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Assessment of Criteria Air Pollutants at Selected Petrol Stations in Lagos State, Nigeria

Ugwoha, E.*[1] and Okeowo, O.A[2]
[1]Department of Civil & Environmental Engineering, University of Port Harcourt, P.M.B. 5323, Nigeria
[2]Centre for Occupational Health, Safety and Environment, University of Port Harcourt, P.M.B. 5323, Nigeria
*Corresponding author's email: ugwohaej@gmail.com

Abstract
Assessment of criteria air pollutants was done in eighteen (18) petrol stations in the five administrative divisions of Lagos State, namely Ikeja (A, B, C, D, E and F), Badagry (G, H, I and J), Epe (K and L), Lagos (M, N, O and P) and Ikorodu (Q and R). Criteria pollutants such as PM_{10}, $PM_{2.5}$, O_3, NO_2, CO and SO_2 of all sites were monitored. The results obtained were in the range of 119.3 – 1191.4 µg/m^3 (PM_{10}), 23.8 – 94.8 µg/m^3 ($PM_{2.5}$), 0.0 – 0.2 mg/l (O_3), 0.03 – 0.033 mg/l (NO_2), 0.0 – 13 mg/l (CO) and 0.00 – 1.69 mg/l (SO_2). The highest level obtained for PM_{10} was 1191.4µg/m^3 at site L due to ongoing road construction at the time of sampling. The concentrations of O_3 and CO were highest at site Q where traffic count and intersections were higher. When compared with Air Quality Standard, all six monitored pollutants were in the range of poor to very poor (PM_{10}), good to very poor ($PM_{2.5}$), very good to very poor (O_3, SO_2 and CO), and good to moderate (NO_2). The overall comparison of data from the different sites shows that concentration of pollutants was highest at sites Q, L and N due to high traffic and road construction. This study concludes that the air quality of petrol stations in Lagos State are poor and could expose the workers to high unacceptable levels of pollutants which can lead to severe health issues.

Keywords: *Criteria pollutants, Assessment, Petrol station, Air quality, Lagos State*

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1. Introduction

The recent population increase in Nigeria has triggered an increase in the demand for petroleum products thus bringing about the need to build more petrol stations in other to meet the increasing demand for fuel. The situation is such that it has become a norm to see petrol stations located in residential areas. The disadvantage of this development is the increased pollution of the air caused by the continued emission of toxic gases into the air. These emissions originate from gasoline delivery to the stations, tank breathing which occurs due to temperature and pressure changes, vehicle refuelling, loosely closed tanks and mishandling of the petroleum leading to spillage (Isabel et al., 2010). There is also the emission of combustion products from vehicle engines present in the station. These products which include nitrogen oxides, particulate matter, carbon monoxide and volatile organic compounds (VOCs) are being emitted into the atmosphere and are hazardous to human health (Helmut et al., 2010).

Air pollution contributes to numerous adverse health effects. Consequently, the Environmental Protection Agency (EPA) has established national ambient air quality standards (NAAQS) for six of the most common air pollutants, namely carbon monoxide, lead, ground-level ozone, particulate matter, nitrogen dioxide, and sulphur dioxide, known as criteria air pollutants, to protect public health and the environment. The presence of these pollutants in ambient air is generally due to numerous diverse and widespread sources of emissions. Exposure to these criteria pollutants can cause health and environmental effects (Department of Environmental Quality, 2019). According to Indiana Department of Environmental Management (2012), children, the elderly, and people with lung disease, such as emphysema and asthma, are especially susceptible to health complications from air pollution. Pollutants in the air can cause both acute health effects, from short-term exposure, as well as chronic health effects, from long-term or repeated exposure. Specific health risks and their severity depend upon the amount of pollutant to which an individual is exposed, the duration of the exposure, and the sensitivity of the individual exposed. Acute exposure to air pollution can cause an irritation of the eyes, nose, throat, coughing, difficulty breathing, inflamed lung tissue, and other health-related problems. Chronic exposure to air pollution could have more severe effects on human health, including cancer, reduced immune defences, and cardiovascular and lung diseases. Without clean air, the health of people, ecosystems, and even economies may be harmed.

This study was undertaken to assess the concentration of criteria pollutants in air at petrol stations. Although a study has been carried out to investigate the health effect of some health hazards on petrol station attendants in Owerri, Nigeria (Nwanjo and Ojiako, 2007), none however to my knowledge has been carried out to determine the prevalence and intensity of criteria pollutants in the ambient air at petrol stations in Lagos. Thus, it is hoped that the outcome of this study will throw light on the need for proper air quality management programs at all petrol stations.

2. Materials and methods

2.1 Study area

This study was conducted in Lagos State located in the southwestern geopolitical zone of Nigeria. Though the smallest in area of Nigeria's 36 States, Lagos State is arguably is the most economically important state of the country, having Lagos (Eko), the nation's largest urban area. On the North and East, it is bounded by Ogun State. In the West, it shares boundaries with the Republic of Benin. Behind its southern borders lies the Atlantic Ocean. Its coordinates are 6° 27' 14.65" N and 3° 23' 40.81" E. Fig. 1 shows the map of Lagos State with the various sampling sites. Lagos State is divided into five Administrative Divisions, which are further divided into twenty (20) Local Government Areas (LGAs) (Table 1). The first sixteen (16) LGAs in Table 1 comprise the statistical area of Metropolitan Lagos. The remaining four (4) LGAs (Badagry, Ikorodu, Ibeju-Lekki and Epe) are within Lagos State but are not part of Metropolitan Lagos.

Fig. 1: Local Government areas in Lagos State of Nigeria

Table 1: Administrative divisions and their respective local government areas of Lagos State

Administrative divisions	Local governments areas
Ikeja	Agege, Alimosho, Ifako-Ijaye, Ikeja, Kosofe, Mushin, Oshodi-Isolo and Shomolu
Lagos	Apapa, Eti-osa, Lagos Island, Lagos Mainland, Surulere
Badagry	Ajeromi-Ifelodun, Amuwo-Odofin, Ojo, Badagry
Ikorodu	Ikorodu
Epe	Ibeju-Lekki, Epe

2.2 Research design

A map of Lagos State was surveyed to select the five administrative divisions so as to obtain a depictive sample. The five (5) divisions selected include Ikorodu, Badagry, Ikeja, Lagos and Epe. Ambient air samples were collected from eighteen (18) petrol stations selected for the study. The allocation of the number of petrol stations per administrative division was based on the size and total number of petrol stations in the division (Table 2). Some petrol station attendants were interviewed and general personal observations were made.

Table 2: Number of petrol stations sampled per administrative division

Administrative division	No. of petrol stations sampled	Av. no. of pumps per station
Ikeja	6	6
Lagos	4	5
Badagry	4	4
Ikorodu	2	7
Epe	2	5

2.3 Sampling techniques

The cluster sampling method was adopted where the population is split into clusters and two to four clusters are selected to be sampled. Lagos State was divided into the different divisions and two to six petrol stations per division (depending on size of division and total number of petrol station in the division) were then selected randomly and sampled to obtain the required data.

2.4 Air quality monitoring

Ambient air quality monitoring was carried out by measuring the presence and concentrations of criteria air pollutants such as particulate matters (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) at petrol stations for a duration of fourteen (14) days. Sampling was done from 10am to 4pm daily with an average of 45mins sampling time per filling station. AEROCET 531 Particle Mass Monitor was used to measure the concentrations of the particulate matters while AEROQUAL Portable Air Monitor was used to measure the concentrations of combustion products such as CO, SO_2, NO_2 and O_3. The results obtained from the ambient air quality measurement were compared with relevant standards (Tables 3 and 4).

Table 3: National ambient air quality standards (NAAQS) for criteria air pollutants

Criteria air pollutants	NAAQS	Averaging time
PM_{10}	150 μg/m^3	24-hour
$PM_{2.5}$	35 μg/m^3	24-hour
CO	9 ppm	8-hour
SO_2	0.140 ppm	24-hour
NO_2	0.053	Annual
O_3	0.070 ppm	8-hour

Table 4: USEPA air quality index rating for priority pollutants

AQI Category	AQI rating	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	O_3 (ppm)
Very good (0-50)	A	0-50	0-12	0-2.0	0-0.02	0-0.02	0.000-0.059
Good (51-100)	B	51-75	12-35	2.1-4.4	0.021-0.03	0.021-0.034	0.060-0.075
Moderate (101-150)	C	76-100	35-53	4.5-9.4	0.031-0.04	0.035-0.144	0.076-0.095
Poor (151-200)	D	101-150	53.1-70	9.5-12.4	0.041 -0.06	0.145-0.224	0.096-0.115
Very Poor (>200)	E	>150	>70	>12.4	>0.06	>0.224	>0.115

2.5 Data analysis

A one-way analysis of variance (ANOVA) was carried out on the measured criteria pollutants from the selected petrol stations of each administrative division to determine if there is any statistical difference.

3. Results and discussion

3.1 Concentration of criteria pollutants

The concentrations of all selected criteria pollutants in all eighteen (18) sampling sites (A-R) are presented in Fig. 2 - 7. Site L (1191.4 μg/m^3) had the highest concentration of PM_{10} while site A (119.3 μg/m^3) had the lowest concentration of PM_{10} (Fig. 2). Fig. 3 shows the concentration of $PM_{2.5}$ with site R having the highest value of

94.8µg/m^3 and site F having the lowest value of 23.8µg/m^3. Site Q (0.2 mg/l) had the highest concentration of O_3 while site G (0.00 mg/l) had the lowest concentration (Fig. 4). For NO_2, sites G, H, K and O have similar concentration of 0.033 mg/l as the highest level while the lowest concentration of 0.030 mg/l was obtained at sites A, B and R (Fig. 5). The results of CO ranged from 0.0 – 13 mg/l with sites A to P having the lowest concentration of 0.00 mg/l and site Q having the highest concentration of 13 mg/l (Fig. 6). Site N had the highest measurement of SO_2 with a concentration of 1.69 mg/l while sites F and G had the lowest concentration of 0.00 mg/l (Fig. 7).

PM_{10} was higher than the NAAQS limit of 150 µg/m^3 in most sites with the exception of only five sites (A, B, F, G and M). The highest concentration at site L was due to road construction at the time of sampling. According to Marlborough District Council (2019), exposure to high concentrations of PM_{10} can result in a number of health impacts ranging from coughing and wheezing to asthma attacks and bronchitis to high blood pressure, heart attack, strokes and premature death. These impacts apply to both the young and old, and have been found to result in 900 premature deaths every year in New Zealand (Marlborough District Council, 2019).

$PM_{2.5}$ concentrations at all sites were above the NAAQS limit of 35 µg/m^3 except for sites F and G. Although there is no safe threshold below which no adverse effects would be anticipated for $PM_{2.5}$ but the biggest impact of particulate matter on public health is understood to be from long-term exposure to $PM_{2.5}$, which increases the age-specific mortality risk, particularly from cardiovascular causes (WHO, 2006). Exposure to short-term high concentrations of $PM_{2.5}$ can also exacerbate lung and heart conditions, and children, the elderly and those with predisposed respiratory and cardiovascular disease, are more susceptible to these health impacts (WHO, 2008; EPA, 2016).

For O_3 concentration, four sites (F, N, Q and R) were above the NAAQS limit of 0.07 mg/l. According to the NAAQS, O_3 concentration of 0.07 mg/l requires a maximum exposure time of 8-hr/day. In comparison to this study, four sites rated above 0.07 mg/l and operate for approximately 18-hr/day, indicating that workers at these sites could have health issues. This is of great concern considering the fact that the inhaling of O_3 could trigger or worsen the case of asthma (EPA, 2017). According to USEPA (2017a), breathing O_3 can trigger several health problems including chest pain, coughing, throat irritation, and airway inflammation. It also can reduce lung function and harm lung tissue as well as worsen bronchitis, emphysema and asthma. These effects have been found even in healthy people (both children and adults), but can be more serious in people with lung diseases such as asthma.

The concentrations of NO_2 for all sites were found to be below the NAAQS limit of 0.053 mg/l. There seem to be no significant difference between the concentrations of NO_2 at all sites as the concentrations fell within a very short range of 0.030 – 0.033 mg/l. According to Department of the Environment and Heritage (2005), only exposure to raised levels of NO_2 has likelihood of causing respiratory problems such as wheezing, coughing, colds, flu and bronchitis.

The concentrations of CO for all sites were below the NAAQS limit of 9 mg/l with the exception of only site Q measuring above the NAAQS limit. This high CO at site Q could be attributed to emission from car due to traffic congestion. At this site, many public transport vehicles pick passengers and a long waiting time for vehicles was observed. The attendants who work in site Q are therefore exposed to unacceptable levels of CO which could cause headaches, dizziness, vomiting and nausea. Exposure to this high level of CO over long periods of time has been linked with increased risk of heart disease (USEPA, 2017b). Although, all people are at risk of CO poisoning, unborn babies, infants, the elderly, and people with chronic heart disease, anaemia, or respiratory problems are generally more at risk than others (USEPA, 2017b).

The concentration of SO_2 at some sites (D, E, F, G, I, J, K, M, O and P) were within the NAAQS limit of 0.140 mg/l while other sites (A, B, C, H, L, N, Q and R) were above the limit. The highest value at site N could be attributed to the observed high traffic count and low wind velocity. High concentrations of SO_2 can cause inflammation and irritation of the respiratory system (National Park Service, 2008; Newton, 2017). According to National Park Service (2008), high SO_2 can affect lung function, worsen asthma attacks, and worsen existing heart disease in sensitive groups. It can also react with other chemicals in the air and change to a small particle that can get into the lungs and cause similar health effects. Children, older adults and people with lung diseases, such as asthma, chronic bronchitis, and emphysema will generally have more serious health effects at higher SO_2 levels (National Park Service, 2008).

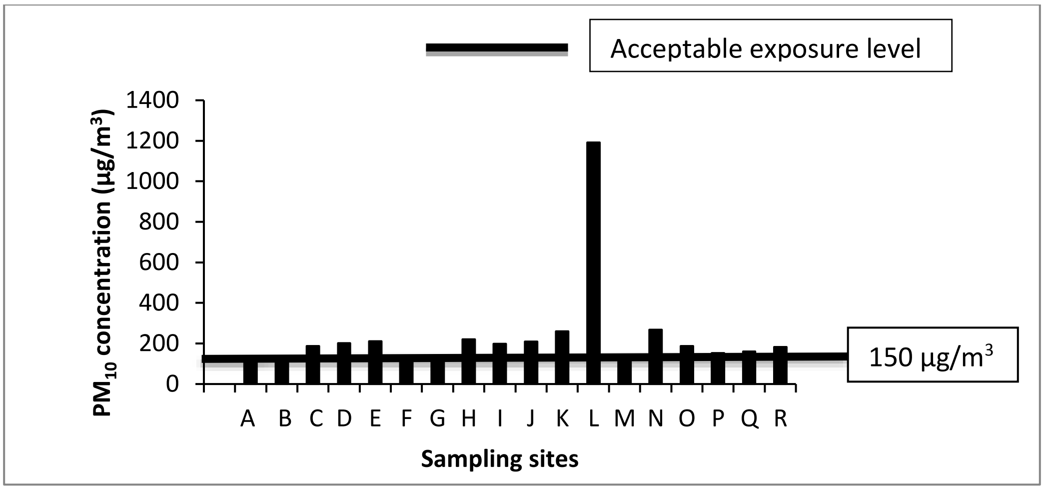

Fig. 2: Concentration of PM_{10} in ambient air at sites

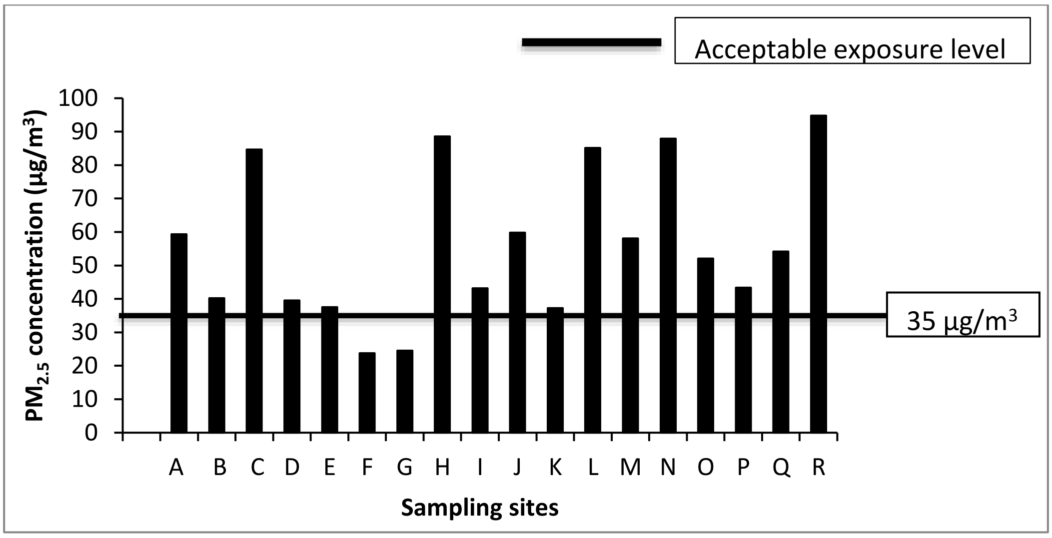

Fig. 3: Concentration of $PM_{2.5}$ in ambient air at sites

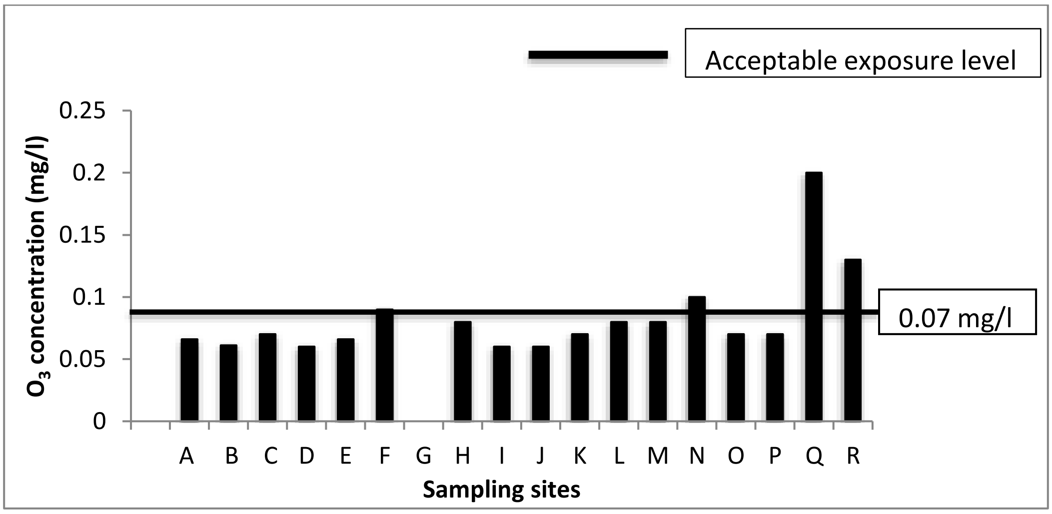

Fig. 4: Concentration of O_3 in ambient air at sites

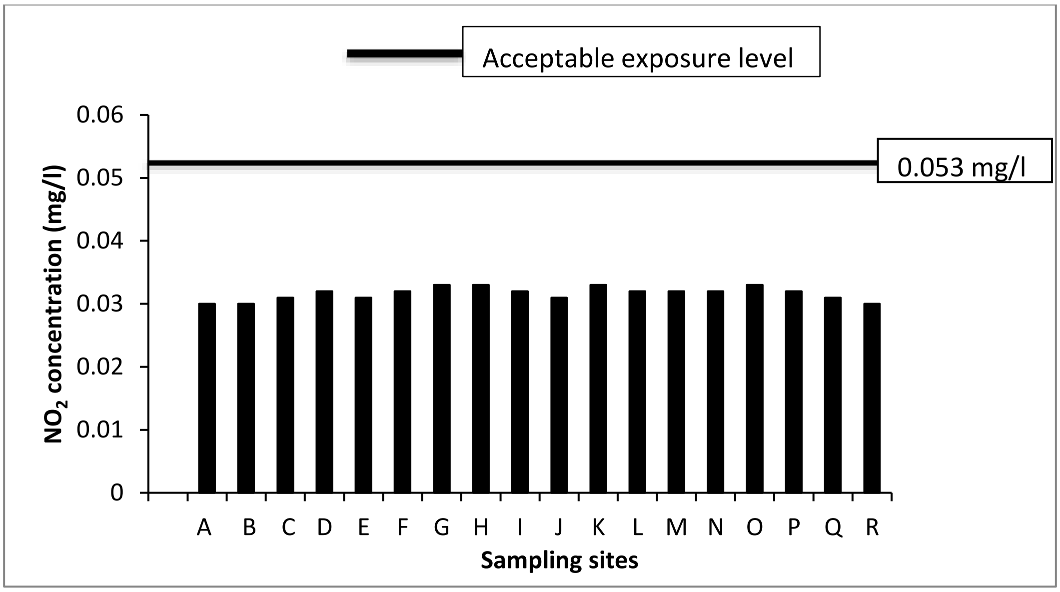

Fig. 5: Concentration of NO_2 in ambient air at sites

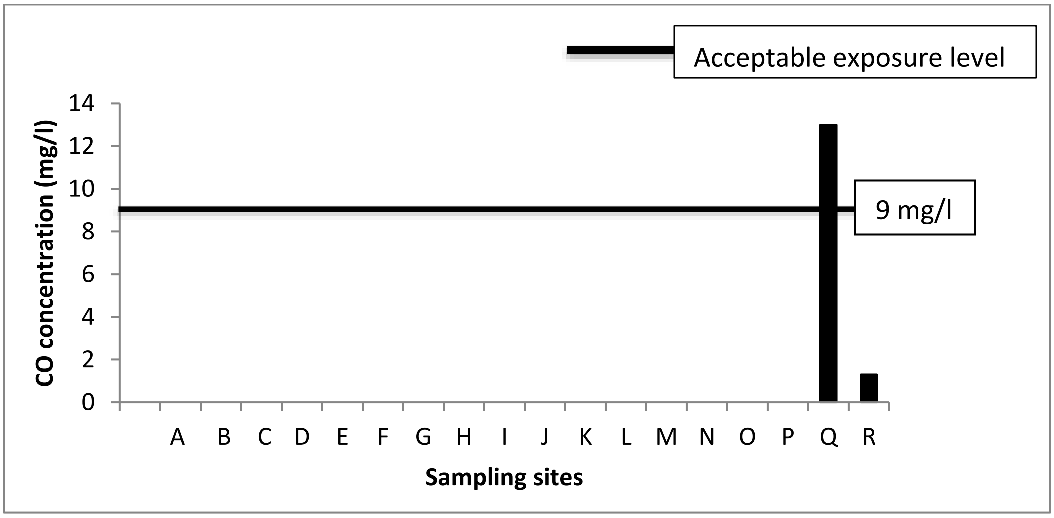

Fig. 6: Concentration of CO in ambient air at sites

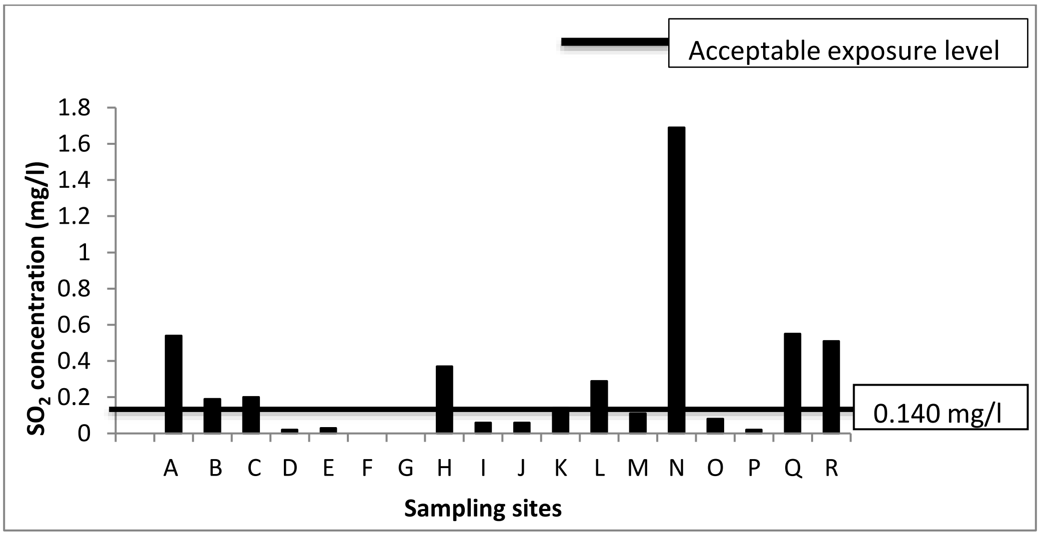

Fig. 7: Concentration of SO_2 in ambient air at sites

3.2 Air quality rating

Table 5 shows the summary of the air quality rating of the selected petrol station sites in Lagos State using the USEPA standard (Table 4). The calculated air quality index (AQI) based on PM_{10} shows that the quality of ambient air is either poor (D) or very poor (E) for all sites and thus can affect the health as well as effectiveness of the petrol station attendants. The calculated AQI based on $PM_{2.5}$ indicates that the quality of ambient air in half of the sites are within good (B) and moderate (C) while the remaining half fall within poor (D) and very poor (E). The calculated AQI based on O_3 suggests that 61.1% of the selected sites have ambient air quality that ranged from very good (A) to good (B) while 22.2% and 16.7% of the sites have moderate (C) and very poor (E) ambient air quality, respectively. The calculated AQI based on NO_2 shows that all selected sites have ambient air quality ranging from good (B) to moderate (C). The calculated AQI based on CO indicates that all selected sites have ambient air quality that are very good (A) except for 1 site at Ikorodu that has very poor (E) ambient air quality. The calculated AQI based on SO_2 suggests that 27.8% of the selected sites have ambient air quality that ranged from very good (A) to good (B) while the remaining 72.2% of the sites have very poor (E) ambient air quality. A critical look at all the sites considering all the criteria air pollutants reveals that 20.4, 14.8, 24.1, 7.4 and 33.3% of the sites have ambient air quality that are very good, good, moderate, poor and very poor, respectively. This implies that majority of the petrol station sites in Lagos State have very poor ambient air quality and thus can be detrimental to the health of the petrol station workers.

Table 5: Summary of air quality rating of selected petrol station sites in Lagos State

Sites	AQI (PM_{10})	AQI ($PM_{2.5}$)	AQI (O_3)	AQI (NO_2)	AQI (CO)	AQI (SO_2)
Ikeja						
A	D	D	B	B	A	E
B	D	C	B	B	A	E
C	E	E	B	C	A	E
D	E	C	B	C	A	A
E	E	C	B	C	A	B
F	D	B	C	C	A	A
Badagry						
G	D	B	A	C	A	A
H	E	E	C	C	A	E
I	E	C	B	C	A	E
J	E	D	B	C	A	E
Epe						
K	E	C	B	C	A	E
L	E	E	C	C	A	E
Lagos						
M	D	E	C	C	A	E
N	E	E	E	C	A	E
O	E	C	B	C	A	E
P	E	C	B	C	A	A
Ikorodu						
Q	E	D	E	C	E	E
R	E	E	E	B	A	E

3.3 Statistical analysis

A one-way analysis of variance (ANOVA) was carried out on the measured air quality parameters at the selected petrol station sites within each administrative division and across the five administrative divisions for any significant difference. The test results within each administrative division showed that there is a significant difference ($P < 0.05$) in the concentrations of the air quality parameters at the petrol station sites in all administrative divisions with the exception of Epe where there is no significant difference ($P > 0.05$). The test result across all administrative divisions showed that there is no significant difference ($P > 0.05$) in the concentrations of the air quality parameters at the petrol station sites in all administrative divisions.

4. Conclusions

Ambient air quality monitoring in eighteen (18) petrol station sites in Lagos State of Nigeria was conducted. The concentrations of the criteria pollutants were determined and compared with acceptable standards. The results of the criteria pollutants were in the range of 119.3 – 1191.4 μg/m^3 (PM_{10}), 23.8 – 94.8 μg/m^3 ($PM_{2.5}$), 0.0 – 0.2 mg/l (O_3), 0.03 – 0.033 mg/l (NO_2), 0.0 – 13 mg/l (CO), and 0.00 – 1.69 mg/l (SO_2). When compared with USEPA Air Quality Standard, the AQIs from the criteria pollutants were in the range of poor to very poor (PM_{10}), good to very poor ($PM_{2.5}$), very good to very poor (O_3, SO_2 and CO), and good to moderate (NO_2). The result of one-way ANOVA across all administrative divisions showed that there is no significant difference ($P > 0.05$) in the arithmetic mean concentrations of the air quality parameters at the petrol station sites in all administrative divisions. This study concludes that the ambient air quality at petrol stations in Lagos State are poor and could expose the workers to high unacceptable levels of pollutants which can lead to severe health issues.

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