Real-Time Quantitative Assessment of Transport Induced Greenhouse Gases Emissions Profile in Lagos, Nigeria.

Chinenye Lilian Okafor (chinenyeokafor2017@yahoo.com)
Lagos State University https://orcid.org/0000-0002-0911-2645
Michael A Ahove
Lagos State University
Samuel G Odewumi
Lagos State University
Michael MacCracken
Climate Accountability Institute
Babatunde Odesanya
Caleb University

Research

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Abstract

Over the years, scientists have established that when fossil fuels are burnt, the resultant effect is pollution of the ambient air with pollutants such as carbon monoxide (CO), methane (CH_4), oxides of nitrogen (NO_X), oxides of sulfur (SO_X), volatile organic hydrocarbons and particulate matter and atmospheric greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4) and heat-warming or cooling aerosols such as black soot and sulfate aerosols, respectively. These pollutants become present in the atmosphere at a concentration that can affect human health, the environment, and even society as a whole. Since around 1750, human activities have increased the concentration of CO_2 and other greenhouse gases in the atmosphere by many tens of percent over the last two centuries. The Federal Government of Nigeria, through the office of National Environmental Standards and Regulation Enforcement Agency (NESREA), established guidelines and standards (limits) for the abatement and control of all forms of pollution through the establishment of Nigerian Ambient Air Quality Standards (NAAQS). Different studies on the impacts of urban road transportation on ambient air quality carried out by scholars have suggested that most pollutant gases in the atmosphere are traffic-related as a result of the combustion of petroleum-based products like gasoline and diesel in internal combustion engines. This study deployed a quantitative technique to determine the emissions profile of transport nodes in Ikeja, Lagos through the use of AEROQUAL 500s portable air monitoring equipment. Results showed that CO, CO_2 and CH_4 emissions were highest during the AM peak and PM peak periods and lower during the inter-peak period, while NO_x emissions were relatively stable throughout the time periods.

1. Introduction

When fossil fuels are burnt, the resultant effect is pollution of the ambient air with pollutants such as carbon monoxide (CO), methane (CH_4), oxides of nitrogen (NO_X), oxides of sulfur (SO_X), volatile organic hydrocarbons, particulate matter and atmospheric greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4) and heat-warming or cooling aerosols such as black soot and sulfate aerosols, respectively. With the growth in the use of fossil fuels, a number of these pollutants are now present in the atmosphere at concentrations that can affect the environment and society as a whole. Monitoring the concentrations of these pollutants therefore has become an essential step in maintaining a set standard. Table 1 shows the ambient air quality standards in Nigeria.

Table 1
Nigerian Ambient Air Quality Standards

Pollutant	Average time	Standard limit
Particulate matter	1-hour average	250μg/m^3
Sulphur oxides (sulphur dioxide)	1-hour average	0.01ppm (26μg/m^3)
Non-methane hydrocarbon	3-hour average	160μg/m^3
CO	8-hour average 1-hour average	10ppm-20ppm(11.4μg/m^3 22.8μg/m^3(Nigerian NAAQs) 9ppm (US NAAQs) 35ppm
Nitrogen oxides (Nitrogen dioxide)	1-hour average	0.04ppm-0.06ppm (75.0μg/m^3-113μg/m^3)
CO_2	1-hour average	20,000ppm
Sources: Adeyanju & Manohar [3], Olajire, Azeez & Oluyemi [12], Soneye [15], Ndoke & Jimoh [8]		

According to EPA [5], monitoring is a term used for an on-going collection and use of measurement data or other type of information to assess performance against a set standard with respect to a specific requirement. They further classified monitoring into two different types based on their functions:

- Ambient air quality monitoring, which collects and measures samples of surrounding air pollutants to evaluate the state of the atmosphere as compared to clean air standards. This type of monitoring is required to determine whether a geographical location is meeting the National Ambient Air Quality Standards (NAAQs) for criteria pollutants.
- Stationary sources emissions monitoring, this also collects and uses measurement data to determine responsibility for emissions from stationary sources. This type of monitoring is thus required to demonstrate that a particular emitting source is meeting the requirements set in Federal or State regulation.

According to Ibe, Opara, Njoku *et al.*,[7], atmospheric air quality is dependent not only on the quantity of pollutant in the atmosphere but also on the prevalent air/weather conditions as this will affect the ability of the atmosphere to concentrate, disperse, or chemically destroy the species that are emitted. Some of the prevailing conditions that can make a difference include temperature, relative humidity, wind speed and direction, and chemical makeup. In view of these prevailing atmospheric conditions, most air quality assessment and monitoring is done by measuring the pollutant gas concentrations and aerosol loadings along with temperature, relative humidity, wind speed and direction (Ibe, Opara, Njoku *et al.*, [7]).

Hena [6] reported the results of the investigation of vehicular emissions in selected areas in Calabar South of Nigeria. Each of the five monitored air pollutants were found to be present at an unacceptable level when compared with Air Quality Index (AQI) level: CO was found to vary from poor to moderate and moderate to poor air quality in different locations, also SO_2 varied from very poor to poor; NO_2, from very poor to poor, and PM10 and noise level were poor at all locations. The study pointed out that air pollution in Calabar city as a result of transportation is very noteworthy and likely leading to health consequences.

Furthermore, Hena [6] also reported another study from the North West of Nigeria -Kano, using the Crowcon gas sensor to collect emission values of various gases. The results showed the concentrations of NO_2, CO, H_2S, and SO_2, with just minor exceptions, at some sampling locations and during the dry season were beyond the AQI threshold stipulated by United States Environmental Protection Agency (USEPA). The study implied that emissions from road transportation within the city of Kano are not within safe limits. Hence, the transport-related pollution in Kano metropolis is significant with potentially hazardous health consequences. Ndoke & Jimoh [8] came to a conclusion, from their study on the impact of traffic emissions on air quality in Minna North Central Nigeria, that the high CO concentration (15ppm) was a little lower than the Federal Environmental Protection Agency (FEPA) limit of 20ppm and could be solely attributed to vehicular emissions. They further pointed out that the CO_2 concentration of 5,000ppm (which is about 12 times the global background concentration) in Minna was still lower than the 20,000ppm limit for congested areas stipulated by the World Health Organization (WHO). A study on the impact of urban road transportation on ambient air was reported by Olajire, Azeez & Oluyemi [12] on three cities in southwest Nigeria these are Lagos, Ibadan and Ado-ekiti. Not surprisingly, Lagos was found to have the highest levels of air pollution with concentrations of CO (233ppm) and SO_2 (2.9ppm) at Idumota in Lagos Island. At Iyana-Ipaja, the concentration of NO_2 was 1.5ppm. These results were seen to be higher than the FEPA limits of CO: 10ppm, SO_2: 0.01ppm, NO_2: 0.04-0.06ppm; clearly indicating the growing risk of traffic-related pollution problem in Lagos and the need for serious emissions control measures as Lagos continues to emerge as a mega city. All these factors contributed to the basis for undertaking this study aimed at determining the emissions profile for some selected areas in Ikeja Lagos.

Over the years, air pollution has become a more serious environmental problem for urban areas around the world (Olajire, Azeez & Oluyemi [12]) especially with the ever-increasing need for fossil fuel whose end products after a complete and/or incomplete combustion activity is detrimental to man and the environment. The energy from these fossil fuels over the years gave rise to a rapid industrial growth with Greenhouse Gas (GHG) emissions as end product inducing global warming which has resulted into what is now referred to as anthropogenic climate change (Ahove & Bankole [1]). Globally, various monitoring programs have been undertaken to evaluate air quality and these have generated vast amounts of data on the concentration of each air pollutant. Often at times, however, these large data sets do not effectively 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. This limitation is usually addressed by summarizing the results in terms of Air Quality Index (AQI) for the particular area. AQI, which is also referred to as an Air Pollution Index (API) as in Olajire, Azeez & Oluyemi [12], has been developed and disseminated by many agencies in US, Canada, Europe, Australia, China, Indonesia, Taiwan, etc. (Cheng, Chen, Zhang *et al.*, [4]).

Njoku, Rumide, Akinola *et al.*, [9] in their study opined that several factors like increasing population density, increased vehicular usage, use of fuels with poor environmental performance, poor maintenance of existing transport systems and ineffective

environmental regulations and policies have contributed to increased air pollution in the urban centers. This was also found in a study by Olajire, Azeez & Oluyemi [12] that investigated the exposure of pedestrians to hazardous air pollutants and unwanted noise when walking along the popular Oba Akran road of Ikeja city. To do this, the impact of industrial and vehicular emissions on ambient air was monitored *in situ* in three locations along Oba Akran road. In each location, CO, NO_2, O_3, SO_2, noise, CH_4, PM10 and meteorological parameters like temperature and wind velocity were measured. The concentrations of CH_4 were determined using a BW Gas Alert micro 5 PID (USA), CO was measured using CHY 670 analyzer (USA), NO_2 by Toxi RAE 11 PGM 1150, SO_2 by Toxi RAE PGM 1130 (USA), temperature and wind velocity by Flexible thermometer and anemometer and locations were determined by GPS 12-channel (USA). Measurements of PM10, wind, temperature and HAPs were averaged over multiple days to determine the corresponding exposure levels at each location in the morning, afternoon and night. They concluded that the relatively high exposure levels of CO and PM10 in Oba Akran road were highly traffic-related and resulted in levels that posed possibly severe health consequences. Strong traffic impacts were very clear from the concentrations of these pollutants measured in the three locations, each of which was exposed to diesel truck traffic activity rich in black carbon concentrations.

In the study by Njoku *et al*, [9], CO, CO_2, O_2, SO_2, NO_X and NO were determined using an ITX multi-gas monitor with one-hour exposure time. Suspended Particulate Matter (SPM) at each location was measured using Personal data RAM-1200 (Park Davis), allowing a period of one hour to trap the suspended particulate matter to determine the reading record as the SPM. Their findings showed that measured levels of NO, NO_2, CO and SPM in all sampling areas were quite high and above the regulatory limits. The air quality index (AQI) further indicated that the ambient air could be described as poor for SPM and varied from good to very poor for CO, NO and NO_2. Overall, air quality was considered to be very good with the exception of some traffic intersections where they were considered both poor and very poor.

In a study by Osuntogun & Koku [14] on the impacts of road transportation on the ambient air and the health of residents of 16 heavily trafficked locations in Lagos, Ibadan and Ado-ekiti; CO, SO_2, NO_2 and suspended particles were the quantities measured using TOXI RAE-II reusable personal toxic gas monitors. Results obtained indicated that the highest level of CO (232ppm) and SO_2 (2.9ppm) were seen at Idumota Lagos; NO_2 (1.5ppm) at Iyana-ipaja bus stop; and total suspended particles (852ppm) at Oshodi bus stop. In Ibadan, CO (271ppm) and SO_2 (1.4ppm) were highest at Mokola round about while NO_2 (1.0ppm) was highest at the Bere round about. At Ado-ekiti, CO (317ppm) was highest at Oke Isha, SO_2 (0.8ppm) was highest at the old garage junction while NO_2 (0.6ppm) was highest at Ijigbo junction. The blood samples of people at these locations also showed a spike in lead concentration with the people reporting frequent cases of air pollution related diseases.

Soneye [15] investigated the concentrations of gases generated by petroleum products tank-farms along the popular Apapa-Oshodi Expressway Lagos, Nigeria. It assessed the levels of NO_2, CO and SO_2 around six bus stops through direct field measurements using ToxiRAE II system SO_2 and NO_2 concentration meters, a REED CO-180 CO meter for CO and Lutron LM-8000 for temperature, RH and wind speed. The results showed that there were no traces of NO_2 at the selected bus stops throughout February to July, as the measurements were taken for 15 wet days and 15 dry days of the entire study period. The absence of traces of NO_2 may be attributed to instrument detection limit, although this was not acknowledged by the author. NO_2 is expected since the entire study area is known to be a heavy traffic area as well as tank farms prone to heavy-duty vehicular emissions. SO_2 value of 0.4 ppm was recorded at some locations, which was above the regulatory limit, while some other locations recorded exactly the regulatory limit. CO was seen to be 3.2 ppm for the entire period and bus stops on the average which was below the regulatory limit.

Nkwocha, Ekeke, Kamalu et al., [10] on the other hand assessed air pollution levels from vehicular emission during the rainy season period. They selected three locations in the Port-Harcourt city noted for high traffic congestion. Air sampling was carried out for eleven days, covering both peak and off-peak periods. NO_x, SO_x, CO and unburnt hydrocarbons (C_xH_y), as well as some climatic elements like temperature and relative humidity, were recorded. Measurement of these air quality parameters was carried out using the Testo 350XL Emission Analyzer. The climatic elements - temperature and relative humidity were obtained using a Thermo-hydrometer- IT202. Results obtained indicated that SO_x was generally not detected; one of the locations experienced higher concentrations of NO_x and CO at evening peak periods and lower concentration of C_xH_y during morning periods, while the highest and lowest concentrations of SO_x were detected at another location during off peak and evening peak periods, respectively. Also, high concentrations of NO_x, CO, and C_xH_y were prominent at evening peak periods. According to them, the NO_x concentrations were

above the limit of 0.04-0.06ppm, for all the locations and periods monitored excluding the last location during peak periods. The level of CO was within local standard (10-20ppm) for the off-peak period but exceeded at peak periods in some locations.

In a study by Utang & Peterside [17], estimation of emissions from vehicles during traffic peak periods within some parts of the Port Harcourt city in Nigeria was carried out. Air quality parameters: CO, NO_X, SO_X, and C_xH_y were measured using a Testo 350XL Emission Analyzer. Results showed that the CO concentration in all the locations during the morning peak periods were within both local and international standards. The value of NO_x at 0.2ppm at their third location was above both local and international standards while the value of SO_x was within the local and international standards. The value of CO (25ppm) in their first location was above local standards but within international standards at all locations. NO_x was generally above the local and international standards in all the locations while the value of SO_x was within local and international standards.

A study by Obanya, Amaeze, Togunde *et al.*, [11] investigated the levels of air pollutants around residential areas and transport sector locations (TSLs) in Lagos, Nigeria. Air quality parameters were assessed in situ using a handheld air tester (CW – HAT 200). SO_2 was estimated with an ITX multi-gas monitor with an exposure time of one-hour. The levels of H_2S, NH_3 and NO_2 were monitored using a GC310 gas detector; a flexible portable gas detector for multi-gases (up to 4 gases). VOCs were measured using a MultiRAE IR (PG M54) meter. The results showed that VOCs, NO_2, H_2S and NH_3 were low, with values below the instrument detection limit. However, other parameters such as CO, SO_2, noise, PM, temperature and humidity were within measurable levels. They concluded that the air quality, most especially PM concentrations around the TSLs, was poor since the measured value was above the threshold set by the USEPA and Nigerian Federal Ministry of Environment (FMEnv). Although values of some other parameters were relatively high, they did not exceed set limits.

Uhuegbu [16] measured CO in some selected areas in Lagos State using carbon monoxide detector (Model DSM 8922). The results indicated that CO concentrations varied between 45 ppm and 835 ppm. The values differed based on the time of the day and also depended on the number and age of vehicles using the road at each point in time. He concluded that the major source of carbon monoxide emission observed in the studied area was from automobiles mainly heavy duty trucks with a minimum of 120ppm to a maximum of 855ppm. Most previous studies monitoring ambient air quality or estimating air pollution due to road transportation in Nigeria have succeeded in doing so for most gases such as CO, PM10, NO_X, and SO_X, other than the major GHGs such as CO_2 and CH_4. Most attempts have also been made to estimate these emissions based on peak and off-peak periods without much reference to inter-peak periods. This study makes a difference to other dimensions of research in the use of AEROQUAL 500s portable air monitoring equipment for the real-time quantitative analysis of CO_2 and CH_4 for three time periods (AM peak, inter-peak and PM peak periods).

2 Materials And Methods

A survey research design was employed in this study. Real time quantitative data were collected from primary sources through the use of AEROQUAL 500s portable air monitoring equipment. Concentrations of emissions were measured in three locations within the Ikeja Local Government Area (LGA) of Lagos State.

2.1 Study area

The selected locations within Ikeja LGA include: Under-bridge/Along for Ikeja Local Council Development Area (LCDA); Ojota for Onigbongbo LCDA and Ogba for Ojodu LCDA covering the three LCDAs in Ikeja L.G.A of Lagos State, Nigeria. Ikeja LGA is chosen for this study because it houses Ikeja metropolis which is both the administrative capital and the commercial nerve center of the State.

2.2 Research Instrument

Aeroqual Series 500 portable air quality monitor was used for the air quality monitoring. It is compatible with up to 30 different sensors like ammonia, carbon dioxide, carbon monoxide, hydrogen sulphide and methane. It fits comfortably in the hand, does not require frequent calibration (in the field) and can be left *in situ* for short term monitoring of air quality. The gas sensor can be changed intermittently and allowed to stabilize within a short time allowing the researcher to measure as many gases as needed. The sampled gases for this study include CO, CO_2, CH_4 and NO_X. As noted earlier, atmospheric air quality is not dependent on only the quantity of the pollutant in the atmosphere but also on the prevalent air/weather conditions, thus making clear the need for

temperature and relative humidity to be sampled. The Altimeter and Barometer applications installed in an Android phone were used to measure temperature and relative humidity respectively.

2.3 Data Collection Method

These gases and other parameters were determined *in situ* using two (2) sets of Aeroqual Series 500 portable quality monitor. Each gas was determined three times at 20 minute intervals for 1 hour during each of the peak periods at these three locations: Ikeja Under-bridge, Ogba garage and Ojota garage. This was done in accordance with the methods of Utang & Peterside [17] and Nkwocha *et al*., [10]. Measurements of PM10, temperature and relative humidity were averaged as the corresponding exposure levels in each location during the am peak, inter-peak and pm peak periods. A 40-minute exposure time was observed during each of the periods. Within this time belt, the reading was taken three (3) times and averaged to get a figure for the time interval (Olajire *et al*., [12] and Soneye [15].

- AM PEAK (8:00–10:00am): CO and CO_2 readings were taken simultaneously with separate instrument at 8:00am, 8:20am and 8:40am while CH_4 and NO_X readings were taken simultaneously at 9:00am, 9:20am and 9:40am.
- INTER PEAK (1-3pm): CO and CO_2 readings were taken simultaneously with separate instrument at 1:00pm, 1:20pm and 1:40pm while CH_4 and NO_X readings were taken simultaneously at 2:00pm, 2:20pm and 2:40pm.
- PM Peak (5-7pm): CO and CO_2 readings were taken simultaneously with separate instrument at 5:00pm, 5:20pm and 5:40pm while CH_4 and NO_X readings were taken simultaneously at 6:00pm, 6:20pm and 6:40pm.

In view of the prevailing air and weather conditions, the air quality assessment was done by measuring the pollutant gases along with temperature and relative humidity (Ibe, Opara, Njoku & Alinor [7]. The air quality data measured were analyzed with reference to the specific threshold limits as prescribed by the Nigerian and US NAAQS.

2.4 Data Analysis

To achieve the objective which was to assess the emission profile of the study area, the quantitative data obtained was presented in graphical illustrations to show the behavior of the gases at different times of the day.

3. Results And Discussion

To achieve the objective of this study, which is to assess the concentration profile of the study area, a portable concentration monitoring system was used for the assessment and the respective results are presented in Tables 2, 3 & 4.

Table 2
Air quality monitoring results, for Ojota motor garage Lagos

TIME 1	CO (ppm)	CO_2 (PPM)	TEMP (^{0}C)	RH (%)	TIME 2	CH_4 (ppm)	NO_x (ppm)	TEMP (^{0}C)	RH (%)
AM PEAK									
8:00	65	807	26	98	**9:00**	19	0.016	27	90
8:20	74	826	26	98	**9:20**	31	0.016	28	90
8:40	65	868	26	95	**9:40**	19	0.016	29	89
INTER PEAK									
1:00	53	775	29	79	**2:00**	1	0.017	31	74
1:20	60	785	30	78	**2:20**	2	0.017	31	73
1:40	55	746	30	78	**2:40**	1	0.017	30	73
PM PEAK									
5:00	69	875	29	80	**6:00**	1	0.016	29	79
5:20	86	800	29	81	**6:20**	2	0.016	30	79
5:40	63	785	28	79	**6:40**	1	0.016	28	82

Table 3
Air quality monitoring results for LASUTH Ikeja Lagos

TIME 1	CO (PPM)	CO_2 (ppm)	TEMP (^{0}C)	RH (%)	TIME 2	CH_4 (ppm)	NO_x (ppm)	TEMP (^{0}C)	RH (%)
AM PEAK									
8:00	65	807	26	98	**9:00**	6	0.016	26	94
8:20	74	826	26	98	**9:20**	11	0.016	27	91
8:40	65	868	26	95	**9:40**	3	0.016	27	90
INTER PEAK									
1:00	63	738	30	79	**2:00**	0	0.016	31	74
1:20	65	775	31	77	**2:20**	0	0.016	31	74
1:40	65	782	31	76	**2:40**	0	0.016	30	74
PM PEAK									
5:00	24	728	30	73	**6:00**	0	0.016	28	86
5:20	46	758	29	83	**6:20**	0	0.016	28	88
5:40	42	721	28	85	**6:40**	0	0.016	27	89

Table 4
Air quality monitoring results for Ogba motor garage Lagos

TIME 1	CO (PPM)	CO_2 (ppm)	TEMP (^0C)	RH (%)	TIME 2	CH_4 (ppm)	NO_x (ppm)	TEMP (^0C)	RH (%)
AM PEAK									
7:20	55	932	25	96	**7:15**	4	0.016	25	96
7:30	106	1134	25	96	**7:35**	3	0.016	26	93
7:40	162	938	26	93	**7:45**	3	0.016	26	94
8:00	76	1032	26	92	**9:00**	1	0.016	27	89
8:20	97	1034	26	93	**9:20**	1	0.016	27	88
8:40	84	951	27	90	**9:40**	1	0.016	28	86
INTER PEAK									
1:00	95	814	31	73	**2:00**	1	0.017	30	76
1:20	80	956	31	72	**2:20**	0	0.017	31	73
1:40	95	819	31	71	**2:40**	1	0.017	31	76
PM PEAK									
5:00	67	954	29	78	**6:00**	0	0.016	30	76
5:20	52	973	29	79	**6:20**	1	0.016	30	77
5:40	56	841	28	81	**6:40**	1	0.016	29	76

Tables 2, 3 and 4 show the air quality monitoring results in the three L.C.D. As in Ikeja L.G.A of Lagos

Table 5
Air Quality Monitoring Results for Ikeja L.G.A

PERIOD	LOCATIONS (Within Ikeja LGA)	CO	CO_2	Temp	RH	CH_4	NO_x	Temp	RH	LAT	LONG
AM Peak (8:00–10:00am)	Ikeja Under-bridge (LASUTH)	65	807	26	98	6	0.016	26	94	N6^{0}35'31.02889"	E3^{0}20'34.97953"
		74	826	26	98	11	0.016	27	91		
		65	868	26	95	3	0.016	27	90		
	Ogba garage	76	1032	26	92	1	0.016	27	89	N6^{0}37'56.79624"	E3^{0}20'27.86964"
		97	1034	26	93	1	0.016	27	88		
		84	951	27	90	1	0.016	28	86		
	Ojota garage	58	817	26	91	19	0.016	27	90	N6^{0}35'19.45356"	E3^{0}22'42.0654"
		58	802	26	91	31	0.016	28	90		
		53	790	27	90	9	0.016	29	89		
Inter peak (1-3pm)	Ikeja Under-bridge (LASUTH)	63	738	30	79	0	0.016	31	74	N6^{0}35'31.02889"	E3^{0}20'34.97953"
		65	775	31	77	0	0.016	31	74		
		65	782	31	76	0	0.016	30	74		
	Ogba garage	95	814	31	73	1	0.017	30	76	N6^{0}37'56.79624"	E3^{0}20'27.86964"
		80	956	31	72	0	0.017	31	73		
		95	819	31	71	1	0.017	31	76		
	Ojota garage	53	775	29	79	1	0.017	31	74	N6^{0}35'19.45356"	E3^{0}22'42.0654"
		60	785	30	78	2	0.017	31	73		
		55	746	30	78	1	0.017	30	73		
PM Peak (5-7pm)	Ikeja Under-bridge (LASUTH)	24	728	30	73	0	0.016	28	86	N6^{0}35'31.02889"	E3^{0}20'34.97953"
		46	758	29	83	0	0.016	28	88		
		42	721	28	85	0	0.016	27	89		
	Ogba garage	67	954	29	78	0	0.016	30	76	N6^{0}37'56.79624"	E3^{0}20'27.86964"
		52	973	29	79	1	0.016	30	77		
		56	841	28	81	1	0.016	29	76		
	Ojota garage	69	875	29	80	1	0.016	29	79	N6^{0}35'19.45356"	E3^{0}22'42.0654"
		86	800	29	81	2	0.016	30	79		
		63	785	28	79	1	0.016	28	82		

From Table 2, it could be seen that CO concentration at Ojota motor garage was high at an hourly averages of 73ppm during the am peak and 68ppm during the pm peak period and lowest during the inter-peak period (56ppm). The same trend was seen in CO_2 concentration with the hourly average of 837ppm and 820ppm during the am peak and the pm peak, respectively and lowest during the inter-peak period (767ppm). These values can be attributed to high vehicular traffic during these periods as earlier reported (Ibe, Opara, Njoku *et al.*, [7]. It can be also seen from the results that CH_4 emissions were usually high during the am peak period; this is likely not unconnected to the presence of Olusosun dumpsite which is the largest dumpsite in Africa (see Ahove, Ojowuro & Okafor, [2]) about 3km away from the motor park. In addition to this, the relative humidity was also highest at this period of time. NO_x

concentrations on the other hand were relatively stable (0.016 ppm-0.017ppm) throughout the three time periods without exceeding the (0.04-0.06ppm) threshold prescribed by NAAQs.

From Table 3, it could be seen that CO emissions at LASUTH Ikeja were highest with hourly averages of 68ppm and 64ppm during the a.m. peak and the inter-peak, respectively, and lowest during the p.m. peak period (37ppm). The same trend is seen in CO_2 emissions with the hourly average of 834ppm and 765ppm during the a.m. peak and the inter-peak, respectively and lowest during the p.m. peak period (736ppm). These values can be attributed to high level of activities during these working and visiting hours with the Lagos State University Teaching Hospital (Okafor, [13]). It is also seen from the results that CH_4 emissions were usually high during the a.m. peak period and undetected throughout the inter-peak and p.m. peak periods in line with the works of Olajire *et al.*, [12]. This is likely not unconnected to the presence of the stench from nearby gutters in addition to the relatively high relative humidity, it being highest at that time period while the temperature was lowest. NO_x concentrations on the other hand were relatively stable at a value of 0.016 ppm throughout the three time periods without exceeding the threshold prescribed by NAAQs.

From Table 4, it could be seen that CO concentrations at Ogba motor garage were highest with hourly averages of 86ppm and 90ppm during the a.m. peak and the inter-peak respectively and lowest during the p.m. peak period (58ppm). CO_2 concentrations however had the highest hourly average of 1006ppm during the a.m. peak and then had a lower hourly average value of 863ppm and 923ppm during the inter-peak and p.m. peak, respectively; these values compare to about 400 ppm for clean air far from source regions. These values can be attributed to high vehicular traffic during these periods as already pointed out by the study of Olajire *et al.*, [12] and Okafor [13]. CH_4 and NO_x concentrations on the other hand were relatively stable (0-1ppm; 0.016-0.017ppm, respectively) throughout the three time periods without exceeding the threshold prescribed by NAAQS.

The undulating behavior of the gases at time periods in the different locations are represented in Figs. 1a, 2a, 3a, 4a, 5a and 6a.

Concentrations measurements were seen to increase with an increasing temperature and a decreasing relative humidity at different times of the day at the three locations sampled (See Figs. 1b, 2b, 3b, 4b, 5b and 6b). This can be attributed to the trapping/absorption of heat/sunlight by the pollutant gases being measured in line with the concept of global warming and greenhouse gas effect. Normally this heat/sunlight would have escaped into the space if the pollutants do not trap it causing more heat. The concentrations in the study areas can also be said to have a particular trend of being highest during the AM and PM peak periods and a bit lower during the inter-peak period. This trend in the study area is an indication that high mean emission estimates are associated with traffic. This finding is corroborated by large numbers of banks and high net-worth commercial centers within the highly accessible and connected locations along Obafemi Awolowo Way, Allen Avenue, Aromire Avenue, Adeniyi Jones, Oba Akran Avenue etc. in the study area.

When compared with previous estimates as found in the literature reviewed, CO_2 and CO concentrations from this study appear to be the highest values ever measured in Lagos and this mainly stems from the locations sampled. Previous locations from the literature reviewed showed busy roads with moving traffic, while the locations sampled in this study were busy road intersections that had loading points (garage) near them.

4. Conclusion

This study revealed that the concentration of CO_2 in all the locations did not comply with both local and international standards. Though, the concentration of CO was within international standard, it did not meet local standards.

There is a need for effective air pollution monitoring and control programs for mobile emission sources. In addition, improved road network and traffic control has the potential to ease congestion and associated air pollution problems. The construction of modern roundabouts and overhead bridges could also be a useful approach; such structures would be expected to improve the flow of traffic and consequently cut down vehicular emissions/fuel consumption by reducing the idle time of vehicles at various intersections. This would help lead to a cleaner environment. There should also be an immediate enforcement of existing laws banning the use of old and obsolete vehicles and carrying out road worthiness test for commercial vehicles.

Declarations

Availability of data and materials

All data generated or analyzed during this study are included in this article and its supplementary materials file. The raw data are available from the corresponding author upon reasonable request.

Competing interests

The authors declare they have no competing interests.

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Authors' contributions

CLO, MAA, and SGO designed the study and carried out the field tests. CLO and MAA drafted and edited the manuscript. MMC contributed to modeling, and manuscript preparation. BO provided the equipment and training from field work. CLO, MAA, MCC and BO critically reviewed and edited the final manuscript. All the authors read, made inputs and approved the final manuscript.

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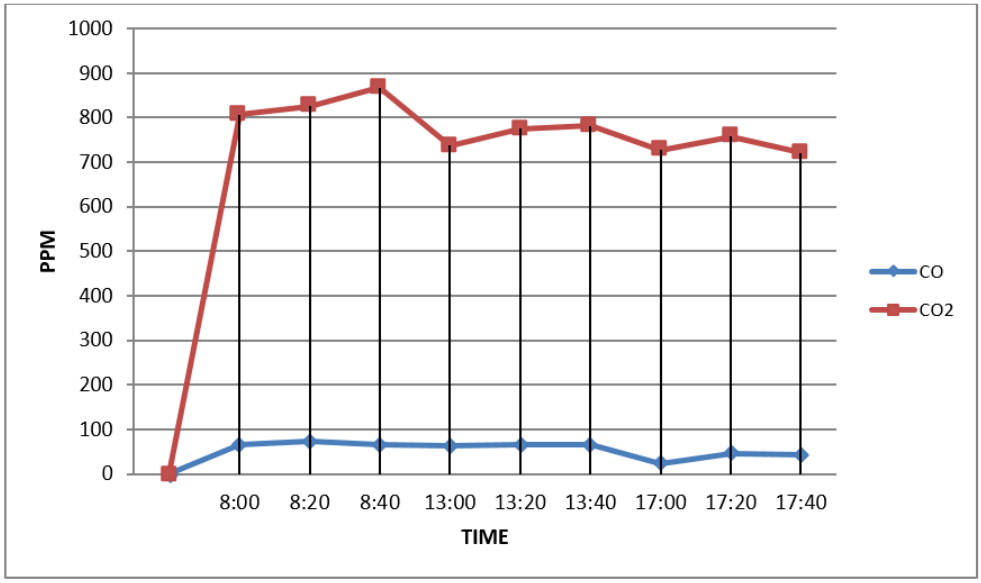
Figures



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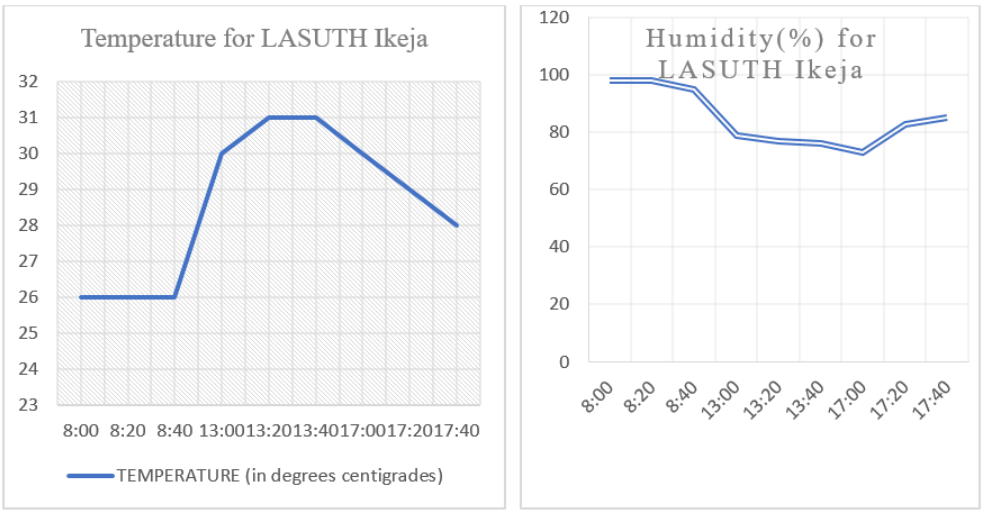
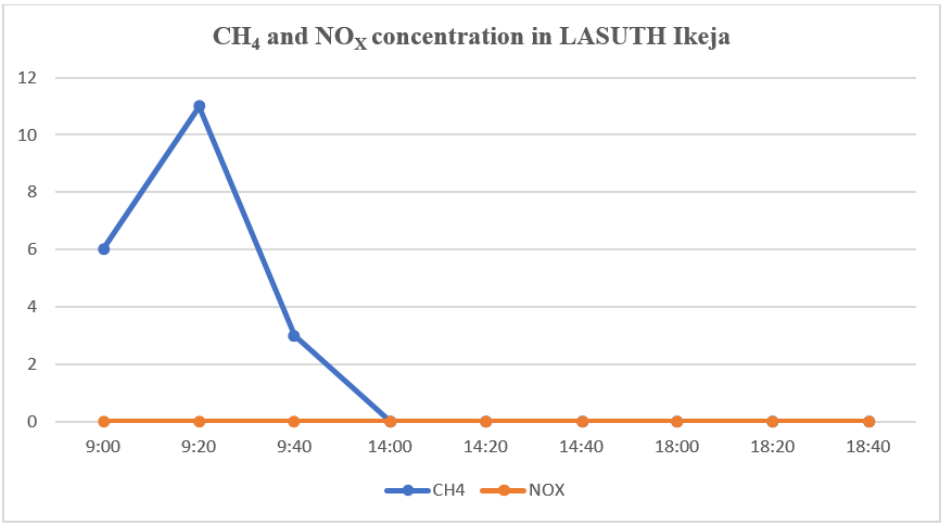


B

Figure 1

a: CO and CO2 concentration history for LASUTH IKEJA showing the concentrations of the gases during the three time periods. b: Time histories for temperature and humidity for LASUTH IKEJA during the measurement of CO & CO2.



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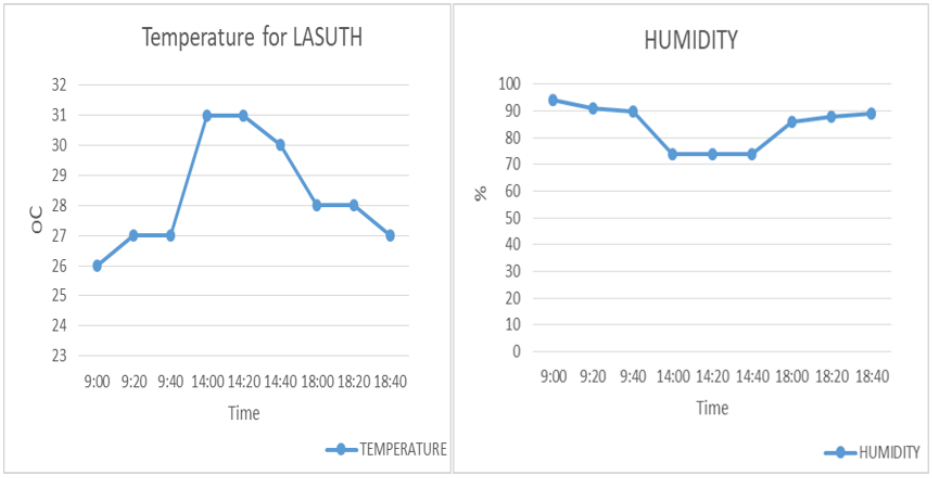
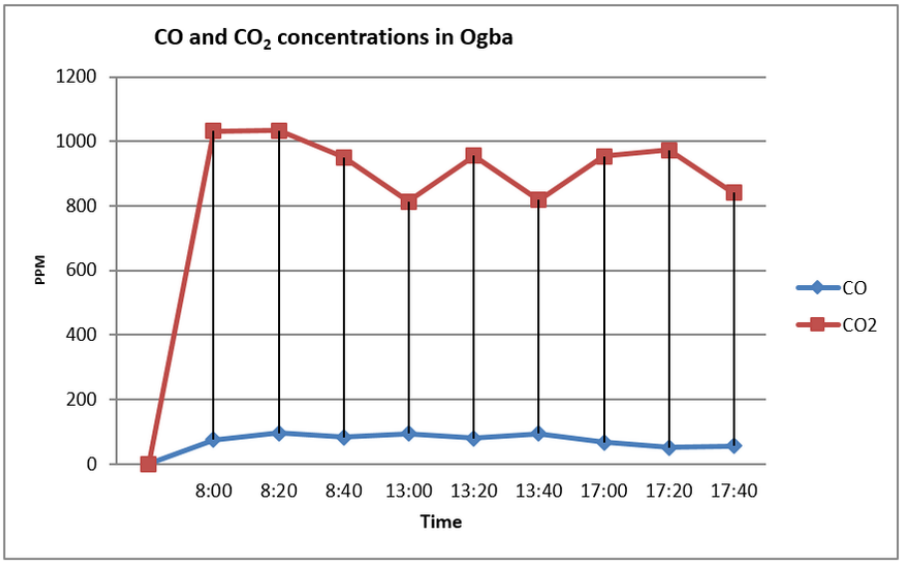


B

Figure 2

a: CH4& NOx emission profile for LASUTH IKEJA showing the concentration of the gases during the three time periods. b: Time histories for temperature and humidity for LASUTH IKEJA during the measurement of CH4 & N0X.



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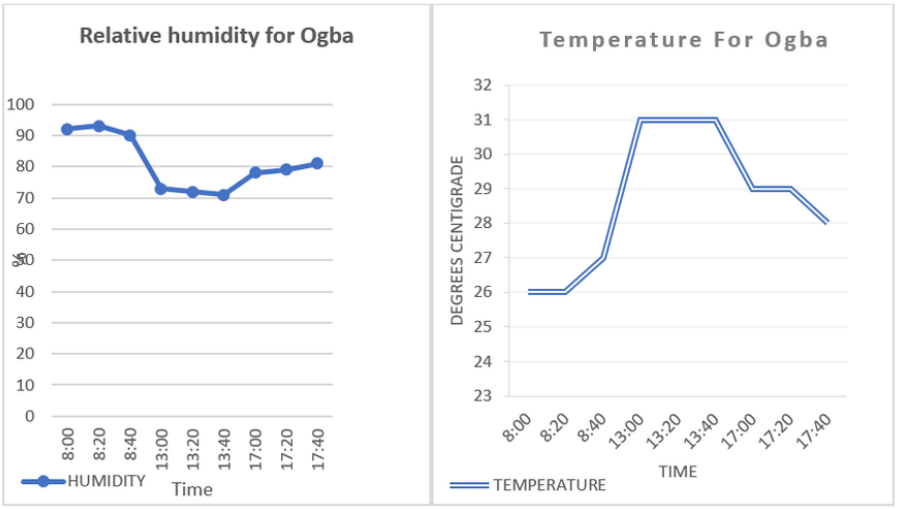
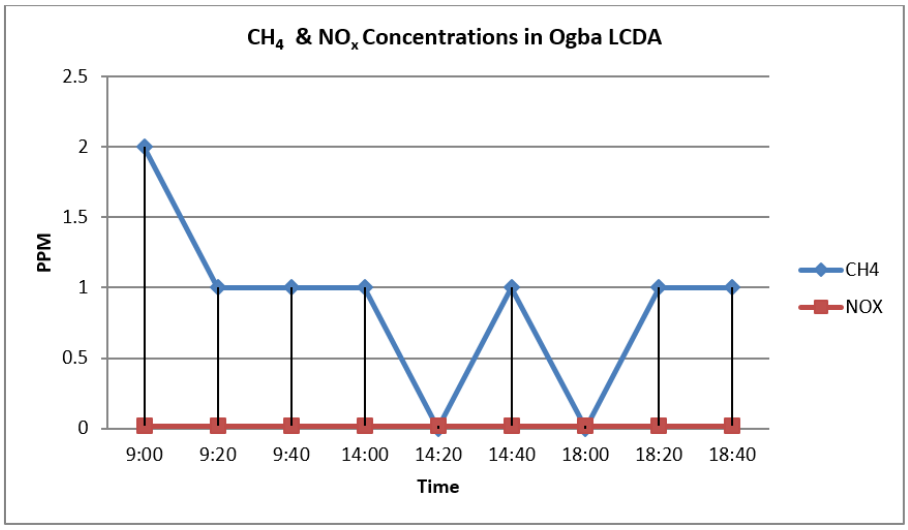


B

Figure 3

a: CO & CO2 emission profile for OGBA LCDA showing the concentration of the gases during the three time periods. b: Time histories for temperature and humidity for OGBA during the measurement of CO & CO2.



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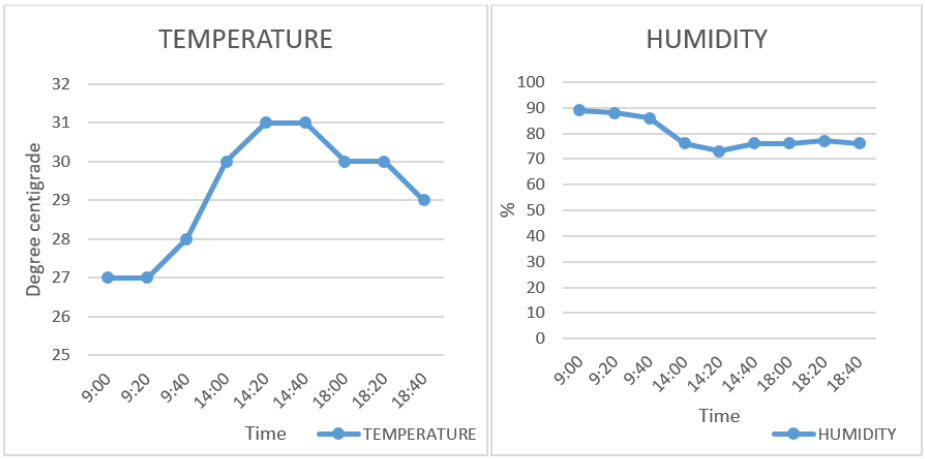
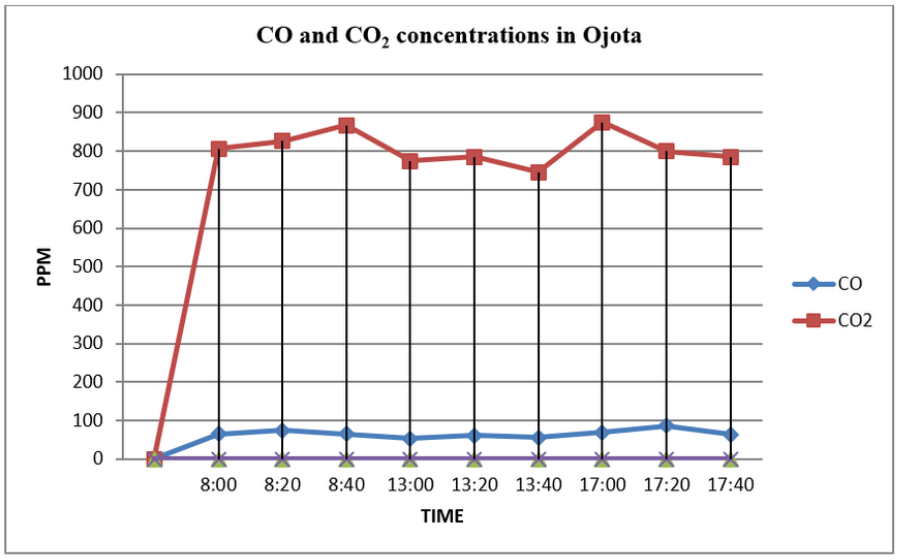


B

Figure 4

a: CH4 & NOx emission profile for OGBA LCDA showing the concentration of the gases during the three time periods. b: Time histories for temperature and humidity for OGBA LCDA during the measurement of CH4 & NOx



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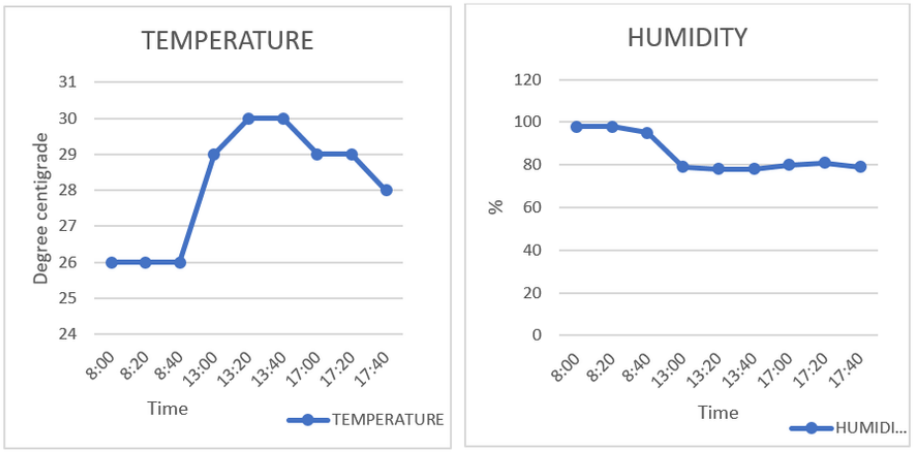
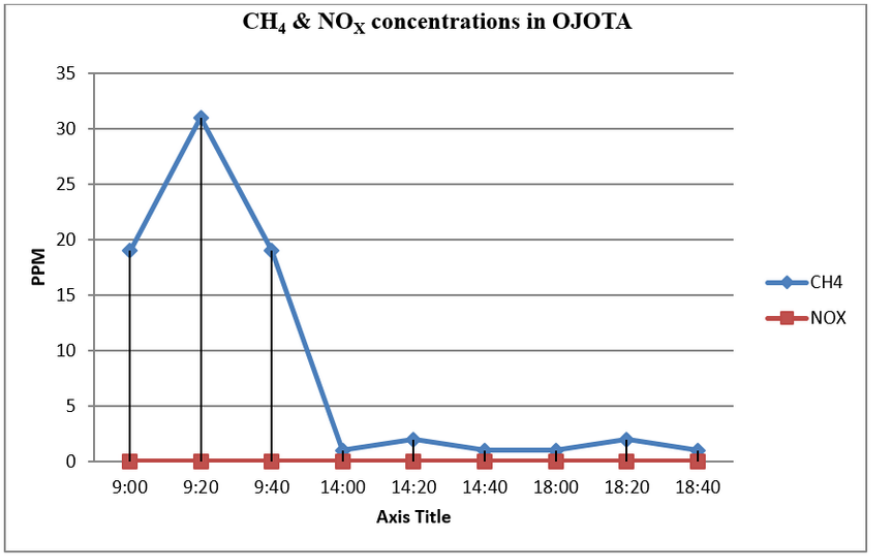


B

Figure 5

a: CO & CO2 emission profile for OJOTA showing the concentration of the gases during the three time periods. b: Time histories for temperature and humidity for OJOTA during the measurement of CO & CO2.



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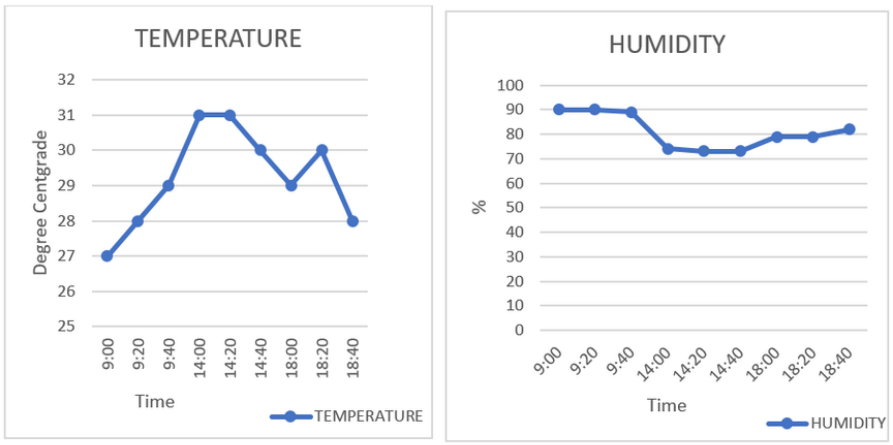

B

Figure 6

a: CH4 & NOx emission profile for OJOTA showing the concentration of the gases during the three time periods. b: Time histories for temperature and humidity for OJOTA LCDA during the measurement of CH4 & NOx