Influence of Electric Power Generator Variables on Indoor Air Quality in Residential Buildings

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Abstract

The study assessed the influence of electric power generator variables on the quality of air in indoor environment of buildings. A quantitative survey method was adopted for the study. Kaduna metropolis was the study area grouped into twelve (12) clusters; and six (6) households were purposively selected from each of the cluster for the survey. A total of 72 households that operate electric power generators for power supply in buildings participated in the study. IMR1400 combustible gas analyzer was used to measure 432 samples of air pollutants' concentration in the 72 households (6 per household). SPSS version 15 was used to correlate the generator variables with the air pollutants measured. The results showed that the characteristics of generator age (at 0.05 significance level) at all the clusters were similar unlike the generator capacities which were different in few clusters. It was also observed that all the generator distances away from the building indoor were the same except for Sabon Tasha. For the indoor air pollutants concentration, carbon monoxide (CO) concentration for all the clusters were the same, while few of the clusters have similar concentration of Sulphur dioxide (SO_2) and half of the clusters have the same oxides of nitrogen (NOx) concentrations. The mean CO concentration recorded in the indoor was 6.18ppm less than the WHO limit (10ppm), while the mean SO_2 concentration was 0.17ppm higher than the WHO limit of 0.01ppm and the mean NOx concentration was 0.14ppm higher than the WHO limit (0.04 to 0.06ppm). The results also showed that the indoor CO concentration (at 0.05 significant level) has no relationship with generator age, capacity and distance. Also, SO_2 and NOx have no significance relationship with the age, capacity and distance. It was concluded that the generator age and capacity did not influence the indoor air pollutants concentrations but the generator distance from the building influenced the emission of CO in the building indoors. It was recommended that studies on the indoor gaseous pollutants concentration and the generator distance from the building should be intensified.

Keywords: *Building indoor environment, air pollutants, households, IMR 1400, electric power generator*

Introduction

Increased awareness of the importance of the building indoor environment in recent times has caught the attention of many researchers (White & Marchant, 2009; Stanley, Mbamali, Zubairu, Bustani, Andrew, & Joshua, 2010). Indoor air quality and noise levels are some established parameters which affect the well-being of building occupants (who spend 80 – 90% of their time indoor) as well as, building components (Ideriah, Herbert & Ideriah, 2007; Stanley, Mbamali & Dania, 2011). Man's activities (fossil fuel combustion, cooking, construction activities; use of building materials, heating and cooling systems, pesticides, etc.) have continued to alter the quality of the building indoor environment (Kandpal, Maheshwari, & Kandpal, 1994 and United State Environmental Protection Agency [USEPA], 2009).

In Stanley *et al.* (2010), improper openings for ventilation in buildings and several other factors also facilitate the accumulation of pollutants indoor which pose health problems. Concentrations of pollutants such as carbon monoxide, nitrogen oxides, Sulphur dioxide, microorganisms, etc. above certain limits in the indoor air are found to affect the health of the building occupants (Ideriah *et al.*, 2007). The combustion of fossil fuel in generators and their products have been observed to be responsible to some extent for air, water, soil and noise pollutions which are particularly acute in urban areas (Hall, 2006). Carbon dioxide (CO_2), nitrogen oxide (NO_x), Sulphur dioxide (SO_2), carbon monoxide (CO), particulate matter (PM), etc. and burnt engine oil are some of the by-products emitted during the combustion of electric power generators. Nitric oxide (NO), nitrous oxide (N_2O) and nitrogen dioxide (NO_2) generate nitrogen oxides (NOx) (César, Carvalho & Nascimento, 2015). Others are heat, vibration and noise (Offiong, 2003; IPCC [Intergovernmental Panel on Climate Change], 1996).

The burning of fossil fuel as observed in Rao (2007) annually releases 7.0 billion tonnes of carbon (in the form of CO_2) into the atmosphere worldwide. Carbon dioxide (CO_2) is a greenhouse gas whose presence in the atmosphere has a warming effect on the earth's climate. Nitrogen oxide (NOx) deplete the ozone layer, an exposure upwards of 150 – 200ppm results in bronchiolitis, a dangerousdisease which occurs within 3 – 5 weeks after exposure (Dimari, Abdulrahman, Akan, & Ogugbuaja, 2007). SO_2 is believed to be responsible for impaired visibility, damage of vegetation and materials, harm to human health and production of acid rain (Rao, 2007).

Nigeria is faced with lots of environmental, social and economic challenges as observed in Akande and Owoyemi (2008), and Stanley *et al.* (2010). Most households (60%) live on less than a dollar a day (CAPPS, 2007), not enough to cater for a minimum standard of living. These have affected the quality of life style and health of most Nigerians. Most households in Nigerian cities operate small capacity fossil fuel electric power generators for electricity supply (Energy Commission of Nigeria [ECN], 2009). This was due to the fact that the Power Holding Company of Nigeria (PHCN) solely responsible for generation and supply of electricity to the public have not fared well in the discharge of its mandate (Stanley *et al.,* 2010).

Study by Stanley *et al.* (2010) showed that small household generators in Nigeria operate an average of six (6) hours daily, while average distance of generator away from building was 5.6m. These alongside poor ventilation (Okafor, Hassan, and Hassan, 2008) have influenced the quality of indoor air and noise level in the households.

The study therefore assessed the impact of fossil fuel electric power generator on the building indoor environment of some selected households in Kaduna metropolis.

Methodology

The study area was Kaduna metropolis located on a flat altitude of about 600m above sea level along the Kaduna River in the North Central region of Nigeria with tropical wet and dry climate (Beddow, 2010). The city is made up of high, medium and low-income settlements with a population of 1,570,331 (FRN 2009). It is made up of four (4) local government areas; Chikun, Igabi, Kaduna North and Kaduna South. Regarded as the "power house and nerve centre" of government and the northern political class in Nigeria, Kaduna is one of the industrialized cities in the country with notable industrial layouts (Kakuri, Barnawa and Zaria road/Mando) (Obioha, 2009). It is also the centre of knowledge with lots of public, private and military institutions sited strategically within the metropolis. It hosts diverse cultural and ethnic groups in Nigeria which makes the metropolis a typical setting of Nigerian cities.

This study assesses the impacts of fossil fuel electric power generator in indoor environment of residential buildings in Kaduna metropolis. The types of the building studied were residential made of sandcrete blocks. Air pollutant concentrations in the building indoor were measured in seventy two (72) households operating fossil fuel electric power generator grouped into twelve (12) clusters (Kawo, Mando, Bakin Ruwa, Gwanin Gora, Kurmin Mashi, Tudun Wada, Barnawa, Gabasawa, Narayi, Sabon Tasha, Malali and Kabala Doki). Cluster sampling technique was adopted in the study due to acceptance of the respondents to give access to their indoors and generators. A random of 6 households who operate electric power generators were selected from each cluster which sum up to 72 households. In each household the measurement of air pollutant concentration were carried out as described below.

The indoor air pollutants measured were CO, SO_2 and NOx. A state of the art combustible gas analyzer (IMR 1400) shown in Fig. 1 was used to assess the indoor air pollutant concentrations in the indoor of the generator operators. The sampling probe of the analyzer was held at a height of 1m in the living room of the generator operators for two (2) minutes after 180 seconds calibration of the analyzer. The average volume of the respondents' living room studied was $40.32m^3$. The concentration of pollutants present were recorded in part per million (ppm) as displayed on the analyzer. Six (6) households were assessed in each cluster and six (6) measurements were also carried out for each of the household surveyed. Three (3) measurements were before operating the generator, while the remaining three (3) during operation. A total of four hundred and thirty two (432) measurements were conducted.

Figure 1: The IMR 1400 Combustion Gas Analyzer

The initial values measured by the IMR 1400 Combustion Gas Analyzer before the operation of the generator were subtracted from the final values. These were done to exclude the background concentration of the pollutants. The mean of the results obtained were compared with standards (limits) provided by Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO).

Sample t-test and correlate analyses were carried out with the aid of SPSS version 15 to test the significance level of the generators profile and pollution levels at 95% confidence interval to ascertain similarities in operation of the generators in the metropolis.

Results and Discussion

Significance Levels of Generator Operation

The significance levels of generator operation in the study area were assessed to ascertained the characteristics of the variables measured (whether the same or different). The results are presented in Tables 1 to 3.

Table 1: Significance Levels of Generator Operation

S/N	Cluster	N	Generator Profile and Pollutant Concentrations at 95% CI					
			Age	Capacity	Distance from Indoor	CO	SO_2	NOx
1.	Kawo	6	0.01	0.11	0.00	0.22	0.00	0.36
2.	Mando	6	0.01	0.07	0.00	0.21	0.36	0.29
3.	Kurmin Mashi	6	0.00	0.00	0.04	0.36	0.24	0.36
4.	Malali	6	0.01	0.01	0.00	0.17	0.00	0.00
5.	Bakin Ruwa	6	0.00	0.07	0.01	0.17	0.08	0.36
6.	Tudun Wada	6	0.00	0.01	0.00	0.36	0.36	0.19
7.	Gabasawa	6	0.00	0.01	0.00	0.21	0.00	0.00
8.	Kabala Doki	6	0.01	0.00	0.00	0.18	0.00	0.00
9.	Narayi	6	0.01	0.01	0.00	0.36	0.00	0.00
10.	Barnawa	6	0.02	0.01	0.00	0.21	0.36	0.36
11.	Sabon Tasha	6	0.02	0.00	0.08	0.12	0.00	0.00
12.	Gwanin Gora	6	0.01	0.10	0.01	0.18	0.00	0.00

Table 2: Generators' Profile

S/N	Variables	Mean	SD	N
1	Generator Age (years)	3.74	2.48	72
2	Capacity (KVA)	2.34	2.40	72
3	Generator Distance from Indoor (m)	3.86	2.64	72

SD: Standard Deviation, N: Number

Table 3: Generator Smoke Control Measures Adopted

S/N	Variables	Frequency (No)	Percentage (%)
1	Close all openings	39	36.4
2	Stop use of generator	4	3.7
3	Locate generator as far as possible from occupancy	70	65.4
4	No action taken	8	7.5
5	Sandcrete block as construction material	72	100

It can be observed that the characteristics of variable for generator age (at 0.05 significance level) at all the clusters are similar with average age of 3.74 years. However in few clusters (Kawo, Mando, Bakin Ruwa and Gwanin Gora), the characteristics of the variable for the generator capacities are different (average of 2.34KVA) with p-values of 0.11, 0.07, 0.07 and 0.10 respectively.

It was also observed that virtually all the generator distances (kept at distances of < 5m, 5m to 10m, 10m to 15m and >15m with average distance of 3.86m) away from the indoor are the same except for Sabon Tasha with $p = 0.08$. For the indoor air pollutants, the characteristics of CO concentration for all the clusters are the same with $p > 0.05$. However, the variables for SO_2 concentration measured are not all the same. The clusters with the variances included Mando, Kurmin Mashi, Bakin Ruwa and Barnawa with p-values of 0.36, 0.24, 0.08, 0.36, 0.36 and 0.36 respectively.

Also, half of the clusters have the concentration of NOx $p > 0.05$. These clusters included Kawo, Mando, Kurmin Mashi, Bakin Ruwa, Tudun Wada and Barnawa with p-values of 0.36, 0.29, 0.36, 0.08, 0.36 and 0.36 respectively. It is therefore evident that the characteristics of the variables from generator operation in the study area (all clusters) can be said to be the same. These enable the study to sum up the clusters as an entity for Kaduna metropolis.

Gaseous Pollutants Concentrations

Sample T-Test and Correlation were used to compare means and test the relationships between gaseous pollutants emitted by generators with related variables as shown in Tables 4 and 5.

Table 4: Mean Indoor Gaseous Pollutants from Generators

S/N	Pollutant	N	Concentrations (ppm)				
			Mean	SD	95% CI		WHO & FEPA Limit
					Lower	Upper	
1	CO Indoor Concentration	72	6.18	14.84	2.70	9.67	10
2	SO_2 Indoor Concentration	72	0.17	0.81	-0.03	0.36	0.01
3	NOx Indoor Concentration	72	0.14	0.50	0.02	0.26	0.04 to 0.06

From Table 4, the indoor CO concentration (with mean 6.18ppm and 95% CI upper limit of 9.67ppm) is less than the WHO limit (10ppm). The average SO_2 indoor concentration was found to be 0.17ppm which is higher than the WHO limit of 0.01ppm. Also, the NOx indoor concentration (with mean 0.14ppm and 95% CI upper limit of 0.26ppm) is higher than the WHO limit (0.04 to 0.06ppm) but was lower (0.02) at the lower limit. It is evident that the indoor CO pollutant concentration in the households was within the WHO and FEPA limits. However, SO_2 and NOx fall below the WHO and FEPA limits.

Table 5: Correlation of Indoor Gaseous Pollutants with Generator Age, Capacity and Distance

S/N	Pollutant	Correlation Values at 0.05 Significant Level		
		Generator Age (year)	Capacity (KVA)	Generator Distance from Indoor (m)
1	CO Indoor Concentration	0.91	0.49	0.05
2	SO_2 Indoor Concentration	0.76	0.82	0.39
3	NOx Indoor Concentration	0.44	0.83	0.16
	N	72	72	72

From Table 5, the indoor CO concentration (at 0.05 significant level) has no significant relationship with the generator age and capacity. It is however, observed that CO have significant relationship with the distance of the generator kept away from the indoor environment ($p<0.05$). This implies that the generator distance (average 3.86m) away from the building contributes to the concentration of CO pollution in the indoor environment. Also, SO_2 and NOx have no significant relationship with the age, capacity and distance ($p>0.05$). It is evident that the indoor pollutants in the building indoor environment are independent of the generator parameters. The relationship between the air pollutants and the generator parameters (age, capacity and distance) showed no statistical significance, except for CO concentration and distance of generator from the indoor environment.

The concentration of the pollutants from the above tables were obvious especially SO_2 and NOx. Mean value of CO were within the normal range. However, SO_2 and NOx were observed to be above the recommended limits of WHO and FEPA which can cause health problems to the building occupants. The health effects of exposure to NOx within limits of 150 – 200ppm results in bronchiolitis, a dangerous disease which occurs within 3 – 5 weeks after exposure (Dimari et al., 2007). NOx is also known to deplete the ozone layer. In César *et al.* (2015), exposure to nitrogen oxides (NOx) emitted by burning fossil fuels has been associated with respiratory diseases. SO_2 is believed to be responsible for impaired visibility, damage of vegetation and materials, harm to human health and production of acid rain (Rao, 2007). The threat could be aggravated by absence of good cross ventilation which is characterized by most Nigerian households (Okafor *et al.,* 2008). Poor ventilation retains the pollutants indoor for long periods and the duration in which the generator is operated is also a contributory factor. The presence of the pollutants in the indoor are also attributed to dispersion and wind effect as observed by Abdulkareem and Kovo (2006) and Ndoke and Jimoh (2005).

Conclusion

Electric power generators in Kaduna metropolis have similar characteristics in age, capacity and distance away from the building indoor environment. The indoor SO_2 and NOx mean concentrations were higher than the FEPA limits (0.01ppm and 0.04 to 0.06ppm respectively). The study established that most of the pollutants in the building indoor have no significant relationship with the generator age and capacity. It was also established that the generator distance from the building indoor influences the CO emission in the building indoors. It is recommended that studies on the adequate distance for generator away from the indoor environment should be carried out to establish the generator safe distance.

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