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APPRISING THE LOCAL AND GLOBAL IMPLICATION OF AMBIENTAIR QUALITY INDEX OF KADUNA METROPOLIS, NIGERIA

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ABSTRACT: *This study apprises the local and global implication of ambient air quality index of Kaduna Metropolis, Nigeria. With the point of investigating the spatial and transient dissemination of the Air Quality Index (AQI) of Carbon monoxide (CO), Sulfur dioxide (SO_2), and Particulate Matter (PM_{10}) and their suggestions on human wellbeing, in view of neighborhood and global measures. Data were collected during the raining season and dry harmattan weather. From traffic, Industrial, commercial and residential areas, utilizing validated portable pollutant monitors (MSA Altair 5x Gas Detector[a]) to collect data on the concentration of air pollutants (CO and SO_2) and (CW-HAT200 Particulate Counter) for the concentration of particulate matters (PM_{10}). Equal allocation stratify sampling and purposive sampling were utilized for the selection of sample points. The data were analyzed in line with USEPA Air Quality Index calculation approach and using descriptive statistics. The findings reveal that the AQI of Kaduna Metropolis ranges from good to hazardous, CO has 57.57% and 24.24% of the sample sites AQI ranging from unhealthy to hazardous based on WHO/USEPA and NESREA standards respectively. Equally SO_2 has about 91%, 34.23%, 42.42% of the sites AQI ranging from unhealthy to hazardous base on WHO, USEPA and NESREA standards respectively. PM_{10} has 75.76% and 18.18 of the sites AQI as hazardous base on WHO and USEPA standards, whereas none of the sites AQI is hazardous base on the NESREA standard. Further analysis shows that the northern part of the metropolis has more sites with unhealth AQI than the southern part of the metropolis. Also, the traffic land use has more of its sites AQI ranging from unhealthy to Sensitive group to hazardous. In conclusion this study provides empirical data on the AQI of Kaduna metropolis which ranges from good to hazardous. Thus, the need for the enforcement agencies to strictly enforce the guide lines regulating ambient pollution in the study area.*

Keywords: *Air Pollutants, Air Quality Index, Urban Land Used, Human Health*

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INTRODUCTION

Air is one of the most important constituents of man's environment. An average human being requires about 12kg of air each day, which is nearly 12 to 15 times greater than the amount of food consumed (Garg, Garg, and Garg, 2006; Ladan, 2013). Clean and pure air is very essential for human health and survival. Any change in the natural or normal composition of air that may adversely affects the living system, particularly the human life invariably causes air pollution (Garg et al., 2006).The air that we breathe daily is comprised of 21% oxygen and 78% nitrogen, with the remainder consisting of trace amounts of rare gases (David and Frederikse, 1997; Delay and Zanetti, 2007; Augustine, 2012; Aremu, 2014).

Air pollution is generally regarded as the presence in the atmosphere of one or more contaminants such as fumes, dust, gases, mist, odour, smoke, smog or vapours in considerable quantities and duration of which is injurious to human, animal and plant life or which unreasonably interferes with the comfortable enjoyment of life and the environment (Odigure, 1998; Anjoneyulu, 2005; Ladan, 2013;Ogwu,Peter,Aliy and Abubakar, 2015). Thus, air pollution is generally disequilibrium condition of air caused by the introduction of foreign elements from natural and man-made sources to the atmosphere so that it becomes injurious to biological communities(Ladan, 2013; Ogwu et al., 2015). The World Health Organization (WHO) defines air pollution as limited to situations in which the outer ambient atmosphere contains materials in concentrations which are harmful to man and his environment (WHO, 2006; Anjoneyulu, 2005 and Ladan, 2013). A substance in the air that can cause harm to humans and the environment is known as an air pollutant and air pollutants are expressed asparts per million (ppm) by volume or micrograms per cubic meter of air (ug/m3) which is subjected to change to variations of temperature and pressure (Das and Behera, 2008).

Air Quality Index (AQI) is an index for reporting daily air quality in the United States (USEPA, 2003). It gives information on how clean or polluted the air is, and what associated health effects might be of concern for individuals (Saniei et al., 2016). Cheng et al. (2007) to convey the air quality status to the scientific community, government officials, policy maker and in particular to the general public in a simple and straightforward manner. The AQI focuses on health effects individuals may experience within a few hours or days after breathing polluted air (Bortnick et al., 2002; USEPA, 2003; Murena, 2004; USEPA, 2014). AQI values below 100 are generally thought of as satisfactory (Mohan and Kandya, 2007). When AQI values are above 100, air quality is considered to be unhealthy, at first for certain sensitive groups of people, then for everyone as the AQI values get higher (Mintz, 2009).

Spatio-temporal analysis and modelling address problems that are spatially distributed (Zeiler, 2010) as well as temporally related (Jorgensen and Bendoricchio, 2001). The two basic methodologies addressing these dimensions are spatial databases managed by the Geographic Information System (GIS) and dynamic models processed by simulation tools on the other hand (Maquire, Batty and Goodchild, 2005;Matejicek, 2011) an additional dimension is added by integration with the monitoring data (Fedra, 1999).In Nigeria, air pollution has become a topic of intense debate at all levels because of the enhanced anthropogenic activities. Urban air pollution in Nigeria has increased rapidly with population growth, numbers of motor vehicles, use of fuels with poor environmental performance, badly maintained transportation systems and above all, ineffective environmental regulations (Gupta, Karar, Ayoob, and John 2008; Olajire et al., 2011; Yusuf et al., 2013).

In spite of increasing urban development and anthropogenic activities, monitored data on urban air pollution are sparse in Nigeria and many developing countries (Baumbach et al., 1995; Gupta et al., 2006; Abam and Unachukwu, 2009). The ability to understand the patterns and magnitude of pollution in the urban environment is increasingly important (Smallbone, 1998; Mwenda, 2011). Maps are needed, equally, to inform environmental managers, town planners and policy makers on the magnitude and pattern of the pollutants. This will aid in the mitigation, management and control of the pollutants. Hence, for the benefit of public health and sustainability of the natural functioning of ecosystems it is necessary to carry out a study like this which aims to analyzed the spatial and temporal distribution of Air Quality Index (AQI) in Kaduna metropolis.

METHODS

The Study Area

Kaduna metropolis is the capital of Kaduna State. The State is located almost at the mid-central portion of the Northern parts of Nigeria and shares common borders with Zamfara (NW), Katsina (N), Niger (SW), Kano (NE), Bauchi (NE), Nasarawa (S), Plateau (SE) States, and the Federal Capital Territory to the South (Nwude, 2006). Kaduna metropolis is located between Latitudes 10°24'39"Nand 10°36'40"N and Longitudes 7°21'26"E to 7°30' 3"E of the Greenwich meridian on the high plains of the north central highlands of Nigeria (Figure 1), with a mean elevation of about 620 M amsl. It covers more than 355 square kilometers, Kaduna metropolis is about 912 Km north of the Gulf of Guinea (Atlantic Ocean), about 530 Km from Nigeria's northern border and 180 Km from the nation's capital city, Abuja. The River Kaduna from which the town derived its name tends to divide the town into two unequal parts. Kaduna metropolis cut across four local governments areas in the state thus: Kaduna North, Kaduna South as well as parts of Igabi and Chikun Local Government Areas (LGAs) (Akpu, 2012).

Kaduna metropolis experienced tropical continental climate with distinct seasonal regimes. The seasonality is characterized with the cool and hot dry season. The climate is also characterized between November and March by dust laden harmattan and wind, which is dry cold and often strong blocks, from north-east originating from the Sahara region across the country with maximum intensity between December and January. The area is influenced by the tropical wet and dry climate (AW by Koppen's classification) with seasonal alternation of moist maritime air mass (tropical maritime/SW trade wind), and dry continental air mass (North easterly trade wind/hamattan) (Abaje, Ati, and Ishaya, 2009). The climatic classification of the study area is the tropical continental climate. It is characterized by two distinct alternating wet and dry seasons. The rainy

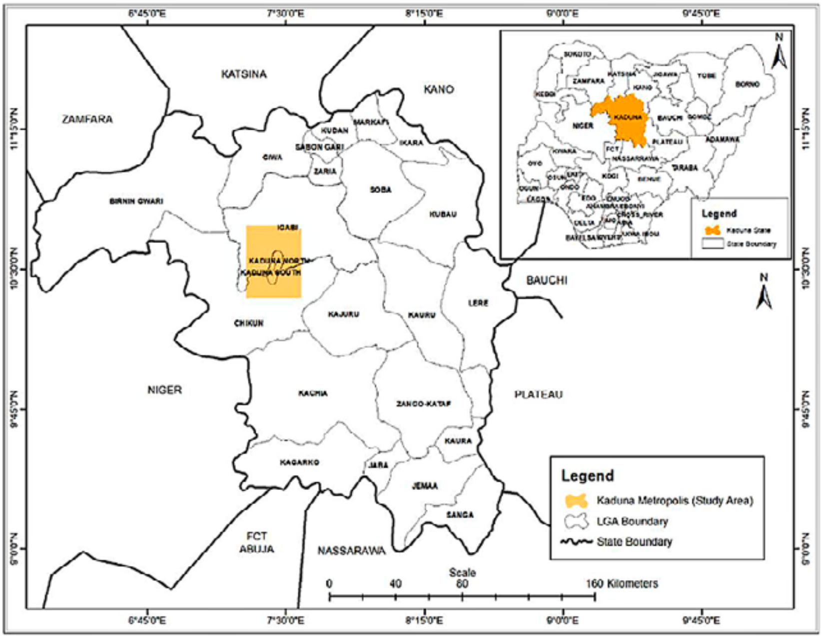

Figure 1: Kaduna Metropolis in Kaduna State

Source: KADGIS (2017)

season usually begins from March/April and runs through September/October. Rainfall begins in April and increases to its peak in August. The rainy season is associated with high intensity of storm and by October, the rain declines. The dry season starts at the end of October to early March of the following year. Average annual rain fall recorded is 1000mm to 1500mm. The rainfall type is convectional with a single regime of maximum peak, which usually occurs in August/September at a stretch (Parkman International Studies, 1997; Abaje et al., 2009).

The population of Kaduna has grown rapidly from about 14,000 in 1929 to 40,000 in 1952 to 149,000 in 1963 to an estimated 150,000 in 1965 and 500,000 in 1984. The 1991 census put the human population of Kaduna metropolis at 971,070 (NPC, 1991). Based on 2.7% growth rate, the population was estimated to have reach 1,448,129 in 2006(NPC, 2009). By 2009, at 3.0% growth rate, the population was estimated to have hit 1,582,409. The population was projected to reach 1,729,142 by 2012. At 3.5% growth rate the population was estimated to 2,031,742 in 2017. This high growth rate can be attributed to natural increase and high rate of immigration (National Bureau of Statistics, 2012; Akpu, 2012).

Methodology

The study started with a reconnaissance survey, with the aim of familiarization with the study area. Also, this was done in order to identify all possible variables as it relates with air quality in the study area, such as identifying and having a good picture of all possible land uses affecting the city air quality (i.e road traffic, industrial, residential and commercial land uses).

The needed information was obtained through direct field survey, the exercise of measurements and observations of the air quality attributes was carried out. This was done by using a handheld air quality monitoring device (MSA Altair 5x Gas Detector[a] with accuracy level of ±10% of reading) to collect data on the concentration of air pollutants (CO, and SO_2), and the particulate matter meter (Chinaway CW-HAT200 Particulate Counter with an accuracy level of +/_5% of reading') to test the concentration of particulate matters (PM_{10}), it measures in µgm-3. The level of each of the study air pollutants concentration were measured daily during peak (7:20 – 9:20 am for morning hours and 5:00 – 7:00 pm for evening hours) and off-peak period (12:00 noon – 2:00 pm) during the harmattan weather (cool dry season) and the wet rainy season. A structured field recording chart was design and used as a guide in the field, to assemble data on each of the study variables. 33 data collection points were selected, for equal representation of the sample sites across each of the land use. Equal allocation stratify sampling was used to allocated 8 sample sites to each of the land uses except the traffic sites which was allocate the extra one site making it to have 9 sample sites. Purposive sampling was used to select the points across the land uses (Table 1).

Analytical Technique

The AQI is a single number reporting the air quality with respect to its effects on human health (Bortnick, Coutantand and Eberly, 2002; Murena, 2004). The result is set of a rule (for example, an equation) that translates parameter values into a more parsimonious form by means of numerical manipulation. AQI is calculated by using the pollutant concentration data and the following equation (USEPA, 2006).

$$T_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} \left(C_p - BP_{Lo} \right) + I_{Lo} \qquad (1)$$

Where:

- I_p = the index for pollutant p
- C_p = the rounded concentration of pollutant p
- BP_{Hi} = the breakpoint that is greater than or equal to Cp
- BP_{Lo} = the breakpoint that is less than or equal to Cp
- I_{Hi} = the AQI value corresponding to BPHi
- I_{Lo} = the AQI value corresponding to BPLo"

Table 1. Sample Collection Sites

Location	Land Use	SID	Easting (m)	Northing (m)
Refinery Junction	Traffic	T01	335255.28977	1154676.87638
Sabon Tasha	Traffic	T02	330932.759925	1155614.04512
Abuja Junction	Traffic	T03	325387.082167	1154788.54347

Location	Land Use	SID	Easting (m)	Northing (m)
Peugeot Junction	Traffic	T04	327503.753067	1156349.58826
Station Roundabout	Traffic	T05	327059.252178	1160482.38819
Leventis Roundabout	Traffic	T06	328302.313731	1163492.95038
Kawo Fly Over	Traffic	T07	330127.942382	1170533.52696
Mando Roundabout	Traffic	T08	328614.522689	1170464.73515
Bakin Ruwa Junction	Traffic	T09	324810.289347	1162710.18431
Refinery	Industrial	I01	334704.81105	1152686.90286
Indomie Noodles	Industrial	I02	335906.021796	1154374.9479
Coca Cola	Industrial	I03	326807.088588	1155671.83216
Brewery	Industrial	I04	326614.471536	1158596.013
AdkadRoverocom Ventures	Industrial	I05	323778.13253	1158670.09649
Yuguda Plastic & Paper Ind	Industrial	I06	329709.39717	1170195.01676
Global Care Industries	Industrial	I07	328738.374392	1169800.46931
Doka Printing	Industrial	I08	328021.352127	1161593.92456
Sabo Market	Commercial	C01	331386.858857	1155656.23935
Barnawa Market	Commercial	C02	328481.728048	1159246.64237
Television Market	Commercial	C03	328209.20667	1155563.635
Kakuri Market	Commercial	C04	325743.285074	1157587.70155
Central Market	Commercial	C05	328256.831765	1163059.29582
Kabala Market	Commercial	C06	329738.501395	1161228.3755
Kawo Market	Commercial	C07	330339.000929	1169846.1894
KasuwanBachi	Commercial	C08	326129.048343	1162870.40411
AngwanShanu	Residential	R01	329244.770974	1166390.85115
Sabo	Residential	R02	331093.894672	1155875.23012
Tudun Wada	Residential	R03	326542.205569	1162149.04267
Rigasa	Residential	R04	324322.241129	1164236.92685
Barnawa GRA	Residential	R05	327741.087967	1159014.6764
UngwanRimi GRA	Residential	R06	330523.981047	1163931.7029
Malali GRA	Residential	R07	332410.993141	1166036.73211
KurminMashi GRA	Residential	R08	326516.805518	1165766.0099

Also, the indexes for each of the pollutants can simply be derived using the mathematical formula in Eq. (2):

$$AQI_{\text{pollutant}} = \frac{\text{pollutant data reading}}{\text{standard}} \cdot 100 \qquad \text{(2)USEPA (2003).}$$

The AQI runs on a yardstick of 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality (USEPA, 2003). A summary of the interpretation of the AQI values according to USEPA (2003) are as presented in Table 2.

Table 2: Interpretations of the AQI Values Classification

Index Values	AQI Category	AQI Rating	PM_{10} (µg/m^3)	CO (ppm)	SO_2 (ppm)
0 – 50	Good	A	0 - 54	0 – 4.4	0 – 0.035
51 – 100	Moderate	B	55 – 154	4.5 – 9.4	0.036– 0.075
101 – 150	Unhealthy for sensitive groups	C	155 - 254	9.5 – 12.4	0.076– 0.185
151 – 200	Unhealthy	D	255 – 354	12.5–15.4	0.186 – 0.304
201 – 300	Very unhealthy	E	355 – 424	15.5– 30.4	0.305 – 0.604
301 – 500	Hazardous	F	425 – 504	30.5- 50.4	0.605 – 1.004

Source: USEPA (2003)

Data Processing

The study involved integrating the air pollutants data from field measurements (AQI data) into digital map layers, this was to aid shows the spatial distribution of the pollutants AQI in Kaduna metropolis. Locational coordinates of Longitude (x-coordinate), Latitude (y-coordinate) and elevation above mean sea level of the sampling sites determined using Garmin Global Positioning System (GPS) device. Also, the AQI result stored in Microsoft excel software using the CSV (comma delimited) format. The excel spread sheet was imported in to ArcGIS 10.6 environment and plot as a point map and also converted in to shapefile for analysis. Attribute data were then assigned to spatial objects and the system become ready for spatio-temporal analysis and management. The findings of the study were presented using maps and descriptive statistics.

RESULT AND DISCUSSION

This Section analyzed the AQI values based on WHO, USEPA and NESREA ambient standard for each of the air pollutants during the raining season and dry harmattan weather.

Raining Season AQI

This section discusses the result of AQI of CO, SO2 and PM during the raining season, using WHO, USEPA and NESREA standard.

Carbon Monoxide: Inhalation of CO reduces the amount of oxygen in the bloodstream, and high concentrations can lead to headaches, dizziness, unconsciousness and death (USEPA 2014; Delay and Zanetti, 2007). The result of finding is presented in Table 2 and Figure 2 to 7.

The finding reveals that the AQI for CO in Kaduna Metropolis ranges from good to hazardous, this agree with the findings of Saniei et al. (2016) on Air quality classifica-

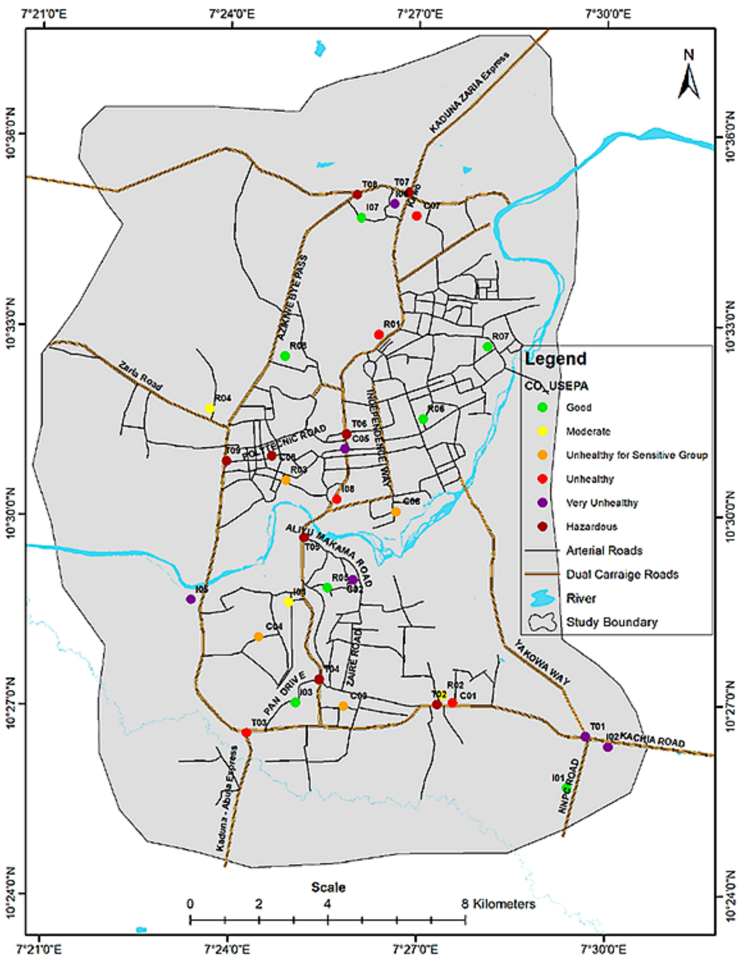

Figure 2. Spatial Analysis of CO AQI for Wet Season Based on WHO/USEPA Standard

Source: Fieldwork (2019)

tion and its temporal trend in Tehran, Iran, and Attah (2015). The finding disagrees with the submission of Chizoruo et al. (2017) on the ambient air quality assessment of Orlu, Southeastern, Nigeria, and Adedeji et al. (2016) whose finding shows only unhealthy and very unhealthy AQI. The result reveals that 21.21% of the sample sites air quality base on USEPA and WHO standard are good, in as the NESREA standard shows that 33.33% are good, the good sites are fairly distributed in both the north and southern part of the study area (Table 2). Similarly, NESREA standard shows that 24.24% of the sites are moderate, while WHO and USEPA standard shows that only 9% of the sites are moderate, the moderate sites are randomly distributed in both the north and southern part of the study area (Table 3). Similarly, NESREA standard reveals that 18.18% of the sample sites are unhealthy to sensitive group, whereas WHO and USEPA standard reveals 12.12%, in both the northern and the southern part of the metropolis have sites that are unhealthy for sensitive group randomly distributed.

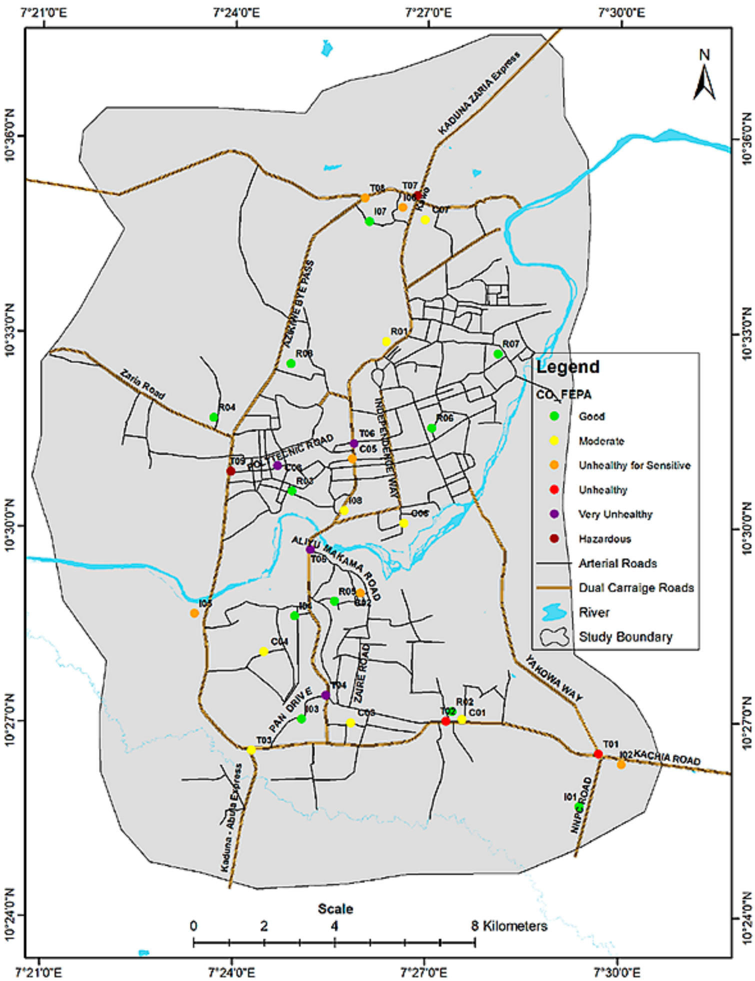

Figure 3: Spatial Distribution of CO AQI for Wet Season Based on NESREA Standard

Source: Fieldwork (2019)

The result of USEPA/WHO standard shows that 15.15% of the sites are unhealthy, whereas, NESREA standard shows a decrease 6% the unhealthy sites where found in both the north and south. USEPA and WHO standard also shows that 18.18% of the sites are very unhealthy, whereas NESREA standard shows a decrease (12.12%), most of the very unhealthy sites are found in the northern part of the metropolis (Table 3). Equally USEPA standard reveals 24.24% of the sites to be hazardous, whereas NESREA standard reveals only 6%, the hazardous sites are found more in the northern part of the metropolis than the southern part. This implies that most of the sites are unsafe for human health.

Thus, according to USEPA (2014) “people with cardiovascular disease, such as coronary artery disease, are most at risk. They may experience chest pain and other cardiovascular symptoms if they are exposed to carbon monoxide, particularly while exercising”. People with marginal or compromised cardiovascular and respiratory systems (for example, individuals with congestive heart failure, cerebrovascular disease, anemia, or chronic obstructive lung disease), and possibly young infants and fetuses, also may be at greater risk from carbon monoxide pollution.

The result further reveals that the traffic sites have about 78% of its sites as hazardous base on USEPA standard, whereas NESREA standard reveals 22%, with Abuja junction and Mando roundabout having moderate and unhealthy to sensitive group AQI respectively, all other sites are unhealthy base on NESREA standard. The NESREA standards shows that the industrial sites CO emission is satisfactory with only 37.5% of the sites unhealthy for sensitive groups, other sites have good and moderate air quality, whereas USEPA standard reveals that 12.5% and 37.5% of the sites are unhealthy and very unhealthy respectively, distributed in both the north and southern part of the study area. Majority (62.5%) of the commercial sites AQI base on NESREA standard is moderate, 25% and 12.5% unhealthy for sensitive groups and very unhealthy respectively, whereas USEPA standard shows that 62.5% of the sites differs from unhealthy, very unhealthy to hazardous, with 37.5% of the sites unhealthy to sensitive groups. The AQI for residential areas is satisfactory for both NESREA and USEPA standards, except for Ungwan Shanu site which is unhealthy base on USEPA standard.

SO_2: SO2 can cause coughing, mucus secretion, and other conditions such as asthma and chronic bronchitis (QEPA, 2001). Some studies show a consistent effect of SO_2 pollution on cardiorespiratory mortality and acid rain (Fischer, Hoek, Brunekreef, Verhoeff and Van-Wijnen, 2003; Venners, et al., 2003; Wong, Tam, Yu, and Wong, 2002; Powe and Willis, 2004; Wai and Steven, 2007).

Table 2: Air Quality Index Percentage Summary for the Raining Season

	CO		SO_2			PM_{10}		
	WHO/ USEPA %	NESREA %	WHO %	USEPA %	NESREA %	WHO %	USEPA %	NESREA %
Good	21.21	33.33	9.09	24.24	24.24	0	15.15	24.24
Moderate	9.09	24.24	0	24.24	30.30	6.06	9.09	9.09
Sensitive	12.12	18.18	3.03	9.09	3.03	12.12	9.09	39.39
Unhealthy	15.15	6.06	3.03	3.03	24.24	3.03	27.27	9.09
Very Unhealthy	18.18	12.12	3.03	30.30	12.12	3.03	21.21	18.18
Hazardous	24.24	6.06	81.82	9.09	6.06	75.76	18.18	0
Traffic Sites								
Good	0	0	0	11.11	11.11	0	0	0
Moderate	0	11.11	0	11.11	11.11	0	0	11.11
Sensitive	0	11.11	0	0		0	11.11	55.56
Unhealthy	11.11	22.22	0	0	55.56	0	44.44	0
Very Unhealthy	11.11	33.33	0	66.67	11.11	0	11.11	33.33
Hazardous	77.78	22.22	100	11.11	11.11	100	33.33	0
Industrial Sites								
Good	37.5	50	12.50	37.5	37.5	0	12.5	37.5
Moderate	12.5	12.5	0	12.5	25	12.5	25	12.5

	CO		SO_2			PM_{10}		
	WHO/ USEPA %	NESREA %	WHO %	USEPA %	NESREA %	WHO %	USEPA %	NESREA %
Sensitive	0	37.5	0	12.5		12.5	2.5	37.5
Unhealthy	12.5	0	12.50		12.5	0	0	12.5
Very Unhealthy	37.5	0	0	25	25	12.5	50	0
Hazardous	0	0	75.00	12.5	0	62.50	0	0
Commercial Sites								
Good	0	0	0	0	0	0	0	0
Moderate	0	62.5	0	50	50	0	12.5	12.5
Sensitive	37.5	25	0	12.5	12.5	0		50
Unhealthy	25	0	0	0	12.5	0	50	12.5
Very Unhealthy	25	12.5	0	25	12.5	0	12.5	0
Hazardous	12.5	0	100	12.5	12.5	100	25	25
Residential Sites								
Good	50	87.5	37.50	50	50	0	50	62.5
Moderate	25	12.5	0	25	37.5	12.5	12.5	
Sensitive	12.5		12.50	12.5		37.5	12.5	12.5
Unhealthy	12.5		0	12.5	12.5	12.5		12.5
Very Unhealthy	0	0	0	0	0	0	12.5	12.5
Hazardous	0	0	50.00	0	0	37.5	12.5	0

Source: Fieldwork (2019)

Table 3: Spatial Analysis of Air Quality Index during the Raining Season

	CO		SO_2			PM_{10}		
	WHO/ USEPA %	NESREA %	WHO %	USEPA %	NESREA %	WHO %	USEPA %	NESREA %
Northern Part								
Good	23.53	35.29	17.65	23.53	23.53	0	17.65	17.65
Moderate	5.88	23.53	0	17.65	29.41	0	0	11.76
Sensitive	11.76	17.65	0	17.65	5.88	17.65	11.76	17.65
Unhealthy	17.65	0	0	5.88	11.76	0	11.76	17.65
Very Unhealthy	11.76	11.76	0	23.53	23.53	0	23.53	35.29
Hazardous	29.41	11.76	82.35	11.76	11.76	82.35	35.29	0
Southern Part								
Good	18.75	31.25	0	25.00	25.00	0	12.50	31.25
Moderate	12.50	25.00	0	31.25	31.25	12.5	18.75	6.25
Sensitive	12.50	18.75	6.25	0	0	6.26	6.25	62.50
Unhealthy	12.50	12.50	6.25	0	31.25	6.26	43.75	0
Very Unhealthy	25.00	6.25	6.25	37.50	6.25	6.26	18.75	0
Hazardous	18.75	0	81.25	6.25	0	68.75	0	0

Source: Fieldwork (2019)

The findings from Figures 4 and 5 reveals that the AQI for SO2 in Kaduna Metropolis ranges from good to hazardous, this result disagree with the submission of Attah (2015) who reported that the AQI of SO2 is good in all the traffic sites in Kaduna metropolis, and also the submission of Chizoruo et al. (2017) who reported the AQI of SO2 to be only very unhealthy and hazardous. However, it agrees with the findings of Adedeji et al. (2016). The findings further reveal that 24.24% of the sites AQI is good base on both USEPA and NESREA standard, it equally shows that the good AQI is fairly well distributed in both the northern and southern part of the metropolis. It also reveals that 24.24% of the sites AQI is moderate base on USEPA standard and 30.30% base on NESREA, randomly distributed in both the north and southern part of the metropolis.

Similarly, USEPA standard shows that 9% of the sites AQI is unhealthy for sensitive group, whereas NESREA standard shows only 3%. Also, NESREA standard shows

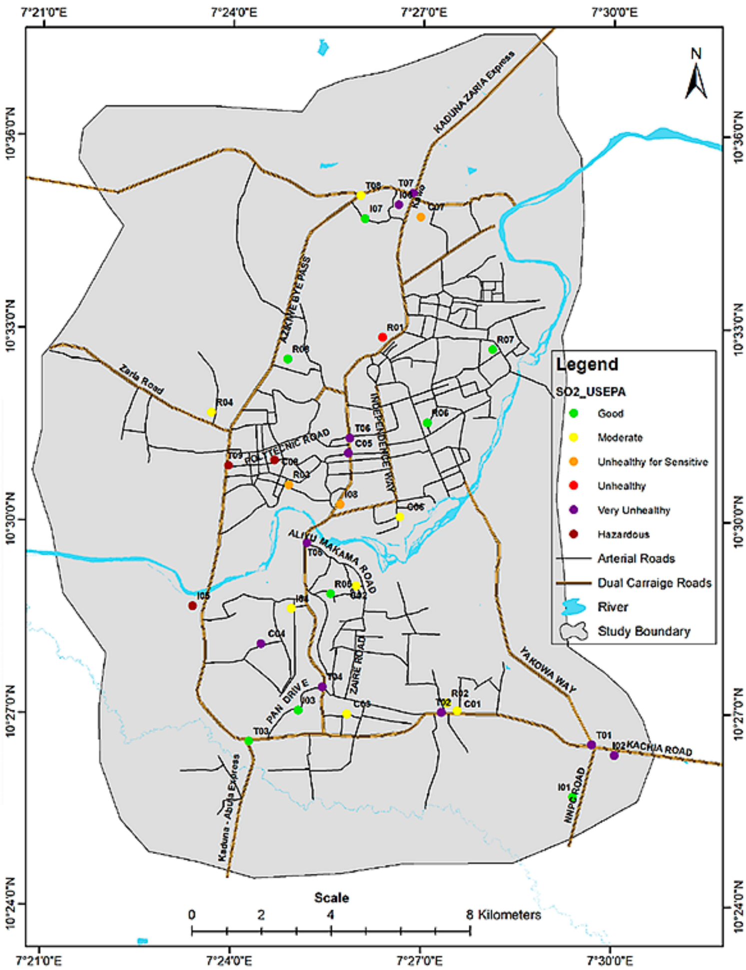

Figure 4. Spatial Analysis of SO_2 AQI for Wet Season Based on USEPA Standard

Source: Fieldwork (2019)

that 24.24% of the sites air quality is unhealthy, whereas USEPA standard shows only 3% to be unhealthy, the unhealthy sites are more in the southern part of the study area than the northern part. 30.3% of the sites are very unhealthy base on USEPA standard, while NESREA standard shows 12.12%, it equally shows more of the very unhealthy sites in the northern part contrary to the unhealthy AQI found more in the southern part of the metropolis. Over 80% of the sites are hazardous base on WHO standard, while only 9% and 6% of the sites are hazardous base on USEPA and NESREA standard respectively, found mostly in the northern part of the metropolis as shown in Figures 4 and 5.

Consequently, according to USEPA (2014) "people with asthma who are physically active outdoors are most likely to experience the health effects of sulfur dioxide. The main effect, even with very brief exposure (minutes), is a narrowing of the airways

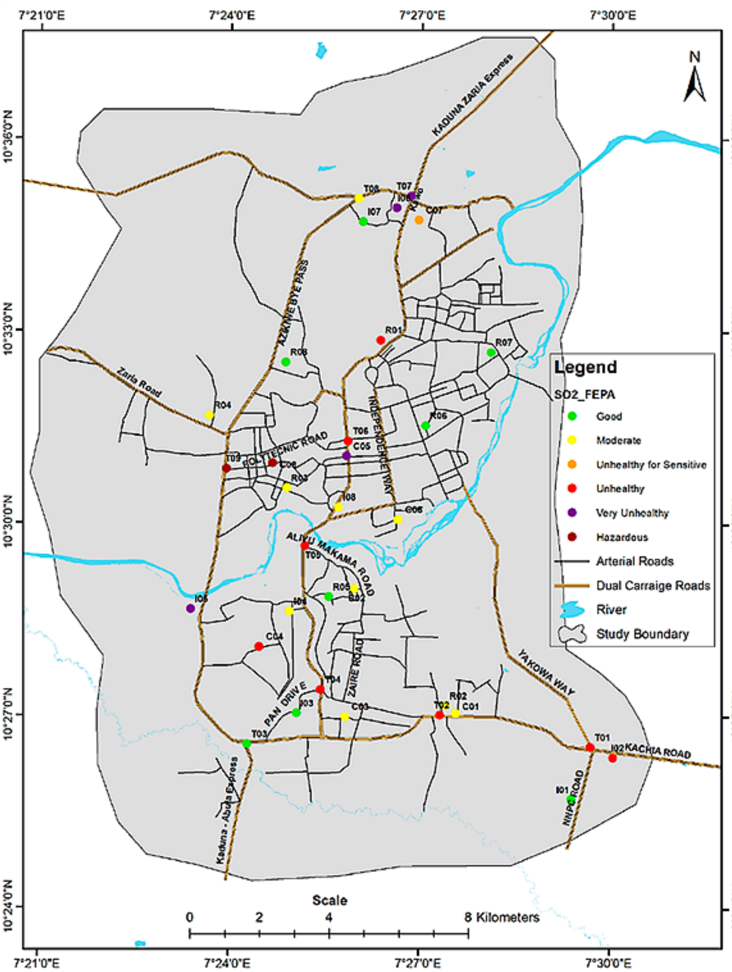

Figure 5. Spatial Analysis of SO_2 AQI for Wet Season Based on NESREA Standard

Source: Fieldwork (2019)

(called bronchoconstriction). This may be accompanied by wheezing, chest tightness, and shortness of breath, which may require use of medication that opens the airways". Symptoms increase as sulfur dioxide levels or breathing rate increases. At very high levels, sulfur dioxide may cause wheezing, chest tightness, and shortness of breath even in healthy people who do not have asthma.

Further probe reveals that the traffic sites have about 78% of its sites as very unhealthy and hazardous base on USEPA standard, NESREA standard also shows that about 78% of the sites differs from unhealthy, very unhealthy and hazardous, with only 22.22% of its sites AQI as satisfactory. The industrial sites reveal that 50% and 62.5% of the sites AQI as safe base on USEPA and NESREA standards respectively, and both USEPA and NESREA standards reveals that 25% of the sites are very unhealthy, also 12.5% of the sites are hazardous base on USEPA standard. The commercial sites reveal that 50% of the sites AQI is moderate base on both USEPA and NESREA standard and also 12.5% are unhealthy to sensitive group, 25% and 12.5% of the sites are very unhealthy and hazardous respectively base on USEPA standard, whereas NESREA standard reveals 12.5% for both very unhealthy and hazardous AQI. The AQI for residential area is satisfactory base on both USEPA and NESREA standard, except for Ungwan Shanu area which is unhealthy.

PM_{10}: The findings from Table 3, Figures 6 and 7 reveals that the AQI for PM_{10} in Kaduna Metropolis ranges from good to hazardous, this agree with the submission of Saniei et al. (2016) and Chizoruo (2017), who's finding equally shows an AQI which ranges from good to hazardous. The analysis base on NESREA standard reveals that 24.24% of the sites are Good, whereas USEPA standard shows a decrease 15.15% of the sites, which are randomly distributed in both the northern and southern part of the metropolis. 9% of the sites AQI is moderate for both the USEPA and NESREA standard, which are found in the southern part of the metropolis for the USEPA standard and more in the northern part in Figure 4b. Also, NESREA standard shows that 39.39% of the sites are unhealthy to sensitive, whereas USEPA standard shows only 9%, the spatial analysis reveals that most of the sites are unhealthy for sensitive groups are found in the southern part of the state. 27.27% of the sites are unhealthy base on USEPA standard, whereas a decrease is observed for the NESREA standard 9.09%, which are distributed in both the northern and southern part of the metropolis, though more are found in the southern part of the metropolis (Figure 6).

Similarly, USEPA standard reveals 21.21% of the sites to be very unhealthy and NESREA standard shows that 18.18% of the locations are very unhealthy, the spatial analysis shows that most of the very unhealthy sites are in the northern part of the metropolis as shown in Figure 7. USEPA standard also reveals that 18.18% of the sites are hazardous while none of the sites is hazardous base on NESREA standard, equally the hazardous sites are only found in the northern part of the metropolis. whereas the WHO standard shows that over 75% of the sites are hazardous, spatially distributed in both the northern and southern part of the metropolis as shown in Table 4. Thus, may cause people with heart disease to experience chest pain, palpitations, shortness of breath, and fatigue. people with existing lung disease may not be able to breathe as deeply or vigorously as they normally would. They may experience symptoms such as coughing and shortness

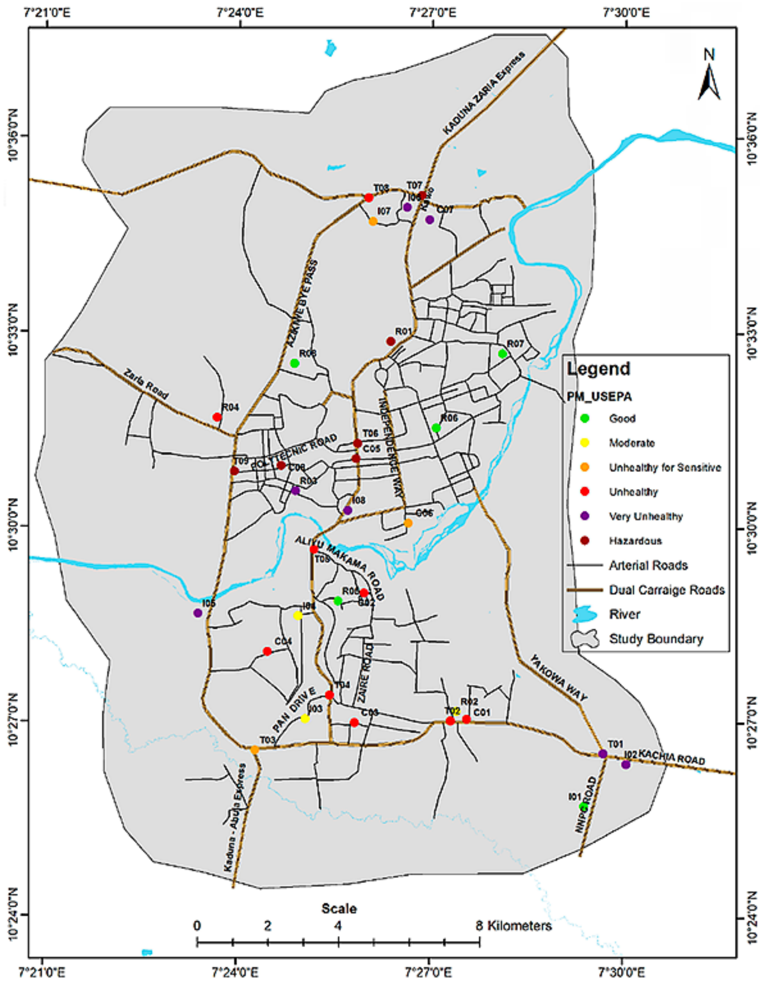

Figure 6. Spatial Analysis of PM10 AQI for Wet Season Base on USEPA Standard
Source: Fieldwork (2019)

of breath. Healthy people also may experience these effects, although they are unlikely to experience more serious effects.

Additional examination of the findings reveals that the traffic sites has about 89% of its sites AQI ranging from unhealthy to hazardous base on USEPA standard, whereas NESREA standard shows 33.33% of the sites to be very unhealthy, majority (56%) of the sites are unhealthy for sensitive group base on NESREA standard. The industrial sites finding reveals that 50% of the sites are very unhealthy base on USEPA standard, whereas NESREA standard reveals only 12.5% of the sites to be unhealthy, and 50% of the sites AQI are satisfactory base on NESREA standard, where, USEPA standard shows 37.5%. likewise, 37.5% of the sites are unhealthy to sensitive groups base on NESREA standard. This also concur with the submission of Notardonato, Manigrasso, Pierno, Settimo, Protano, Vitali, ... and Avino, P. (2019) that particular matter emission are mostly as result of fossil fuel emission.

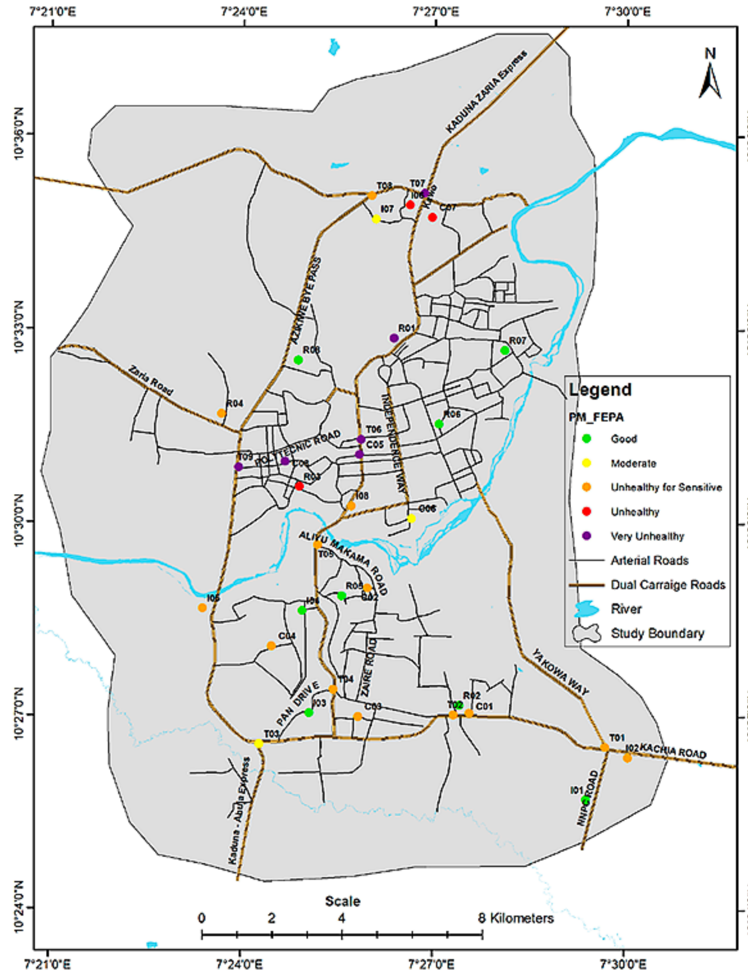

Figure 7. Spatial Analysis of PM10 AQI for Wet Season Base on NESREA Standard

Source: Fieldwork (2019)

A probe of the commercial sites AQI reveals that 50% and 25% of the sites are unhealthy and hazardous respectively base on USEPA standard, whereas NESREA standard reveals that 50% and 25% of the sites are unhealthy for sensitive groups and hazardous respectively, both USEPA and NESREA standard reveals 12.5% of the sites AQI to be moderate. The residential sites further probes reveal that 62.5% of the sites AQI are satisfactory base on both standards, similarly 12.5% of the sites are unhealthy for sensitive groups and another 12.5% very unhealthy base on both USEPA and NESREA standard.

Harmattan Weather AQI

This section confers the AQI of CO, SO_2 and PM during the Harmattan Weather, using WHO, USEPA and NESREA standard. The findings are presented in Figures 8 to 13 and Table 4 and 5.

CO: The finding reveals that the AQI for CO in Kaduna Metropolis during the harmattan weather ranges from good to hazardous, this agree with the findings of Saniei et al. (2016) on Air quality classification and its temporal trend in Tehran, Iran and Attah (2015), but disagree with the submission of Chizoruo et al. (2017) on the ambient air quality assessment of Orlu, Southeastern of Nigeria, and Adedeji et al. (2016) whose finding shows only unhealthy and very unhealthy AQI. The result also reveals that 27.27% of the sample sites air quality base on WHO and USEPA standard are good, in as the NESREA standard shows that 45.45% are good, the good sites are fairly distributed in both the north and southern part of the metropolis. Similarly, NESREA standard shows that 27.27% of the sites are moderate, while USEPA/WHO standard shows that only 15.15% of the sites are moderate, the moderate sites are also randomly distributed in both the north and southern part of the study area. this implies that about 72% of the sites are safe base on NESREA standard, while USEPA and WHO standard reveals only about 42% of the sites to be safe.

Also, NESREA standard reveals that 6.06% of the sample sites are unhealthy to sensitive group, whereas USEPA and WHO standard reveals 21.21%, in both the northern and the southern part of the metropolis have sites that are unhealthy for sensitive group randomly distributed. USEPA/WHO standard shows that 9.09% of the sites are unhealthy, whereas NESREA standard shows a decrease (3%), the unhealthy sites where found in both the north and south, though NESREA standard reveal only the southern part of the metropolis. USEPA and WHO standard also shows that 3% of the sites are very unhealthy. Whereas, more of the very unhealthy sites are found in the northern part of the metropolis.

Equally WHO and USEPA standard reveals 24.24% of the sites to be hazardous, whereas NESREA standard reveals only 3% hazardous sites are found more in the northern part of the metropolis than the southern part as shown in Tables4 and 5. This implies that most of the sites are unsafe to human health. Consequently, according to USEPA (2014) "people with cardiovascular disease, such as coronary artery disease, are most at risk. They may experience chest pain and other cardiovascular symptoms if they are exposed to carbon monoxide, particularly while exercising". Persons with compromised respiratory and cardiovascular systems and possibly young infants and fetuses, also may be at greater risk from carbon monoxide pollution.

A further investigation reveals that About 78% of the traffic sites are hazardous base on WHO and USEPA standard, whereas NESREA standard shows only about 11% of its sites to be hazardous to humans. Likewise, 62.5% of the commercial sites are unhealthy base on WHO/USEPA standard whereas NESREA standard shows only 12.5% of the commercial sites as unhealthy, and while about 50% of the industrial sites are safe for human day to day activities. The AQI for residential areas is satisfactory for both NESREA and USEPA standards, except for Ungwan shanu area which is unhealthy base on WHO and USEPA standard.

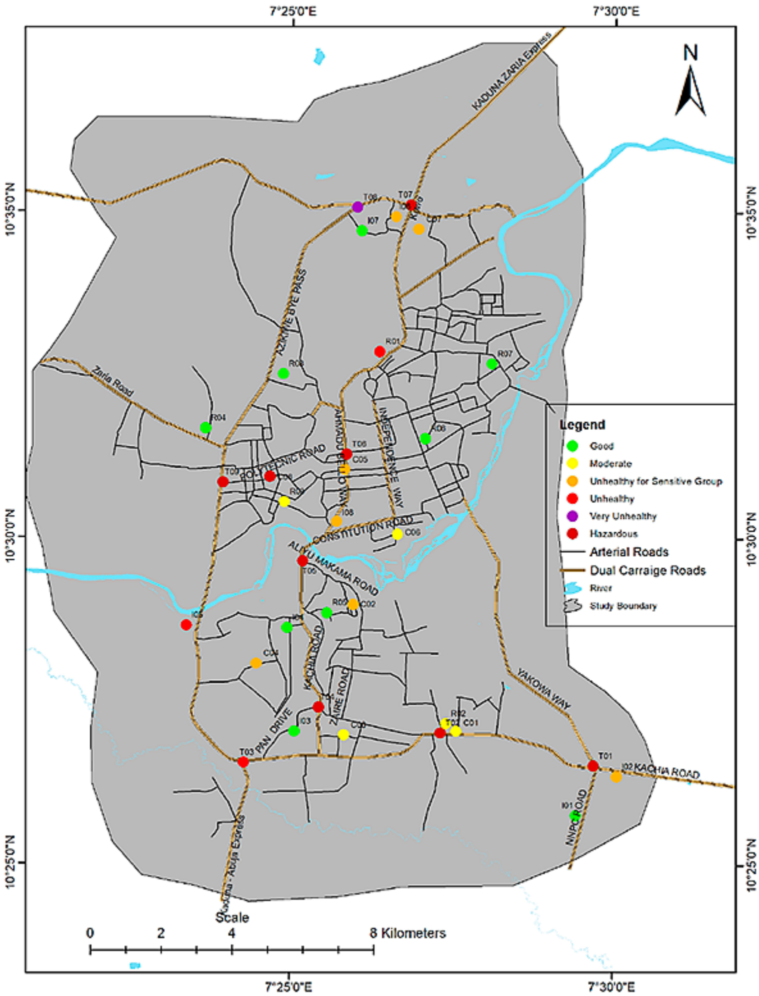

Figure 8. Spatial Analysis of CO AQI for Harmattan weather base on USEPA/WHO Standard

Source: Fieldwork (2019)

SO_2: The findings from figure 6a and 6b reveals that the AQI for SO2 during the harmattan weather in Kaduna Metropolis ranges from good to hazardous. This result disagrees with the submission of Attah (2015) who reported that the AQI of SO_2 is good in all the traffic sites in Kaduna metropolis, and also the submission of Chizoruo et al. (2017) who reported the AQI of SO_2 to be only very unhealthy and hazardous. However, agrees with the findings of Adedeji et al. (2016). The finding equally reveals that 27.27% of the sites AQI is good base on USEPA standard and NESREA standard shows an increase 36.36% of the locations. The result equally shows that the good AQI is fairly well distributed in both the northern and southern part of the metropolis. It also reveals that 30% of the sites AQI is moderate base on USEPA standard and 33% base on NESREA, randomly distributed in both the north and southern part of the metropolis. This implies that SO_2 emission in most of the sites (about 70%) base on NESREA standard and

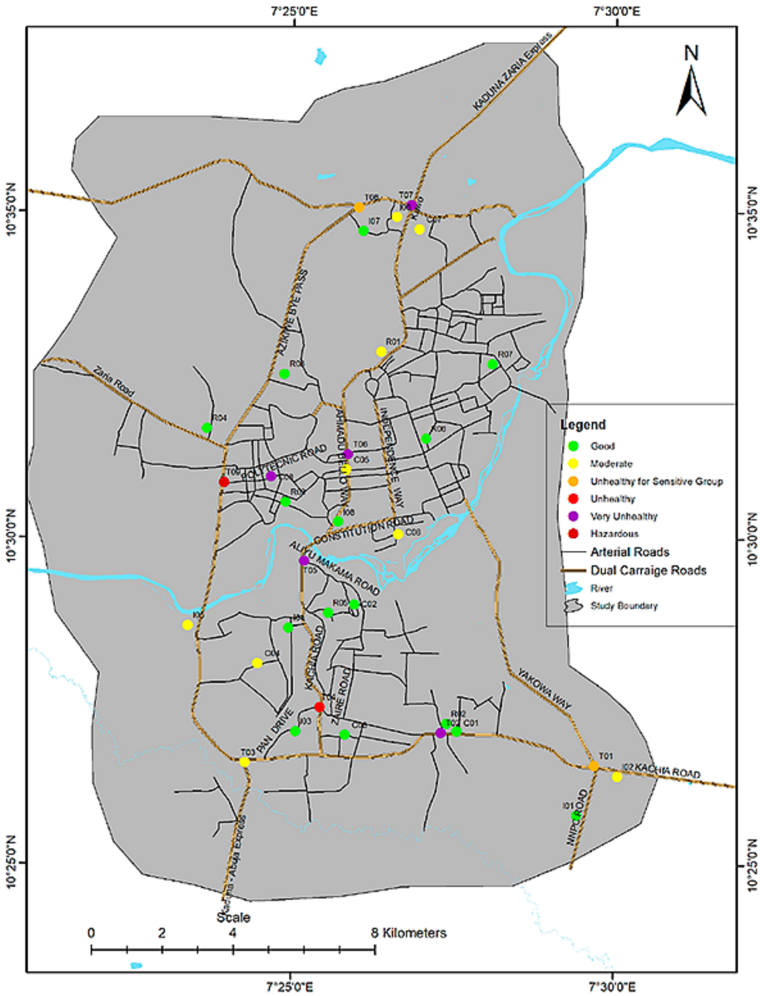

Figure 9: Spatial Distribution of CO AQI for Harmattan Weather Basedon NESREA Standard

Source: Fieldwork (2019)

about 60% base USEPA standard is safe for the environment and its inhabitants. Whereas, WHO standard shows that about 85% of the sites are unsafe.

Table 4. Air Quality Index Percentage Summary for the Dry Harmattan Weather

	CO		SO_2			PM_{10}		
	WHO/ USEPA %	NESREA %	WHO %	USEPA %	NESREA %	WHO %	USEPA %	NESREA %
Good	27.27	45.45	6.06	27.27	36.36	0	0	15.15
Moderate	15.15	27.27	3.03	30.30	33.33	0	18.18	18.18
Sensitive	21.21	6.06	0	12.12	18.18	0	9.09	30.30
Unhealthy	9.09	3.03	3.03	18.18	6.06	3.03	27.27	15.15
Very Unhealthy	3.03	15.15	3.03	6.06	6.06	15.15	18.18	18.18
Hazardous	24.24	3.03	84.85	6.06	0	81.82	27.27	3.03
Traffic Sites								
Good	0	0	0	0	0	0	0	0
Moderate	0	11.11	0	33.33	44.44	0	0	0
Sensitive	0	22.22	0	11.11	44.44	0	0	22.22
Unhealthy	11.11	11.11	0	44.44	0	0	11.11	22.22
Very Unhealthy	11.11	44.44	0	0	11.11	0	22.22	44.44
Hazardous	77.77	11.11	100	11.11	0	100	66.66	11.11
Industrial Sites								
Good	50.00	62.50	12.50	37.50	37.50	0	0	12.50
Moderate	0	37.50	0	12.50	25.00	0	25.00	37.50
Sensitive	37.50	0	0	12.50	12.50	0	25.00	25.00
Unhealthy	12.50	0	12.50	12.50	25.00	12.50	12.50	37.50
Very Unhealthy	0	0	0	25.00	0	12.50	25.00	0
Hazardous	0	0	75.00	0	0	75.00	12.50	0
Commercial Sites								
Good	0	37.50	0	25.00	37.50	0	0	0
Moderate	37.50	50.00	0	50.00	50.00	0	0	25.00
Sensitive	50.00	0	0	12.50	0	0	0	50.00
Unhealthy	0	0	0	0	0	0	75.00	12.50
Very Unhealthy	0	12.50	0	0	12.50	0	12.50	12.50
Hazardous	12.50	0	100	12.50	0	100	12.50	0
Residential Sites								
Good	62.5	87.50	25.00	50.00	75.00	0	0	50.00
Moderate	25.00	12.50	12.50	25.00	12.50	0	50.00	12.50
Sensitive	0	0	0	12.50	12.50	0	12.50	25.00
Unhealthy	12.50	0	0	12.50	0	0	12.50	0
Very Unhealthy	0	0	12.50	0	0	50	12.50	12.50
Hazardous	0	0	50.00	0	0	50.00	12.50	0

Source: Fieldwork (2019)

Thus, according to USEPA (2014) "people with asthma who are physically active outdoors are most likely to experience the health effects of sulfur dioxide. The main effect, even with very brief exposure (minutes), is a narrowing of the airways (called bronchoconstriction)". This may be accompanied by wheezing, chest tightness, and shortness of breath, which may require use of medication that opens the airways. Symptoms increase as sulfur dioxide levels or breathing rate increases. At very high levels, sulfur dioxide may cause wheezing, chest tightness, and shortness of breath even in healthy people who do not have asthma.

Table 5: Spatial Analysis of Air Quality Index during the Dry Harmattan Weather

	CO		SO_2			PM_{10}		
	WHO/ USEPA %	NESREA %	WHO %	USEPA %	NESREA %	WHO %	USEPA %	NESREA %
Northern Part								
Good	29.41	41.18	11.76	23.53	29.41	0	0	17.65
Moderate	11.76	29.41	0	29.41	35.29	0	17.65	11.76
Sensitive	23.53	5.88	0	11.76	17.65	0	5.88	35.29
Unhealthy	5.88	0	0	17.65	5.88	0	29.41	5.88
Very Unhealthy	5.88	17.65	5.88	5.88	11.76	17.65	17.65	23.53
Hazardous	23.53	5.88	82.35	11.76	0	82.35	29.41	5.88
Southern Part								
Good	25.00	50.00	6.25	31.25	43.75	0	0	12.50
Moderate	18.75	25.00	6.26	31.25	31.25	0	18.75	25.00
Sensitive	18.75	6.25	0	12.5	18.75	0	12.50	25.00
Unhealthy	12.50	6.25	6.25	18.75	6.25	6.25	25.00	25.00
Very Unhealthy	0	12.50	0	6.25	0	12.5	18.75	12.50
Hazardous	25.00	0	81.25	0	0	81.25	25.00	0

Source: Fieldwork (2019)

The result shows that USEPA standard have 12.12% of the sites AQI being unhealthy for sensitive group, whereas NESREA standard shows 18.18%. Also, NESREA standard shows that 24.24% of the sites air quality is unhealthy, whereas USEPA standard shows only 6% to be unhealthy, the unhealthy sites are more in the southern part of the study area than the northern part. 2% of the sites are unhealthy and hazardous base on both the USEPA and NESREA standard, found mostly in the northern part of the metropolis (Figures10 and 11).

Further probe reveals that the 33% of the traffic sites are safe base on both USEPA and NESREA standard, however, WHO standard shows that all the traffic sites are unsafe. While about 45% of the traffic sites are unhealthy base on USEPA standard, whereas NESREA standard shows the same 45% of the traffic sites to be unhealthy only for sensitive group of people. Also 50% of the industrial sites are unhealthy base on USEPA standard whereas, NESREA standard shows only about 25% of the sites to be unhealthy.

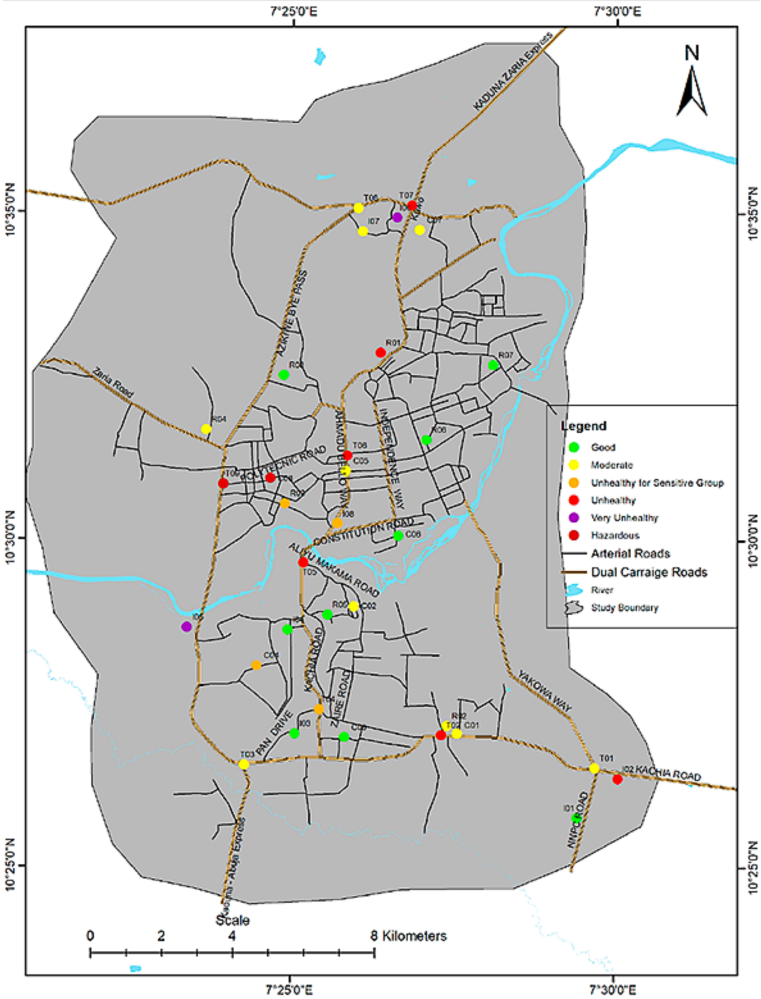

Figure 10. Spatial Analysis of SO_2 AQI for Harmattan Weather Basedon USEPA Standard

Source: Fieldwork (2019)

The emission level of SO2 is safe in the commercial area except for Kasuwan Barchi which shows a very unhealthy and hazardous AQI base on NESREA and USEPA standards respectively. Equally the emission level of the SO2 in residential areas are safe except for Ungwan Shanu area which shows an unhealthy AQI base on USEPA standard and unhealthy for sensitive group base on NESREA standard.

PM_{10}: The results reveal that the AQI for PM_{10} during the harmattan weather in Kaduna Metropolis ranges from good to hazardous. This result agrees with the submission of Saniei et al. (2016) and Chizoruo (2017), who's finding equally shows an AQI which ranges from moderate to hazardous. The study findings base on NESREA standard reveals that about 40% of the sites are safe, while USEPA standard shows that only about 25% of the sites to be safe, which are randomly distributed in both the northern

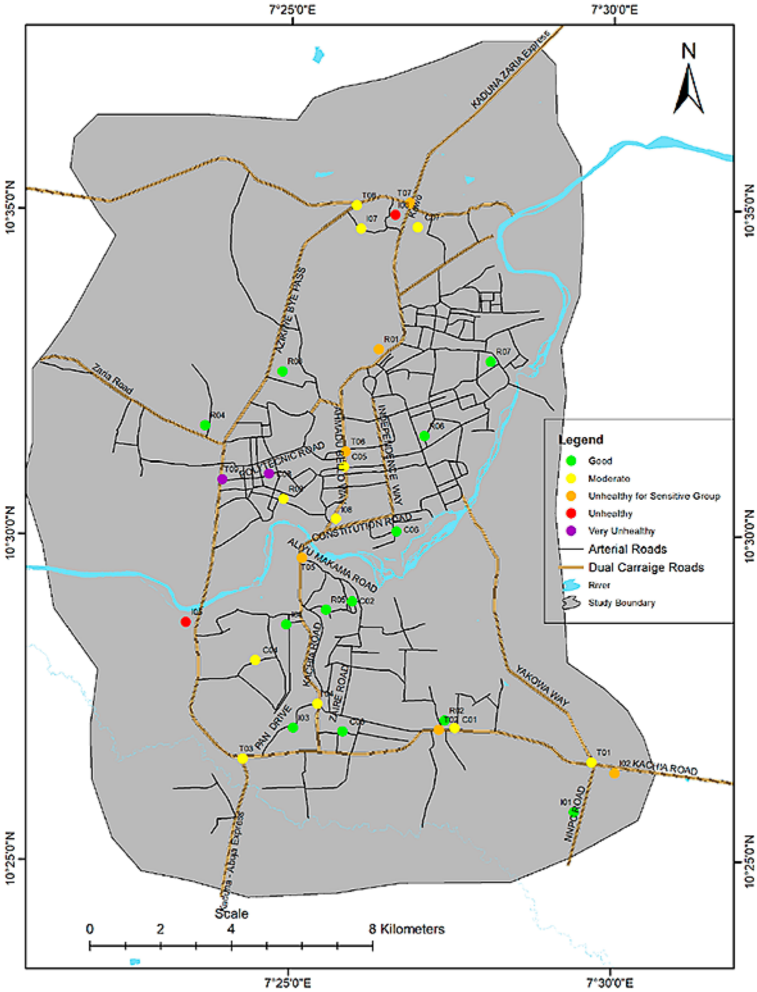

Figure 11. Spatial Analysis of SO_2 AQI for Harmattan Weather base on NESREA Standard

Source: Fieldwork (2019)

and southern part of the metropolis. Also, 9.09% and 30% of the sites are unhealthy for sensitive group of people base on USEPA and NESREA standard respectively. Equally 27.27% and 15.15% of the sites are unhealthy base on USEPA and NESREA standard respectively. 18.18% of the sites are very unhealthy base on both the USEPA and NESREA standard. And a good number of the sites about 27.27% are hazardous base on USEPA standard, while the NESREA standard shows only 1 of the sites is hazardous, equally the hazardous sites are mostly found in the northern part of the metropolis. whereas, WHO standard shows that about 82% of the sites are hazardous and spatially distributed in both the northern and southern part of the metropolis. This implies that most of the sites are unsafe for human beings and equally affects the natural functioning of the environment. This aggress with the submission of Notardonato, Manigrasso, Pierno, Settimo, Protano, Vitali, ... and Avino, P. (2019) that particular matter emission is mostly as result of fossil fuel emission, and that of Emetere, (2016) which shows higher aerosols (particulate matter concentration during the dry harmattan weather in northern Nigeria cities mostly as result of the north east trade wind.

Thus, may cause people with heart disease to experience chest pain, palpitations, shortness of breath, and fatigue. people with existing lung disease may not be able to breathe as deeply or vigorously as they normally would. They may experience symptoms such as coughing and shortness of breath. Healthy people also may experience these effects, although they are unlikely to experience more serious effects. Further probe reveals that most of the traffic sites are hazardous base on WHO and USEPA standard, while NESREA standard shows that only Dustema junction is hazardous. Also, 25% of the industrial sites are safe based on USEPA standard while NESREA standard shows more industrial sites 50% to be safe. Also, none of the commercial sites PM10 concen-

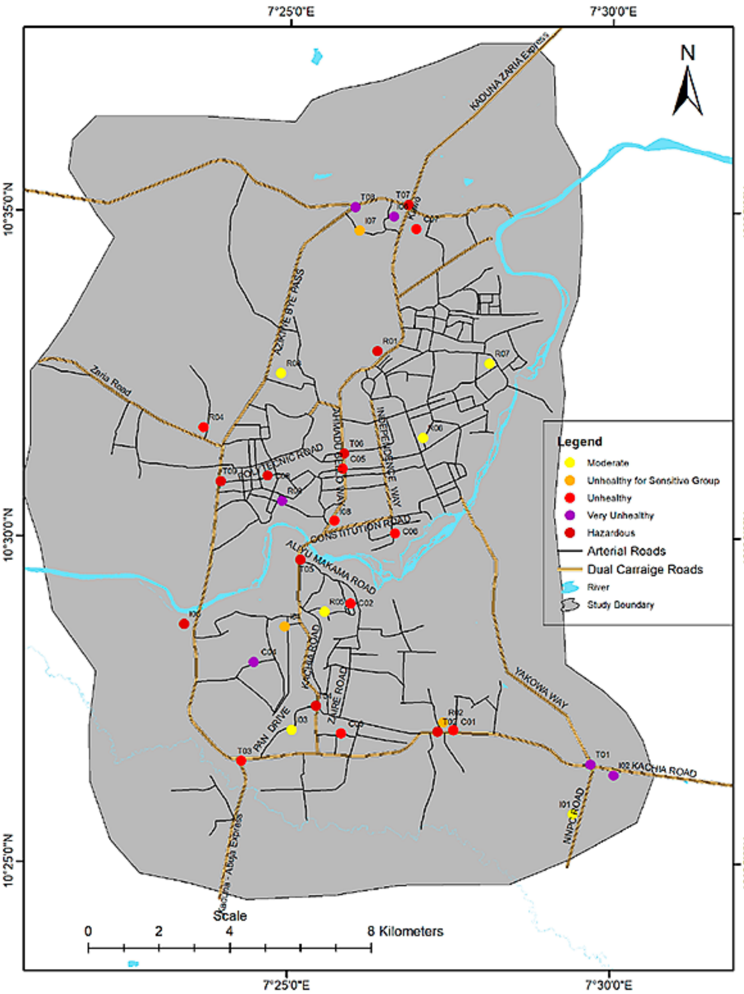

Figure 12. Spatial Analysis of PM_{10} AQI for Harmattan Weather base on USEPA Standard

Source: Fieldwork (2019)

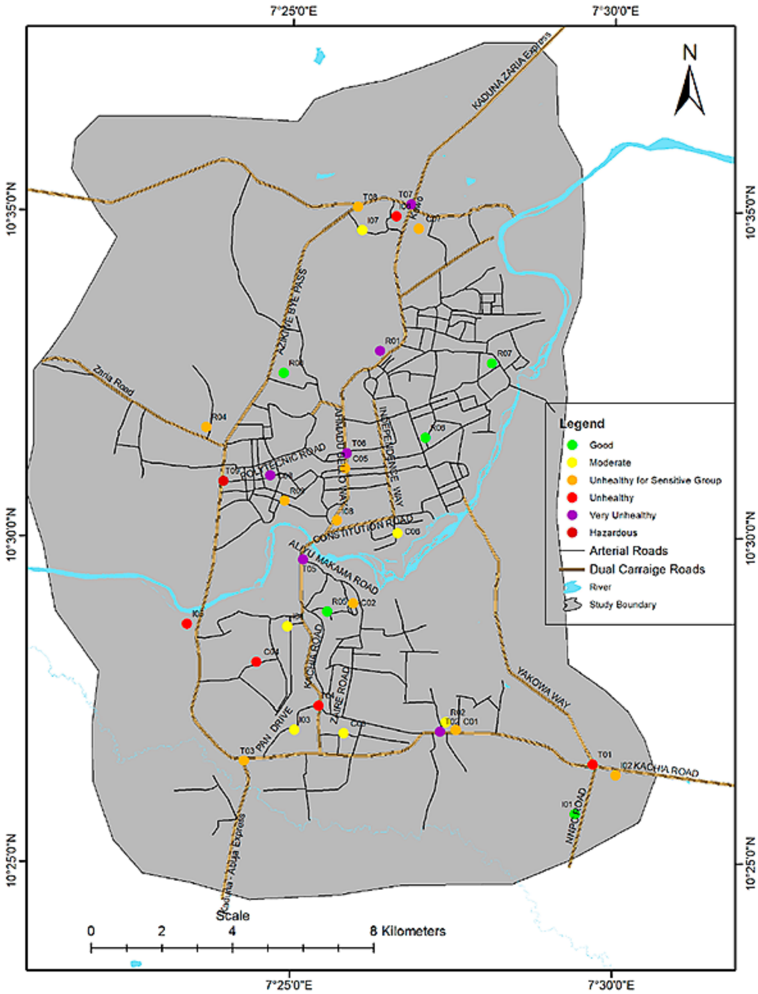

Figure 13. Spatial Analysis of PM_{10} AQI for Harmattan Weather base on NESREA Standard

Source: Fieldwork (2019)

tration is safe for human existence's base on USEPA standard, while NESREA standard shows that the AQI index in 2 of the commercial sites is moderately safe. Equally Base on NESREA standard the AQI for the residential sites are safe except for Ungwan shanu site which is very unhealthy, whereas only the GRA sites AQI is safe base on USEPA standard. also, more of the unsafe sites are found in the northern part of the metropolis.

CONCLUSION

The findings from this study shows that air quality in Kaduna metropolis have deteriorated with Air Quality Index ranging from good to hazardous. Residence and commuters are exposed to this level of pollution by chemicals such as CO, SO_2 and PM10 which are detrimental to human wealth being. Understanding of the spatial distribution of the implication of the AQI in the metropolis will aid residence and commuters plan their daily activities in manners that will be less detrimental to their wealth being and will equally aid in the planning for the control of toxic emission in Kaduna metropolis.

CO has 57.57% and 24.24% of the sites AQI ranging from unhealthy to hazardous based on WHO/USEPA and NESREA standards respectively. Equally SO_2 has about 91%, 34.23%, 42.42 of the sites AQI ranging from unhealthy to hazardous base on WHO, USEPA and NESREA standards respectively. PM_{10} has 75.76% and 18.18 of the sites AQI as hazardous base on WHO and USEPA standards, whereas none of the sites AQI is hazardous base on the NESREA standard. further analysis shows that the northern part of the metropolis has more sites with unhealth AQI than the southern part of the metropolis. The temporal analysis for the seasonal variations shows that Air Quality Index for the concentration of CO and SO_2 shows more unhealthy side in the raining season than in the dry harmattan weather. However, the AQI for PM_{10} shows more unhealthier sites during the dry harmattan weather than during the raining season. Also, the study concludes that most of the unhealthy AQI are within traffic areas, whereas, most of the healthy sites were within residential areas. This shows that most of the unhealthy AQI are as result of the burning of fossil fuels within the metropolis. thus, the need to strongly enforce existing laws guiding ambient emission in Kaduna metropolis and also to provides a more efficient transport system that will make the use of private vehicles less attractive will go a long way in improving the air quality index of the metropolis.

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CONFLICTS OF INTEREST

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