Conference Proceedings Paper

Preliminary Assessment of Air Pollution Quality Levels of Lagos, Nigeria

Francis Olawale Abulude [1*], Usha Damodharan [2] Sunday Acha [3], Ademola Adamu [4] and Kikelomo Mabinuola Arifalo [4]

Published: date
Academic Editor: name

[1] Science and Education Development Institute, Akure, Ondo State, Nigeria; e-mail:walefut@gmail.com.
[2] Department of Ecology and Environmental Sciences, Pondicherry University, India; e-mail: ushadamodhar@gmail.com
[3] Department of Geography, Federal University of Technology, Minna, Niger State, Nigeria; e-mail: edahacha@gmail.com
[4] Department of Chemistry, University of Education, Science, and Technology, Ikere, Ekiti State, Nigeria. e-mail: adamu.ademola@coeikere.edu.ng
[4] Department of Chemistry, University of Education, Science, and Technology, Ikere, Ekiti State, Nigeria. e-mail: karifalo@yahoo.co.uk
* Correspondence: e-mail:walefut@gmail.com; Tel.: +234803458674.

Abstract: Owing to the effect on people, livestock, and materials, air pollution is a hazard globally. To this end, stakeholders have taken on the challenge of quantifying the environment with the use of tools and eventually using the data produced to provide solutions to the problems. However, low-cost sensors and IoT have come to the rescue due to the high cost and operational complexity of equipment and methodologies in environmental monitoring. They are relatively inexpensive and reliable. It is on this assumption that we have decided to use the World Air Quality satellite data supplied by air matters.com. This study is a 40-day preliminary work in which air quality (AQI, $PM_{2.5}$, PM_{10}, NO_2, CO, SO_2, and O_3) and meteorological (temperature, humidity, and wind speed) parameters were monitored. The data collected was for five locations in Lagos State, Nigeria (Ojodu, Opebi, Ikeja, Maryland, and Eti-Osa). The data obtained were subjected to basic descriptive, multivariate and time series statistical analyses. The findings showed that the AQI of all locations presented the levels of contamination as 'Unhealthy for Vulnerable Groups', there were relationships between the parameters monitored and meteorological influences, and the effects of natural and man-made activities may be the sources of the elevated pollutants throughout the locations.

Keywords: Air Pollution, Air Quality Index, Satellite, Lagos State, Sensitive Groups

---

1. Introduction

Urban air pollution is typically caused by a wide variety of emission sources, including commercial/residential fuel traffic, manufacturing and combustion, and consists of a complex mix of gaseous and particulate air pollutants such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), fine particulate matter ($PM_{2.5}$) and ground-level ozone ($PM_{2.5}$) (defined as aerodynamic diameter particulate matter ($PM_{2.5}$). Air quality has been a big concern in many countries. According to the World Health Organization (WHO) [1], more than seven million people die each year because of this disease, and more than 80 percent of the population of urban areas live in places where air quality increases above WHO guideline limits [2].

Growing use is being made of low-cost sensors, satellite modelling and citizen scientists, non-scientists interested in specific issues who collect or analyze data to contribute to scientific research, or advocate for environmental or public health improvements. Several organizations such as New York City Community Air Survey (NYCCAS), AirVisual, and Air Matters, just to name a few have developed into this field of community engagement and community-based participatory research by developing air quality toolkits for 'citizen-science' and AQI modelled using satellite to accessible pollution source data, using fresh, low-cost air pollution surveys to construct community air pollution surveys.

According to Iskandaryan et al. [3] and Giffinger et al. [4], a smart city is a city in which there are six main components, including smart economy, smart transport, smart environment, smart citizens, smart life, and smart management, or The use of smart computing technologies to render critical infrastructure components and services of a city, including city governance, education, and smart management. The availability of data produced by sensors is a significant characteristic of smart cities [5, 6]. In other words, because of the above explanation, there is the aspiration of Lagos becoming a smart town in Nigeria.

In Nigeria, Nigerian scientists and their international collaborators have taken a variety of air quality measurements [7 – 9]. These are however, limited-point measurements around the city (background, commercial, roadways, and informal settlement households) and limited numbers of contaminants, primarily $PM_{2.5}$ and PM_{10}. In certain cases, PM levels appear far above the World Health Organization (WHO) 24-h average guideline. We used standard AQI-modelled satellite data from Lagos, Nigeria's former headquarters, in this study to monitor air quality. It is expected that the study will last 24 months. Consequently, the purpose of the study was to carry out a 40-day preliminary air quality assessment ($PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, and O_3) at five separate locations (Opebi, Ojudu, Ikeja, Maryland, and Eti-Osa) in Lagos State, Nigeria, and to assess the effect of meteorological parameters (wind speed, temperature and humidity) on air quality.

2. Experiments

The air quality was assessed in this study using regular AQI satellite data from Air Matters [10] at five locations in Lagos State, Nigeria (elevation: 38 meters, latitude: 06 35N, longitude: 003 20E). From the 1st of October and 9 November 2020. The stations are Ojodu (6.625, 3.354); Ikeja (6.601, 3.351); Eti-Osa (6.458, 3.601); Maryland (6.571, 3.372); and Opebi (6.589, 3.361) (Figure 1). A tropical savanna climate with dry and wet sessions (Cfa following Köppen climate classification) characterises the study cycles in Lagos.

For the year in Lagos, the average temperature is 27.2°C. On average, the warmest month is February, with an average temperature of 28.9°C. On average, the coolest month is August, with an average temperature of 25°C. For the year in Lagos, the total amount of precipitation is 1506.2 mm. On average, the month with the most rainfall is June, with 315 mm of precipitation. On average, the month with the least rainfall is January, with an average of 12.7 mm. There is an average of 53.0 days of precipitation, with 9.0 days being the most precipitation in September and 1.0 days being the least precipitation in January. There is an average of 53.0 days of rain in terms of liquid precipitation, with the most rain occurring in September with 9.0 days of rain, and the least rain occurring in January with 1.0 days of rain [11].

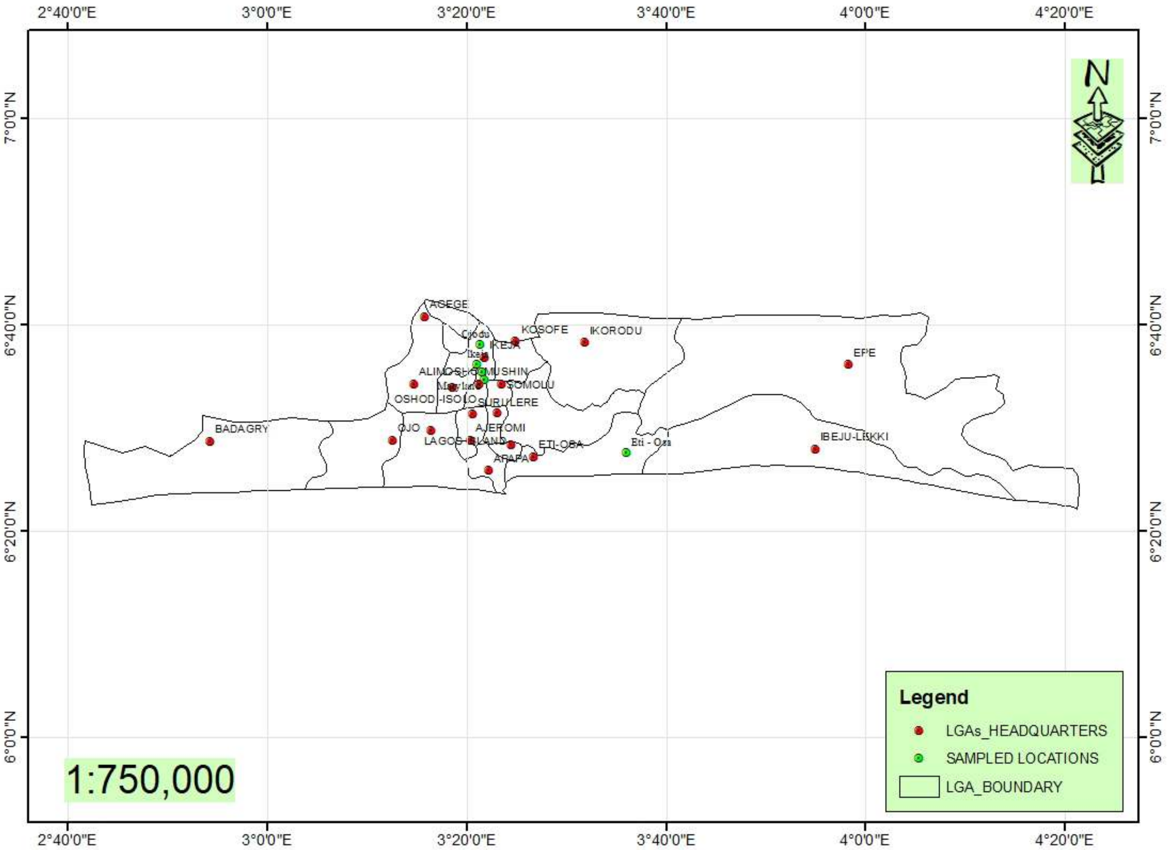

Figure 1: The Sampling Points in the different Local Government Area (LGA)

Air-quality.com (powered by Air Affairs) is a low-cost real-time, citizen-based PM sensor network deployed in more than 180 countries and regions (https:/air-quality.com). Air-quality.com provides measurements via satellite images of contaminants ($PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, O_3) and meteorological parameters (humidity, wind speed and temperature). In this analysis, measurements of hourly pollutants and meteorological parameters were used. In this research, the available data on AQI, pollutants and meteorological parameters in Ikeja, Ojodu, Opebi, Eti-Osa, and Maryland were computed and statistically analysed using Minitab software version 16 (Descriptive, Pearson correlation, Box map, and Times series).

3. Results

Table 1 shows the mean values for AQI are as follows: Ikeja (127.88), Opebi (141.82), Ojodu (109.88), Eti-Osa (101.4) and Maryland (127.88). The health details for the locations ranged from 'good' to 'very unhealthy'. The mean concentration of $PM_{2.5}$ and PM_{10} over Ikeja was between 20 - 123 μg/m^3 and 30 - 176 (μg/m^3); Maryland was between 22 - 120 μg/m^3 and 33 - 173 μg/m^3; Ojodu was between 17μg/m^3 - 81μg/m^3 and 27 - 121μg/m^3; and Eti-Osa was between 5μg/m^3 - 212μg/m^3 and 9μg/m^3 - 298μg/m^3. In Opebi, however, $PM_{2.5}$ and PM_{10} were between 26 - 163 (μg/m^3) and 40 - 241 (μg/m^3) respectively. In all the locations, the mean values of O_3 are as follows: 32.52, 38.7, 36.2, 37.85, and 36.13μg/m^3 for Ikeja, Maryland, Opebi, Ojodu, and Eti-Osa. Opebi had the highest value (3179μg/m^3), followed by Eti-Osa (2978μg/m^3), and the lowest value in Maryland (1943μg/m^3). The coefficient variations of NO_2 and SO_2 varies from 61.63 - 77.06 percent and 26.86 - 37.36 percent respectively in all locations, with the exception of Eti-Osa with variations of 120.97 percent and

Table 1: Summary of the Data in all the five locations

	AQI	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	CO ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	Temp °C	Humidity (%)	Wind Speed (m/s)
Ikeja										
Mean	127.88	57.4	84.97	35.52	1110.2	17.77	3.95	27.38	84.63	12.42
Std Dev.	42.58	28.29	20.03	26.34	58.5	11.07	1.06	1.51	7.92	5.58
Minimum	70	20	30	16	302	2	3	23	66	2
Maximum	188	123	176	98	2576	45	7	30	100	24
Opebi										
Mean	141.82	69.28	107.38	38.7	1392	23.98	6.08	26.7	92.7	6.55
Std Dev.	39.62	38.18	52.35	31.93	708	15.08	2.27	0.85	2.42	1.95
Minimum	80	26	40	11	332	4.25	2	25	84	2
Maximum	211	162	241	113	3179	55	15	28	94	11
Ojodu										
Mean	109.28	40.38	63	37.85	69.6	8.82	2.83	27	85.5	13.73
Std Dev.	38.41	19.68	27.4	24.13	43.7	6.8	0.78	2.18	7.86	6.21
Minimum	61	17	27	12	273	2	2	23	70	4
Maximum	163	81	121	88	1968	28	4	30	94	20
Maryland										
Mean	127.88	57.05	84.97	36.2	964	15.12	3.4	28.33	82.75	9.95
Std Dev.	40.79	28.91	41.85	22.5	473	9.31	1.01	0.57	2.7	4.24
Minimum	69	22	33	13	115	2	2	28	72	6
Maximum	192	120	173	90	1943	33	6	30	84	24
Eti-Osa										
Mean	101.4	58.3	84.5	36.13	1013	17.58	5.03	23.5	93.37	3.79
Std Dev.	77.3	63.1	89.2	25.32	1007	21.26	3.26	0.56	1.42	1.91
Minimum	21	5	9	10	124	1	1	23	90	2
Maximum	256	212	298	111	2978	66	11	25	94	6

64.84 percent respectively. Table 1 also indicates the variations (mean) in temperature (23.5-28.33), wind speed (3.79-13.73), and relative humidity (82.75-93.37).

For the data collected, Pearson correlation statistics are applied. Strong correlations (r) were observed in Eti-Osa AQI, $PM_{2.5}$, PM_{10} at above 0.90. Also in other locations there were strong correlations in AQI, $PM_{2.5}$, PM_{10}, CO, and O_3 at >0.84. (Table 2). The gases and the values of the PM are negatively correlated. Strong correlations were in the meteorological parameters and the pollutants.

Table 2: Pearson Correlation Coefficient of the locations

Parameter	AQI	$PM_{2.5}$	PM_{10}	O_3	CO	NO_2	SO_2	Temp	Humidity	Wind Speed
AQI	1									
$PM_{2.5}$	0.97	1								
PM_{10}	0.97	0.99	1							
O_3	-0.53	-0.56	-0.57	1						
CO	0.93	0.92	0.92	-0.58	1					
NO_2	0.84	0.84	0.85	-0.59	0.97	1				
SO_2	0.92	0.86	0.86	-0.39	0.92	0.84	1			
Temperature	-0.64	-0.58	-0.58	0.14	-0.65	-0.57	-0.75	1		
Humidity	0.07	0.09	0.09	0.05	0.16	0.13	0.18	-0.45	1	
Wind Speed	-0.83	-0.74	-0.74	0.23	-0.79	-0.69	-0.91	0.79	-0.23	1

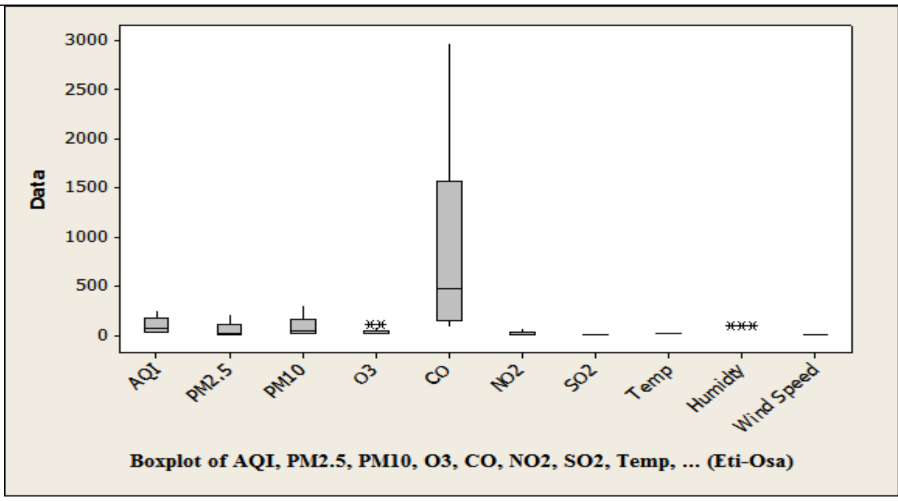

Figure 2: The box plot of the locations

Box and Whisker plots are shown in Figure 2 to display the data distribution in terms of the lower quartile, upper quartile, median, minimum and maximum in each of the five locations. This was carried out to demonstrate the difference in regular concentrations of air pollutants. A brief sketch of the distribution of the underlying data is basically shown in the Box plot.

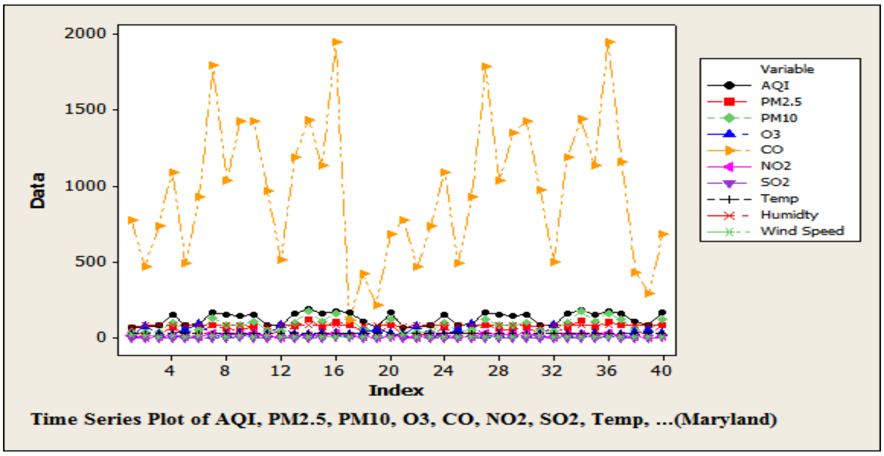

Figure 3: The Time Series of the locations

Time series plot is depicted in Figure 3. From the graph, it could be deduced that there was variability in this pollutants data with time. The variability is much lower near the valleys than near the peaks.

Table 3: PCA of the Data from the Different Locations

Parameter	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
AQI								0.82
PM2.5	0.61		0.65					
PM10	0.66							
O3		-0.5	0.63	0.5				
CO								
NO2		0.61	0.72		0.72		-0.82	
SO2								
Temperature		0.5				-0.65		
Humidity		-0.65	-0.66					
Wind Speed							-0.51	
Total Variance (%)	70.42	14.3	7.4	3.1	2.5	1.6	0.5	0.2
Cumulative (%)	70.4	84.7	92	95.1	97.6	99.3	99.8	99.9

The Principal Component Analysis (PCA) of AQI, the pollutants, and meteorological factors over data set from the locations are depicted in Table 3. For Eti-Osa, Ojodu, Maryland, Ikeja, and Opebi, the maximum variance defined for PCs was 70.42 percent, 35.9 percent, 50.6 percent, 48.8 percent, and 52.3 percent. Eight PCs were obtained in which the highest variance was clarified by PC1 with high loads from $PM_{2.5}$ and PM_{10}.. PC2 and PC3 contain pollutant mixed loadings from PM, SO_2, NO_2, temperature and humidity.

4. Discussion

The AQI obtained in this study is far less of what was obtained in Port Harcourt by Akinfolarin et al. [12] Their results depicted 'Very unhealthy' to 'dangerous', while ours was from 'good' to 'unhealth'. In this analysis, most of the $PM_{2.5}$ findings were above the NAAQS limit of 35μg/m^3 [9]. Likewise, most of the findings on PM_{10} in this study are above the limit of 150μg/m^3. Also the NO_2 levels are well above the recommended 1-hour mean (0.5μg/m^3) of the Federal Ministry of Environment (FMEnv) Nigeria, but less than the recommended 24-hour WHO limit (40μg/m^3). The SO_2 values obtained were lower than the WHO limit suggested for 24 hours (500μg/m^3), and the CO values were also well above the WHO limit of 55μg/m^3 for 8 hours. The effect of the high results is that it can lead to secondary pollutant(s) polluting water sources and soil if the elevated contaminants are washed down by rainfall. This is the case with HNO_3-forming NO_2, which acidifies surface water, soil water and soil water. The burning of fossil fuels, vehicular movements, high population rise, rapid economic development, and re-suspended soil dust are the contributing variables of airborne contaminants in different cities of the world [13]. There were relationships between the meteorological factors. The coefficients of correlation obtained may be due to the washout phase as rain indicates an effect of wet deposition on particulate. Temperature can influence the formation of particles and gases, so the photochemical reaction between precursors can be encouraged by temperature.

The PCA shows that the CO, NO_2 and SO_2 indicated biomass burning and vehicular emissions. This implies that the contribution of CO and NO_2 to this portion comes from emissions from vehicles. It is proposed that contaminants can be released from vehicle exhaust [14, 15] and from vehicle interior sections [16], suggesting that vehicle emissions are the dominant sources. PC2 contains heavy pollutant loads, which may be from the burning of biomass. The contaminants may be produced from the burning of plastic and waste too. It has been stated that pollution sources can be from road side litter and landfill trash burning. [15, 17]. The PCA suggested that the predominant sources in the study areas, with the exception of Eti-Osa near the lagoon, were vehicular, dumping and burning of wastes, and industrial sources.

5. Conclusions

The study is a preliminary results (40 days) of a year monitoring study of Lagos, Nigeria. The data generated in this study was received via satellite model provided by Air.Quality.com. The AQI, the pollutants ($PM_{2.5}$, PM_{10}, O_3, CO, SO_2, and NO_2), and the meteorological factors were use for the assessment. It was observed the AQI values were high translating into 'Very Unhealthy' but most of the results in Eti-Osa area were 'good' due to its location near the lagoon. Most of the results for the pollutants were above the WHO, NAAQS, and FMEnv limits 1-hour mean. Pearson Correlation coefficient revealed a great relationships between the pollutants and the meteorological factors. In conclusion, it was depicted that elevated concentrations of the pollutants were caused by man made activities like vehicular movements, burning of biomass and wastes, industrial, and national demonstration by the youths of the country. No doubt, the locations are in danger in terms of air pollution, efforts to reduce the menace and the aftermath effects should be put in place by all stakeholders (Government, residents, NGOs, environmental scientists, journals, philanthropists, just to mention a few).

Acknowledgments: The authors wish to acknowledge Air.Quality.com for making the data available for use.

Author Contributions: F.O.A a**nd U** conceived and designed the experiments; S., A., and K.M produced the map of the location and the statistical analyses. A.K.M performed the experiments; F.O.A. wrote the paper. All authors proof read the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AQI: Air Quality Index
IoT:Internet of Things
WHO: World Health Organisation
NGO: Non-Governmental Organisation
NAAQS: National Ambient Air Quality Standards
NYCCAS: New York City Community Air Survey
PCA: Principal Component Analysis
FMEnv: Federal Ministry of Environment

References

1. World Health Organization (WHO). RHN workshop on environment and health (air pollution and active mobility) Ljubljana, Slovenia 30 Nov 2018; p. 39. Available online: https://www.euro.who.int/en/about-us/ networks/regions-for-health-network-rhn/activities/network-updates/rhn-workshop-on-environmentand -health-air-pollution-and-active-mobility-at-the-11th-european-public-health-conference (accessed 26 September 2020).
2. Air Pollution. Available online: https://www.who.int/health-topics/air-pollution#tab=tab_1/ (accessed on 13 March 2020).
3. Iskandaryan, D, Ramos, F. , and Trilles, S. Air Quality Prediction in Smart Cities Using Machine Learning Technologies based on Sensor Data: A Review. *Applied Science*. *Appl. Sci.* 2020, *10*, 2401; doi:10.3390/app10072401.

4. Giffinger, R.; Fertner, C.; Kramar, H.; Kalasek, R.; Pichler-Milanovi´C, N.; Meijers, E. Smart cities: Ranking of european medium-sized cities. vienna, austria: Centre of regional science (srf), vienna university of technology. Available online: http://www.smart-cities.eu/download/smart_cities_fifinal_report.pdf accessed on 31 March 2020).
5. Trilles, S.; Calia, A.; Belmonte, Ó.; Torres-Sospedra, J.; Montoliu, R.; Huerta, J. Deployment of an open sensorized platform in a smart city context. *Future Gener. Comput. Syst.* 2017, *76*, 221–233.
6. Granell, C.; Kamilaris, A.; Kotsev, A.; Ostermann, F.O.; Trilles, S. Internet of Things. In *Manual of Digital Earth*; Springer: Singapore, Singapore, 2020, 387–423.
7. Daful , M.G., Adewuyi , T.O., Muhammad, M. N., Oluwole, O. A., Dadan-Garba, A., and Ezeamaka, C.K. Assessment of the Spatial Relationship between Air Pollutants in Kaduna Metropolis, Nigeria. J*ournal of Sustainable Development*; 2020. Vol. 13 (4): 204-223.
8. Croitoru, L., Chang, J.C. and Akpokodje, J. The Health Cost of Ambient Air Pollution in Lagos. *Journal of Environmental Protection*, 2020. 11, 753-765. https://doi.org/10.4236/jep.2020.119046.
9. Osimobi, O. J., Yorkor, B. and Nwankwo, C. A. Evaluation of daily pollutant standard index and air quality index in a university campus in Nigeria using PM_{10} and $PM_{2.5}$ particulate matter. *Journal of Science, Technology and Environment Informatics*, 2019. 07(02), 517-532.
10. Air-quality.com-https://air quality.com/place/nigeria/lagos/ba6302a2?lang=en&standard=aqi us. Accessed 12th November, 2020.
11. CantyMedia, Lagos, Nigeria. https://www.weatherbase.com/weather/weather-summary.php3?s=10256&cityname=Lagos%2C+Lagos% C+Nigeria&units=metric. Accessed 23rd October 2020).
12. Akinfolarin OM, Boisa N, Obunwo CC. Assessment of Particulate Matter-Based Air Quality Index in Port Harcourt, Nigeria. *J Environ Anal Chem.* 2017. 4: 224. doi:10.4172/2380-2391.1000224.
13. Abulude, F.O., Ndamitso, M.M., Abdulkadir, A. Environmental Situation of an Agricultural Area in Akure, Nigeria, Based on Physico-Chemical Properties of Rainwater. *Pollution.* 2018. 4(2), 317-325.
14. Fu, P.Q., Kawamura, K., Pavuluri, C.M., Swaminathan, Y., and Chen, J. Molecular characterization of urban organic aerosol in tropical India: contributions of primary emissions and secondary photooxidation. *Atmos. Chem. Phys*. 2010. 10(6): 2663-2689.
15. Bahino, J.,Yoboué, V., Galy-Lacaux, C., Adon, M., Akpo, A., Keita, S., Liousse, C., Gardrat, E., Chiron, C., Ossohou, M., Gnamien, S., and Djossou, J. A pilot study of gaseous pollutants' measurement (NO_2, SO_2, NH_3, HNO_3 and O_3) in Abidjan, Côte d'Ivoire: contribution to an overview of gaseous pollution in African cities. *Atmos. Chem. Phys*., 2018. 18, 5173–5198.
16. Haddad, E.I., Marchand, N., Dron, J., Temime-Roussel, B., Quivet, E., Wortham, H., Jaffrezo, J.L., Baduel, C., Voisin, D., Besombes, J.L., and Gille, G. Comprehensive primary particulate organic characterization of vehicular exhaust emissions in France. *Atmos. Environ*. 2009. 43(39), 6190-6198.
17. Simoneit, B.R., Medeiros, P.M., Didyk, B.M. Combustion products of plastics as indicators for refuse burning in the atmosphere. *Environ. Sci. Techno*l. 2005. 39 (18), 6961-6970.

© 2020 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons by Attribution (CC-BY) license (http://creativecommons.org/licenses/by/4.0/).