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Comparative Analysis of Emissions from Diesel and Gasoline Powered Generators Within Bingham University Campus, Karu, Nasarawa State, North-Central, Nigeria

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ABSTRACT

This study presents a comparative analysis of emissions from diesel and gasoline-powered generators within Bingham University, Karu, Nasarawa State, with the aim of assessing their impact on air quality and potential health risks. Three generators of different ages comprising two diesel-powered and one gasoline-powered, each situated approximately 100 m apart were selected, and their gaseous and particulate emissions were measured in-situ using Altair 5X Multi-Gas Detector and AEROCET 531 combined Mass Profiler and Particle Counter. Key pollutants analyzed included carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), carbon dioxide (CO_2), and particulate matter (PM_1, $PM_{2.5}$, PM_7, and PM_{10}), each measured over a 30-minute duration. Results revealed that emissions from all generators exceeded recommended air quality guidelines in several cases. The gasoline-powered generator recorded significantly higher CO levels compared to the diesel-powered generators, surpassing the World Health Organization (WHO) limits on both days of observation. SO_2 and H_2S concentrations from all generators were consistently above safe thresholds, indicating serious environmental and health concerns. While $PM_{2.5}$ levels were generally within acceptable limits, PM_{10} levels from all generators were above recommended limits, suggesting a high risk of respiratory exposure. The findings highlight that generator emissions, particularly from gasoline-powered units, pose substantial risks to human health and the environment. Factors such as generator age (as observed with the older generators having higher concentrations in majority of cases), exhaust orientation, and atmospheric conditions influenced pollutant dispersion. We therefore conclude that reliance on fossil fuel generators contributes significantly to localized air pollution, and furthermore recommend centralized power systems, routine emission monitoring, increased public awareness, and a transition to cleaner energy sources such as solar power to mitigate adverse impacts.

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INTRODUCTION

Due to population growth and industrial developments in recent decades, the demand for energy has skyrocketed (Al Rashdi *et al.,* 2024). For more than 150 years, fossil fuels such as coal, crude oil, and natural gas have fueled economies and now provide approximately 80 percent of global energy. Relying primarily on fossil fuels for energy has led to environmental consequences, including air pollution, greenhouse gas emissions, and climate change (Al Rashdi *et al.,* 2024). Climate change is the long-term change in the average state of the atmosphere that is caused by human activity, either directly or indirectly, and that is observed across similar time periods in addition to natural climate variability (Houghton, 1990, Abbass *et al.,* 2022). Sometimes referred to as global warming, climate change is becoming more widely acknowledged as the biggest threat of the twenty-first century. This is because it has the potential to annihilate life on Earth either through persistent flooding or permanent drought (Onoja *et al.,* 2011). This is beside extreme weather conditions such as suffocating heat waves currently being experienced in some parts of the world.

Worldwide, Nigeria represents the biggest market for backup generators, making up 16 percent of global energy consumption from generators (Nduka, 2023). In Nigeria, fossil fuels are unavoidably employed as alternative energy sources to power generators because of the country's severely insufficient and epileptic energy supply. In actuality, it is projected that Nigeria's national power grid can only supply less than 10% of the country's electricity needs. To make up for this shortfall, the majority of commercial and industrial facilities rely significantly on fossil fuels for their generators (Anjorin *et al.,* 2020). Diesel is commonly used in heavy-duty engines (100 kVA and up) for commercial and technological reasons. Several dangerous contaminants have been discovered in the exhaust of fossil fuel-burning power plants, especially those that use diesel. Benzene, arsenic, and formaldehyde are among the carcinogenic substances released by diesel engines, along with nitrogen dioxide, carbon dioxide, and sometimes sulfur dioxide. The efficiency, type, fuel quality, engine temperature, and workload requirements of a generator engine determine the common byproducts of internal combustion, which include carbon dioxide, sulfur dioxide, nitrogen oxides, water vapor, oxygen, carbon monoxide, and unburned hydrocarbons (Oguntoke *et al.,* 2016). Additionally, many residences use generators, and due to their close proximity and extended operation, the pollutants from these machines pose greater risks to human health and the environment (Ogunkeyede *et al.,* 2025).

Considering the huge number of electricity generators in use by Nigerians with a disproportionately higher share in cities and institutions like Bingham University, it is pertinent to investigate the impact of emissions on air quality and human health. This study therefore carried out in-situ assessment of emissions directly from the exhaust of selected generators within the Bingham University campus to ascertain the aerosol present and their degree of contamination of the atmosphere.

MATERIALS AND METHODS

Materials

The materials employed in this research are: Altair 5X Multi-Gas Detector, The AEROCET 531, a global positioning system (GPS), two 500 kVA Mikano diesel powered generators and a 5.0 kVA petrol (gasoline) powered generator.

Plate 1: Altair 5X Multi-Gas Detector

Plate 2: AEROCET 531

Plate 3: GPS Device

Plate 4: 500 kVA Diesel Powered Mikano Generator (Relatively New)

Plate 5: 500 kVA Diesel Powered Mikano Generator (Relatively Old)

The Study Area

Bingham University is located along the Abuja-Keffi expressway in Karu Local Government Area, Nasarawa State, Nigeria. It sits at latitude 8.9565ºN and longitude 7.6997ºE, and covers a total landmass of 259 hectares. Seasonal streams surround the study area, which is drained by both surface and groundwater (Danjuma *et al.,* 2023).

Methods

Sample Collection

Three generators of different ages were used in this research. Generator 1 is a 500 kVA Mikano diesel powered generator, purchased about three years ago (2023), generator 2, a 500 kVA Mikano diesel powered generator has been in use for at least six years, while generator 3 is a 5 kVA gasoline powered generator which also has been in use for about five years.

With the ALTAIR 5X Multi-Gas Detector and the AEROCET 531 held at about 1.2 meters above the ground level, the Carbon II Oxide (CO) otherwise known as carbon monoxide, Carbon IV Oxide (CO_2) Hydrogen Sulfide (H_2S) and Sulphur IV Oxide (SO_2) emissions from the exhaust of each generator were detected and recorded in-situ using the ALTAIR 5X Multi-Gas Detector while particulate matter (PM) present in the emissions were recorded using the AEROCET 531 over a period of thirty minutes in each case. The PM detected were recorded as PM_1, $PM_{2.5}$, PM_7 and PM_{10}.

The geographical coordinates of these generators situated at an approximate distance of 100 m apart were also collected and recorded with the aid of a Global Positioning System (GPS). Generator 1 sits at a latitude of 8.958199ºN and longitude 7.701024ºE, generator 2 is positioned at 8.958011ºN and 7.698983ºE, while generator 3 is situated at 8.958197ºN and 7.701044ºE.

Calculations and Conversions

Conversions for chemicals or gases in air are typically made assuming a pressure of 1 atmosphere and a temperature of 25 degrees Celsius. The equation therefore required to convert from concentration in parts per million (ppm) to concentration in milligrams per cubic meter (mg/m^3) is thus expressed:

$$Conc.(mg/m^3) = 0.0409 \times conc.(ppm) \times molecular\ weight \left(\frac{g}{mol}\right) \quad (1)$$

where 0.0409 is the conversion factor (Boguski, 2006).

Air Quality Guidelines (AQGs)

Particulate matter (PM) also referred to as particle pollution is a term for a mixture of solid particles and liquid droplets found in the air having diameters less than 10 µm (WHO, 2024 & NAAQS, 2020). Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected with the aid of an electron microscope (WHO, 2024 & NAAQS, 2020). Particulate matter falls in this category of microscopic particles and contains microscopic solids or liquid droplets that are so small that they can cause serious health problems when inhaled. Some particles less than 10 micrometers in diameter can get deep into the lungs and some may even get into the bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or $PM_{2.5}$, pose the greatest risk to health (WHO, 2024).

Particulate matter ($PM_{2.5}$) can easily penetrate through the lungs (NAAQS, 2020) and further enter the body through the blood stream, affecting all major organs. Exposure to $PM_{2.5}$ can cause diseases both to our cardiovascular and respiratory system, provoking diseases or ailments like stroke, lung cancer, and chronic obstructive pulmonary disease (COPD) (WHO, 2024).

On this premise, the World Health Organization (WHO) air quality guidelines (AQGs) are intended for worldwide use. It has been developed to support actions to achieve air quality that protects public health in different contexts. The following are guidelines stipulated by the WHO for some air pollutants:

Table 1: World Health Organization (WHO) Air Quality Guidelines (AQGs) and Estimated Reference Levels (RLs)

Pollutant	Averaging period	AQG	RL	Comments
PM_{10}	1 day	45µg/m^3		99th percentile (3-4 exceedance days per year). Updated 2021 guideline
	Calendar year	15µg/m^3		Updated 2021 guideline
$PM_{2.5}$	1 day	15µg/m^3		99th percentile (3-4 exceedance 3days per year). Updated 2021 guideline
	Calendar year	5µg/m^3		Updated 2021 guideline
O_3	Maximum daily 8-hour mean	100µg/m^3		99th percentile (3-4 exceedance days per year). New 2021 guideline
	Peak season$^{(b)}$	60µg/m^3		New 2021 guideline
NO_2	1 hour	200µg/m^3		
	1 day	25µg/m^3		99th percentile (3-4 exceedance days per year). New 2021 guideline
	Calendar year	10µg/m^3		Updated 2021 guideline
BaP	Calendar year		0.12ng/m^3	
SO_2	10 minutes	500µg/m^3		
	1 day	40µg/m^3		99th percentile (3-4 exceedance days per year). New 2021 guideline
CO	1 hour	30mg/m^3		
	Maximum daily 8-hour mean	10mg/m^3		
	1 day	4mg/m^3		99th percentile (3-4 exceedance days per year). New 2021 guideline

(European Environment Agency, 2023)

RESULTS AND DISCUSSION

Results

The gaseous and particulate pollutants from various power generating sets within Bingham University Campus were observed using the ALTAIR 5X Multi-Gas Detector and AEROCET 531 Mass Profiler and Particle Counter. The gaseous emissions include Carbon (II) Oxide (CO), Carbon IV Oxide (CO_2), Hydrogen Sulfide (H_2S) and Sulphur (IV) Oxide, and their presence as well as their concentrations were observed in-situ in parts per million (ppm) using the ALTAIR 5X Multi-Gas Detector. The particulate matter (PM) in the emissions include PM_1, $PM_{2.5}$, PM_7, PM_{10}, Volatile Organic Compounds (VOCs) and Total Suspended Particles (TSP), and were ascertained in-situ in milligrams per cubic meter (mg/m^3) using the AEROCET 531 combined Mass Profiler and Particle Counter.

The details of these emissions from each point under consideration are presented in Tables 2, 3 and 4.

Table 2: Mean pollutants from Generator 1 for Days One and Two

Period	CO (mg/m^3)	SO_2 (mg/m^3)	H_2S (mg/m^3)	CO_2 (mg/m^3)	VOC (mg/m^3)	PM_1 (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_7 (mg/m^3)	PM_{10} (mg/m^3)
Day 1	20.6138	1.309	1.669	3419.24	0.14	0.00475	0.00975	0.0283	0.03375
Day 2	3.2064	1.623	0.000	3987.914	0.138	0.00540	0.0092	0.0202	0.0244
Mean	11.9401	1.466	0.835	3703.577	0.139	0.00508	0.00948	0.0242	0.0291

Table 3: Mean Pollutants from Generator 2 for Days One and Two

Period	CO (mg/m^3)	SO_2 (mg/m^3)	H_2S (mg/m^3)	CO_2 (mg/m^3)	VOC (mg/m^3)	PM_1 (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_7 (mg/m^3)	PM_{10} (mg/m^3)
Day 1	2.2904	2.7224	0.2782	6417.374	0.1667	0.004	0.00825	0.0445	0.058
Day 2	0.916	1.5708	0	5267.789	0.124	0.0054	0.0092	0.0202	0.0244
Mean	1.6032	2.1466	0.1391	5842.5815	0.1454	0.0047	0.00873	0.0324	0.0412

Table 4: Mean Pollutants from Generator 3 for Days One and Two

Period	CO (mg/m^3)	SO_2 (mg/m^3)	H_2S (mg/m^3)	CO_2 (mg/m^3)	VOC (mg/m^3)	PM_1 (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_7 (mg/m^3)	PM_{10} (mg/m^3)
Day 1	569.1642	2.8268	1.6968	6478.56	0.220	0.005	0.01125	0.069	0.0955
Day 2	672.069	1.720	0.397	5560.764	0.791	0.004	0.008	0.022	0.030
Mean	620.6166	2.2734	1.0469	6019.662	0.5055	0.0045	0.0096	0.0455	0.0628

Table 5: Independent Samples t-Test (Diesel vs. Gasoline)

Pollutant	Diesel(G1 + G2) Mean	Gasoline(G3) Mean	t-value	p-value	Decision
CO	11.27	620.62	11.61	<0.001	Significant
SO_2	1.81	2.27	1.86	0.071	Not significant
H_2S	0.49	1.05	2.32	0.027	Significant
CO_2	4773.08	6019.66	2.78	0.009	Significant
VOC	0.142	0.506	4.31	<0.001	Significant
PM_1	0.0049	0.0045	0.58	0.565	Not significant
$PM_{2.5}$	0.0091	0.0096	0.36	0.720	Not significant
PM_7	0.0283	0.0455	2.44	0.021	Significant
PM_{10}	0.0352	0.0628	3.18	0.003	Significant
TSP	0.0486	0.0993	3.69	0.001	Significant

An independent-samples t-test was conducted to compare emissions from diesel-powered (Generators 1 and 2) and gasoline-powered (Generator 3) generators. The analysis revealed that fuel type significantly influenced the emissions of several pollutants.

The gasoline-powered generator produced significantly higher concentrations of CO, H_2S, CO_2, VOC, PM_7, PM_{10} and TSP than the diesel-powered generators with a p-value less than 0.05 ($p < 0.05$). However, SO_2, PM_1 and $PM_{2.5}$ did not differ significantly between the two fuel types ($p > 0.05$). The largest difference was observed for carbon monoxide (CO), where gasoline generators emitted substantially higher concentrations than diesel generators ($t = 11.61$, $p < 0.001$).

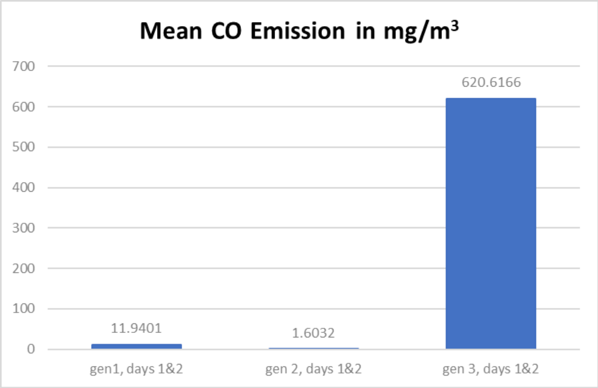

Figure 1: Mean Observed CO Emission

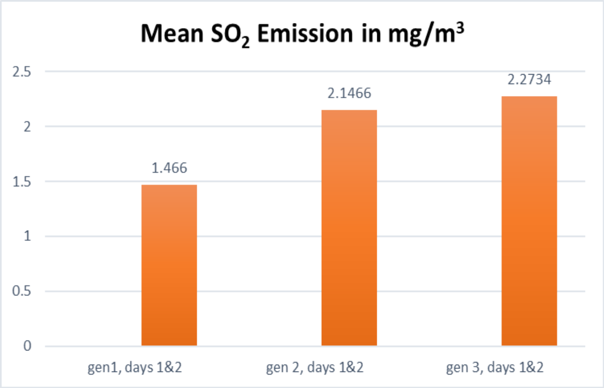

Figure 2: Mean Observed SO_2 Emission

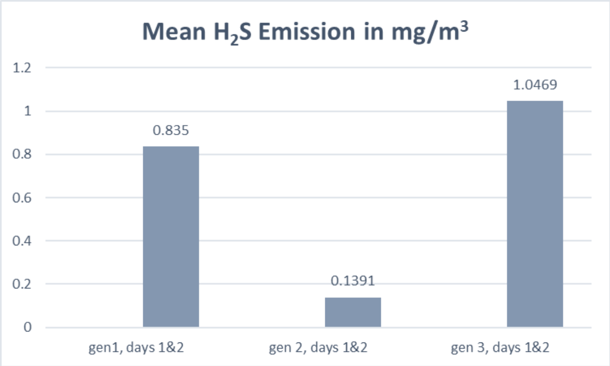

Figure 3: Mean Observed H_2S Emission

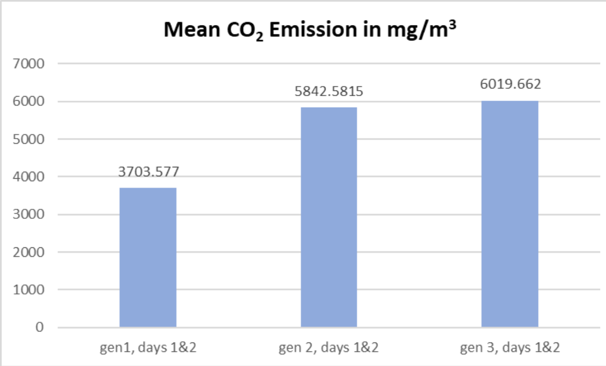

Figure 4: Mean Observed CO_2 Emission

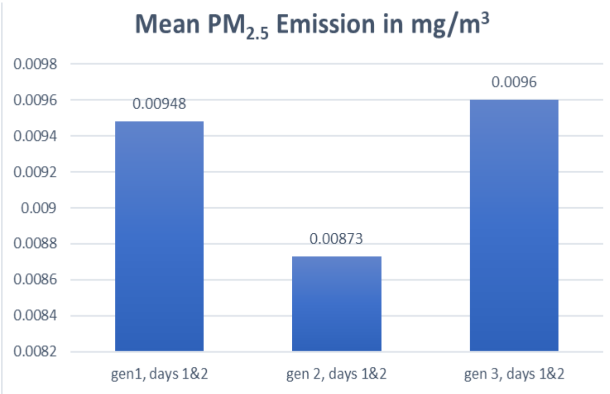

Figure 5: Mean Observed $PM_{2.5}$ Emission

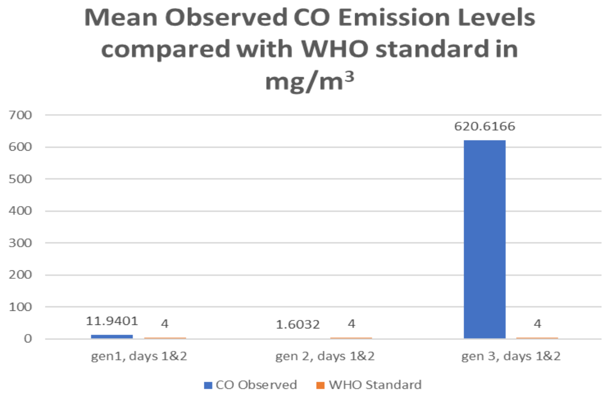

Figure 6: Mean Observed CO Emission Levels and WHO Standard

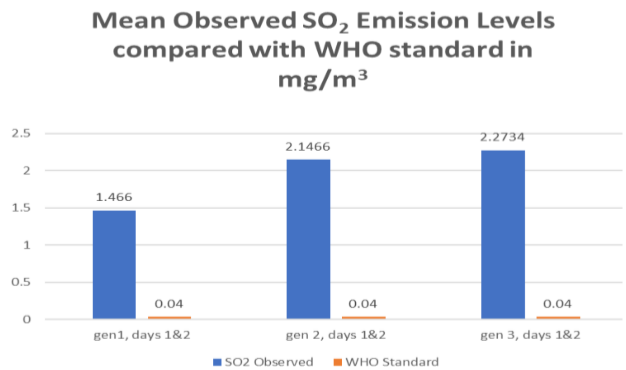

Figure 7: Mean Observed SO_2 Emission Levels and WHO Standard

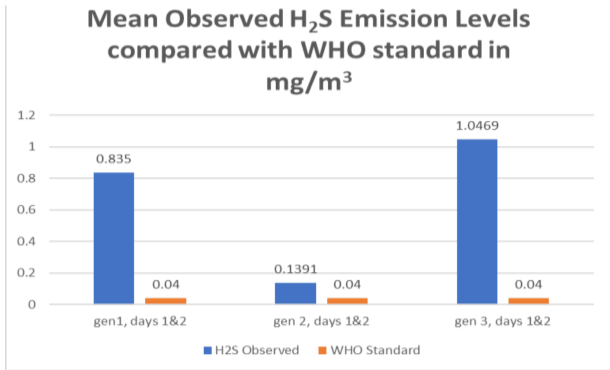

Figure 8: Mean Observed H_2S Emission Levels and WHO Standard

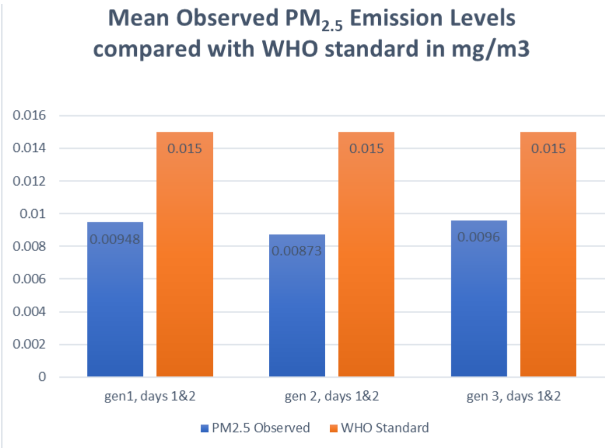

Figure 9: Mean Observed $PM_{2.5}$ Emission Levels and WHO Standard

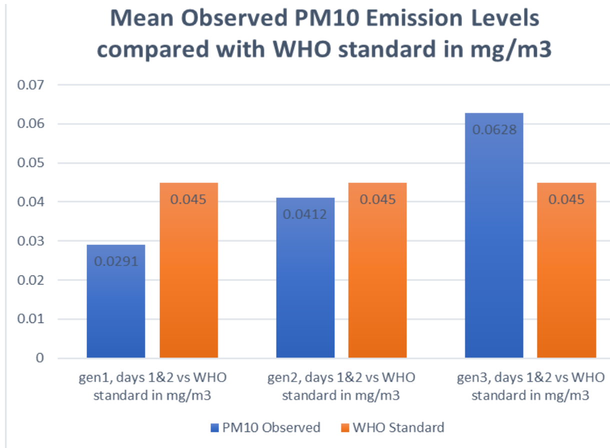

Figure 10: Mean Observed PM_{10} Emission Levels and WHO Standard

Discussion

The mean CO, SO_2, H_2S, CO_2, and PM concentrations in the atmosphere, within the microenvironments of the diesel and gasoline powered generators in Bingham University have been presented in Tables 2, 3 and 4.

The carbon monoxide (CO) emission from the diesel-powered generators was observed to be relatively low as opposed to that of the gasoline powered generator which was observed to be significantly higher. The stoichiometric air-fuel combination for gasoline is roughly 14.7 to 1, meaning that 14.7 grams of air are needed for every gram of fuel, but the ratio for petrol is roughly 14.5 to 1. Speight (2011) states that the air fuel mixture of diesel is a lean mixture while that of gasoline is a rich mixture. In addition, the use of compression ignition technology in diesel engines as opposed to spark ignition technology in gasoline engines, which allows for full fuel burning, may be the reason for the lower CO emissions. However, from a public health standpoint, diesel engines typically emit greater levels of particulates (such $PM_{2.5}$ and PM_{10}) (Ismaila *et al.,* 2013). Research has shown that CO has the potential to cause brain damage, decreased fetal weight and increased number of infant deaths (Gantina *et al.,* 2024).

The emissions from all generators under study were observed to be significantly above the WHO air quality guideline of 0.04 mg per unit volume of air for SO_2. This gas, sulfur dioxide (SO_2) is a colorless, soluble gas that is created by volcanoes and other industrial activities. It is a precursor to atmospheric particles. Volcanic eruptions account for 67% of its natural source, while burning fossil fuels is an anthropogenic source. Human health can also be impacted by SO_2 in ambient air, especially in people with asthma and other long-term lung conditions. In sensitive people, SO_2 aggravates respiratory symptoms and breathing difficulties. It impairs vision as well. When particle and other pollution concentrations are high, it is deemed more dangerous. Acid rain and aesthetic harm are further effects of SO_2 (NAAQS, 2020).

The emissions from the three generators as seen in Figure 8 showed elevated levels of H_2S; levels significantly higher than the WHO AQGs. High concentrations of H_2S is known to have the potential to induce unconsciousness, low blood pressure, slow breathing, and cramping in the muscles. An extended exposure to hydrogen sulfide will irritate breathing passages and may result in pulmonary edema (fluid buildup in the lungs). Short-term exposure to moderate concentrations of hydrogen sulfide (between 1 and 10 ppm) will cause eye, nose, and throat irritation, nausea, dizziness, breathing problems, headaches, loss of appetite, and problems sleeping (Anjorin *et al.,* 2020).

While $PM_{2.5}$ levels in the atmosphere as observed with the three generators were found to be within safe limits as they showed no emission above the recommended threshold level, PM_{10} deposits in the atmosphere from the diesel powered generators showed levels lower than the WHO AQGs on both days, except for the gasoline powered generator which recorded pollutant levels exceeding permissible thresholds. PM_{10}, after inhalation, can lodge in the bronchi and lungs and cause health problems such as respiratory illness, visual impairment, and can aggravate existing heart and lung disorders (NAAQS, 2020).

The variations in the levels of these pollutants in the atmosphere could be attributed to factors like age, where the concentration of the pollutants increase as the generator gets older (Jinyemiema *et al.,* 2025), the orientation of the exhaust of the generator, the height above the ground, the ambient temperature or wind speed. Although meteorological variables like the ambient temperature, humidity and wind speed were not measured, we infer based on other scientific assertions and day to day experiences that where the atmosphere is windy, dispersal is inevitable and could lead to decreased level of particulate matter in the atmosphere. Also, in terms of the height of the exhaust, it is easier for the pollutants to be diffused at higher altitudes than when they are closer to the ground where they would have enough room and time to hover around at the detriment of both flora and fauna within the area. For the diesel-powered generators, the heights of their exhausts were measured to be approximately 2.6 meters above the ground and are also oriented such that they point upwards as seen in Plates 4 and 5. This position provides that the fumes are emitted high into the air and are easily dispersed and diffused by air, which could account for the low pollution levels observed in comparison with that of the gasoline-powered generator. Humidity also contributes to the high concentrations because the moisture in the atmosphere inhibits air circulation, which means that pollutants and other harmful particles are trapped in the air close to the ground thereby preventing them from circulating or from being easily diffused into the atmosphere.

CONCLUSION

The CO levels for all the selected generators happened to be at levels higher than the recommended AQGs except for generator 2 with CO emission at 1.6032 mg/m^3 as against the recommended level of 4 mg/m^3. Similarly, SO_2 was observed at very high levels as seen in figure 7, significantly higher than the WHO recommended level. H_2S was observed also to show significant levels that exceeded the WHO AQG, implying that human and environmental health within these regions are negatively impacted. $PM_{2.5}$ emission was observed to fall below the recommended level while PM_{10} recorded emission levels exceeding safety recommendations for the gasoline powered generator, with the diesel powered generators falling below safe limits.

Based on the findings as recorded and analyzed, there are clear indications that the emissions from these fossil fuel powered generators are significantly higher than the recommended levels which are actually stated for the preservation of the environment as well as the safety of human lives. These emissions, if not controlled would lead to long or short term ailments that may culminate in cancer as in the case of particulate matter that finds its way into the blood stream after inhalation. Nigeria happens to be a place where proper records, guidelines and sensitizations are not kept and adhered to. Due to the erratic power supply in Nigeria, many households and businesses operate on diesel or gasoline powered generators. Though these generators may be small units which may likely pose no threat, their collective emissions can trigger great concerns which usually is the case as a result of the large clusters of these generators in a small enclosure where there can be easy build-up of toxic and harmful air pollutants due to insufficient oxygen-rich air to diffuse or neutralize the emissions.

RECOMMENDATIONS

i. In the absence of the national power supply, the power generation system to the entire Bingham University community can be centralized to reduce the degree of aerosol pollution of the atmosphere which would be the case when all businesses on campus are left with no alternative than to power on their generators for power supply.
ii. A sensitization should be organized to create awareness among the members of the University community on the dangers of exposure to emissions from fossil powered generators, and exposures of the operators should be monitored
iii. Periodic monitoring of the exhaust fumes from these generators for contaminants especially those close to their end-of-life cycle.
iv. The university should reduce its carbon footprint by replacing generators with solar PV systems which provides cleaner and renewable energy.

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