

transportation, and acid rain [Cohen et al., 2004; Cohen et al., 2005; Dyominov and Zadorozhny, 2005; Jain et al., 2008; Ramanathan and Feng, 2009]. Exposures to common air pollutants have been linked to a wide range of adverse health outcomes, including respiratory and cardiovascular diseases, asthma exacerbation, reduced lung function and premature death [Touloumi et al., 2004; Clougherty et al., 2008; Jain et al., 2008; USEPA, 2009; Gulliver and Briggs, 2011; WHO, 2011; Brezzi and Sanchez-Serra; 2014].

The ability to understand the patterns and magnitude of pollution in the urban environment is increasingly important [Smallbone, 1998; Mwenda, 2011] and many developed countries of the world have in place programmes for monitoring urban air pollution. These were done by operating a certain number of monitoring stations located in several sites [Allegrini and Costabile, 2002], which is however lacking in developing countries like Nigeria. There are no proper records or documentation in the urban atmosphere in these countries despite having the fastest growing urban populations [Rahmatizadeh et al., 2003]. This is because that the cost of establishing and implementing ordinary monitoring systems is extremely high; use of analytical instruments are time-consuming, expensive, and can seldom be applied for real-time monitoring in the field, even though these can give a precise analysis [Hadjimitsis et al., 2012]. Urban traffic-related air pollution is becoming problematic because of continuing uncertainty about the causal agents, the likelihood of important interactive and cumulative effects from different pollutants, high levels of both spatial and temporal variability in pollutant concentrations and a dearth of monitoring data [Bellander et al., 2001; Zhu et al., 2002; Briggs, 2007; Banja et al., 2010; Enkhtur, 2013]. Against this background, there is a need for improved information on levels of traffic-related air pollution which can be used to help investigate the relationship involved as inputs to health risk assessment, to assist in establishing and monitoring air quality standards [Raju et al., 2012; Dons et al., 2013]. It has been established that the measuring urban air pollutants requires a spatio-temporal data management, which is provided by advances in geographic information systems (GIS) and earth observations [Wu, 2006; ESRI, 2007; Hadjimitsis et al., 2010; Dubey, 2014; Sameen et al., 2014]. GIS-based pollution mapping, using interpolation techniques, such as inverse distance weighting and kriging have proved efficient in the assessment of urban air pollution [van der Kasstele, 2006; ESRI, 2007; Chattopadhyay et al., 2010]. Air pollution maps are potentially powerful tools particularly for urban areas for use in epidemiological studies and in identifying the "hot-spots" in need of special investigation or monitoring [Matejicek, 2005; Ettouney et al., 2009; Banja et al., 2010; Sampson et al., 2011; Sameen et al., 2014]. Integrating spatial analysis in GIS and statistical modelling can help the

researcher to expand the understanding concerning the distribution of the pollutants in some locations or areas and to understand the factors that influence the trends and significance [Rahman et al., 2015]. Estimation of small-area variations in traffic pollution are important to the exposure experience of the population and may detect health effects that would have gone unnoticed with other exposure estimates [Watmough et al., 2014]. Despite 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], hence the collection of accurate and reliable data necessary for the evaluation of urban air quality is therefore very important. This study aim to collect, analyze and map the gaseous traffic related air pollutants (CO , NO_x , NO_2 and SO_2) at road junctions, intersections, and motor garages in order to facilitate the management of air pollutions in the study area.

2. The Methods

Ijebu-ode is the second largest city in Ogun State, southwest Nigeria with about 192 km² of land. It is approximately located between latitudes 6° 42' N and 6° 54' N and longitude 3° 55' E and 4° 6' E (Figure 1) with an average elevation of 120 metres. The climate fall into two distinct seasons i.e. the harmattan season (November to March) and the raining season (April to October) interrupted by short August break. The rains reach its peak in the months of June and September. The mean annual rainfall is about 1590 mm; with an average annual temperature is 27.5°C. The city is situated about 110 km by road northeast of Lagos the commercial nerve centre of Nigeria and about 53 km southeast of Ibadan, the second largest r city in Africa. It has an estimated population of 222,653 as at 2007 (NPC, 2006), comprising people from different parts of the country with and population density of 481 persons per hectare. Owing to its strategic location, the city has continued to expand with physical and social infrastructural developments. The development of the city has been rapid in the past 20 year due to influx of people, industries and schools.

Air pollution sampling

Gaseous traffic related air pollutants (CO , NO_x , NO_2 and SO_2) were chosen as indicators of urban traffic related air pollution in the study area. The spatial and temporal of traffic related air pollution in Ijebu-ode, Nigeria is investigated based on ambient air quality levels in wet and dry seasons. Air quality measurements took place at all selected locations within Ijebu-ode in May-July 2013 (wet season) and October-December 2013 (dry season).

The designated locations were chosen after reconnaissance survey to ascertain the characteristics and distribution of pollutant sources as well as the traffic

Table 1. Characteristics at A Selection of The Monitoring Sites/Street in The Study Area

Street name	Speed limit (km/h)	Configuration	Traffic volume (day-1)
Alapo/Fidipote Junction	30 km/h	1 lane, Residential	Medium 2000-3000
Balogun Kuku/Oke Aje Junction	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
Epe Garage Roundabout	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
Erinlu/Molipa Roundabout	50 km/h	2 lanes, commercial and residential	Light 1000-2000
FCMB/Imepe Junction	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
Ibadan Garage	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
Lagos Garage Roundabout	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
New Market Park	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
Oke-Aje Market	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
Oke-Owa/Ikoto./Ilese	50 km/h	1 lane, commercial and residential	Medium 2000-3000
Oyingbo/Olisa Junction	50 km/h	2 lanes, commercial and residential	Light 1000-2000
Sabo Junction	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
Sagamu/Ore_Expressway Junction	80 km/h	2 lanes, commercial, major highway	Heavy > 3000
Stadium/Oke Aje Junction	50 km/h	2 lanes, commercial and residential	Medium 2000-3000
Taused/Igbeba Junction	30 km/h	1 lane, residential, schools	Medium 2000-3000

Source: Traffic survey 2013.

a simple and straightforward manner. The concept of air quality index (AQI) has been developed and used effectively in many industrialized countries for over last three decades. AQI is defined as an overall scheme that transforms the weighted values of individual air pollution related parameters such as sulphur dioxide (SO₂), nitrogen dioxide (NO₂) and particulate matter < 10µm (PM10), etc., into a single number or set of numbers. The AQI is a single number reporting the air quality with respect to its effects on human health [Bortnick et al., 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 [EPA, 2006].

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

where

- Ip = the index for pollutant p
- Cp = the rounded concentration of pollutant p
- BPHi = the breakpoint that is greater than or equal to Cp
- BPLo = the breakpoint that is less than or equal to Cp
- BPHi = the breakpoint that is greater than or equal to Cp
- IHi = the AQI value corresponding to BPHi
- ILo = the AQI value corresponding to BPLo

3. Result and Discussion

The study revealed that major parts of the city are experiencing high concentration of gaseous pollutants mainly from traffic related emission which are in excess of the maximum levels allowable under WHO guidelines. Figure 2 shows the map of the urban road network and traffic volume in the study area. The average hourly number of vehicles running on the main roads in the city ranges from 1000 to above 3000 vehicles/day. Summary statistics of pollution concentrations within the study area are given in Table 2. A clear distinction is observed between the spatial distribution of these pollutants at locations such as the Sagamu/Ore Expressway, Oke-Aje Market and Oke-Owa/Ikoto/Ilese which have high concentration of CO: 13.7, 12.7 and 10.5 ppm respectively compared to other areas.

Concentrations of NO₂ in the study area range from 100-662 ppb with an overall average value (OAV) of 299.8 ppb, while concentration of nitrogen oxide (NO) ranges between 67-302 ppb an overall average value (OAV) of 166.23 ppb. Sulphur dioxide, which is a predominately anthropogenic pollutant had a concentration ranging between 38-245 ppb and an overall average value (OAV) of 139.07 ppb (Table 2). Traffic congestion in the rush hours especially in the morning and evening periods within Ijebu-ode and along major highways surrounding the city are major contributors to the CO, NO_x, NO₂, and SO₂ levels in the air. Several studies have attributed motor vehicles as the major source of nitrogen oxides (NO_x) emitted to the atmosphere in most industrialized countries where road length and traffic volumes are increasing [CMRTHS, 2013;

in the study area (Figures 3-6). Concentration of air pollutants such as CO is higher around Sagamu/Ore Expressway, Oke-Aje Market, Stadium/Oke Aje Junction, New Market Park and Oke-Owa/Ikoto/Ilese road which always have high concentration of traffic. Mean concentration of nitrogen oxide (NO) was almost uniform in all locations in the study area (Figure 4) ranging from 67-302 ppb. The spatial patterns of ambient concentrations of pollutants (Figure 3)

shows highest concentration of CO around the south-eastern part of the metropolis which is noted for high concentration of luxurious buses, trailers and tankers that uses diesel as fuel. The vehicles are often plying the roads or parked along the highways releasing lots of CO from their exhaust pipes. High concentration of NO, NO₂ and SO₂ were along found around these specific areas and can be attributed to high volume of traffic.

Table 2. Concentration of Pollutants Within Selected Areas in The City

Location	Abbreviation	Latitude	Longitude	NO	NO ₂	SO ₂	CO
Abasi Olisa/Central Mosque Junction	ACJ	6.81766	3.916136	100	123	156	5.7
Adeola Odutola/Water Junction	AWJ	6.824951	3.907805	97	130	202	9.2
AGGS/Police Station Junction	APJ	6.832251	3.90569	76	100	67	7.3
Alapo/Fidipote Junction	AFJ	6.822862	3.912175	234	421	234	9.02
Awokoya/Bonojo Junction	ABJ	6.831854	3.924758	109	120	231	8.23
Balogun Kuku_Oke Aje Junction	BKO	6.814568	3.929744	124	203	110	9.1
Bonojo/Lekuti Junction	BLJ	6.824464	3.924756	143	212	87	5.3
Classic Hotel Roundabout	CHR	6.851995	3.935237	99	170	202	6.2
Degun/Molipa Junction	DMJ	6.828811	3.916506	99	150	189	10.5
Epe Garage Roundabout	EGR	6.812152	3.930823	201	506	202	11.2
Erinlu/Molipa Roundabout	EMR	6.839881	3.902179	67	100	219	4.8
FCMB/Imepe Junction	FIJ	6.812367	3.912684	221	455	220	5.2
Folagbade/New Road Roundabout	FNR	6.824951	3.919002	187	300	176	6.8
High Court/Prison Junction	HPJ	6.821417	3.928478	132	230	90	8.2
Ibadan Garage	IBG	6.834461	3.921871	170	300	210	10.9
Lagos Garage Roundabout	LGR	6.810567	3.910477	298	606	245	11.8
New Market Park	NMP	6.816219	3.91312	212	346	145	12.3
Obalende Garage	OBG	6.83115	3.906206	200	304	123	11.02
Ogbogbo/Igbeba Road Junction	OIJ	6.846302	3.946556	106	107	101	10.1
Oke-Aje Market	OAM	6.82022	3.930709	208	372	92	12.7
Oke-owa/Ikoto.Ilese	OII	6.806006	3.939301	172	209	79	10.5
Osinubi/Bonojo Roundabout	OBR	6.822482	3.924966	149	256	38	9.02
Ososa Junction	EOJ	6.805987	3.875384	227	458	88	12.8
Oyingbo/Olisa Junction	OOJ	6.815758	3.915332	208	442	102	10.6
Post Office/Ita-Ale Roundabout	PIR	6.819568	3.916918	99	278	44	9.12
Sabo Junction	SAJ	6.818163	3.90629	238	508	101	11.2
Sagamu_Ore_Expressway Junction	SOE	6.791604	3.943007	302	662	230	13.7
Stadium/Oke Aje Junction	OMR	6.818703	3.933694	202	322	78	9.7
State Hospital Roundabout	SHR	6.813942	3.925609	107	296	66	8.34
Taused/Igbeba Junction	TIJ	6.829573	3.933988	200	308	45	9.6
MAX				302	662	245	13.7
MIN				67	100	38	4.8
AVG				166.23	299.8	139.07	9.34

Air quality index (AQI)

The air quality index (AQI) rating for three principal air pollutants in selected parts of the study area are tabulated in Table 3. The table also showed the AQI categories of each of the pollutants. NO_2 , SO_2 and CO are major air pollutants in the study area as their concentration levels mostly falls within the AQI categories that is unhealthy for sensitive groups and generally unhealthy to all categories of people in the area. For this study, the monitoring process took place during the rush hour when vehicular traffic is expected to increase due to increased traffic density. Most of the areas shown in the table are road intersections, roundabout and areas of concentration of traffic where large volume of traffic including motor vehicles, tricycles, motorcycles, trailers and various truck crowd every day. Pollution in the area is aggravated by the incessant and intractable traffic congestion especially during the early hour between 7.00 a.m. to 10.00 a.m. in the morning and between 3.00 p.m. and 5.00 p.m. in the evening.

Many of the vehicles plying the roads are not in good condition of services thus emitting huge volume of poisonous gases into the atmosphere. The air quality in these areas continue to worsen due to increase in the number of motorcycles popularly called Okada used as informal means of commercial transportation within the city. The motorcycles that are banned in some other countries because of their level of pollution are far more than taxis in number in the city. High emissions from vehicles are caused by leaking valve shafts and loose piston rings that lead to a leaking of oil into the combustion chambers of the engines. The uncombust oil releases blue plumes, bad odour and unburnt hydrocarbons. This indicate the fact that vehicular emission in typical mega cities constitutes 60% of total pollutant emission compared to industry, power plant, etc. [Abam and Unachukwu, 2009]. In terms of AQI, the results of this indicate very unhealthy air quality in the street of the study area especially at road intersection, roundabout, market areas and motor parks that usually have high concentration of humans.

Figure 3. Concentration of CO along major roads in Ijebu-ode.

Figure 4. Concentration of NO_2 along major roads in Ijebu-ode.

Figure 5. Concentration of NO_x along major roads in Ijebu-ode.

Figure 6. Concentration of SO_2 along major roads in Ijebu-ode.

This will pose significant human risk due to exposure to air pollution in urban microenvironment. Annual mean concentrations of NO₂ in urban areas are generally in the range of 10-45 ppb (20-90 µgm-3), which vary significantly throughout the day, with peaks generally occurring twice daily as a consequence of “rush hour” traffic. Figure 7 shows the percentage contribution of each of the pollutants to air pollution in selected sampling stations. NO and NO₂ together contributed more than 60 % of the pollutant inn majority of the area studied. Table 4 shows the correlation among the different pollutants and traffic volume. It indicated positive correlation between the pollutants and traffic volume showing that the pollutants are primarily from traffic related emissions.

Table 4. Pearson Correlation of Selected Pollutants and Traffic Volume

	Traffic Volume	NO	NO2	SO2	CO
Traffic Volume	1				
NO	0.613	1			
NO2	0.513	0.924	1		
SO2	0.14	0.221	0.38	1	
CO	0.534	0.605	0.525	-0.162	1

4. Conclusion

Results from this study show that air quality in the study area is on the increase as a result of traffic-related pollution. Many residents are exposed to dangerous levels of air pollution by pollutants such as CO, NO, NO₂ and SO₂ which may affect their health significantly. Knowledge of the interactions among these gases is crucial to understanding their

Table 3. Concentration of Pollutants Within Selected Areas in The City

Location	NO ₂ (ppb)			SO ₂ (ppb)			CO (ppm)		
	Conc.	AQI	AQI category	Conc.	AQI	AQI category	Conc.	AQI	AQI category
AFJ	421	161	Unhealthy	234	171	Unhealthy	9.02	96	Moderate
BKO	203	120	Unhealthy for Sensitive Groups	110	116	Unhealthy	9.1	97	Moderate
EGR	506	176	Unhealthy	202	158	Unhealthy	11.2	130	Unhealthy for Sensitive Groups
EMR	100	100	Moderate	219	165	Unhealthy	4.8	54	Moderate
FIJ	455	165	Unhealthy	220	165	Unhealthy	5.2	58	Moderate
IBG	301	139	Unhealthy for Sensitive Groups	210	161	Unhealthy	10.9	125	Unhealthy for Sensitive Groups
LGR	606	193	Unhealthy	245	176	Unhealthy	11.8	140	Unhealthy for Sensitive Groups
NMP	346	147	Unhealthy for Sensitive Groups	145	132	Unhealthy for Sensitive Groups	12.3	148	Unhealthy for Sensitive Groups
OAM	372	153	Unhealthy	92	108	Unhealthy for Sensitive Groups	12.7	154	Unhealthy
OII	209	121	Unhealthy for Sensitive Groups	79	102	Unhealthy for Sensitive Groups	10.5	118	Unhealthy for Sensitive Groups
OOJ	442	165	Unhealthy	102	113	Unhealthy for Sensitive Groups	10.6	120	Unhealthy for Sensitive Groups
SAJ	508	176	Unhealthy	101	112	Unhealthy for Sensitive Groups	11.2	130	Unhealthy for Sensitive Groups
SOE	662	203	Unhealthy	230	169	Unhealthy	13.7	171	Unhealthy
OMR	322	143	Unhealthy for Sensitive Groups	78	102	Unhealthy for Sensitive Groups	9.7	104	Unhealthy for Sensitive Groups
TIJ	308	140	Unhealthy for Sensitive Groups	45	62	Moderate	9.6	103	Unhealthy for Sensitive Groups

atmospheric concentrations and lifetimes and the environmental impacts that can be expected with modifications to their sources and sinks. In order to address the problems of traffic-related air pollution in the study area, there should be establishment of a national fuel quality standard to be supported by tighter vehicle emission standards. Concerted efforts should be made towards developing and promoting alternative fuels and encouraging the use of non-motorized forms of transportation within cities. In countries like Nigeria, there is the need to establish and strengthen the health-based standard for air pollutants. The new standard will protect public health, including the health of sensitive populations such as people with asthma, children and the elderly.

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