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AIR QUALITY INDEX PATTERN OF CRITERIA AIR POLLUTANTS AROUND A HAULAGE TRUCK STOP

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Abstract

This study investigated the air quality index (AQI) pattern of criteria pollutants around a haulage truck-stop in southwestern part of Nigeria using carbon monoxide (CO) and nitrogen dioxide (NO_2) as indicators. Concentrations of these pollutants were quantified at five different sampling points using ToxiRAE II Gas Monitor. The results showed the 8-hours averaging period mean concentrations of carbon monoxide (CO) ranged between 0.0875 and 0.4556 ppm, while the extrapolated 1-hour averaging period mean concentration of nitrogen dioxide (NO_2) were of the range 121.60 – 633.14 ppb. The mean AQI concentrations determined indicates good and moderate AQI categories for CO while the AQI categories of NO_2 indicates unhealthy for sensitive groups at all sampled point. This study establishes that vehicular activities at the truck-stop could pose great impact on the ambient air quality with sensitive groups most at risk.

***Keywords**: Air quality index; breakpoint; criteria pollutants; vehicular activities; haulage truck-stop; mixing ratio; airshed.*

1. Introduction

Air pollution has continued to receive attention worldwide due to its harmful effects on human health, especially in many urban areas around the world. Anthropogenic sources of air pollution are major contributors to ambient air pollution [1-4], these include emission from industries, homes and internal combustion engines exhaust [5]. Automotive pollution has been established to account for gas and other air toxics in ambient air along motorways and urban sites [6]. Emission from products of incomplete combustion (PIC) of vehicular engine has been identified to be responsible for about 90-95% of the ambient CO levels, 80-90% of the NOx and hydrocarbons and a large portion of the particulates which poses a significant threat to human health and natural resources [7].

The air quality index (AQI) is an index for reporting daily air quality. It is a tool for communicating air quality status to people in simple terms, it also transforms complex air quality data of various pollutants into a single number, nomenclature and colour [8]. These index informs the public on how clean or unhealthy the ambient air is with all the associated health effects which might be of concern [9]. It has therefore proven to provide a clearer picture of local air quality to the general public and has been adopted effectively in many nations [9-10]. AQI index is a tool that present complex air quality data of six common air pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2, SO_2 and O_3) in a single number and colour with respect to the effects on human health [11-13]. Fakinle [1] and Sonibare [9] analyzed the air quality index pattern of particulate around a haulage vehicle park in southwestern Nigeria and around petroleum production facilities in Niger Delta sub region of Nigeria, respectively. AQI was also adopted by [14] to analyze the evolution of air pollution in a space of two decades in Germany, also [12,15] used the tool for air quality assessments for Naples in Italy and Athens, respectively. However not much work has been done on the usage of the tool for air quality assessment in Sub-Saharan Africa especially in Nigeria. Due to the undeveloped railway system in Nigeria, major goods and petroleum product are being conveyed to the major cities by trucks which could cause a great deal of air pollution [7]. There are many truck stop in the Nigeria designated to provides refuelling, rest and other services to motorists and truck drivers. Due to large number of the trucks, these truck stops have become hot-spots experiencing frequent exceedance in pollutant ambient air limit. Hence the present study investigated the air quality index pattern of criteria air pollutants around a truck-stop using carbon monoxide (CO) and nitrogen dioxide (NO_2) as indicators, these is with a view of assessing ambient air quality around the truck-stop.

2. Methodology

2.1. Study area

The study area was a truck-stop located in Ogere along popular Lagos –Ibadan highway, Ogun State of Southwestern part of Nigeria. Ogere is situated in a hilly area and on geographical coordinate 6˚ 56' 0" North and 3˚ 38' 0" East. Ogere truck-stop is about 0.6km^2 area is located between 56 kilometer and 59 kilometer of Lagos-Ibadan expressway and has remained a major stop-over for long-haul trucks and other haulage vehicles. Air sample were taken in five locations which is labeled A, B, C, D and E where considered for the study. Figure 1 shows the map of the study region with sampling points.

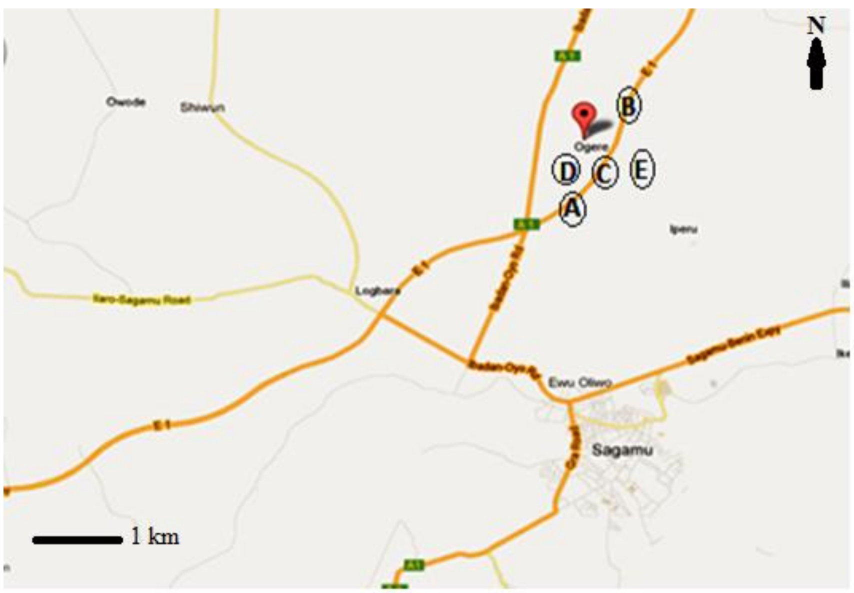

Figure 1. Map of Ogere truck-stop

2.2. Criteria air pollutant sampling

Sampling of carbon monoxide (CO) and nitrogen dioxide (NO_2) in the airshed of Ogere truck-stop were carried out using ToxiRAE II Gas Monitor for CO and NO_2, respectively. Sampling was done for 15 consecutive days with averaging time of 8 hours per day. The Gas monitors were positioned on a sampling stands of 1m height above the ground level to prevent measurement of fugitive gases mobilized by tides. Also four (4) principal meteorological parameters - temperature, wind speed, relative humidity and pressure were determined using Kestrel 4000 Pocket Weather Tracker. Sampled concentration data obtained in ppm were converted to ppb using Equation 1 and also converted from ppm to $\mu g/m^3$ using concentration unit conversion formula [16-17] given in Equation 2, for easy comparison with some air quality standards.

$$ppb = ppm * 1000 \quad (1)$$

$$\mu g/m^3 = \frac{PM_i}{RT} x(ppm) * (1000) \quad (2)$$

where $\mu g/m^3$ is the concentration in microgram per cubic meter, *ppm* is the concentration in parts per million, *ppb* is the concentration in parts per billion, *P* is the sampled atmospheric pressure, *T* is the sampled ambient temperature, *Mi* is the molecular weight of the gaseous pollutant and *R* is the universal gas constant.

The concentration data for NO where extrapolated from the sampled 8-hours averaging time to 24-hours averaging time and also from 24-hours averaging time to 1-hour averaging time using an atmospheric stability dependent equation [1,18] Equation 3.

$$C_0 = C_1 * \left({T_1}/{T_0}\right)^n \quad (3)$$

where C_0 is the shorter averaging time concentration, C_1 is the longer averaging time concentration, T_1 is the longer averaging time, T_0 is shorter averaging time and *n* is the stability dependent exponent given as 0.28 for the conversion from 8-hours averaging time to 24-hours averaging time [1] and 0.2 for extrapolating between 1-hours and 24-hours averaging time [18].

2.3. The air quality index (AQI)

AQI for CO and NO_2 were calculated using the EPA (2016) method with the equation given as Equation 4.

$$I_p = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}} \left(C_p - BP_{LO}\right) + I_{LO} \quad (4)$$

where I_p is the index value of pollutant p, C_p *is* the concentration of pollutant p, BP_{HI} *is* the breakpoint that is greater than or equal to C_p as given in Table 5, BP_{LO} is the breakpoint that is less than or equal to C_p as given in Table 5, I_{HI} is the AQI value corresponding to BP_{HI} and I_{LO} is the AQI value corresponding to BP_{LO}. Concentrations of CO (ppm) were truncate to 1 decimal place and NO_2 (ppb) truncate to integer [19]. Table 1 show AQI breaking points for CO and NO_2.

Table 1. Air quality index breaking points

Breaking points		AQI	AQI category
CO (ppm) 8-hour	NO_2 (ppb) 1-hour		
0.0 – 4.4	0 – 53	0 – 50	Good
4.5 - 9.4	54 – 100	51 – 100	Moderate
9.5 - 12.4	101 – 360	101 – 150	Unhealthy for sensitive groups
12.5 - 15.4	361 – 649	151 – 200	Unhealthy
15.5 - 30.4	650 – 1249	201 – 300	Very unhealthy
30.5 - 40.4	1250 – 1649	301 – 400	Hazardous
40.5 - 50.4	1650 – 2049	401 – 500	Hazardous

3. Results and discussion

The daily sampled 8-hours averaging period of NO_2 concentrations ranged, 0.0875 - 0.4556 ppm (Table 2). The minimum daily sampled and minimum average concentration of NO_2 were observed at sampling point D, this may be due to low vehicular activity at this region as it is a mini-park within the truck-stop, also the maximum daily sampled and maximum average concentration of NO_2 were noticed at sampling point B. Sampling point B is located along the road side with higher volume of trucks compared to other points. Sampled data obtained in ppm for CO were converted to $\mu g/m^3$ (Table 3), also NO_2 data were extrapolated from 8-hours averaging period to 24-hours and 1-hour averaging period as presented in Table 4, Table 5 and Table 6.

Table 2. Sampled 8-hours averaging period concentration with standard error of mean

SP	Gaseous pollutants					
	NO_2 (ppm)			CO (ppm)		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
A	0.1333±0.11	0.3208±0.0913	0.2458±0.06	5.7917±0.75	6.0000±0.38	5.8333±0.09
B	0.5750±0.11	0.3250±0.0848	0.4667±0.06	6.8333±0.53	7.0000±0.36	6.2083±0.36
C	0.1542±0.07	0.3583±0.1082	0.2250±0.07	7.0417±0.89	5.7917±0.54	6.6250±1.45
D	0.0292±0.02	0.1083±0.0510	0.1250±0.05	1.5833±0.42	1.0000±0.36	1.1667±0.37
E	0.1667±0.09	0.1667±0.0932	0.3333±0.18	1.7083±0.47	1.2917±0.42	1.8750±0.47

Table 3. 8-hours averaging period mean concentration for sampling points

Sampling point	Gaseous pollutants concentration							
	NO_2 (ppm)				CO (ppm)			
	Day 1	Day 2	Day 3	Average	Day 1	Day 2	Day 3	Average
A	0.1333	0.320	0.2458	0.2333	5.7916	6.00	5.8333	5.8750
B	0.5750	0.3250	0.4667	0.4556	6.8333	7.00	6.2083	6.6805
C	0.1542	0.3583	0.2250	0.2458	7.0417	5.79	6.6250	6.4856
D	0.0292	0.1083	0.1250	0.0875	1.5833	1.00	1.1667	1.2500
E	0.1667	0.1667	0.3333	0.2222	1.7083	1.29	1.8750	1.6244

Table 4. 8-hours averaging period concentration of CO (μg/m^3)

Sampling point	CO (μg/m^3)			
	Day 1	Day 2	Day 3	Average
A	6379.05	6596.32	6434.88	6470.08
B	7538.30	7646.50	6762.05	7315.62
C	7696.29	6314.95	7366.24	7125.83
D	1729.64	1094.07	1271.78	1365.16
E	1856.35	1410.09	2044.24	1770.23

Table 5. Extrapolated 24-hours averaging period concentration for NO_2 (μg/m^3)

Sampling point	CO (μg/m^3)			
	Day 1	Day 2	Day 3	Average
A	6379.05	6596.32	6434.88	6470.08
B	7538.30	7646.50	6762.05	7315.62
C	7696.29	6314.95	7366.24	7125.83
D	1729.64	1094.07	1271.78	1365.16
E	1856.35	1410.09	2044.24	1770.23

Table 6. Extrapolated 1-hour averaging period concentration of NO_2 (ppb

Sampling point	NO_2 (ppb)			
	Day 1	Day 2	Day 3	Average
A	185.29	445.86	341.63	324.26
B	799.08	451.65	648.67	633.14
C	214.23	497.97	312.68	341.63
D	40.54	150.55	173.71	121.60
E	231.62	231.62	463.23	308.83

Table 7. Extrapolated 1-hour averaging period concentration of NO_2 (μg/m^3)

Sampling Point	NO_2 (μg/m^3) Day 1	Day 2	Day 3	Average
A	339.26	803.10	618.59	586.98
B	1454.84	814.20	1159.43	1142.82
C	383.52	890.98	571.28	615.26
D	74.67	269.13	311.21	218.34
E	414.88	414.37	825.57	551.60

Table 8. Air quality index rating for the study region

Sampling point	AQI for CO 8-hours (ppm)	AQI category	AQI for NO_2 1-hour (ppb)	AQI category
A	64.75	Moderate	143.24	Unhealthy for sensitive groups
B	72.81	Moderate	197.30	Unhealthy
C	70.86	Moderate	146.52	Unhealthy for sensitive groups
D	14.20	Good	104.90	Unhealthy for sensitive groups
E	18.46	Good	140.32	Unhealthy for sensitive groups

When compared with 24-hours averaging standards of 75-113 μg/m^3 and 150 μg/m^3 set by Nigeria Federal Ministry of Environment [20] and World Bank [21] respectively, all extrapolated daily sampled concentration of NO_2 at all locations exceeded the standards except Day 1 and Day 2 sampling at location D which were below the World Bank set limit. The average concentrations were also greater than the set limits at all sampling points except point D which is slightly below the World Bank standard. When compared with 1-hour averaging standard of 200 μg/m^3 set by World Health Organization WHO [21] and World Bank [22], extrapolated average concentrations at all sampling point exceeded the set limit. Daily sampled 8-hours averaging period concentration of CO for sampling point A to E ranged between 1365.16 – 7315.62 μg/m^3 (Exhibit 4), these concentrations are far below the set limit of 22,800 μg/m^3 given by Nigeria Federal Ministry of Environment [20] and 10,000 μg/m^3 limit given by World Bank [21] and World Health Organization [22]. The reason associated to these is as of readily conversion of CO to CO_2 when it is emitted into air. Figure 2 shows the distribution of pollutant at the various sampling locations, the trend showed the concentrations both pollutants were high at sampling points A, B and C these could be as a result of the large number of the truck parked at that location and their proximity to the high way. However relatively lower concentrations of these pollutants were observed at the sampling point D and E, these could be connected with the fewer number of the trucks and vehicular activities at these points.

The AQI indicates the level of ambient air pollution with respect to health effect associated with few hours or days after breathing the polluted air. EPA [20] method was to calculate the AQI, Table 7 shows Air quality index rating for the study region. The AQI of CO for the sampled region ranges from 14.20 to 72.81 which indicates good to moderate AQI category. The air quality Indexes at the sampling points D and E are good while AQI at sampling points A, B and C are moderate. For NO_2. The AQI ranges from 104.90 to 143.24, sampling points A, C, D and E fall to AQI category of unhealthy for sensitive groups while sampling point B falls to a more serious category of unhealthy represented. At every location within the sampling region, people with asthma, children, and older adults are most at risk [1,20]. The colour representation of AQI is depicted in Figure 3 and 4.

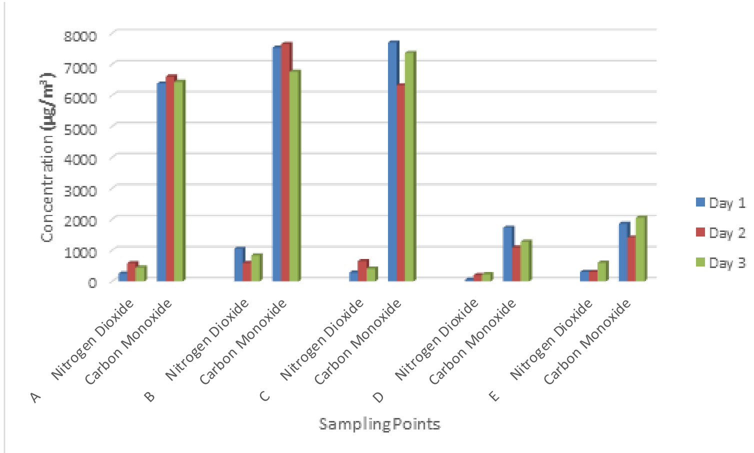

Figure 2. Distribution average sampled concentration of pollutant at the various sampling locations

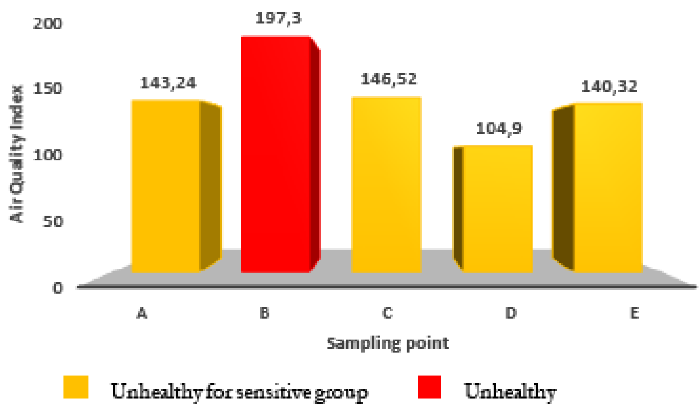

Figure 3. Air quality index pattern for NO_2 around Ogere truck-stop

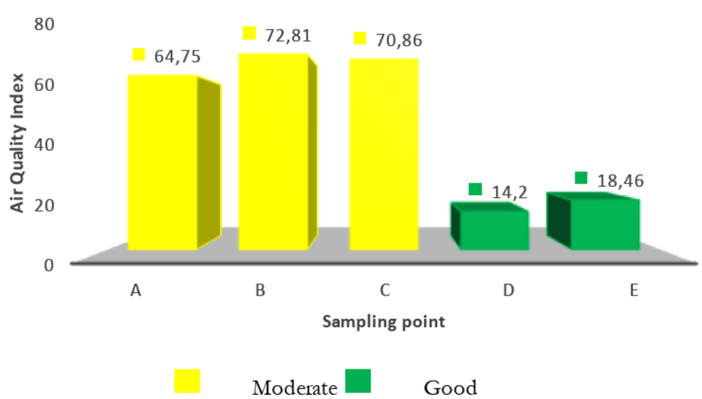

Figure 4. Air quality index pattern for CO around Ogere truck-stop

4. Conclusion

The air quality index pattern of criteria pollutants around a truck-stop was investigate in this study using carbon monoxide (CO) and nitrogen dioxide (NO_2) as indicators. The studied area is a typical truck-stop located between 56 kilometer and 59 kilometer Lagos-Ibadan expressway of Southwestern part of Nigeria. Concentrations of the criterial air pollutants were quantified at five (5) selected sampling points using ToxiRAE II Gas Monitor. The results indicated that the extrapolated 24-hours and 1-hour average period concentration of NO_2 at almost all the sampled point exceeded the limits set by Nigeria Federal Ministry of Environment, World Health Organization and World Bank, while 8-hours averaging period concentrations of CO at all sampled point were below the set limits. The AQI pattern obtained for the studied region show further that AQI of CO ranges from 14.20 to 72.81 which indicates good to moderate AQI category with no known health effects. The AQI for NO_2 ranges from 104.90 to 143.24 indicating AQI category of unhealthy for sensitive groups to unhealthy, therefore people with respiratory or heart disease, the elderly and children should be prevented from this region. The study established that vehicular activities at the truck-stop could pose great impact on the ambient air quality with sensitive groups most at risk.

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