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ASSESSMENT OF THE IMPACT OF CARBON MONOXIDE EMISSIONS FROM POWER GENERATING PLANTS ON RESIDENTS OF NIGER- DELTA

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ABSTRACT

The poor supply of electricity to different settlements in Nigeria, continuing over the years now, has forced building occupants to shift to dependence on generators. This study assesses the impact of carbon monoxide emissions from power generating plants on both residential and commercial buildings residents of Niger- Delta. The study was carried out in the three States of Niger-Delta, Nigeria, which included Akwa-Ibom, Delta and Rivers. Consequently, five (5) Points of both residential and commercial buildings were purposively selected in each of the sampled State of the study area. The HT-1000 digital LCD carbon monoxide meter was used to take measurements of the emissions of carbon monoxide with conformity to NESREA and OSHA standards. The population of the study consists of all the households of the sampled States. A total of four hundred (400) copies of the questionnaire were administered with three hundred and seventy-seven (377) returned well filled, giving a percentage response of 94%. The result of the analysis the outdoor emission levels of carbon monoxide before or during the use of generators were taken at 0, 2 and 4m, respectively, from the external walls of the buildings sampled and the corresponding indoor measurements were taken internally at 1.2-1.5m above floor area. The data collected were analysed with the use of statistical methods, such as t-test, ANOVA, trend analysis and Kolmogorov Smirnov test. The results show that the values of outdoor and indoor measurements of carbon monoxide emissions levels were the highest in buildings in the sampled points of each State either before or during the use of generating sets. Reduced carbon monoxide levels during the use of generators were obtained at distance limits beyond 2m from the external walls of buildings across the zones of the study area. In view of the measurements taken and the obtained results ranging above the limits set by statutory bodies, as well as the attendant effects on the environment and building occupants, it is recommended that users of the generators should be forced to position them in enclosures located away from external walls of buildings and that the government should license only sales of generating sets with emission control mechanisms.

Keywords; Carbon monoxide, Power generating plants, Residents, Air pollution, Effects

1. Introduction

Globally, anthropogenic air pollution has been an important issue of concern for many years due to its adverse effects on plants, animals, environment and human health. Continuous increase in the level of air pollution emission has been reported to be the consequence of increasing population, industrialization, density of traffic, and space heating (Benaissa et al., 2019; Edokpolo et al., 2015; Odekanle et al., 2017; Riyadh et al., 2020). Carbon Monoxide

(CO) is a by-product when the carbon in fossil fuels is only partially burned. It reduces the body's ability to absorb oxygen and can be dangerous to humans at relatively low levels. It also has direct effects on pulmonary and non-pulmonary diseases, such as bronchitis, asthma, myocardial infraction, stroke and cancer (Kaplan et al 2017). Several epidemiology studies have shown relationship between air pollution and several health effects.

This trend is likely to continue as the country's industrial development increases. Energy has a major impact on every nation's socioeconomic life and development. An inadequate supply of energy will restrict socioeconomic activities, limit economic growth, and adversely affect the quality of life (Ugwu, Nwankwojike, Ogbonnaya, & Ekoi, 2016). The inadequate supply of energy from the power sector in Nigeria has led to a loss of faith among citizens, causing them to resort to the self-generation of electric power through the use of diesel and petrol engine generators in order to meet their required energy needs (Adegbola, Kolawole, & Olabiyi, 2014). In regard to the operation of diesel engines, gaseous emissions are of great concern. A major component of the criteria air pollutants emitted by generators is carbon monoxide (CO) (Idiata, Omoruyi, & Aiwize, 2010), which is the focus of this study. Pollution is undesirable change in the physical, chemical or biological characteristics of environment including air, water and solid which causes harmful effects to various form of life and property. According to World Health Organization (WHO) definition, Pollution is "the presence of material in air in such concentrations which are harmful to human and environment". CO is readily absorbed from the lungs into the blood stream, resulting in competitive binding between it and oxygen to hemoglobin in the red blood cells, forming carboxyhemoglobin and oxyhemoglobin, respectively. Carboxyhemoglobin causes a decrease in the oxygen carrying capacity of the blood, thus inducing toxic effects that are dangerous to human health (World Health Organization WHO, 1999). Furthermore, several health effects associated with NOx have created a need for a threshold level in the atmosphere (WHO, 2000). The impacts of pollutants released to the atmosphere are not always restricted to the point of release. Contaminants discharged into the air are transported over long distances by large-scale airflows and dispersed by small-scale airflows or turbulence, which serve to mix contaminants with clean air (Gilmore, Adams, & Lave, 2014). Emission rates, wind speed, and wind direction are strong factors influencing the transport of these pollutants away from their sources. Atmospheric dispersion models are widely used to make predictions and/or to solve problems associated with the emission of pollutants into the atmosphere (Zannetti, 1990). The focus of this study is on the nearby environmental impact of CO emissions from the diesel and petrol power generating plants on residence of Niger- Delta region, Nigeria.

2 Aim and Objectives of Study

The study assessed the impact of carbon emissions from power generating plants on the residents of Niger-Delta States.

Objectives are to:

1. Determine the concentration levels of carbon monoxide emissions from power generating plants in the Niger-Delta
2. Determine the health impacts of carbon monoxide emissions on the residents and its environs in Niger-Delta.
3. Establish the levels of carbon monoxide on the various sampled areas and compare with national ambient air quality standards.

3 The Study Area

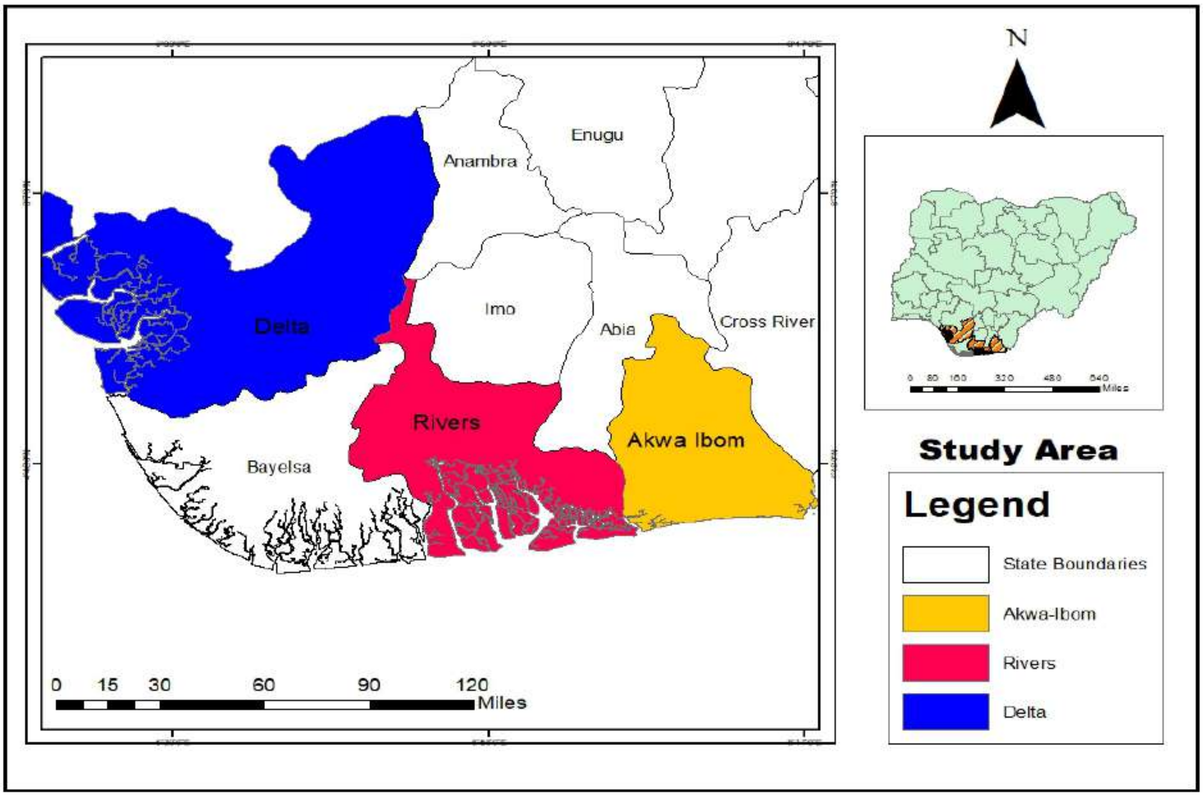

Figure 1: Niger-Delta Showing the study States

The Niger Delta region of Nigeria, located in the southern part of the country, stretches over an area of about 75,000 sq. km, between longitude 5^0 E to 8^0 E and latitude 4^0 N to 7^0 N (Adagunodo et al., 2017). The region is a large arcuate delta (Nwaejije et al., 2017), with the biggest wetland in the African continent, freshwater swamp, lowland forest, mangrove swamps and coastal barrier islands (Edino et al., 2010). The region is made up of nine administrative states with diverse ethnic groups (Odalonu, 2016) which are Edo, Ondo, Abia, Akwa Ibom, Imo, Rivers, and Cross River. The Niger Delta States are the oil producing states in Nigeria (Odalonu, 2016) as well as the study area States (Akwa Ibom, Delta and Rivers)

4 Materials and Methodology

The study adopted the cross sectional and experimental research design. The descriptive design was based on a cross-sectional sampling of the opinions of individuals on the impact of carbon monoxide emissions from power generating plants in the study area. The experimental design involved the measurement of point source emission of carbon monoxide from the generating sets and ambient air as well as the geographic coordinates of the areas sampled. The population for this study consists of all the residential and commercial buildings in the Niger-Delta region.

The major target unit of inquiry for this study involved the household heads which was drawn from the respective residential and commercial areas. The population for this study consisted of 45,715,000 households of Niger-Delta states determined using 6 persons per household composition figure as stipulated by NDHS report (2013). The sampling technique adopted to elicit information from the Sample State capitals for this study was as follows: In the first stage, Niger-Delta was grouped into six (6) states. The second stage involves the stratification of each State into highly, moderately and low populated residential areas. Three States which includes Rivers, Delta, and Akwa Ibom were purposively selected based on their population projection sizes totally 22,970,000.

This research was conducted at six (6) sampling points in each selected State capital covering six settlements (i.e., six standard enumeration areas (SEAs) in three (3) states' capitals [Akwa Ibom (Uyo), Delta (Asaba) and Rivers states (Port Harcourt)] of Niger-Delta, spread out in the following strata: • 2 SEAs in Low density areas, • 2 SEAs in medium density areas, and • 2 SEAs in the high-density areas.

To determine appropriate sample size based on the population projection of Households, Taro Yamane method was adopted.

Below is the mathematical illustration for the Taro Yamane formula:

$$n = \frac{N}{\left(1 + N\left(e^2\right)\right)}$$

Where:
n-signifies the sample size
N-signifies the population under study
e-signifies the margin error = 0.05

$$n = \frac{22970000}{\left(1 + 22970000\left(0.0025\right)\right)}$$

$$n = \frac{22970000}{57426} \approx 400$$

The instrument adopted for data collection for this study was a structured questionnaire, face to face interview with respondents and direct measurement of ambient air quality, carbon monoxide emissions from generating sets with the aid of GasAlert® detector. The range of detection was between 0.01-100ppm with alarm set at 2.00ppm and 20.00ppm.

The results of carbon monoxide emissions recorded from the different sources was presented in tables and Figures. The instrument was taken from place to place to measure different sources of the carbon monoxide gas. The exposure time duration shall be 2 hours at a time per a place. The average values for each type of sources from different locations shall be computed while Descriptive statistics such as frequency distribution and percentages shall be used to analyse the data collected through questionnaire administration. Mean and standard deviation tables shall be constructed to indicate responses from each item used. However, responses shall be coded, processed, and entered into the computer using the Statistical Package for Social Science (SPSS).

5 Result and Discussion

5.1 Concentration levels of CO emissions from power generating plants in the Study Area

This section is intended to determine the CO emissions from power generating plants in the study areas. This was important because knowing the level of CO emissions from power generating plants that affect the households in the study area is the first step that must be taken in any effective management efforts. Questionnaire respondents and interview participants' responses are displayed in this section and compared to what scholars and policy documents say about the level of CO emissions from power generating plants in Niger Delta States.

Table 1 Concentrations of CO air pollutants measured around the study areas per State

State	**Levels of CO (ppm) in the study area**		
	Sample Points	**Location**	**Levels of CO**
Akwa-Ibom	Abak-Roads	Commercial	20.8
	Calabar - Itu Road	Commercial	22.6
	Ewet- Housing Estate	Residential	3.2
	Ikot- Ekpene Road	Commercial	24.2
	Ibono -Eket Industrial zone	Industrial	19.6
		Mean ($\bar{X}$)	**18.08**
		Std σ	**3.62**
	Agbor	Commercial	20.5
	Delta State Junior Staff Residential quarter	Commercial	2.7
Delta	Ogbwashiku	Commercial	17.4
	Sapele Industrial Zone	Industrial	21.3
	Udu	Commercial	16.7
		Mean ($\bar{X}$)	**15.72**
		Std σ	**3.14**
	Garrison PH	Commercial	36.04

	Oil Mill	Commercial	21.6
Rivers	Old GRA	Residential	3.03
	Rumuokoro	Commercial	23.9
	Trans-Amadi industrial layout	Industrial	19.0
		Mean ($\bar{X}$)	**20.71**
		Std σ	**4.14**

Source: Researcher’s Fieldwork, 2021

Sampled carbon monoxide and suspended particulate matter level are shown in Table 1.

For carbon monoxide and suspended particulate matter level across all the sampled commercial and residential areas, Rivers State has the highest mean and standard deviation value of 20.71 (4.1 4ppm) followed by Akwa-Ibom State with the mean and standard deviation of 18.08 (3.62 ppm) while the least is obtained around Delta sampled points with the mean 15.72 (3.14 ppm) respectively. This an indication that concentrations of CO air pollutants measured around the study areas is more in Rivers State sampled points. Across residential areas sampled, CO concentration range from 2.7 ppm to 3.3, commercial CO concentration ranging from 17.4 ppm to 36.04 while industrial zones range from 19.0 to 21.3. Carbon monoxide levels in commercial and industrial areas closely reflect traffic density (in combination with weather conditions. In this study the two highest CO concentrations were recorded at two major traffic intersections in Port Harcourt, followed by Akwa-Ibom and Delta, these may be due to the high presence of generators during sampling. Air Quality Index (AQI) is used for describing ambient air quality. It is an indicator of air quality based on pollution levels for the criteria air pollutants that have adverse effects on human health and the environment. In terms of air quality index (AQI), the CO variation across the sampling sites revealed that the air quality was very good (A) around all the sampled residential areas, between good to moderate (B-C) in all the sampled major commercial intersection while around the industrial areas it was between Good and moderate except in Akwa-Ibom and Delta where it was observed to be very good. Carbon monoxide binds to hemoglobin in red blood cells, reducing their ability to transport and release oxygen throughout the body. Moderate exposure of CO to the occupants along the study area can aggravate cardiac ailments such as the brain and heart (Yusuf et al., 2013). CO also plays a role in the generation of ground-level ozone. It contributes to the formation of CO2 and ozone (O3), greenhouse gases that warm the atmosphere (USEPA, 2007). Comparing the concentrations of CO at different sampling sites in the study area, the CO levels in Port Harcourt traffic intersection (21 ppm) was lower than US national ambient air quality standard of 35 ppm at one hour exposure time.

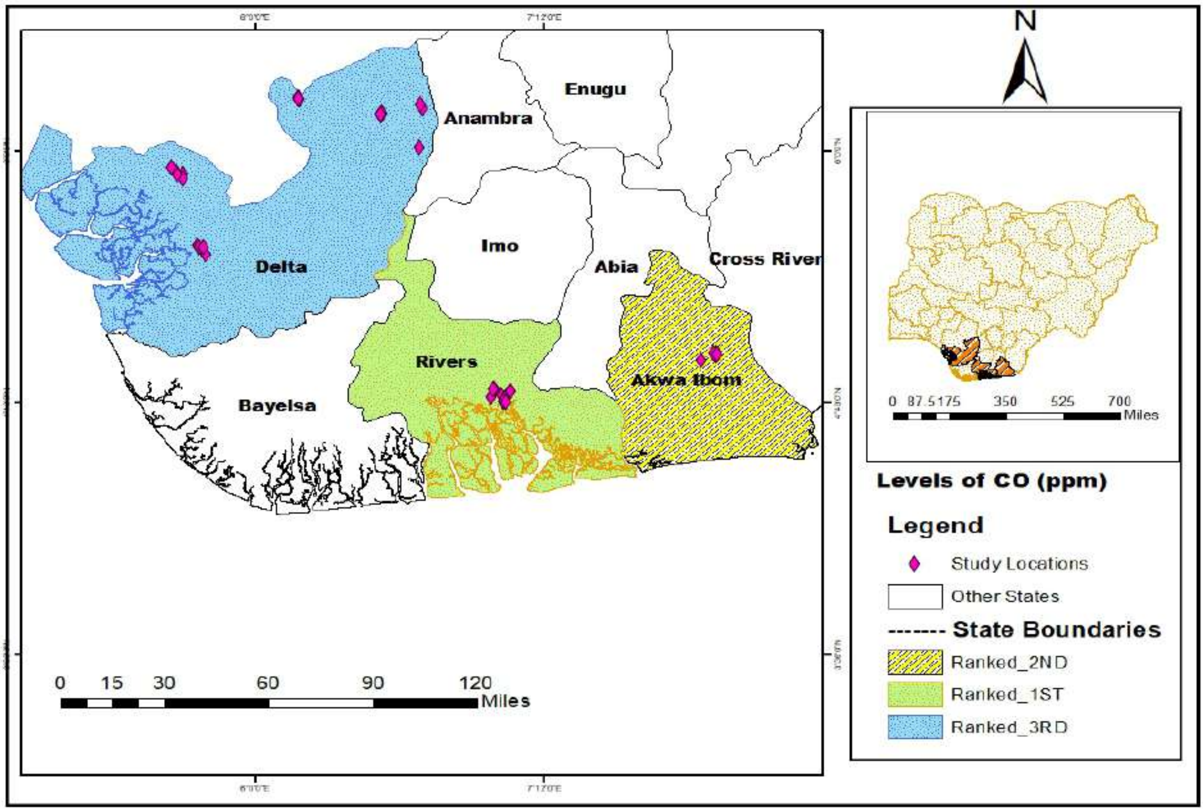

Figure 2 Levels of CO (ppm) in the study area

5.2 Health impacts of CO emissions on the residents and its environs

Table 2 Source of pollution

S/N	Source of pollution	Akwa-Ibom= 112				Delta=119				Riverine=146			
		Yes		No		Yes		No		Yes		No	
		F	%	F	%	F	%	F	%	F	%	F	%
1	Vehicles	84	75.0%	28	25.0%	98	82.4%	21	17.6%	120	82.2%	26	17.8%
2	Industries	78	69.6%	34	30.4%	119	100.0%	0	0.0%	120	82.2%	26	17.8%
3	Biomas	35	31.3%	77	68.8%	80	67.2%	39	32.8%	39	26.7%	107	73.3%
4	Dust	80	71.4%	32	28.6%	30	25.2%	89	74.8%	115	78.8%	31	21.2%
5	Generator	112	100.0%	0	0.0%	119	100.0%	0	0.0%	146	100.0%	0	0.0%
6	Household heating	18	16.1%	94	83.9%	17	14.3%	102	85.7%	24	16.4%	122	83.6%
7	Others	91	81.3%	21	18.8%	51	42.9%	68	57.1%	125	85.6%	21	14.4%

Response Categories Per State

Source: Researcher's Fieldwork, 2021

Analysis in table 2 shows the opinion of the participants on the Source of pollution in their environment. Based on their perceptions, Vehicles attracted the percentage responses agreement of 75.0% by the Akwa-Ibom, 82.4% for Delta and Rivers 82.2% respectively.

Further, Industries attracted the percentage responses of 69.6%, 100.0% and 82.2% by the respondents across the States which Delta ranked 1ST, Rivers ranked 2ND and Akwa-Ibom ranked 3RD. Biomass, attracted percentage disagreement by the Akwa-Ibom respondents with percentage scores of 68.8%, Rivers 73.3% while Delta respondents agreed that they use Biomass as a source of energy with 67.2%. Dust attracted agreement from respondents of Akwa-Ibom and Rivers while majority of Delta respondents disagreed to the item. Respondents across the three states indicated their level of disagreement on Generator as their major source of energy with percentage scores of Akwa-Ibom 100.0%, Delta 100.0%, and Rivers 100.0% respectively. Household heating attracted general disagreement from the respondents across the studied States with the percentage scores of 83.9% for Akwa-Ibom, Delta 85.7% and Rivers 83.6%. Other sources attracted percentage agreement from Akwa-Ibom and Rivers while Delta respondents disagreed.

Table 3 Health Effects of CO on Households

S/N	Item	Response Categories Per State					
		Akwa-Ibom= 112		**Delta=119**		**Riverine=146**	
		$\underline{X}$	**σ**	**$\underline{X}$**	**σ**	**$\underline{X}$**	**σ**
1	Felt air pollution effects	3.81	0.95	3.82	0.95	3.80	0.95
2	ENT problems/irritation/allergies	3.85	0.96	3.69	0.92	3.73	0.93
3	Respiratory problems	3.91	0.98	3.92	0.98	3.93	0.98
4	Coughing or wheezing	3.39	0.85	3.44	0.86	3.54	0.89
5	Headaches and dizziness	2.99	0.75	3.02	0.75	2.95	0.74
6	Reduced energy level	3.79	0.95	3.85	0.96	3.97	0.99
7	Sleeping disorder i.e., insomnia	3.58	0.90	3.79	0.95	3.66	0.92
8	Breath shortening or reduced lung function	3.96	0.99	3.87	0.97	3.87	0.97
9	Skin diseases	3.37	0.84	3.57	0.89	3.68	0.92
10	Sneezing, runny nose, dry throat, or eye Irritation	3.51	0.88	3.55	0.89	3.40	0.85
11	Breath shortening or reduced lung function	3.81	0.95	3.82	0.95	3.80	0.95
	Grand Mean ($\underline{X}$) & σ	**3.62**	**0.90**	**3.65**	**0.91**	**3.65**	**0.91**

Source: Researchers' Fieldwork, 2021

The analysis of data in Table 3 is for the Perception of respondents to the Health Effects of CO on Households. Felt air pollution effects mean score obtained are 3.81 for Akwa-Ibom, 3.82 for Delta and 3.80 for Rives. ENT problems/irritation/allergies with the obtained mean scores of 3.85 for Akwa-Ibom, 3.69 for Delta and 3.73 for Rivers. Item three which is on Respiratory problems attracted the mean scores of 3.91, 3.92 and 3.93. Coughing or wheezing as one of the effects of carbon monoxide attracted the mean scores of 3.39, 3.44 and 3.54. Headaches and dizziness attracted the mean scores of 2.99, 3.10 and 3.02 and 2.95 respectively. Reduced energy level, sleeping disorder i.e., insomnia, Breath shortening or reduced lung function, Skin diseases, Sneezing, runny nose, dry throat, or eye Irritation and Breath shortening or reduced lung function attracted general agreement from the respondents as a problem encountered from the emission of CO in the environment.

The analyses revealed overall mean scores of 3.62 for Akwa-Ibom, 3.65 for Delta and 3.65 for Rivers with standard deviation of 0.90, 0.91 and 0.91. Since the scores are greater than 2.5 index score, it means that, carbon monoxide (CO) has negative health effects on households.

Table 4 Households' perception towards air quality

S/N	Item	Response Categories Per State					
		Akwa-Ibom= 112		Delta=119		Riverine=146	
		$\underline{X}$	σ	$\underline{X}$	σ	$\underline{X}$	σ
1	My community paid attention to the air pollution	1.76	0.44	1.97	0.49	1.97	0.49
2	I am satisfied with the air quality in my community	1.78	0.44	1.82	0.46	1.95	0.49
3	The overall air quality in my community is adequate	1.77	0.44	1.45	0.36	1.20	0.30
4	There is severe air pollution in the community	3.83	0.96	3.34	0.84	3.66	0.92
5	Improving the environment is the responsibility of every citizen	3.88	0.97	3.92	0.98	3.87	0.97
6	Air quality will improve with time	1.80	0.45	2.24	0.56	2.19	0.55
	Grand Mean ($\underline{X}$) & σ	2.47	0.62	2.46	0.61	2.47	0.62

Source: Researchers' Fieldwork, 2021

Table 4 result revealed the opinion of participants on air quality in the study areas**.** Majority 1.76 of Akwa-Ibom, 1.97of Delta, and 1.97 of Rivers respondents' responses show their level of disagreement on their community paying attention to the air pollution as an effect of CO.

The majority of Akwa-Ibom representing 1.78, of Delta accounting for 1.82, and 1.95 of Rivers participants disagreed which means they are not satisfied with the air quality in their community. Items 3 and 6 i.e., the overall air quality in my community is adequate and air quality will improve with time were disagreed by the respondents across the three States while items 4 and 5 attracted a general agreement which means that there is severe air pollution in the community and improving the environment is the responsibility of every citizen. This implies that air quality is generally poor in the study area since the overall mean is less than 2.50.

Table 5 Households Preference of Energy Type for Cooking

S/N	Energy Option	Preference / Frequency (f)								
		Akwa-Ibom= 112		**Rank**	**Delta=119**		**Rank**	**Riverine=146**		**Rank**
		$\underline{X}$	**σ**		$\underline{X}$	**σ**		$\underline{X}$	**σ**	
1	Electric cooker	3.60	0.90	2	3.56	0.89	2	3.48	0.87	2
2	Gas cooker	3.79	0.95	1	3.82	0.96	1	3.76	0.94	1
3	Kerosene stove	3.07	0.77	3	2.18	0.54	4	2.02	0.51	3
4	Saw dust stove	1.70	0.42	6	1.66	0.42	5	1.49	0.37	5
5	Fire wood	2.19	0.55	4	2.47	0.62	3	2.12	0.53	4
6	Charcoal stove	1.94	0.48	5	1.57	0.39	6	1.42	0.36	6
	Grand Mean ($\underline{X}$) & σ	**2.71**	**0.68**		**2.54**	**0.64**		**2.38**	**0.60**	

Source: Researchers' Fieldwork, 2021

The preference of the households for the listed energy types for cooking indicate that cooking with gas is the most preferred. This is followed by the use of electricity, kerosene, wood, charcoal, sawdust and dung respectively. The ranking of gas as the most preferred cooking fuel is a pointer to the relatively high level of awareness of the households about the advantages of cooking with gas and this implies that a lot of reduction in GHG emissions through cooking with electricity and biomass (wood, sawdust and dung) can be achieved through some advocacy and support to households by government to acquire gas cylinders and cookers and also some subsidy on the cost of gas.

5.3 Proportion of CO in the sampled areas to national ambient air quality standards

Table 6 Indoor carbon monoxide levels before and during use of generators in commercial and Residential buildings

S/N	Location	0m		2m		4m	
		Before use (ppm)	During use (ppm)	Before use (ppm)	During use (ppm)	Before use (ppm)	During use (ppm)
Akwa-Ibom	Abak-Roads	12.0	66.7	5.0	15.3	3.5	34.2
	Calabar - Itu Road	16.1	58.0	4.0	22.3	6.3	33.2
	Ewet- Housing Estate	1.8	11.2	3.0	8.1	2.2	7.5
	Ikot- Ekpene Road	11.0	49.1	6.2	42.3	5.2	41.1
	Ibono -Eket Industrial zone	11.6	59.4	4.6	53.3	4.6	36.3
Delta	Agbor	6.5	69.2	3.0	34.0	3.2	27.0
	Delta State Junior Staff Residential quarter	2.4	9.3	2.3	6.8	2.3	6.1
	Ogbwashiku	7.6	67.2	7.8	43.0	3.3	30.3

	Sapele Industrial Zone	13.0	51.3	6.7	37.3	3.0	44.3
	Udu	6.3	48.2	6.0	43.3	2.6	30.1
Rivers	Garrison PH	5.4	43.6	4.0	37.5	3.0	47.3
	Oil Mill	11.3	61.3	3.0	46.0	2.0	36.1
	Old GRA	2.0	7.1	1.8	7.9	2.0	6.0
	Rumuokoro	9.3	82.6	4.0	38.4	4.0	32.3
	Trans-Amadi industrial layout	11.3	43.7	2.0	33.4	3.3	29.1

Source: Researchers' Fieldwork, 2021

Table 6 shows the indoor carbon monoxide levels before and during use of the generators in the residential buildings, commercial and industrial buildings. It was revealed that prior their usage, residential indoor carbon monoxide levels were the lowest in the buildings (1.8 ppm) located in the Ewet- Housing Estate of Akwa-Ibom State and the highest (2.4 ppm) in Delta State Junior Staff Residential quarter. During the use of generators, indoor carbon monoxide level was the lowest in the Port Harcourt Old GRA (7.1 ppm) and also the highest in the buildings in the Ewet- Housing Estate (11.2 ppm). This was attributed to the distances of positioning of the generators, house-keeping practices adopted, typology of buildings and profile of the respondents in the buildings sampled. The differences in the rate of change of indoor carbon monoxide levels before and during the use of generators in the residential buildings sampled were carried out through the use of trend analysis. The analysis showed that the mean increase in the values of indoor carbon monoxide in residential buildings in the Akwa-Ibom, Delta and Rivers States before and during use of the generators was 5.63, 4.87 and 4.48, respectively. It further indicated that in all the residential buildings sampled in the study area, the mean increase in the values of indoor carbon monoxide before and during use of generators was 4.99. This indicates the range of mean increase in the indoor carbon monoxide levels that occupants of the residential buildings in the study area could be exposed to. Also, indoor carbon monoxide levels both before and during the use of generators in commercial and industrial buildings were comparably higher than the measurements taken in the residential buildings. This could be due to the level of commercial and industrial activities close to the buildings sampled. Table 8 further reveals that in commercial and industrial buildings, the indoor carbon monoxide value 2.0 ppm in the Port Harcourt Oil Mill recorded before the use of generators was lower than that of 7.8 ppm and 6.3 ppm obtained in Ogbwashiku in Delta State and Calabar - Itu Road of Akwa-Ibom State while on the other hand, the lowest before use for industrial zones was obtained from Trans-Amadi industrial layout Port Harcourt (2.0 ppm), followed by Sapele Industrial Zone in Delta and Ibono-Eket industrial area (4.6 ppm) respectively. This was due to the volume of commercial and industrial activities going on in the buildings in each zone and operational characteristics of the generating sets used by the occupants. However, during the use of generators, the range of indoor carbon monoxide levels in Akwa-Ibom, Delta and Rivers were higher. The performance, closer distance of positioning of the generators to the external walls of commercial buildings than that of residential buildings and house-keeping practices maintained influenced this trend. It also indicated that in all the commercial and industrial buildings sampled across the States, the percentage increase was higher and it was thrice that of the residential buildings.

Table 7 Outdoor carbon monoxide concentrations levels before and during use of generators in commercial and Residential buildings

S/N		0m		2m		4m	
	Location	Before use (ppm)	During use (ppm)	Before use (ppm)	During use (ppm)	Before use (ppm)	During use (ppm)
Akwa-Ibom	Abak-Roads	13.3	312.3	13.0	205.1	13.0	92.7
	Calabar - Itu Road	19.2	337.6	16.0	144.6	14.0	87.3
	Ewet- Housing Estate	2.3	108.3	2.0	135.0	1.3	77.6
	Ikot- Ekpene Road	23.3	391.1	22.4	233.0	21.3	109.9
	Ibono -Eket Industrial zone	30.1	435.2	33.4	231.1	32.0	96.4
Delta	Agbor	11.7	341.7	9.0	245.1	9.0	79.6
	Delta State Junior Staff Residential quarter	3.0	116.2	2.3	217.3	2.0	75.2
	Ogbwashiku	9.3	388.6	9.3	148.6	9.3	110.1
	Sapele Industrial Zone	9.7	416.5	9.0	238.0	8.0	114.2
	Udu	8.7	308.1	8.7	215.1	8.0	92.7
Rivers	Garrison PH	15.3	411.3	16.0	223.0	13.0	99.3
	Oil Mill	12.3	362.1	11.0	178.8	12.0	101.3
	Old GRA	2.7	235.6	3.2	143.2	3.0	75.4
	Rumuokoro	15.3	429.0	14.0	146.0	14.0	100.3
	Trans-Amadi industrial layout	16.3	396.7	14.0	141.0	16.3	99.6

Source: Researchers' Fieldwork, 2021

The measurements of outdoor carbon monoxide levels taken in the commercial and industrial buildings were different to those obtained in the residential ones. Tables 7 demonstrate that outdoor carbon monoxide levels were the highest during use of the generators with (435.2 ppm) for Ibono-Eket industrial zone in Akwa-Ibom State followed by (416.5 ppm) for Sapele Industrial Zone in Delta and (396.7 ppm) for Trans-Amadi industrial layout in Rivers State when positioned by the external walls of the buildings. For commercial, Rumuokoro in Rivers State ranked the highest during use with (429.0 ppm), followed by Ikot- Ekpene Road in Akwa-Ibom State with (391.1 ppm) and Ogbwashiku in Delta State with (388.6 ppm) respectively. This was due to the house-keeping practices and operational performance of the generating sets used in those buildings. Apart from this, Tables 8 also show that carbon monoxide levels decreased with distance from the external walls of the buildings as also found in residential and commercial buildings. The degree of variation in the outdoor carbon monoxide levels taken in the sampled commercial and industrial buildings showed that the mean levels of outdoor noise were significantly higher in the buildings located in the Akwa-Ibom State than in the other areas under analysis. In all the measurements taken, it was found that outdoor carbon monoxide levels were also comparatively higher when the measurements were taken at the external walls followed by the measurements taken at 2 and 4m, respectively. The trend analysis carried out on the rate of decrease of outdoor carbon monoxide measurements in the commercial, industrial and residential buildings sampled during use of generating sets in the study areas showed that the percentage decrease in the values of outdoor carbon monoxide measured from the external walls of commercial buildings to the 2m point of measurement. It further showed that there was a decrease from 2 to 4m point of measurement and a decrease was obtained at the 4m point of measurement from the external walls of the buildings.

Comparison of the carbon monoxide levels in the buildings with the statutory limits

An assessment was made of the impact of the use of generators in the study area by comparing the values of carbon monoxide measured both indoor and outdoor, before and during the use of generators in residential, commercial and industrial buildings in the areas under analysis.

The One Sample t-test statistical method was used to analyse the impact of its usage through the level of deviation from the limits set by the NESREA (2011) and the WHO (2010) in residential and commercial buildings, respectively.

Table 8 Outdoor carbon monoxide levels before and during use of generators in residential buildings

One –Sample Test Test Value = 10						
Variables	**T**	**Df**	**Sig (2- tailed)**	**Mean difference**	**95% Confidence interval of the difference**	
					Lower	Upper
Outdoor CO Before Use	-14.621	91	.000	-3.770	-5.473	-4.107
Outdoor CO During Use	129.532	91	.000	362.307	355.213	349.226
One-Sample Statistics						
	N	**Mean**	**Std. deviation**	**Std. error mean**		
Outdoor CO Before Use	91	3.306	2.531	.2424		
Outdoor CO During Use	91	331.533		2.469		
Test value of NESREA (2011) = 10ppm						

Source: Researchers' Fieldwork, 2021

The results of the analysis as contained in Table 8 show that in the residential buildings, the t-test indicated that mean values of outdoor carbon monoxide before and during the use were 3.31 ppm and 331.53 ppm, while the mean difference in outdoor carbon monoxide before the use was -3.77 ppm and 362.31 ppm during the use of generators from the test value of 10 ppm.

It further shows that at 95% confidence interval, the upper difference between the carbon monoxide limit set by NESREA (2011), WHO (2010) and the values measured was -4.11 and 349.23, respectively for before and during the use of generators. The mean values of the outdoor carbon monoxide before and during the use were 3.31 ppm and 331.53 ppm, respectively. The relationship is as follows: t =-14.621, p < 0.001 – before the use and t = 129.532, p < 0.001 – during the use).

Table 9 Comparison of the indoor CO levels in the residential buildings

One –Sample Test Test Value = 10						
Variables	**T**	**Df**	**Sig (2-tailed)**	**Mean difference**	**95% Confidence interval of the difference**	
					Lower	Upper
Indoor CO Before Use	-21.230	91	.000	-4.547	-5.441	-5.315
Indoor CO During Use	-1.451	91	.000	1-.0332	-2.175	-1213
One-Sample Statistics						
	N	**Mean**	**Std. deviation**	**Std. error mean**		
Indoor CO Before Use	91	2.021	1.652	.162		
Indoor CO During Use	91	6.721	3.242	.411		
Test value of NESREA (2011) = 10ppm						

Source: Researchers' Fieldwork, 2021

The result of the t-test shows that the mean difference in the indoor carbon monoxide before and during use were -4.55ppm and 1-.033ppm at before and during use, while at 95% confidence interval, the upper difference from the limit of NESREA (2011) and the values of carbon monoxide measured -5.315 and -1213 before and during the use of generators, respectively. The mean values before and during the use of generators were 2.021 ppm and 6.721 ppm. The relationship is given as: t = -21.230, p < 0.001 – before the use and t = -1.451, p < 0.001 – during the use). The results obtained from the analysis reveals that carbon monoxide produced by generators is more impactful on the environment and would thus, expose building occupants to severe interrelated cardiovascular and other physiological effects because of the significant difference of the outdoor or indoor carbon monoxide level measured during the use and before the use of generators in the buildings.

Table 10 Comparison of the outdoor carbon monoxide levels in the commercial and industrial buildings with the NESREA standards

One –Sample Test Test Value = 10						
Variables	**T**	**Df**	**Sig (2- tailed)**	**Mean difference**	**95% Confidence interval of the difference**	
					Lower	**Upper**
Outdoor CO Before Use	.523	91	.621	.331	-1.0110	1.567
Outdoor CO During Use	83.768	91	.000	356.160	347.147	344.152

One-Sample Statistics				
	N	**Mean**	**Std. deviation**	**Std. error mean**
Outdoor CO Before Use	91	9.323	4.957	.570
Outdoor CO During Use	91	7.833	31.732	3.017
Test value of NESREA (2011) = 10ppm				

Source: Researchers' Fieldwork, 2021

Table 10 reveal the results of the t-test in the commercial and industrial buildings, the mean difference in outdoor carbon monoxide before and after the use of generators was .331 ppm and 356.160 ppm, respectively. They also show that at 95% confidence interval, the upper difference between the carbon monoxide limit (10 ppm) set by NESREA (2011) and WHO (2010), and the values measured was 1.56 and 344.15 for before and during the use of generators, respectively. The relationship is as follows: $t = .523$, $p < 0.001$ – before the use and $t = 83.76$, $p < 0.001$ – during the use).

Table 11 Comparison of the indoor CO levels in the commercial and industrial buildings

One –Sample Test Test Value = 10						
Variables	**T**	**Df**	**Sig (2- tailed)**	**Mean difference**	**95% Confidence interval of the difference**	
					Lower	**Upper**
Indoor CO Before Use	-3.643	91	.000	-3.605	-4.2779	-3.732

Indoor CO During Use	14.810	91	.000	26.961	22.3343	32.528

One-Sample Statistics				
	N	**Mean**	**Std. deviation**	**Std. error mean**
Indoor CO Before Use	91	4.394	2.623	.317
Indoor CO During Use	91	34.963	12.364	1.620
Test value of NESREA (2011) = 10ppm				

Source: Researchers' Fieldwork, 2021

The t-test carried out shows that the mean difference in the indoor carbon monoxide for before and during the use of generators were -3.605 ppm and 26.961 ppm, respectively, while at 95% confidence interval, the upper difference set from the limit of NESREA (2011) and the values of carbon monoxide measured were -3.732 and 32.528 for before and during the use of generators, respectively. The mean values for before and during the use of generators were 4.394 and 34.963 ppm. The relationship is given as: $t = -3.643$, $p < 0.001$ – before the use and $t = 14.810$, $p < 0.001$ – during the use). The results of the analysis equally show the that impact of generators usage is more significant outdoor during their use, and also greater than the impact recorded in the residential buildings. The results of the measurement of carbon monoxide levels both indoor and outdoor associated with the use of generators show anthropogenic implications of their use above the limits set by statutory bodies.

6 Conclusion and Recommendation

Based on the findings of the study, the study shows that an inadequate quality and quantity of electricity lead to a wide and ubiquitous use of electric power generators by respondents in the study area. The results prove that outdoor and indoor measurements of carbon monoxide emissions levels were the highest in buildings located in the core zone either before or during the use of generating sets. This was found to be directly related to the levels of compliance of the building occupants to housekeeping practices, building typology, physical planning statute, and their socio-economic characteristics. Reduced carbon monoxide levels were measured at distance limits beyond 2m from the external walls of buildings across the zones of the study area during the use of generators.

In light of the findings of the study, the researcher recommends that:

1. There is a need to license sale of generating sets with emission control mechanisms that would be properly tested at the point of manufacturing to guarantee its operational performance so as to conform to ISO 3744 and local codes.

2. The users of generating sets should adopt best house-keeping practices by positioning them in properly built enclosure features (generator house) located away from external walls of their buildings. This will allow conformity to the laws of the National Standards of Environmental Regulation (NESREA).
3. Adoption of environment-friendly alternative power sources should be considered as ways of mitigating the environmental pollution.

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