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Analysis ofAge and Multiple Generator Sets Operation on Exhaust Gas Emissions

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ABSTRACT
This study analysed the effects of generator set age and multiple generator sets running at the same in a specified area on the emission of carbon monoxide (CO), nitrogen oxide (NO_2), sulphur dioxide (SO_2) and volatile organic carbon (VOC).Both generators running on gasoline and diesel were analysed. The gas emissions were analysed from generators with ages of 2, 5, 10 and 15 years, while the investigation on effect of multiple generators was analysed on 2, 3, and 5 generators operating at the time. The results showed that the concentrations of CO, NO_2, SO_2 and VOC emitted from gasoline and diesel generators increased with generator age and the number of generators running at the time in a specified area. Gasoline generators emitted lesser concentration of the gases compared to diesel generators. The concentrations of CO, NO_2 and SO_2 analysed across the generators with different ages are generally below the maximum permissible limit for 1 hour time weighted average specified by NESREA, whilethe combined concentrations of gases emitted from 2 – 5 generators separated by few distances were above the maximum permissible limit for 1hr time weighted average. However, the concentrations of gases released from older generators, particularly from 10 – 15 years old were slightly above the permissible limits. Therefore, it is recommended that proper maintenance and adequate spacing of generator sets are observed to control the emission of exhaust gases into environment.

KEYWORDS: Environment, Sustainability, Hazardous, Businesses, Concentration, Electricity

I. INTRODUCTION

Nigeria is one the countries that is faced with the challenges of power supply. This has led to self-help by her citizens to provide electricity for their businesses and homes. Gasoline and diesel fuelled-generators are mostly major sources of power for electricity and energy generation in Nigeria for small-scaled businesses. Gasoline and diesel are fossil fuels refined from petroleum hydrocarbons.

While the use of generator sets has helped in solving individuals and organizational energy challenges, particularly in the sustenance of small and medium scaled businesses in Nigeria, their usage has equally caused serious environmental and health concerns. The fossil fuel used in the running of these electricity generators releases hazardous gases, volatile organic compounds and other components from the exhaust during combustion. This is a concern for environmental sustainability. Fossil fuels increase the rate of gas emission that lead to climate change (Bagewadi et al., 2017). An earlier study by Giwa et al. (2016) linked some health issues to continuous usage of generator sets. They also found that noise and exhaust gases released during continuous operation of generator sets after 1 hour were higher than maximum recommended values.

Generator age and operation of multiple generator sets in a specified area or point can lead to emission of excessive concentration of gases in the atmosphere. According to Giwa et al. (2019), the amount of carbon monoxide released from gasoline generator exhaust was vividly high in aging generator sets. Also, when two or more generators are operated at the same time with close distance apart, the gases released combined to increase the concentration level in the air per time, which can spread easily to adjoining homes and business premises. This scenario can cause some degree of health concerns when inhaled. Robert and Dibia (2022) reported excess concentrations of various gases and particulate matters in air around business premises located in a University Campus in Rivers State due to effect of operating multiple generator sets in a specified area.

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Therefore, in this study, the influence of generator set age and numbers of generator sets running at the same in a specified area on the emission of carbon monoxide (CO), nitrogen oxide (NO_2) and sulphur dioxide (SO_2) was investigated for both gasoline and diesel generators.

II. MATERIALS AND METHODS

Experiments were conducted on several generator sets at various homes, commercial business centres and industrial areas in Port Harcourt, Rivers State of Nigeria.

The experiments for evaluation of generators' age on the level of gases released from the exhaust were conducted at an average distance of 5m away from the generator and1m above the ground. The ages of the generator sets were recorded before setting up the instrument for measurement of the exhaust gases. This analysis was randomly conducted in private homes for gasoline generator sets, while fordiesel generator sets were also randomly selected in both commercial business centres and companies operating diesel generator engines. The ages of generators investigated are 2, 5, 10 and 15 years.

The experiments for evaluation of the effect of operating more than one gasoline generator sets at the same time in specified area on the level of gases released from the exhaust were conducted at variouscommercial business centres in Port Harcourt, Rivers State. On the other hand, the evaluation on the level of gases released from two or more diesel generator sets was conducted at Trans-Amadi industrial area in Port Harcourt, Rivers State. The distances apart for the generator sets running on gasoline ranged from 0.5 m - 5 m apart, while the generators running on diesel were separated by average distances of 10 – 20 m apart.

The gases analysed include carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and volatile organic carbon (VOC). The instrument used for the measurement is an industrial gas analyzer called IBIRID MX6 industrial scientific meter.The instrument was set-up and allowed to record the concentrations of the gases for 1 hour before recording the displayed concentration values of the gases on the digital display screen of the instrument.

III. RESULTS AND DISCUSSION

3.1 Effect of Generator Age on Exhaust Gases Emission

The composition of hazardous gases emitted from small-scale generator exhaust into in ambient air due to aging of generator ispresented Table 2. Thepermissible limits established by the National Environmental Standard and Regulation Enforcement Agency (NESREA, 2021) for analysed gases arepresented in Table 1.

Table 1: Nigeria's National Environmental (air quality control) Regulations

Pollutants	**Time Weighted Average**	**NESREA, (2021) Standard (mg/m^3)**
Carbon monoxide (CO)	8 hours	5.00
	I hour	10.00
Nitrogen dioxide (NO_2)	24 hours	0.12
	1 hour	0.20
Sulphur dioxide (SO_2)	24 hours	0.20
	1 hour	0.35

Table 2: Measured concentration of exhaustgases of generator sets with different ages

	CO (mg/m^3)		**NO_2 (mg/m^3)**		**SO_2 (mg/m^3)**		**VOC (mg/m^3)**	
Age (Years)	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
2	2.64	4.13	0.05	0.09	0.04	0.12	0.15	0.24
5	4.98	6.34	0.13	0.16	0.17	0.25	0.27	0.36
10	6.56	8.42	0.17	0.22	0.21	0.28	0.33	0.41
15	9.81	11.07	0.24	0.31	0.29	0.37	0.42	0.47

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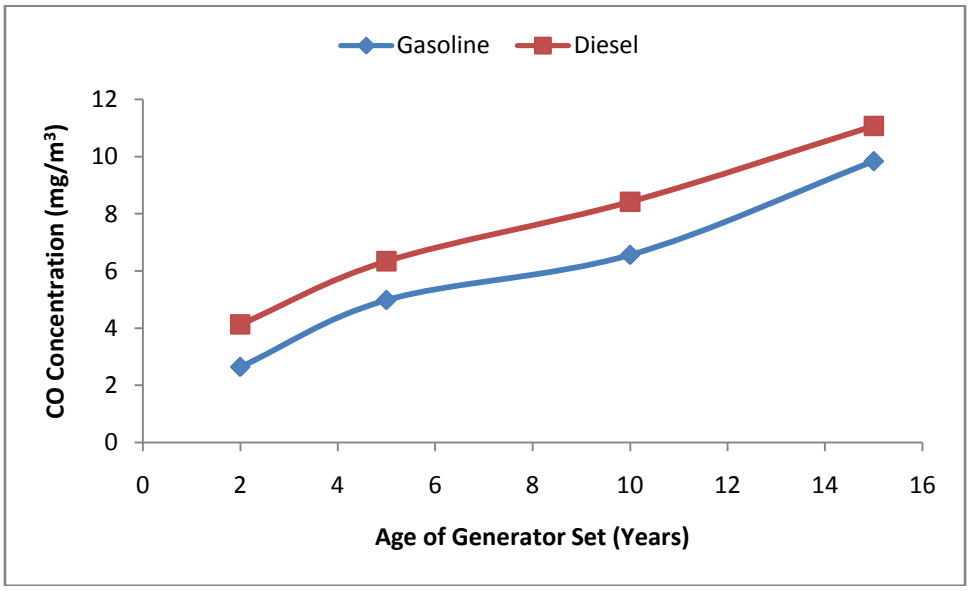

Fig 1: CO emission from different ages of gasoline and diesel generator sets

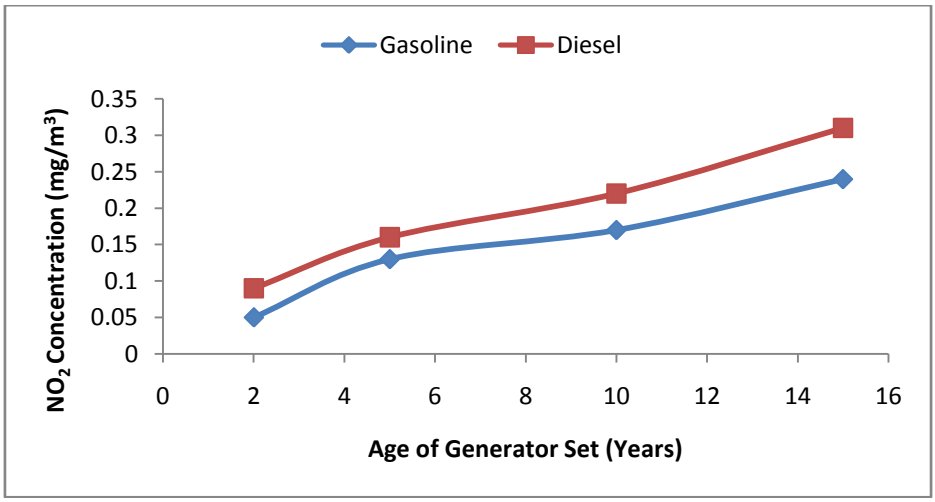

Fig 2: NO_2emission from different ages of gasoline and diesel generator sets

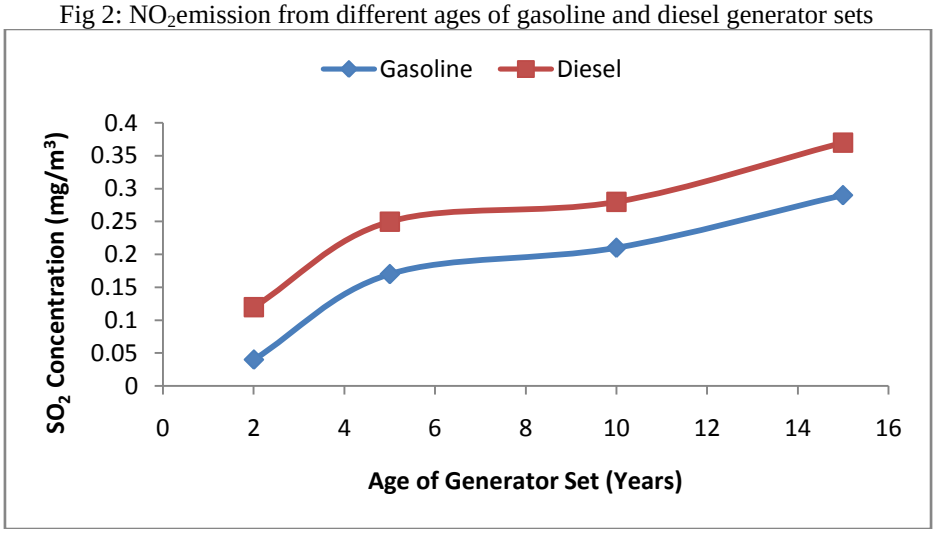

Fig 3: SO_2emission from different ages of gasoline and diesel generator sets

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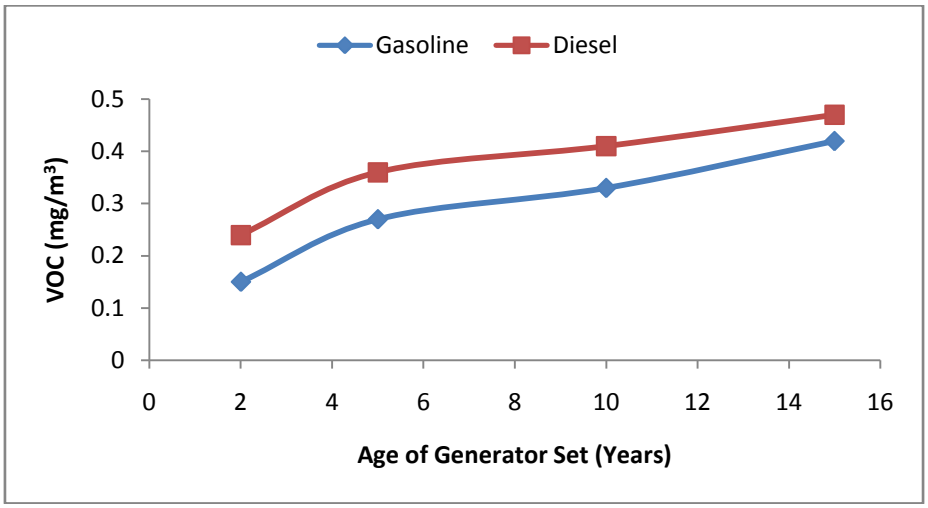

Fig 4: VOC emission from different ages of gasoline and diesel generator sets

Figure 1 shows the trends of CO concentration emitted from different ages of generator exhaust running on gasoline and diesel. The results indicate that CO emission increased with the age of the generators. Thus, as shown in Table 2, a 2-year oldgasoline generator emitted 2.64 mg/m^3 of CO after 1 hour of operation, while a 15-year old gasoline generator emitted 9.81 mg/m^3 of CO at same 1 hour of operation. Similarly, a 2-year olddiesel generator emitted 4.13 mg/m^3 of CO after 1 hour of operation, while a 15-year old diesel generator emitted 11.07 mg/m^3 of CO after 1 hour of operation.

Similarly, Figure 2 shows the trends of NO_2 concentration emitted from different ages of generator exhaust running on gasoline and diesel. Again, the concentration of NO_2 emitted from the generator exhaust increased with generators' age. The 2-year oldgasoline and diesel generators emitted 0.05 mg/m^{3}and 0.09 mg/m^{3}of NO_2respectively after 1 hour, while the 15-year old gasoline and diesel generators emitted 0.24 mg/m^{3}and 0.31 mg/m^3 forthe same time interval.

Figure 3 shows the trends of SO_2 concentration emitted from gasoline and diesel generator exhaust. The analysis showed that SO_2 emission from the generator exhaust increased with age of the generator sets. The 2-year oldgasoline and diesel generators emitted 0.15 mg/m^3 and 0.24 mg/m^3 of VOC respectively after 1 hour, while the 15-year old gasoline and diesel generators emitted 0.42 mg/m^3 and 0.47 mg/m^{3}VOC respectively after 1 hour.

Finally, Figure 4 shows the trends of VOC emitted from gasoline and diesel generator exhaust. The concentration of VOC emitted from the generator exhaust also increased with age of the generators. Thus, the 2-year oldgasoline and diesel generators emitted 0.04 mg/m^3 and 0.12 mg/m^3 of SO_2 respectively after 1 hour, while the 15-year old gasoline and diesel generators emitted 0.29 mg/m^3 and 0.37 mg/m^3 SO_2 respectively after 1 hour.

Comparatively, the gasoline generators emitted lesser concentration of thegases than the diesel generators. Nevertheless, the aging of generator, whether gasoline or diesel generator, significantly influence the concentration of gaseous emission from the exhaust. In addition, the results revealed that the concentrations of COand SO_2 analysed across the different generator ages are below the maximum permissible limit for 1 hour time weighted average, established by NESREA (2021) except for the 15 years old diesel generator. On the other hand, NO_2concentrations were slightly above the permissible limit for gasoline generator with 15 years old and the diesel generator with over 10 – 15 years old.

3.2 Cumulative Effect of Multiple Generators on Exhaust Gases Emission

The composition of exhaust gases analysed at a point surrounded bygenerator setsrunning on gasoline and diesel after 1 hour is shown in Table 3.

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Table 3: Concentration of gases in the atmosphere due to effect of multiple generator sets

	CO (mg/m^3)		NO_2 (mg/m^3)		SO_2 (mg/m^3)		VOC (mg/m^3)	
Gen. Set	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
1	9.84	11.07	0.24	0.31	0.29	0.37	0.42	0.47
2	12.07	12.94	0.27	0.33	0.28	0.39	0.44	0.5
3	13.83	15.46	0.31	0.38	0.35	0.43	0.47	0.52
5	16.05	18.38	0.36	0.41	0.37	0.44	0.53	0.58

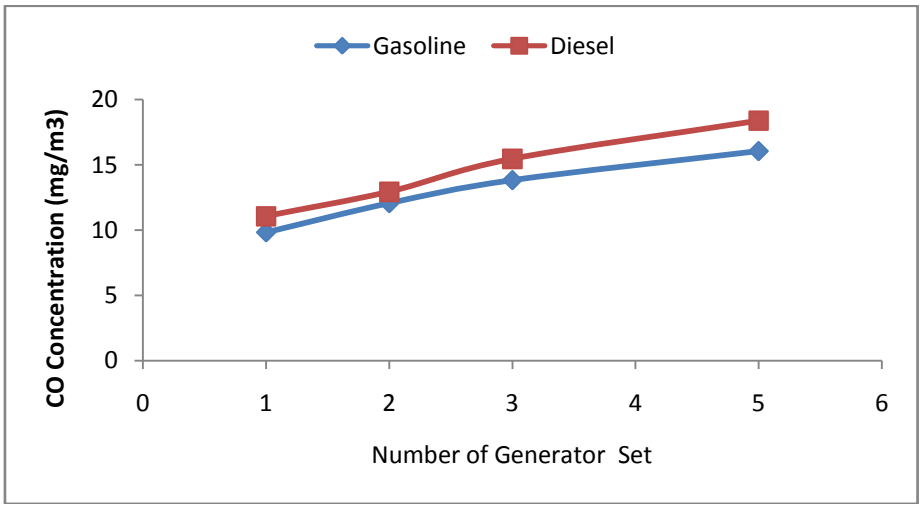

Fig 5: CO emission from different multiple generator exhausts

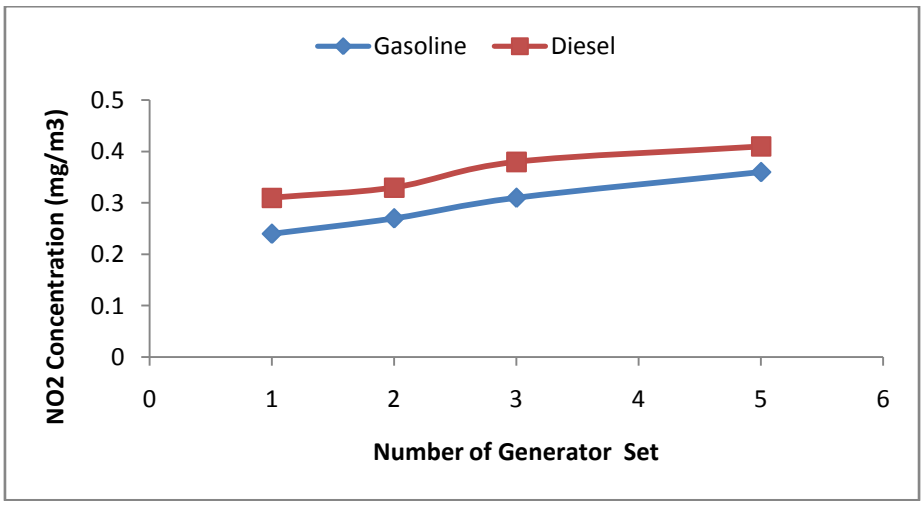

Fig 5: NO_2 emission from different multiple generator exhausts

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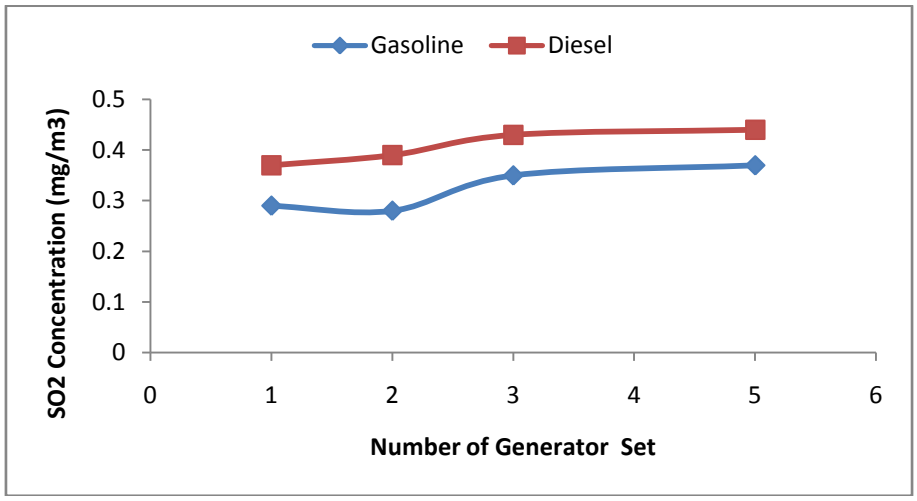

Fig 5: SO_2 emission from different multiple generator exhausts

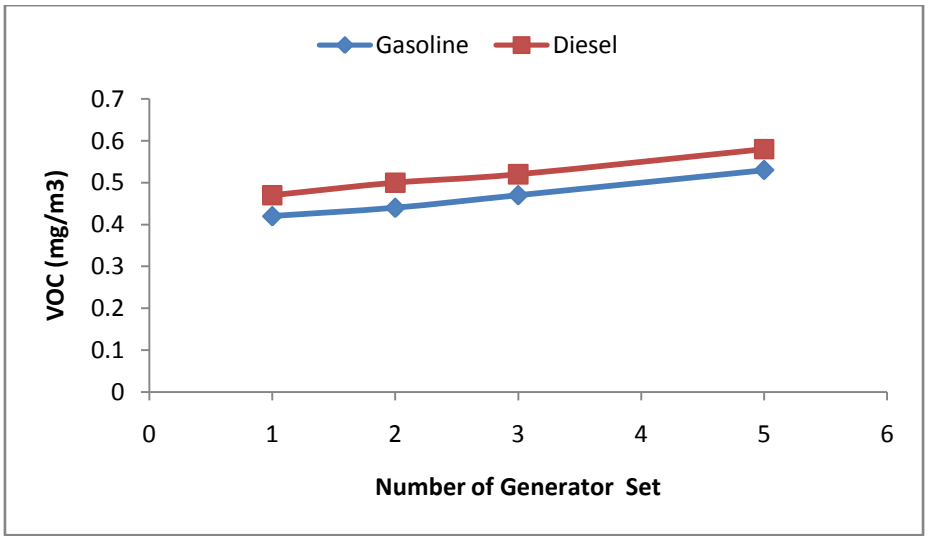

Fig 8: VOC emission from different multiple generator exhausts

Figure 5 shows the profiles of CO released from the exhaust of gasoline generatorsseparatedby 0.5m to 5m apart in commercial business centres and diesel generators separated by 10m – 20m apart in an industrial area in Port Harcourt, Rivers State. This analysis revealed the cumulative effect of two or more generators running at the same time on emission of hazardous gases into the atmosphere. Analysed results are displayed in Table 3.

The results show that the concentrations of CO, NO_2, SO_2 and VOC varied with the number of generators operating at the same time in specified distances apart. The concentration of CO, NO_2, SO_2 and VOC emitted from the exhausts of generator sets running at the same time increased with increase in number of generators. The combined concentrations of gases emitted from two to five generators separated by few distances were higher than the concentration of gases released from the exhaust of one generator. Even the 15 years old generators emitted less concentration of gases compared to the amount released by two or more generator sets separated by few distances. Again, the concentrationsof CO, NO_2, SO_2 and VOC released by generator running on gasoline arelower compared to generator running on diesel.

These results imply that diesel generators have the potential of emitting hazardous gases more than gasoline generators. The results also suggest that environments withvery old generators or multiple generators separated by few distances apart are susceptible to emission of higher concentrations ofCO, NO_2, SO_2 and VOC, thereby contributing to environmental pollution. These harmful gases can spread, even into buildings,

leading to health disorders such as cancer, respiratory infections, carbon monoxide poisoning, fatigue and low immune system. Therefore,it is recommended that proper maintenance and adequate spacing of generator sets are observed to control the emission of exhaust gases. Again, operators should be discouraged from using generator sets of age 10yrs and above for domestic applications and in commercial areas close to individuals or residential quarters.

IV. CONCLUSION

This study shows thatage of generator set and numbers of generator sets running at the same in a specified area influenced the emission rate of toxic gases such as carbon monoxide (CO), nitrogen oxide (NO_2), sulphur dioxide (SO_2) and volatile organic carbon (VOC) for generators running onboth gasoline and diesel. The concentrations of CO, NO_2, $SO_2$and VOC emitted from gasoline and dieselgeneratorsincreased with generator age, as well as the number of generators in a specified area.

Gasoline generators emitted lesser concentration of the gases compared to diesel generators. The concentrations of CO,$NO_2$and SO_2 analysed across the generatorswithdifferent ages are generally below the maximum permissible limit for 1 hour time weighted average specified byNESREA. However, the concentrations of gasesreleased from oldergenerators, particularly from 10 – 15 years old were slightly above the permissible limits.

In conclusion, very old generators or multiple generators separated by few distances apart that run at the same timehave the potentialsto pollute the environment. Therefore, it is recommended that proper maintenance and adequate spacing of generator sets are observed to control the effect of toxic gases on human beings and the environment.

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