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Monitoring the spatial distribution of CO_2 within the University of Lagos Main Campus

Alademomi A. S.[1,2,3], Animashaun M. B.*[1,2], Abolaji O. E.[1,2], Okolie C. J.[1,2,3], Ojegbile B. M[1,2], Daramola O. E.[1,2] Alozie, N.S.I[4]

[1]*University of Lagos, Faculty of Engineering, Department of Surveying and Geoinformatics, Lagos, Nigeria*
[2]*Geospatial and Environmental Research Group, University of Lagos, Nigeria*
[3]*Centre for Multidisciplinary Research and Innovation (CEMRI), Abuja, Nigeria*
[4]*University of Lagos, Faculty of Engineering, Department of Mechanical Engineering, Lagos, Nigeria*

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ABSTRACT

The University of Lagos environment chosen as a case study is a higher institution in Lagos Nigeria which is located within areas of residential, commercial and industrial activities. These activities put out emissions into the atmosphere through motor vehicles, use of electricity generating plants, firewood, coal, kerosine and refuse burning. Anthropogenetic substances such as carbon monoxide (CO), unburnt hydrocarbon (UC), oxides of nitrogen (NOx) and particulate matter (PM) are released into the atmosphere and pollute the air. Thus, effective pollution monitoring and control is required. To assess the University's air quality, the carbon dioxide (CO_2) concentration was mapped and evaluated. Although CO_2 is not an environmental pollutant in a strict sense, but its precursor, the CO is a dangerous one. CO_2 is a major indicator of carbon footprint, and a major issue in climate change studies. Data for the study was collected through direct field measurements using gas sensors. The USEPA Air Quality Index was used to rate the air quality. Also, a one-tailed ANOVA test was used to assess the land use influence on CO_2 variation. The results show that CO_2 emission is substantial around the University First Gate, Faculty of Education and New Hall. This suggests that the initial release of the pollutant CO, a precursor of CO_2 must have been high around these areas.

1. Introduction

Every living organism requires the atmospheric oxygen for survival and growth. Atmospheric air is naturally safe and clean for humans, animals and plants in the spectrum of our biodiversity. However, due to industrialization and other anthropogenic activities, the air gradually becomes polluted, making it unsafe for humans. Anyone living around heavily polluted environments will likely face the risk of respiratory diseases.

The World Health Organization (WHO) in a bid to effectively monitor the sustainable development goals (SDGs) of any global region has repeatedly reported that air pollution is highly responsible for many infectious and viral diseases such as tuberculosis, asthma, nearly all cancers, respiratory and skin diseases which has terminated more lives than AIDS (Mehta et al., 2013). In 2012, the report from WHO revealed an estimated global mortality of 10%, an equivalent of 7 million people resulted from air pollution in 2012 (WHO, 2014). The cause of high rate of mortality due to air pollution in low and middle-income countries can be connected with the remark from the work of Mohan et al. (2013) which revealed that toxicity of exhaust nanoparticles is rapidly growing due to increasing motor vehicle traffic and rapid industrialization which have contributed enormously to urban pollution.

In particular, the harmful impacts of air pollution on human health have been on the increase in the developing countries where electricity power supply is mainly through fossil fuel generating sets for both domestic and commercial purposes (WHO, 2014; Bernstein et al., 2004). Predominantly, the pollutants of global concern are CO, NOx (which comprises of nitrogen oxide – NO, and nitrogen dioxide - NO_2, PM, volatile organic compounds, hydrocarbon substances (HC), and sulphur oxides (SOx) (Bernstein et al., 2004).

* **Corresponding Author**

*(musaanimashaun@gmail.com) ORCID ID 0000-0002-2989-5771

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This study is concerned with the mapping of the concentration of carbon dioxide. As stated, CO_2 is itself not a major pollutant but can indicate emission of CO, a very dangerous emission variable. Combustion studies have shown that in well-designed combustion systems, if there is complete combustion, the emissions variables are water (H_20) and CO_2. However, in most practical combustion systems or devices, combustion is never complete. This leads to emission of CO which upon further reaction with atmospheric oxygen yields CO_2. Therefore, increase in atmospheric CO_2 is indicative of increase in human activities involving the use of fossil fuels as a result of increase in population. One of the densely populated areas in Lagos State is the University of Lagos environment where the steady growth in social, commercial and industrial activities are ongoing. In recent times, these increases in human activities are in turn having significant effects in the air quality. Poor air quality in any environment has the potential to affect human health. The need to monitor and maintain good air quality as part of sustainable developmental goals is of interest to researchers in this study. In monitoring the air quality of any area of interest, the United States Environmental Protection Agency has designed a standardized air pollution level indicator for rating the air quality over an area. It is a rating scale for outdoor air called Air Quality Index (AQI). The lower the AQI value, the better the air quality. AQI rating A stands for Very Good (0 -15), B for Good (16 -31), C for Moderate (32 – 49), D for Poor (50 – 99) and E for Very poor (100 and over) (EPA, 2000). The air quality is determined with reference to the standard by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). According to ASHRAE (2016), the standard for carbon dioxide is 1000ppm.

$$AQI_{POLLUTANT} = \frac{Data}{Standard} \times 100 \quad (1)$$

In this study, the geospatial mapping of the concentration of CO_2 has been considered as a first attempt because of the proven integrity of Geographic Information System (GIS) in air quality monitoring and management due to vehicular density within and around the University of Lagos environment.

1.1. Description of study area

The University of Lagos is a higher institution in Lagos State, Nigeria (Figure 1). It is located at approximately, latitudes 6°30'N to 6°31'N and longitudes 3°25'E to 3°27'E in the Lagos Mainland Local Government Area. The main campus which is largely surrounded by the scenic view of the Lagos lagoon and is located on 802 acres (3.25 km^2) of land in Akoka, northeastern part of Yaba, Lagos has been chosen as the study area. The focus on the main campus is justifiable based on the level of human activities as described and for the convenience of available geo-spatial data, as well as ease of environmental data collection.

2. Methods

2.1. Station selection

The siting of the monitoring stations has a profound effect on the resulting measurements and on achieving monitoring objectives. Thus, thirty-four (34) monitoring stations were established at strategic locations within the study area such as major road intersections (for vehicular emissions), dumpsites, commercial centers, academic areas, and residential sites as shown in Fig. 1.

2.2. Variables, equipment and measurement

The evaluated parameter was CO_2 gas which is a strong variable for assessing environmental air quality. To measure the concentration level of this gas, we adopted the use of a very simple device: calibrated hand-held solid-state gas sensor. Compu-Flow CO_2 Handheld meter, a gas monitor designed to provide continuous exposure monitoring of carbon dioxide was used to measure the CO_2 concentration levels in parts per million (ppm). Data was collected over six (6) observation windows within three days of observation. The average value for the pollution parameter readings were carefully recorded. All measurements were executed in 2-hour duplicates (i.e., repeated twice – morning peak period and afternoon off-peak period) over 3 days' observation period across all monitoring stations. The sampling was done in-situ and each sample station was geo-referenced using Garmin GPSMAP 78SC Marine handheld GPS. The duration for exposure was set at 5 minutes at a time per station. The average values for each of the locations were computed and recorded.

Figure 1. Study area extent and spatial distribution of measurement stations

2.3. Generation of CO_2 Distribution Map

The acquired data was transferred to a Microsoft Excel worksheet and imported into ArcGIS environment where it was represented by point shapefiles.

Kriging interpolation (an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with values), was used to generate maps showing the spatial variation of CO_2.

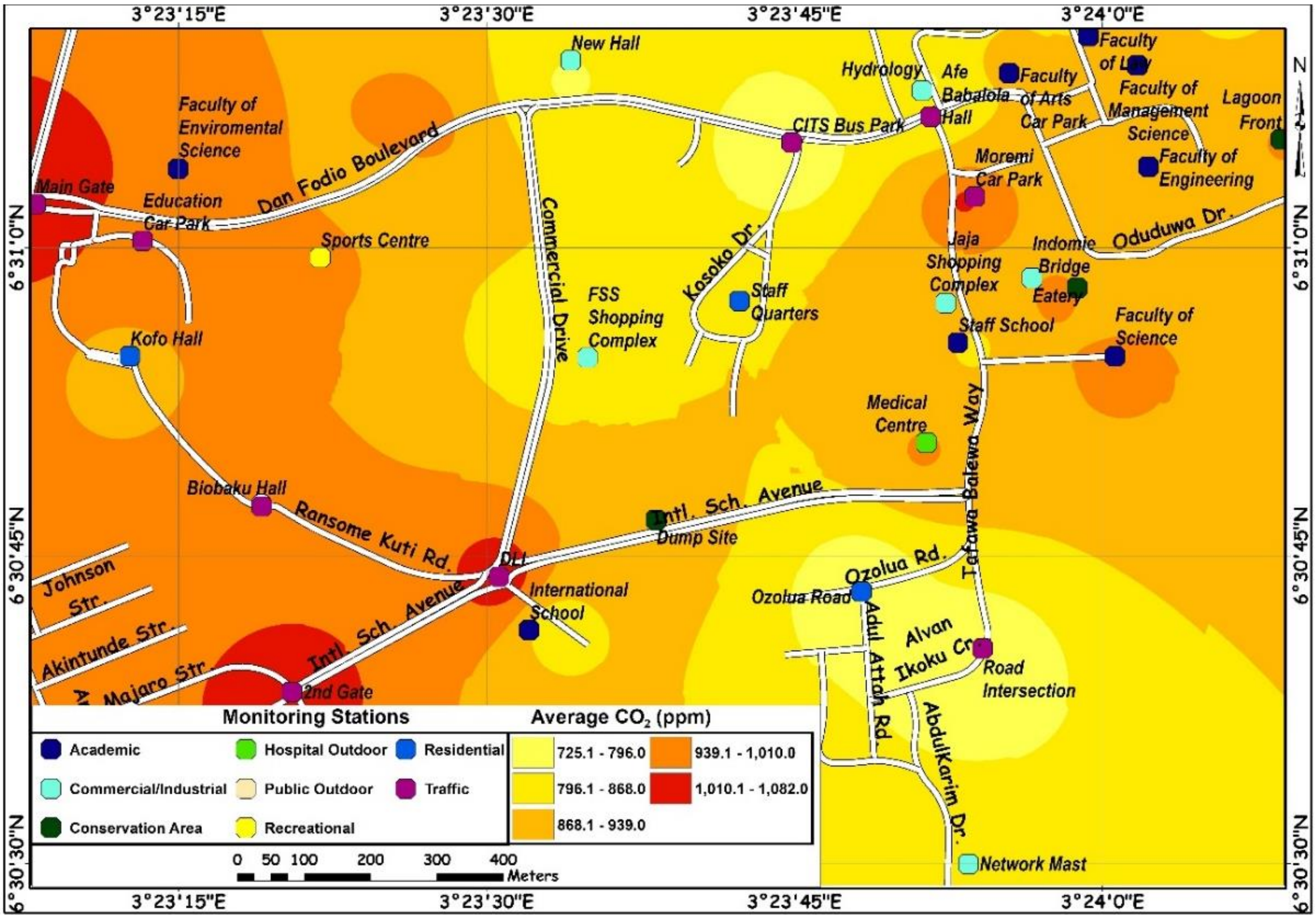

Figure 2. Spatial distribution of mean CO_2 for the entire duration of observation

Table 1. CO_2 statistics by land use type

Environment type	N	Mean	SD	SE	95% CI for Mean		Min	Max	AQI	Rating	Remark
					Lower Bound	Upper Bound					
Academic	10	861.3	52.1	16.5	824.04	898.64	788.2	982.6	86.13	D	Poor
Commercial/ Industrial/ Shopping	5	888.3	67.6	30.2	804.46	972.2	791.5	956.2	88.83	D	Poor
Conservation Area	4	889.8	48.3	24.2	812.92	966.75	825.8	942.6	88.98	D	Poor
Hospital Outdoor	1	945.7	.	.	.	.	945.7	945.7	94.57	D	Poor
Public Outdoors	1	894.3	.	.	.	.	894.3	894.3	89.43	D	Poor
Recreational	1	951.4	.	.	.	.	951.4	951.4	95.14	D	Poor
Religious	1	977.3	.	.	.	.	977.3	977.3	97.73	D	Poor
Residential	4	807.3	96.9	48.4	653.19	961.48	725.3	915.1	80.73	D	Poor
Traffic	7	985.6	122	46.1	872.87	1098.27	725.4	1082	98.56	D	Poor
Total	34	897.4	92	15.8	865.3	929.48	725.3	1082			

Table 2. Analysis of Variance (ANOVA) Test

		Sum of Squares	df	Mean Square	F	Sig.
AVG. CO_2	Between Groups	112156.2	8	14019.5	2.099	0.075
	Within Groups	166972.7	25	6678.91		
	Total	279128.9	33			

3. RESULTS

Table 1 shows the statistics of the data acquired with respect to environment types. As seen, the residential land use has the lowest mean concentration of 807.3ppm. CO_2 is mostly concentrated around the traffic corridors with mean 985.57ppm. The religious, recreational and hospital outdoor maintained a close level of concentration averagely yielding 977.3ppm, 951.4ppm, and 945.7ppm respectively. The table also contains the calculated air quality index per land use and their corresponding rating values. In addition, Figure 2 represents the outcome of the kriging interpolation which is made into a map showing the spatial distribution of mean CO_2 for the entire duration of observation. Furthermore, Table 2 represents the outcome of the ANOVA test. When the relational impact of one land use is considered between it and the other land use types, the degree of freedom is 8 but when they are considered within the groups of the land use types, the degree of freedom is 25.

4. Discussion

The low concentration of CO_2 observed in the residential areas such as the Ozolua Junction and Staff Quarters in Figure 2 is as a result of minimal carbon-generating activities around there. On the other hand, the intense concentration noticed at the traffic cores (i.e., Main Gate, 2nd Gate, DLI Roundabout, and Moremi Car Park is linked to the massive vehicular movements around those places. Also, we can infer from Figure 2 that the western part of the school which is bounded by numerous road networks has higher CO_2 levels compared to the eastern end which is adjacent to the Lagoon. In addition, CO_2 level is generally high around the faculties and eateries and this is due to the presence of laboratories that utilize combustion engines and electricity generating plants as well as cooking. Also, the substantial concentration noticed around the dumpsite and Indomie Bridge (crossing a canal) is suspected to be as a result of CO_2 constituting 50% of the gas emitted due to decomposition of waste by microorganisms from landfills and canals. The AQI ratings in Table 1 further prove that the air quality with respect to CO_2 is generally poor in the campus.

5. Conclusion

In this study, atmospheric CO_2 was measured and analyzed at different environment types for variability over the duration of study using statistical and visualization approaches. The relationship between the gas and land uses was also analyzed. Also, the in-situ observed measurements have been compared with the ASHRAE standard for CO_2 (1000ppm). Furthermore, A one-tailed ANOVA test for content of the CO_2 was executed to ascertain the influence of the land use on the concentration. Overall, the study shows that CO_2 is majorly concentrated around traffic pivots, laboratories, eateries, and industrial areas, and is generally low in the residential areas of the university.

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