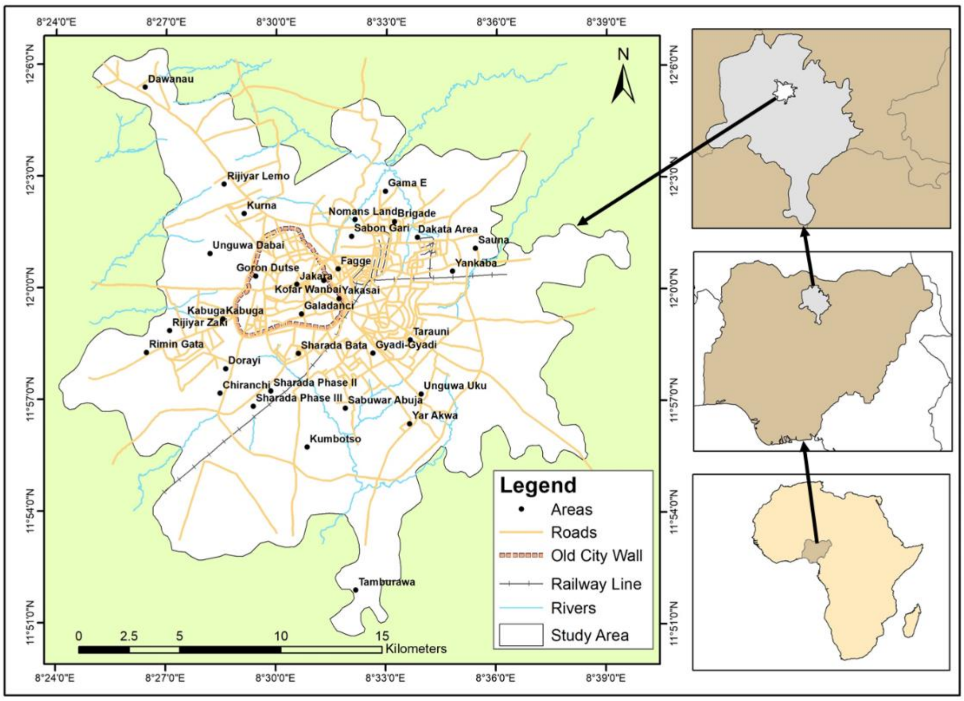

Fig 1: The Study Area

Methods of data collection: Portable digital mobile gas sensor (Aeroqual Portable Environmental Air Quality Monitor S500 V6 ENV) was used to measure and monitor the concentration of O_3 from across 34 sampled points over twelve (12) calendar months (March 2017 to February 2018) (Masey *et al*., 2018). Ten days were randomly selected from each of the twelve months for data collection The data was also collected in both morning and evening periods. The study period was divided into four seasons cold-dry, hot-dry, warm-wet and warm-dry.

Methods of data analysis: Descriptive and inferential statistical methods were employed to analyse the O_3 data obtained from the sampled sites. Descriptive statistics, specifically the mean and standard deviation, were calculated to summarize the data. The visual trends of the concentrations were depicted in a line graph. For inferential analysis, Analysis of Variance (ANOVA) was used to determine whether significant differences existed in the data across seasons and temporal intervals. Seasonal variability was assessed by treating seasons as categorical factors, while temporal variability was evaluated by analysing differences across specific time points.

RESULTS AND DISCUSSIONS

Ozone (O_3) concentrations were generally measured in part per million (ppm) but, the concentration breakpoints of O_3 are calculated based on the ppb unit of measurement (Table 1); hence, the monitored concentrations were converted to ppb to compute Air Quality Index (AQI) for the monitored concentrations.

Table 1: Ozone Concentration and Index Breakpoints

Concentration Breakpoints ($C_{high} - C_{low}$)	Index Breakpoints ($I_{high} - I_{low}$)	Level of Health Concern	Colours
O_3 (ppb)			
0 - 54	0-50	Good	Green
55 - 124	51-100	Moderate	Yellow
125 - 164	101-150	Unhealthy for Sensitive Groups	Orange
165 - 204	151-200	Unhealthy	Red
205 - 404	201-300	Very Unhealthy	Purple
405 - 604	301-500	Hazardous	Maroon

Source: USEPA (2019b)

The computation of AQI essentially requires the average concentration of an air pollutant over a specified period which is usually obtained from an air monitor. Put together, the level of contaminants and time represent the dose of the air pollutant. Hence, the AQI, when computed, shows the possible health effects that correspond to a given dose of the contaminants (Table 1). The AQI of O_3 for the metropolis is computed using the following formula adapted from USEPA (2019b):

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low} \quad (1)$$

Where: *I = the (Air Quality) index, C = the pollutant concentration, C_{low} = the concentration breakpoint that is $\leq C$, C_{high} = the concentration breakpoint that is $\geq C$, I_{low} = the index breakpoint corresponding to C_{low}, I_{high} = the index breakpoint corresponding to C_{high}.*

Since Air pollutants vary in potency, therefore, the function used to convert from air pollutant concentration to AQI varies by pollutant. This function is called 'concentration breakpoints'. Hence, the AQI is computed based on the individual pollutant's concentration breakpoint along with the index breakpoint, which is general for all the CAPs (Equation 1).

The AQI of ozone is poor throughout the year. Except for a few spots in the hot-dry season and the warm-wet season, the AQIs of all the other sampled points are unhealthy. In the hot-dry season (Figure 2a), only the Bayero University Kano (BUK) old campus sample location had moderate air quality. While in the warm and wet (Figure 2b), BUK new campus, Hotoro and Chalawa had moderate air quality. In the other seasons; the warm-dry (Figure 2c) and the cold-dry (Figure 2d) the AQI generally range from unhealthy for sensitive groups to hazardous.

The concentration of O_3 in all the seasons was significantly high. However, the commercial areas (Bata, Yankura, Kantin Kwari, Kofar Wambai etc.) and the industrial areas (Chalawa, Sharada phase I and Bompai) recorded the highest concentrations. This is because the formation of O_3 in the air is highly dependent on precursor pollutants created by human activities (Wang et al., 2022). These include hydrocarbons and nitrogen oxides, largely emitted by cars and other vehicles. They also include fossil fuel power plants, oil refineries, agriculture, and several other industries (Y. Liu and Wang, 2020). Since it is not emitted directly from any source, its formation as a secondary atmospheric pollutant is not independent. It depends on sunshine intensity, atmospheric convection, the height of the thermal inversion layer, nitrogen oxides and VOCs concentrations, and the ratio of VOCs to nitrogen oxides (WHO, 2006).

Works on O_3 AQI are scarce in Nigeria. However, hazardous AQI was reported in Abuja (Ihedike *et al*., 2023), good in Owo, Nigeria (Abulude *et al*., 2023) and moderate in Ibadan, Ado-Ekiti, Osogbo, Akure and Abeokuta in Nigeria (Abulude *et al*., 2023). Studies elsewhere reported hazardous O_3 AQI in Athens City, Greece (Stergiopoulou *et al*., 2018), very unhealthy in North Carolina, USA. (Tong *et al.*, 2019), unhealthy in Tehran, Iran (Javanmardi *et al*., 2018; Yousefi, *et al*, 2019) and moderate in Kerman City, Iran (Heidarinejad *et al*., 2018).

Unhealthy O_3 AQI has serious health implications. It is capable of causing impairment in human olfactory functioning (Muttray *et al*., 2018), mortality (Cakmak *et al*., 2018; Faustini *et al*., 2019), impaired lung function in the elderly (Zhang *et al.*, 2019), acute irritant-induced asthma (Goodman *et al.*, 2018; Færden *et al.*, 2018), chronic obstructive pulmonary disease (Guo *et al*., 2018), and blood pressure and pulmonary health effects (Pun and Ho, 2019).

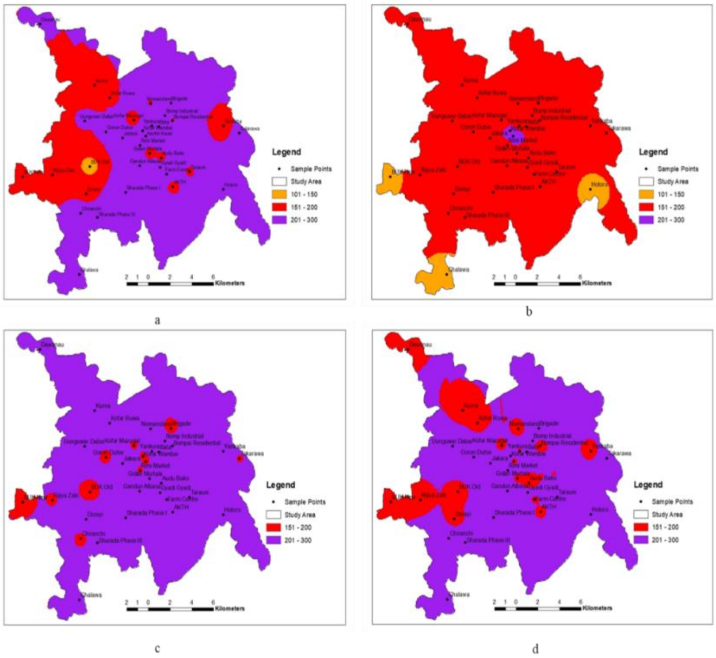

Fig 2: Ozone AQI (a. the hot-dry season, b. the warm-wet season, c. the warm-dry season, d. the cold-dry season)

Also, studies reported elevated concentrations of O_3 in Nigeria and other parts of the world. Ipeaiyeda and Adegboyega (2017) recorded elevated O_3 concentrations as high as 61±12 μg/m^3 (0.061ppm) in four locations in Ibadan, Oyo State, Nigeria. The results were associated with industrial and other anthropogenic activities such as residential heating. Also, Otu *et al*, (2018) detected O_3 values higher than the permissible in three locations Ajaokuta (0.078ppm), Lokoja (0.077ppm) and Obajana (0.131ppm) out of the five sampled locations in Kogi State, Nigeria. These were also attributed to industrial activities in addition to automobile emissions. Also, concentrations as high as 0.143ppm were recorded in Malaysia (Awang *et al*, 2013), 0.06ppm was recorded in continental South Africa (Laban *et al.*, 2018), 0.06ppm in Shenyang, China (Liu *et al.*, 2018), 0.02ppm in Patiala, Punjab, India (Rana *et l.*, 2019) and 0.02 in Tehran, Iran (Ezimand and Kakroodi, 2019). These were all associated with anthropogenic activities which include traffic, industrial activities and burning of biomass.

To examine the spatial and temporal variations in O_3 concentrations, the data were subjected to Analysis of Variance (ANOVA). The ANOVA results for both spatial and temporal variations indicated no statistically significant differences [$F(3, 135) = 0.896$, $p = 0.445$], suggesting that the variability in O_3 concentrations across the study area was not significant (Table 2). This means that the concentrations of O3 are almost similar in all the points and across the seasons.

Table 2: ANOVA Test for O_3 Variability

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.013	3	.004	.896	.445
Within Groups	.656	132	.005		
Total	.669	135			

Seasonal variations in the results obtained in this study (Table 2) conform to the pattern of variations reported by Liu *et al*. (2018) in China's urban areas. However, when formed, O_3 gas can last for weeks in the atmosphere and is most often transported to farther locations. Its effects are not, therefore, felt only in the emission source areas. This is what resulted in the high concentration of the pollutant throughout the metropolis.

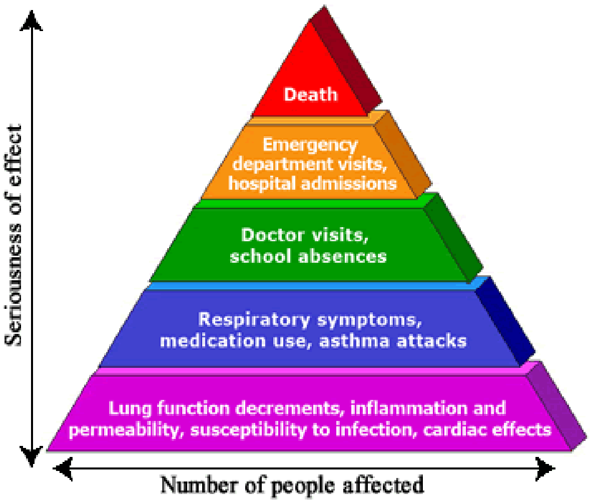

Figure 3: Pyramid of health effects of ozone
Source: USEPA (2019a)

Prolonged exposure to O_3 even at low concentrations can affect human health and can lead to death at high levels (Figure 3) (Feng *et al.*, 2024). This is because O_3 is a highly reactive and oxidative gas. Studies have extensively associated it with a series of acute and chronic health effects (Nuvolone *et al.*, 2018). For instance, cardiovascular-related mortality and myocardial infarction (Cakmak *et al*, 2016; Javanmardi *et al.*, 2018), coronary artery dilation impairment (Weaver *et al.*, 2015), skin damage (Fuks *et al.*, 2019), skin ageing (Fuks *et al.*, 2019), ischemic heart disease and cerebrovascular disease (Stieb *et al.*, 2018) and pulmonary effects (Rohr, 2018).

Conclusion: This study underscores the significant and persistent threat posed by elevated O_3 concentrations across urban communities. The results reveal that O_3 levels were consistently high throughout all seasons, with the highest concentrations observed in areas with increased human activities that generate precursor pollutants. These pollutants, largely from transportation, industrial emissions, and commercial activities, drive the formation of O_3 in the atmosphere. The prolonged exposure to these elevated O_3 levels in urban communities has far-reaching health consequences, including respiratory illnesses, cardiovascular issues, and overall degradation of public health. Addressing this pressing environmental and public health challenge is necessary through air quality monitoring and enforcement of minimum emissions by industries and motorists. There is a need to increase public awareness about the health risks associated with O_3 pollution and ways to minimize exposure to O_3 it.

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Data Availability: Data are available upon request with the corresponding author.

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