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Full Length Research

Community Exposure to Indoor Air Pollution arising from the Use of Gasoline Generator in Rukpokwu, Port Harcourt, Rivers State, Nigeria

*Adenubi B.C.,and Mmom P.C.

Department of Geography and Environmental Management, University of Port Harcourt, Port Harcourt, Nigeria.

*Corresponding E-mail Address: talk2mommyb@yahoo.com

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The study examined community exposure to indoor air pollution arising from the use of gasoline generators in Rukpokwu, Port Harcourt, Nigeria. Data was collected through field surveys and questionnaires. Five pollutants were purposively sampled in 48 households which include CO, SO_2, NO_X, VOC, and H_2S. aeroQUAL 500 series gas analyzer was used to measure these pollutants. The paired wise t-test and Spearman's rho correlation analysis were employed to test the hypothesis stated. The result obtained show that there is variation in indoor air quality across the study area, indoor air quality across the study area differs from WHO and FEPA standard, majority of the households sampled had high level of CO, SO_2, NO_X, VOC save for H_2S which about 81% of the households were within the limit set by WHO and FEPA and there is no relationship between the house characteristics measured to indoor air quality in Rukpokwu. The study therefore recommended that government should ensure that adequate power supply is provided and there should be public enlightenment on long time effects of poor IAQ.

Keywords: Indoor air, Pollution, Gasoline, Rukpokwu, Nigeria.

INTRODUCTION

Indoor air pollution can be seen as a significant source of potential health risks to exposed populations throughout the world (Tsakas et al., 2011; Laumbach et al., 2015). The major sources of indoor air pollution worldwide include the combustion of fuels, tobacco and coal, ventilation systems, emissions from furnishings and construction materials (WHO, 2010). These sources vary considerably between developing and developed nations. Over a decade in Nigeria, the electric power supply generator has been the main source of alternate power supply following the crisis of inadequate, unstable power supply from the national grid. Nigeria as a developing country is faced with several environmental, social and economic challenges such as power supply (electricity), adequate waste pollution system, unemployment, lack of water supply etc (Akande and Owoyemi 2008; Stanley et al ., 2010). Adequate and uninterrupted supply of electricity in Nigeria for example has been a reoccurring problem that has always been on the list of our leaders since the democratic regimes in the country. According to (Hall 2006, FRN 2009), it is believed that of the estimated population of 150 million of people in Nigeria, less than 40% have access to electricity power supply from the national grid. Most households in Nigerian cities operate small capacity fossil fuel electricity power generators for electricity supply (ECN, 2009). Stanley et al., 2010 noted that the result behind that is because Power Holding Company (PHCN) that is responsible for the generation and supply of electricity to the public has not performed well in the discharge of its mandate. It has shown that small household generators in Nigeria operate an average of six hours daily, while average distance was 5.6m (Okafor et al., 2008) included poor ventilation as part of what have influenced the quality of indoor air in the households.

Substantial amounts of toxic pollutants are emitted when fossil fuel generator are in use. These pollutants emitted include respiratory particles, carbon-monoxide (CO), Nitrogen oxide (NO), Chlorofluorocarbons (CFCs), Sulphur dioxide (SO_2), benzene and polyaromatic compounds (Sarah and Aigbokhaode, 2014); and this has led to serious effect in the livelihoods of people at a given time. Smith et al .(2003) said that poor indoor air quality has claimed over 1.6 million lives and has left 38.5 million disabled worldwide over in 2000. Some illness associated with poor indoor air quality among others includes irritation of the eyes, nose and throat, headaches, dizziness and fatigue, asthma, cancer, heart disease and acute lower respiratory infections (ALRI) in children aged under 5 years. Households with limited ventilation as is common in many developing countries including Nigeria, are exposed to these indoor air pollutants which are commonly experienced by household members, particularly women and young children who spend a large proportion of their time in indoor (Salvin and Barnes, 2009; World Health Organization (WHO), 2012). WHO (2014) and Obanya et al. (2018) estimated that 10% of global mortality, amounting to 7 million people, resulted from air pollution in 2012 while WHO (2016) reiterated that 2.9 million annual deaths were reported, of which more than 85% occurred in low- and middle-income countries.

Several studies have been done on indoor and outdoor pollution. These studies included Ladan (2013), who reviewed air pollution and control measures in urban centers of Nigeria while Asubiojo (2016) also reviewed pollution sources in the Nigerian environment and their health implications. Obanyan et al. (2018) monitored air pollution around residential and transportation sector locations in Lagos Mainland while Omole et al. (2016) reported the causative factors of indoor air pollution in Nigerian households. Nnaji et al. (2014) examined the effects of diesel-powered generator fumes on ambient air quality over Lagos Island, Nigeria. Few of these studies are literature review while few are quantitative in nature but the truth is that their work did little on indoor pollution through generating set. Thus, the present study is focused at unraveling the effects of gasoline generator set on the indoor air quality in Rupokwu, Port Harcourt, Rivers State, Nigeria.

MATERIALS AND METHODS

The study was carried out in Rukpokwu, Port Harcourt, Rivers State, Nigeria (Figure 1). The study area is located in Obio/Akpor LGA of Rivers State, Niger Delta Region of Nigeria.

Obio/Akpor has become a metropolis to Port Harcourt the capital city of Rivers State. It is the hub of industrial, commercial, administration and other activities in the state. The area lies between latitude 7^0 00' 00'-$7^0$2' 30''E and 4^0 52' 30''-4^0 55' 00''N. It covers an estimated area of 1811.6 square kilometers. The study area is bounded in the north by Ikwerre, East by Eleme, West by Emohua and South by Port Harcourt City Local Government Areas respectively. It is situated in the equatorial region and thus enjoys the tropical climate. The area is characterized by a mean yearly rainfall of about 2300 mm (Kolebaje et al., 2016). The mean annual temperature is 30ºC and a mean annual relative humidity is 80% -100%. The vegetation of Port-Harcourt is consistently nourished with high rainfall and high temperature, which provide favourable condition for the growth of a varieties of tall and big trees like *Khaya grandifoliola*, *Triplochiton scleroxylon*, *Terminalia superba* and abundance of oil palm trees and several other species of economically valuable trees (Eludoyin et al ., 2010). The population of Port Harcourt Metropolis was estimated to be 1,865,000 inhabitants, as at 2016 (Demographia World Urban Areas, 2019).The area falls within the coastal belt dominated by low-lying coastal plains which structurally belong to the sedimentary formations of the recent Niger Delta. The drainage of the area is poor, essentially due to a combination of low relief, high water table and high rainfall. The low relief of the region results in strikingly gentle slopes which have the effect of making the flow velocities of the rivers very low. This situation results in the formation of well-developed river meanders (Aisuebeogun, 1995).

For the effectiveness of the study, survey research design was used because it deals with the

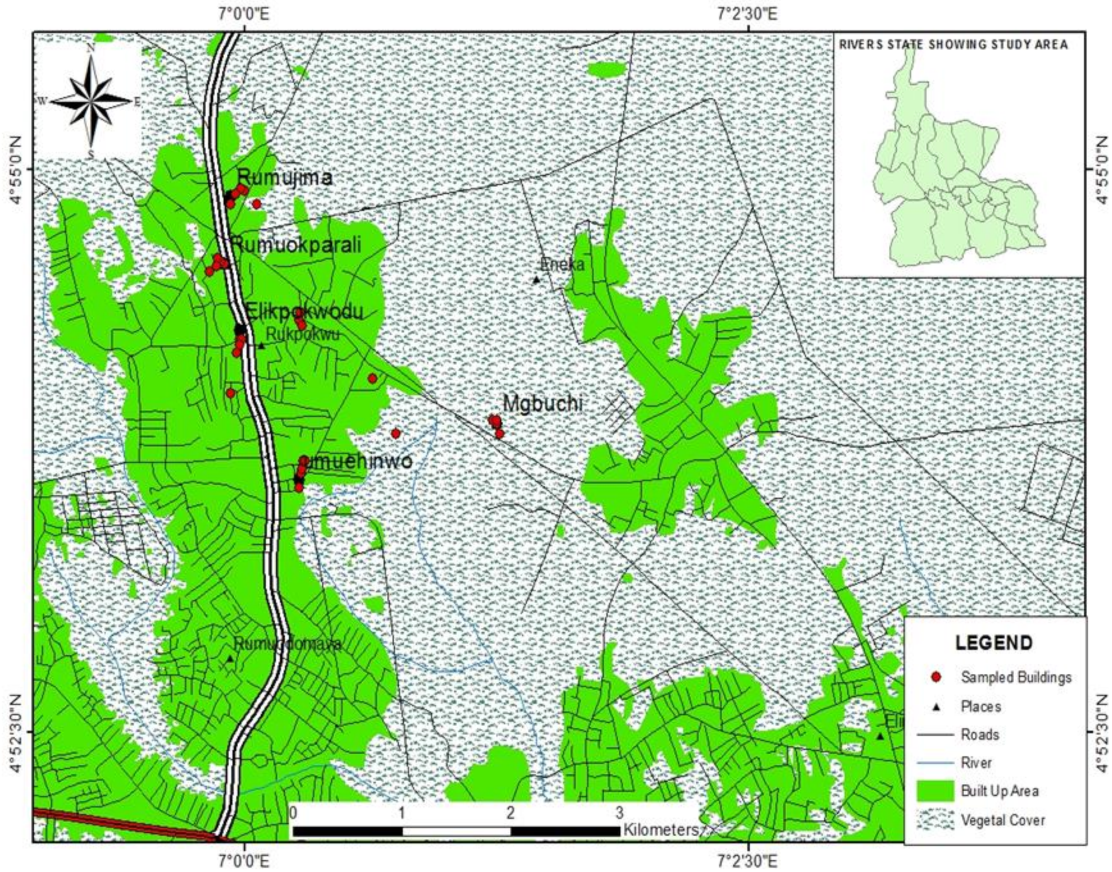

Figure 1. Rukpokwu and Its Environs showing the Study Locations.

observational method of data collection. Household population was used for data collection with the use of structured questionnaire through purposive sampling technique. Questionnaires were administered to respondents in the study area to examine the perception of the respondents on the effect of fuel generator use on indoor air quality. The sample size used for the research was generated from 30% of the number of streets in Rukpokwu and its environs. A sample size of 48 was shared amongst the six (6) communities namely Mgbuchi, Rumuokparali, Rumujima, Elikpokwodu, Umuehinwo and Rukpokwu. Eight (8) households were randomly sampled in each community making up to forty-eight (48) households. The questionnaire administered was collected immediately from the respondents. Care was taken to establish a good response or report from the respondents; given the fact the study was purely academic. Hence it is believed that accurate information was given.

Quantitatively, five pollutants were measured which are carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxide (NO_x), Hydrogen sulphide (H_2S) and volatile organic compounds ($VOC_{s)}$. AEROQUAL Gas Analyzer series 500 was used to measure these pollutants. The gas analyzer was calibrated for 180seconds (3 minutes) before the start of measurement. Recalibration of 30seconds was carried out at subsequent interval and average of three (3) consecutive measurements for each pollutant was recorded for each household. Measurements of pollutants were carried out at the period of generator operation mostly in the evening/night. The average period of generator operation was 6 hours daily. Both descriptive and inferential statistics were employed in this study. The descriptive statistical method was used to describe the observed data collected from field survey while the inferential statistical method was used to determine the significant variation between the prevailing indoor air quality across the study area and standards laid down by Federal Ministry of Environment (FMEnv) and World Health Organisation (WHO) using one sample T-test. The

Table 1. Housing Characteristics.

Building type	Frequency	Percent
Bungalow	31	64.6
One storey	13	27.1
Two storey	4	8.3
Total	48	100.0
Household Types	**Frequency**	**Percent**
Single family compound	31	64.6
Double family compound	8	16.7
Multiple family compound	9	18.8
Total	48	100.0
Apartment Types	**Frequency**	**Percent**
Self contain	7	14.6
Wagon rooms	5	10.4
One bedroom flat	10	20.8
Two bedroom flat	10	20.8
3 or more bedroom flat	16	33.3
Total	48	100.0
Number of windows	**Frequency**	**Percent**
One window	5	10.4
Two windows	4	8.3
Three windows	4	8.3
Four windows	4	8.3
Above four windows	31	64.4
Total	48	100.0

relationship between house characteristics and indoor air quality in the study area was also determined using the Spearman's rho correlation statistics. All analyses were carried out using SPSS version 21. The results of the analyses were presented in tables and charts.

RESULTS AND DISCUSSION

Characteristics and Nature of Building and Household Types

Table 1 shows that the number of bungalows sampled was 31(64.6%) which was the highest in building types followed by one storey which was 13(27.1%) while the remaining 4(8.3%) was two storey building. In addition, 31(64.6%) of the house type sampled were mostly single family compound, next was 8(16.7%) which were double family compound while the remaining 9(18.8%) were multiple family compound. However, of all total 48 apartment types sample, 7(14.6%) were self contain, next was 5(10.4%) for single rooms, next was 10(20.8%) for one bedroom and two bedrooms flat respectively and finally was 16(33.3%) which were for three or more bed room flats. Furthermore, the highest number of windows in houses sampled were 5 windows and above with 31(64.4%), followed by one window with 5(10.4%) while the remaining number of windows had 4(8.3%) respectively.

Cross-tabulations of Distribution of House Characteristics

Building Type and Apartment Type

Table 2 shows a crosstab of building type and apartment type. For Bungalow building type, 5 self contain, 5 single rooms, 6 one bedroom flat, 7 two bedrooms flat and finally 8 three or more bedroom flat were sampled. For one storey building type, 2 self contain, 2 one bedroom flat, 3 two bedrooms flat and 6 three or more bedroom flat were sampled. For

Table 2. Building Type and Apartment Type.

	APARTMENT TYPE					
	Self contain	Single Room	One Bedroom flat	Two Bedroom flat	Three or more Bedroom flat	Total
Bungalow	5	5	6	7	8	31
One storey	2	0	2	3	6	13
Two storey	0	0	2	0	2	4
Total	7	5	10	10	16	48

Table 3. Building Type and Number of Windows.

	Number of Windows per Apartment					
	One window	Two windows	Three windows	Four windows	Five windows and above	Total
Bungalow	5	4	2	3	17	31
One storey	0	0	2	1	10	13
Two storey	0	0	0	0	4	4
Total	5	4	4	4	31	48

Table 4. Building Type and House Type.

	HOUSE TYPE			
	Single family compound	Double family compound	Multiple family compound	Total
Bungalow	22	4	5	31
One storey	7	3	3	13
Two storey	2	1	1	4
Total	31	8	9	48

two storey building type, only 2 one bedroom flat and 2 three or more bedroom flat were sampled as seen in Figure 1.

Building type and number of windows

Table 3 shows a crosstab of building type and number of windows sampled. For bungalow building type, 5 one window, 4 two windows, 2 three windows, 3 four windows and 17 five and above windows were sampled. For one storey building type, 2 three widows, 1 four windows and 10 five and above widows were sampled. For two storey building type, only 4 five and above windows were sampled.

Building type and House type

Table 4 shows that 22 bungalows sampled were single family compound house type, 4 bungalows were double family compound while the remaining 5 bungalows were multiple family compound house

Table 5. Indoor Air Quality in Rukpokwu and Its Environs.

	COMMUNITIES						
Pollutants (ppm)	Rumuapu	Rumuehinwo	Rumuijima	Elikpokwodu	Mgbuchi	Rumuopara	t-Value
	Mean ±SD	Mean ±SD	Mean±SD	Mean ±SD	Mean ±SD	Mean ±SD	
CO	21.36±3.91	22.63 ±4.62	22.08± 4.51	15.83± 7.56	16.10±6.22	20.82± 4.26	10.0*
SO_2	0.37 ±0.48	0.24 ± 0.33	0.72 ± 0.88	0.54± 0.81	0.48 ± 0.51	0.44± 0.73	0.12*
NO_x	0.86±0.69	0.23± 0.52	0.57± 0.56	0.61 ± 0.60	0.22 ± 0.48	0.79± 0.61	0.04*
H_2S	0.11±0.16	0.08± 0.13	0.03± 0.02	0.06 ± 0.04	0.04± 0.02	0.12 ± 0.13	0.1005*
VOC	2.39±5.07	0.95 ± 0.68	1.99 ±2.96	0.66 ± 0.76	1.35±1.13	2.50 ± 4.05	0.10*

*Significantly varied at $p<0.05$

type. For one storey building, 7 of them were single family compound, 3 were double family compound while the remaining 3 one storey building sampled were multiple family compound. For the two storey building, 2 were single family compound, 1 were double family compound while the remaining 1 goes for multiple family compound house type.

Variation of Indoor Air Quality in Rukpokwu and Its Environs

Table 5 indicates the mean levels of the pollutants measured in the study area. The mean CO in Rumuehinwo community was the highest (22.63 ppm) and the lowest was observed in Elikpokwodu community with mean CO of 15.83 ppm. Rumuijima community has the highest mean of 0.72 ppm for SO_2 followed by Elikpokwodu community with 0.54 ppm andRumuehinwo had the least mean which was 0.24 ppm. The analysis also revealed that variation existed in the concentrations of NO_X in different communities of Rukpokwu and its environs whereby Rumuapu had 0.86 ppm, Rumuehinwo 0.23 ppm, Rumuijima 0.57 ppm, Elikpokwodu 0.61 ppm, Mgbuchi 0.22 ppm and Rumuopara 0.79 ppm. The highest mean H_2S (0.11 ppm) was observed in each of Rumuapuand Rumuijima while the least was recorded in Rumuijima having 0.03 ppm. The mean VOC was highest in Rumuopara (2.50 ppm), followed by Rumuapu which had 2.39 ppm while the least was recorded in Elikpokwodu having 0.66 ppm. In addition, the one sample T Test analyses showed that the concentrations of CO, SO_2, NO_X, VOC, and H_2S across Rukpokwu significantly varied from the FEPA and WHO standards.

Spatial Variation of Pollutants in Relation with Building Characteristics

Table 6 shows the number of households within and above the WHO and FEPA standard for the pollutants measured on the study area. For CO 13% of the Household falls within the standard limits of (0-10ppm) set by WHO and FEPA while 87% are above the limits. For SO_2 52% of the household falls within the standard limit of (0-0.12ppm) set by WHO and FEPA while 48% are above the limits. For NO_x, the standard limits set by WHO and FEPA is (0-0.04ppm), 35% of the household sampled falls within the standard limits while 56% are above the limits. For VOC, 4% of the households fall within the standard limits of (0-0.10ppm), while the remaining 96% of the households sampled are above the limits. For H_2S, households within the standard limits set by WHO and FEPA (0-0.1005ppm) are up to 81% while the remaining 19% of household sampled are above the limits.

Variation in Pollutant Concentrations per Housing Characteristics among the Selected Communities

The concentrations of pollutants in varying degrees of housing characteristics in the selected communities are presented in Table 7. In Rumuagwu, Rumuopara and Eliokpwodu, the mean CO was higher in the Bungalow than the one storey building whereas in Rumuehinwo, Rumuijima andMgbuchi, the mean CO was higher in the one storey building than the Bungalow. Generally, SO_2 was higher in concentration under bungalow in most

Table 6. Number of Household Within and Above WHO and FEPA Standard Limits.

Pollutant	Standards	Numbers of households	Percentage (%)
CO (ppm)	Within (0-10ppm)	6	13
	Above Standards (>10ppm)	42	87
	Total	48	100
SO_2 (ppm)	Within (0-0.12ppm)	25	52
	Above Standards (>0.12ppm)	23	48
	Total	48	100
NO_x (ppm)	Within (0-0.04ppm)	17	35
	Above Standards (>0.04ppm)	31	65
	Total	48	100
VOC (ppm)	Within (0-0.10ppm)	2	4
	Above Standards (>0.10ppm)	46	96
	Total	48	100
H_2S (ppm)	Within (0-0.1005ppm)	39	81
	Above Standards (>0.1005ppm)	9	19
	Total	48	100

of the selected communities (Rumuehinwo, Rumujima, Elipokwodu and Rumuopara) than other types of building type. However, H_2S concentration was higher in the bungalow than other types of building. NOx was higher in the two storey building in Rumujima and Elikpokwodu while VOC was higher in the two storey building type (Table 8). In most of the communities, H_2S reduced slightly from bungalow to two storey buildings. Considering the type of apartment in Table 9, the concentration of CO was higher in single family compound in Rumuagwu and Elikpokwodu while it was higher in the double family compound in Rumuehinwo and Mgbuchi; and in Rumujima and Rumuopara, the CO was higher in the multiple family compound. In terms of apartment, two-bedroom flat was observed to have higher concentrations of CO and NOx in Rumuagwu while SO_2 and VOC was higher in the apartment above two bedroom flat. CO concentrations were higher in one bedroom flat in Rumuehinwo and higher in the apartment above two-bedroom flat in Rumujima, Elikpokwodu and Mgbuchi. In Rumuagwu, indoor pollutants were highest in the buildings having above four windows (Table 10). CO concentration was highest in the building having four windows while SO_2, H_2S and VOC were highest in the building having more than four windows in Rumuehinwo. In addition, CO was higher in the buildings having three windows in Rumujima and Mgbuchi. Meanwhile in Rumujima, Elikpokwodu and Mgbuchi recorded highest concentrations of SO_2, NOx, and VOC in the buildings having more than four windows (Table 10).Generally, it was discovered in the study that the concentration of CO in the one storey building was higher than other types of building while SO_2 and H_2S were highest in the bungalow. However, NOx and VOC were highest in the two storey building. Considering the type of house, findings showed that multiple family compound had the highest concentrations of CO, SO_2, H_2S and VOC. Regarding the type of apartment, buildings with more than two bedroom apartment recorded the highest concentrations of CO, NOx and VOC while the two bedroom apartment had the highest concentration of SO_2 and self-contain had the highest concentration of H_2S. However, analysis reveals that buildings with two windows had the highest CO (24.602 ppm) and H_2S (0.133 ppm) while buildings with more than four windows recorded the highest concentrations in SO_2 (0.468 ppm), NOx (0.644 ppm) and VOC (2.065 ppm). It is also discovered that in the entire study area, CO was conspicuously higher than every other air

Table 7. Concentration of Pollutants in Varying Degrees of Building Types.

	Building Type				
Rumuagwu	Pollutants	Bungalow	One Storey	Two Storey	Above Two Storey
	CO	21.39	21.12	0	0
	SO_2	0.27	1.1	0	0
	NO_X	0.78	1.32	0	0
	H_2S	0.12	0.05	0	0
	VOC	0.6	14.9	0	0
Rumuehinwo	CO	21.47	24.56	0	0
	SO_2	0.25	0.16	0	0
	NO_X	0.34	0.037	0	0
	H_2S	0.034	0.16	0	0
	VOC	0.98	0.9	0	0
Rumujima	CO	20.05	28.57	19.26	0
	SO_2	0.79	0.785	0.22	0
	NO_X	0.416	0.56	1.33	0
	H_2S	0.028	0.025	0.05	0
	VOC	0.86	4.75	2.1	0
Elikpokwodu	CO	16.08	0	14.06	0
	SO_2	0.57	0	0.32	0
	NO_X	0.52	0	1.23	0
	H_2S	0.06	0	0.07	0
	VOC	0.74	0	0.1	0
Mgbuchi	CO	13.93	19.72	0	0
	SO_2	0.48	0.48	0	0
	NO_X	0.31	0.06	0	0
	H_2S	0.05	0.03	0	0
	VOC	1.58	0.97	0	0
Rumuopara	CO	23.57	21.53	17.86	0
	SO_2	1.56	0.06	0.09	0
	NO_X	0.65	0.98	0.54	0
	H_2S	0.24	0.07	0.05	0
	VOC	0.4	1.63	6.35	0

pollutants investigated (Figures 2, 3, 4and 5). The concentrations of the pollutants were higher than the WHO and FEPA standards (Table 11) with respect to various housing characteristics within the study except SO_2 in the building having 1 window (0.084 ppm) and 3 windows (0.075ppm).

Relationship between Pollutants and Housing Characteristics

The analysis in Table 12 presents the relationships between the concentrations of pollutants and building type, house type, apartment type and

Table 8. Concentration of Pollutants in Varying Degrees of Type of the House.

Rumuagwu		Type of House		
		Single Family Compound	Double Family Compound	Multiple Family Compound
	CO	21.39	0	21.12
	SO_2	0.27	0	1.1
	NO_X	0.78	0	1.32
	H_2S	0.12	0	0.05
	VOC	0.6	0	14.9
Rumuehinwo	CO	22.23	24.22	20.83
	SO_2	0.41	0.13	0.13
	NO_X	0.53	0.04	0.04
	H_2S	0.43	0.03	0.22
	VOC	1.47	0.57	0.75
Rumujima	CO	21.88	19.1	22.97
	SO_2	0.84	0.04	0.8
	NO_X	0.486	0.21	0.723
	H_2S	0.016	0.01	0.045
	VOC	0.233	1.2	3.5
Elikpokwodu	CO	17.21	14.06	9.31
	SO_2	0.66	0.32	0.09
	NO_X	0.59	1.23	0.03
	H_2S	0.065	0.07	0.03
	VOC	0.65	0.1	1.3
Mgbuchi	CO	13.93	19.72	0
	SO_2	0.48	0.48	0
	NO_X	0.31	0.06	0
	H_2S	0.05	0.03	0
	VOC	1.58	0.97	0
Rumuopara	CO	19.78	0	28.11
	SO_2	0.34	0	1.11
	NO_X	0.89	0	0.08
	H_2S	0.07	0	0.4
	VOC	2.8	0	0.4

number of windows per apartment. The analysis shows that CO, NO_2, and H_2S were positively correlated with Building Type, though the correlations coefficients were insignificant and low. Housing type had positive correlation with CO (r=0.113), SO_2(r=0.223), VOC (r=0.027) and H_2S(r=0.187). On the other hand, house type had negative relationship with NOx (r=-0.235). Apartment type had positive correlations with CO (r=0.141), No_2(r=0.085) and H_2S(r=0.050) while negative correlations with SO_2(r=-0.066) and VOC (r=-0.024). Finally, number of windows per apartment had positive relationship with CO, SO_2, NO_2, VOC and H_2S with low correlation coefficients.

Table 9. Concentration of Pollutants in Varying Degrees of Type of Apartment.

Rumuagwu		Type of Apartment				
		Self Contain	Wagon Rooms	One Bedroom Flat	Two Bedroom Flat	Above Two Bedroom Flat
	CO	0	0	17.42	28.75	20.81
	SO_2	0	0	0.08	0.12	0.47
	NO_X	0	0	1.23	1.58	0.67
	H_2S	0	0	0.5	0.06	0.06
	VOC	0	0	0.6	0.4	0.64
Rumuehinwo	CO	19.26	26.43	27.26	20.2	0
	SO_2	0.08	0.11	0.1	0.37	0
	NO_X	1.51	0.04	0.03	0.05	0
	H_2S	0.07	0.01	0.04	0.12	0
	VOC	1.4	0.9	0.2	1.23	0
Rumujima	CO	24.61	19.23	21.74	17.45	28.37
	SO_2	1.32	0.15	0.465	2.33	0.08
	NO_X	0.3	1.23	0.467	0.04	1.12
	H_2S	0.05	0.05	0.025	0.02	0.02
	VOC	1.4	1.4	3.15	0.1	0.4
Elikpokwodu	CO	8.79	9.31	16.09	17.24	19.71
	SO_2	0.09	0.09	1.27	0.17	0.49
	NO_X	1.1	0.03	0.65	1.03	0.46
	H_2S	0.02	0.03	0.09	0.11	0.05
	VOC	0.2	1.3	0.25	0.5	0.93
Mgbuchi	CO	13.85	13.57	0	18.09	19.71
	SO_2	0.07	0.065	0	1.08	0.31
	NO_X	0.065	0.04	0	0.49	0.06
	H_2S	0.03	0.04	0	0.05	0.02
	VOC	1.75	0.3	0	1.8	1.3
Rumuopara	CO	23.17	0	19.03	0	20.25
	SO_2	0.6	0	2.01	0	0.06
	NO_X	0.08	0	1.21	0	0.98
	H_2S	0.26	0	0.08	0	0.05
	VOC	0.8	0	0.4	0	3.6

DISCUSSION OF FINDINGS

The mean for CO in Rumuapu Community was 21.36 ppm different from other communities in Rukpokwu, which simply shows that air quality in Rukpokwu varied. This could be as a result of variation in the house characteristics measured such as number of windows in the building or level of ventilation. This is similar to the findings of Senitkova (2017) who believed that good building design always lead to healthy environment for the occupants. Also, Ndoke and Jimoh (2005) noted that different house characteristics could lead to variation in Indoor air quality. The study revealed

Table 10. Concentration of Pollutants in Varying Degrees of Type of Apartment.

Rumuagwu		Numbers of Windows				
		One	Two	Three	Four	Above Four
	CO	0	0	0	0	21.36
	SO_2	0	0	0	0	0.37
	NO_X	0	0	0	0	0.86
	H_2S	0	0	0	0	0.11
	VOC	0	0	0	0	2.39
Rumuehinwo	CO	0	22.85	0	27.26	18.21
	SO_2	0	0.1	0	0.1	0.37
	NO_X	0	0.78	0	0.03	0.05
	H_2S	0	0.04	0	0.04	0.12
	VOC	0	1.15	0	0.2	1.23
Rumujima	CO	19.23	0	24.61	19.1	22.74
	SO_2	0.15	0	1.32	0.04	0.85
	NO_X	1.23	0	0.3	0.21	0.564
	H_2S	0.05	0	0.05	0.01	0.026
	VOC	1.4	0	1.4	1.2	2.38
Elikpokwodu	CO	9.31	0	8.79	18.12	18.09
	SO_2	0.09	0	0.09	2.21	0.39
	NO_X	0.03	0	1.1	0.07	0.73
	H_2S	0.03	0	0.02	0.11	0.07
	VOC	1.3	0	0.2	0.4	0.68
Mgbuchi	CO	11.53	0	20.25	0	18.5
	SO_2	0.06	0	0.09	0	0.89
	NO_X	0.04	0	0.09	0	0.39
	H_2S	0.04	0	0.02	0	0.05
	VOC	1.23	0	0.4	0	1.68
Rumuopara	CO	0	28.11	18.22	19.03	20.25
	SO_2	0	1.11	0.08	2.01	0.06
	NO_X	0	0.08	0.07	1.21	0.98
	H_2S	0	0.4	0.11	0.08	0.05
	VOC	0	0.4	1.2	0.4	3.6

that there is significantly high concentration of CO affecting the indoor air quality of households in Rukpokwu. The implication of severe exposure of CO could be severe poisoning, which may lead to unconsciousness, and cause neurological damage (Townsend and Maynard, 2002).Based on the findings, it was observed that majority of households (87%) had its concentration above the WHO standard limit while few (13%) households are within the standard limit. This could be as a result of the limited distance of generator to building, poor ventilation, number of windows and opening in their apartment, and the effect of wind dispersion (Ndoke and Jimoh, 2005). For the few that were within the recommended limit by WHO and FEPA, it could be attributed to level of awareness in distance away

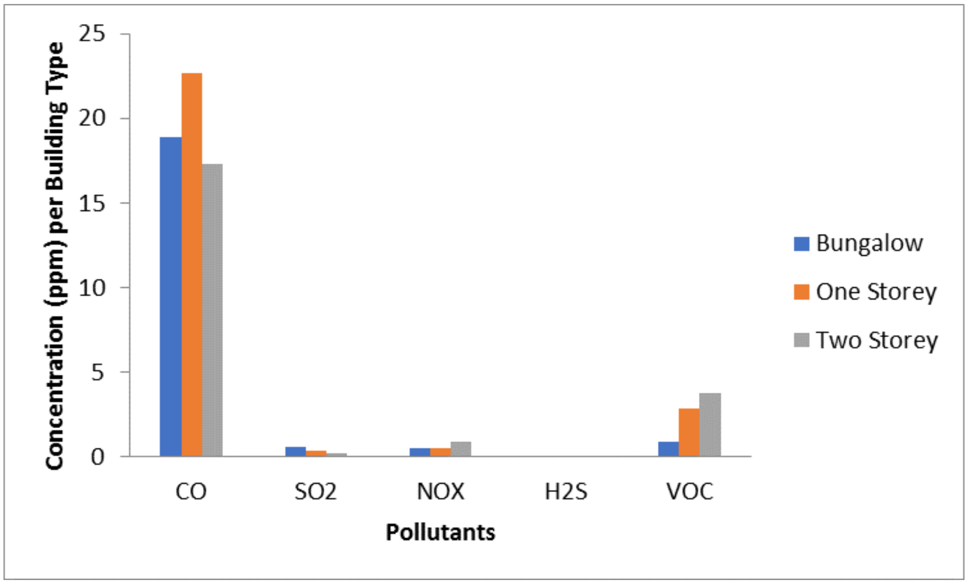

Figure 2. Air Pollutants Concentrations under Different Types of Building.

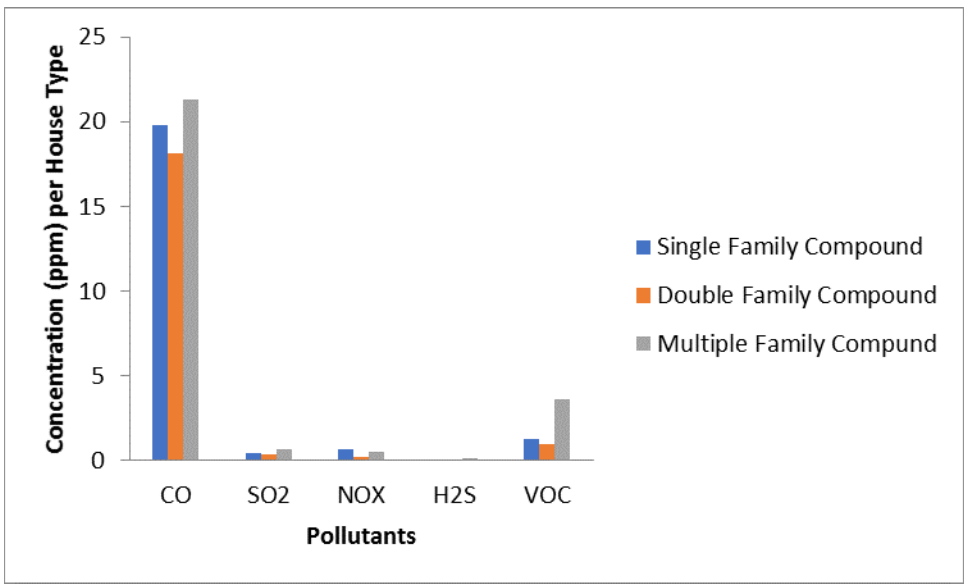

Figure 3. Air Pollutants Concentrations under Different Types of House.

from building, adequate provision of windows and openings in the building. Poor indoor air quality according to Smith and Mehta (2003) has been reported to claim over 1.6 million lives and has disabled 38.5 million lives worldwide in 2000. Chronic obstructive pulmonary disease (COPD), lung cancer, asthma, dizziness, fatigue and headaches, etc. alongside with poor ventilation are the resultant diseases being experienced with the inhalation of the pollutants. Therefore, the use of gasoline generator should be reduced both in residential areas, commercial areas as well. It was observed that SO_2 in Rukpokwu has (60%) of its concentration within WHO and FEPA standard limit which simply implies that there is less amount of SO_2 in the area, while (40%) had a trace of SO_2 in their household. It is a great concern because the presence of SO_2 could lead to coughing, chest pain,

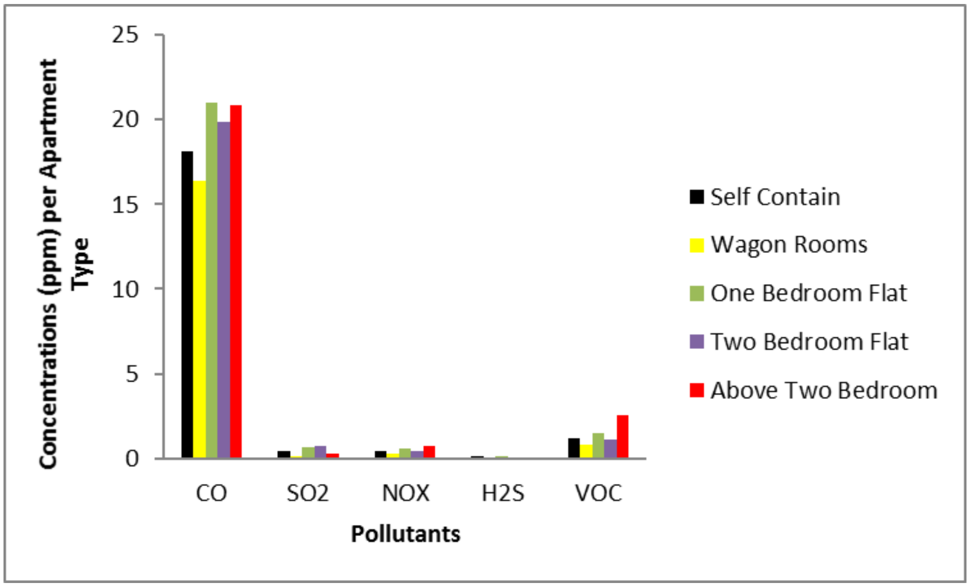

Figure 4. Air Pollutants Concentrations under Different Types of Apartments.

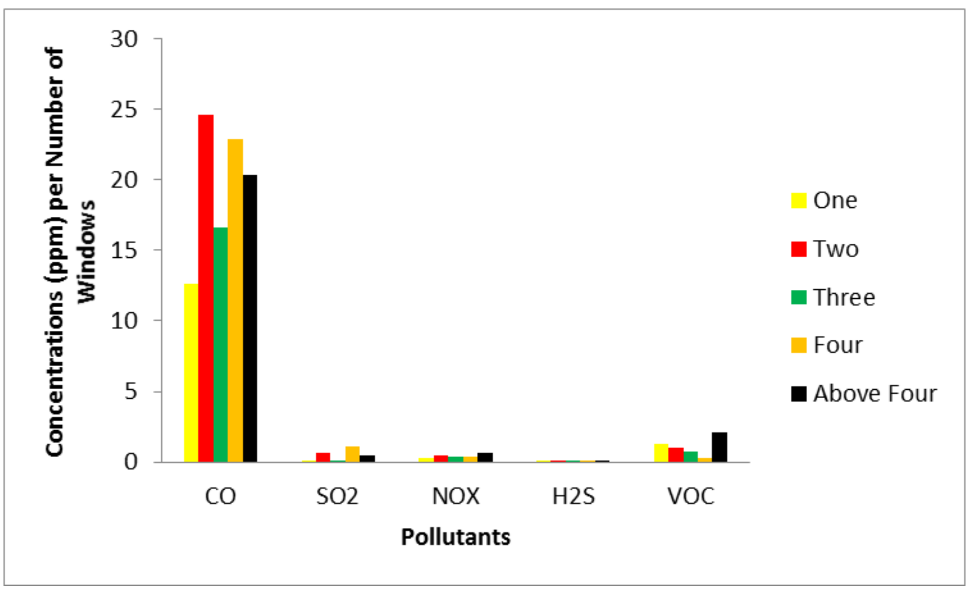

Figure 5 Air Pollutants Concentrations under Different Number of Window.

shortness of breath, emphysema and bronchitis (Osuntogun and Koku, 2007). NOX concentration in the indoor air as observed in households had (43%) of its concentration within the standard limit by WHO and FEPA, while (57%) households were above the standard limit set. There is also a great concern as the health of the occupants are exposed to several illness and diseases like irritation of the eyes and respiratory track, fluid buildup in the lungs, highly corrosive and toxic. The WHO standard for VOC is < 0.10ppm, from observation, majority (53%) of households' falls within the standard limit whereby

Table 11. General Pollutants Level Per Housing Characteristics.

BUILDING TYPE	CO (ppm)	SO_2 (ppm)	NO_X (ppm)	H_2S (ppm)	VOC (ppm)
Bungalow	18.92	0.54	0.508	0.074	0.88
One Storey	22.68	0.37	0.513	0.072	2.81
Two Storey	17.26	0.18	0.91	0.053	3.73
TYPE OF HOUSE	**CO (ppm)**	**SO_2 (ppm)**	**NO_X (ppm)**	**H_2S (ppm)**	**VOC (ppm)**
Single Family Compound	19.78	0.441	0.645	0.065	1.265
Double Family Compound	18.13	0.36	0.208	0.041	0.925
Multiple Family Compound	21.34	0.637	0.489	0.121	3.566
TYPE OF APARTMENT	**CO (ppm)**	**SO_2 (ppm)**	**NO_X (ppm)**	**H_2S (ppm)**	**VOC (ppm)**
Self Contain	18.097	0.403	0.456	0.101	1.157
Wagon Rooms	16.422	0.096	0.276	0.034	0.84
One Bedroom Flat	21.012	0.668	0.567	0.094	1.45
Two Bedroom Flat	19.833	0.736	0.432	0.083	1.13
Above Two Bedroom	20.831	0.309	0.72	0.049	2.537
NUMBER OF WINDOWS	**CO (ppm)**	**SO_2 (ppm)**	**NO_X (ppm)**	**H_2S (ppm)**	**VOC (ppm)**
One	12.624	0.084	0.276	0.04	1.28
Two	24.602	0.655	0.483	0.133	1.025
Three	16.59	0.075	0.368	0.04	0.75
Four	22.92	1.105	0.335	0.068	0.3
Above Four	20.354	0.468	0.644	0.074	2.065
*WHO Standards	10	0.1	0.012	-	0.10

*WHO and FEPA Standards; Ashrae, 2004.

(47%) households were above the limit set. This suggests that frequent gas exposure has effects on humans'health. Based on the result from the pollutants measured, it is certain that continuous emission of carbon monoxide (CO), Nitrogen oxide (NO_X), Sulphur dioxide (SO_2), Volatile organic compounds (VOC_S) and Hydrogen sulphide (H_2S) and gasoline generator contributes greatly to the quality of air in households. In a developing country like Nigeria, it is believed that most households use gasoline generator to argument the shortfall of power electricity supply by (PHCN) Power Holding Company of Nigeria (Stanley et. al. 2010).

CONCLUSION AND RECOMMENDATIONS

From the findings of the study, it is glaring that indoor concentration of CO, SO_2, NO_X, VOC in majority of the households are above the standard limit set by WHO and FEPA. It can be concluded that generating set has serious influence in the concentrations level of pollutant with respective to different housing characteristics. The study therefore recommended among others that multiple family compound should be discouraged and apartments of minimum of two bedroom flat should be cautiously managed with respect to indoor pollution level. More so, public awareness can go a long way in educating people on the negative effect or health risk associated with increasing rate of generator use in the neighbourhood; and government should ensure that adequate power supply is provided and should also come up with appropriate polices that will help minimize the use of generator. Landlords should ensure adequate ventilation/ opening whenever a building is being constructed and the occupants of the househould

Table 12. Correlation analysis between Pollutants and Building Types.

Pollutants	Building Type	House Type	Apartment Type	Number of Windows per apartment
Co	0.151	0.113	0.141	0.171
Sig. 2 tail	0. 307	0.443	0.340	0.247
SO_2	-0.042	0.223	-0.066	0.141
Sig. 2 tail	0.775	0.127	0.655	0.340
NO_x	0.062	-0.235	0.085	0.154
Sig. 2 tail	0.677	0.107	0.566	0.296
VOC	-0.006	0.027	-0.024	0.046
Sig. 2 tail	0.967	0.857	0.870	0.759
H_2S	0.247	0.187	0.050	0.030
Sig. 2 tail	0.090	0.204	0.734	0.842

ensure that their generator is far apart from the building.

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