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RESEARCH ARTICLE OPEN ACCESS

Determination of Carbon Dioxide (CO_2) Emissions from Perkins P220-3 AGO-Based Generating Plant in Variable Temperature and Relative Humidity

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Abstract:

The main aim of this research is for the determination of Carbon-dioxide (CO_2) concentration level emitted from PERKINS P220-3 AGO-based generating plant using Series 500 Portable Air Quality Monitor with varying temperature and relative humidity. The generating plant services the facilities in the Faculty of Engineering, Federal University Otuoke (FUO), Bayelsa State. The air sampling was done for a consecutive period of twenty-one working days in the month of July, 2023. This was to ascertain the health risk that could possibly emanate from the emissions of CO_2 into the environment on the safety of personnel exposed daily to those facilities. The results were compared to "The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)" and "Occupational Safety and Health Administration (OSHA)" as <1,000 ppm limit or no severe health effect. The results showed that CO_2 have total average concentration of 898.23 ppm, total average temperature at 29.7ºC and total average relative humidity at 85.81%. The overall average results showed that the CO_2 concentration emissions level were below the WHO ambient allowable limits of not more than 1000 ppm in 8 hours average.

Keywords — **Environment, CO2 concentration, Emissions Level, AGO-Based, Sampling and Monitoring, Generating Plants, Facilities, Faculty of Engineering, Temperature, Relative Humidity, Air Quality**

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I. INTRODUCTION

The necessity for an efficient, clean and environmentally friendly condition of an improved ambient air quality (AAQ) can never be over emphasized, owing to various methods of wasteful discharges that generate from human activities that pollute the environment, which produces particulate matter and greenhouse gases that causes global climate change (Pachauri et al., 2007, IPCC, 2013). These particulate matter and gases in excess are poisonous to human health. Some of their sources are from human nonferrous activities such as gas flaring (Etienne Romsom and Kathryn McPhail 2021), part of transportation sector (Farooq et al., (2021), wood fire (Sakwe Adianimovie and Gbeinzi Ebinimi, 2023) and others which includes electricity power generation especially on gas turbines (Olugboji and Adepoju in 2018) as gas-base fuel, power plants (Smith et al,. 2018) as well as from diesel fuel commonly called automotive gas oil (AGO). However, the effect of carbon-dioxide (CO2) emissions is from various fuel blends of AGO-based (Hossain et al., 2020).

Gaseous pollutants thrive better with respect to humidity and temperature, as all living things survive effectively in the presence of humidity in air (Peter, 2005). Naturally, pollutant concentrations depend on the temperature and humidity of the environment, this is because relative humidity contributes to the absorption of moisture during storage of materials. Similarly, relative humidity also contributes to the regulation of the body temperature in ensuring good perspiration, it is the

total amount of water vapor present in a given volume of air at the same temperature which also relates to the emissions of CO2 in AGO-based generating plant.

AGO-based fuel employed in running power plants is on main source of carbon-dioxide (CO_2) emissions worldwide. The use of automotive gas oil (AGO) from fossil fuel-based power plants results in substantial emissions of CO_2, which are part of the contributing factors in global warming (Bilichi, 2018). An accurate determination of the amount of CO_2 emitted per unit of energy generated from these plants help to quantify the environmental impact and identify areas for improvement which can give a precise and economically viable result (Feng et al., 2019), and data-driven methodology (Zhang et al., 2019). Though, estimated CO_2 emissions from AGO-based power plants could significantly differ in different locations (Nizamuddin et al., 2020), yet there is need to increase energy efficiency and lower CO_2 emissions especially in developing nations (Yara et al., 2019), in improving air quality (Ede P.N. and Edokpa, D.O. 2015). This actually shows that high amount of CO_2 emissions is also a result of the producing facilities based on automotive gas oil AGO (Bilici, 2018). Understanding the CO_2 emissions from these power plants, which primarily burn AGO-based fuel, is very essential for efficient environmental management and energy efficiency (Smith 2021, IEA, 2016).

AGO-based fuel plants emits significant amounts of carbon-dioxide as used daily in various industries, factories, real estates, businesses and most tertiary institutions in Nigeria including the Engineering faculty of the Federal University, Otuoke, Bayelsa State. Therefore, this study focused on the PERKINS P220-3 AGO-based power plant at the Faculty of Engineering, Federal University Otuoke, where measurements and estimation of CO_2 emissions with respect to temperature and relative humidity variation was done and results compared to the outdoor CO_2 emissions with (ASHRAE)" and (OSHA)" as < 1,000 ppm limit or no severe health effect as well as WHO CO_2 allowable limits of not more than 1000 ppm in 8 hours average (WHO, 2021).

II. MATERIALS AND METHODS

A. Study Area Description

This research took place in the main/administrative premises of the Faculty of Engineering, Federal University Otuoke, West Campus. The Federal University, Otuoke, is a Nigeria Federal Government-owned University, located in Otuoke in Ogbia Local Government Area of Bayelsa State, Southern Nigeria in the Niger Delta Region as presented in Figure 1. The institution is located about 27 kilometers south of Yenagoa, the Bayelsa State Capital, which is 100 kilometers West of Port Harcourt, Rivers State. The faculty and area in view consists of three major block buildings of one story each vis-à-vis Block A, Block B and Block C and a mini lecture theatre building adjacent to Blocks B and C but directly opposite Block A. These blocks consist of the Dean's office, the central Engineering Conference room, and the Head of Department (HOD) offices for the five departments (Chemical, Civic, Electrical, Mechanical/Mechatronics and Petroleum Engineering), Staff offices, faculty's Library, the National Union of Engineering Student Association (NUESA) office, Laboratories and classrooms. The sampling and monitoring was carried out from Monday through Friday between the hours of 8:00 a.m. and 4:00 p.m. daily for a total of 7 hours per day.

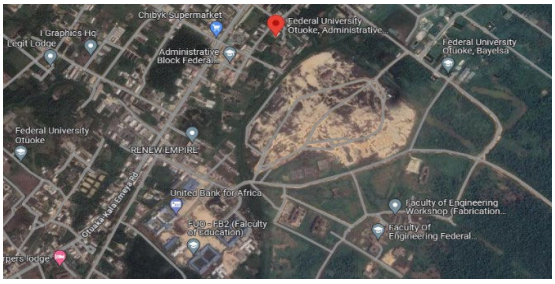

Figure 1: Sampling Location: Source (Ogunlowo O.O and Sakwe, A 2023)

B. Sampling Equipment

The main equipment used for the sampling was the Series 500 Portable Air Quality Monitor. With its special sensor head structure, the series 500 portable air quality monitor allows air quality suitable with interchangeable sensor heads that can measure up to 16 distinct pollutants appropriate for usage on a variety of applications, such as short-term fixed monitoring, personal exposure monitoring, and wide-area air quality surveys. It samples particulate matter ($PM_{2.5}$, PM_{10}, PM_1, TSP), and gaseous pollutants such as CO, CO_2, NO_2, VOC, O_3, SO_2, H_2S etc.

C. PERKINS P220-3 AGO-Based Generating Plant

Table 1: Major parameters of the Perkins P220-3 AGO-Based Generating Plant

S/No	Parameters	Specifications
1	Model	9011
2	Prime Power (kW)	160.0
3	Standby Power (kW)	176.0
4	Standby Power (kVA)	220
5	Noise	@ 7mt
6	Run Time	11 hours @ 75% load
7	Warranty	1 year
8	Dry Weight (KG)	1708
9	Phase	3
10	Fuel Type	Diesel

D. Automotive Gas Oil (AGO)/ Diesel

The diesel which was used for the running of the power plant throughout the sampling period was received from the direct distribution outlet of the Nigeria National Petroleum Cooperation (NNPC) Bayelsa State and must have met the standard requirement quality assurance product specification by the NNPC/DPR (Department of Petroleum Resources) as presented in Table 2

Table 2: NNPC/DPR standard requirement quality assurance product specification

S/No	Parameters	Units
1	Density:	8.45-8.60 g/ml
2	Viscosity (at 40°C):	4.5-4.6
3	Flash Point:	74-800C
4	Octane Number:	47-52
5	Sulphur Content:	0.0516
6	Water Content:	Nil
7	Colour:	Pale Yellow
8	Appearance:	Clear and Bright

Source: (ENX Energy and Chemicals Nig. Ltd, 2023).

E. Relative Humidity and Temperature

The measurement of relative humidity and temperature was done by taking the daily average recordings directly gotten from the results of the Bayelsa State daily weather forecast (Yenagoa, Bayelsa, Nigeria Weather 2023).

F. Methods

The Series 500 Portable Air Quality Monitor was placed on the top of the PERKINS P220-3 Generating Power Plant, closed to the exhaust/waste outlet attached with the CO2 sensor placed one meter (100 cm) away from the discharge pipe. The readings were recorded by the portable air quality monitor at 30 minutes interval for 7 hours daily for a period of 21 working days. This continues monitoring and measurement took place from 9:00 am to 4:00 pm for five days in a week (Monday to Friday) throughout the month of July, 2023. The power plant was allowed to run for a minimum of 45 minutes to enable stability at its maximum load before monitoring was done.

III. RESULTS AND DISCUSSION

The monitoring was done for 7 hours per day from 9:00 am to 4:00 pm in 30 minutes interval. Readings were taken and the average results were calculated as presented in Table 3.0 below. The computed results were compare with the ASHRAE and OSHA daily outdoor CO_2 emissions standard guidelines to ascertain the safety conditions and health risk of those daily exposed to the facilities of the Faculty of Engineering, Federal University Otuoke.

Figure 2 shows the pattern of daily carbon-dioxide release from the AGO-based power generating machine, while Figure 3 shows the daily percentage concentration of CO_2 emission respectively.

The results of the 21 days monitoring indicated that CO_2 concentration was highest on the 3rd and 16th days at 1015 ppm and 1002 ppm respectively, which occurred on the 5th and 24th of July, 2023. The temperature and relative humidity for the 3rd day were 27°C and 95.60 %, while that of the 16th day were 27°C and 94.80% respectively.

These were the only two days that the results exceeded the ASHRAE and OSHA as < 1,000 ppm limit or no severe health effect. The lowest readings of CO_2 concentration was 770 ppm and 773 ppm at temperatures of 36°C and 31°C with relative humidity of 75.90 % and 82.20 % respectively. This occurred at day 10 and day 5 been the 14th and 7th of July, 2023.

However, 19 days results showed that CO_2 concentration was below the ASHRAE and OSHA recommended limits of < 1,000 ppm limit or no severe health effect. Percentage wise, it was discovered that 90.5 % of the samples were below the recommended limits, while 9.5 % of samples were above the ASHRAE and OSHA limits.

Similarly, Figure 3 showed that 16 days out of the 21 days sampling and monitoring indicated 5 % of CO_2 emission while 5 days had 4 % equal distributions, though there were clear daily variations in figures on CO_2 concentration level as shown in Table 3 and Figure 3 respectively.

Table 3: Daily Average reading of CO2 at Varying Temperature and Relative Humidity at Constant Time Intervals

No. of Days	Dates (July, 2023)	CO_2 (Ppm)	Temp (°C)	Relative Humidity (%)	Time (Hrs)
1	3	950	30	85.30	7
2	4	988	29	83.60	7
3	5	1015	27	95.60	7
4	6	908	30	85.80	7
5	7	773	31	82.20	7
6	10	880	30	84.90	7
7	11	870	30	85.05	7
8	12	890	29	87.60	7
9	13	900	29	88.90	7
10	14	770	36	75.90	7
11	17	986	30	84.10	7
12	18	997	30	83.70	7
13	19	775	30	84.60	7
14	20	787	29	89.98	7
15	21	968	30	85.86	7
16	24	1002	27	94.80	7
17	25	898	30	85.00	7
18	26	907	29	85.85	7
19	27	909	29	82.90	7
20	18	800	29	85.20	7
21	21	890	30	85.08	7
Total Average		898.23	29.7	85.06	7

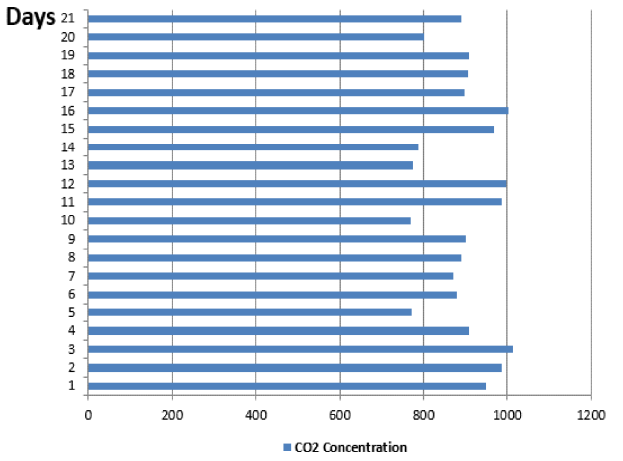

Figure 2: Daily Concentration of CO_2 Emissions

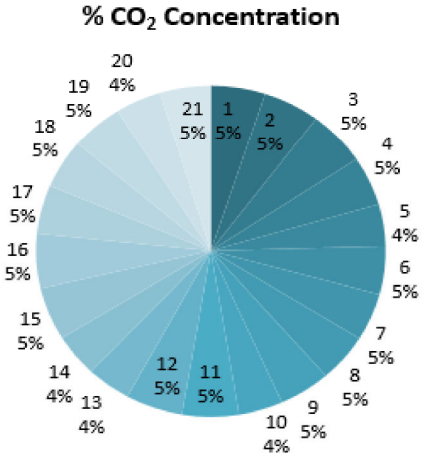

Figure 3: Daily Percentage Concentration of CO_2 Emissions

Four (4) days showed the lowest CO_2 concentration level during the sampling period which ranged between 770 ppm to 800 ppm at relatively high temperatures but low relative humidity Table 3. Furthermore, from all indications the results of the sampling showed that CO_2 concentrations vary with respect to temperature and relative humidity. That is, at higher temperature, relative humidity was low as well as CO_2 concentrations. While at lower temperature, CO_2 concentration was high as well as relative humidity (Table 3 and Figure 3).

On the overall average, CO_2 concentration level recorded was 898.23 ppm, temperature at 29.7ºC and relative humidity at 85.81%. The overall average results showed that the PERKINS P220-3 AGO-based generating plant released CO_2 that was below the ASHRAE and OSHA limits of < 1,000 ppm limit or no severe health effect, indicating that personal exposure to the environment under investigation was safe and free from any health risk on the bases of CO_2 emission. However, other metrological parameters were not taken into consideration during the 21 days sampling and motoring period using the Series 500 Portable Air Quality Monitor.

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IV. CONCLUSION

Efficient, liveable, sustainable, and environmentally friendly conditions of an improved ambient air quality (AAQ) is of serious concern. No doubts, humans are adversely contributing to the poor air quality in the environment and has really become an overbearing issue. These activities are from different sources such as bush burning, gas flaring, and the use of power generating plants etc. which have increased the release of greenhouse gases including Carbon dioxide (CO_2). The release of Carbon-dioxide into the atmosphere has led to several issues including climate change and global warming. In this study, CO_2 was sampled and monitored in the month of July, 2023 for 21 working days consecutively using the Series 500 Portable Air Quality Monitor in the facilities of the Faculty of Engineering, Federal University, Otuoke powered by PERKINS P220-3 AGO-based generating plant. The sampling was done with varying temperatures and relative humidity, though other metrological parameters were not under consideration. The investigation showed that personal exposure to the facilities are safe and free from Carbon-dioxide based health risks. This was because 90.5 % of CO_2 emissions were below the ASHRAE and OSHA limits of < 1,000 ppm limit or no severe health effect,

as compared to the 9.5% that was above the standards.

While the results in this study indicated low release of Carbon-dioxide into the atmosphere, other air pollutants like $PM_{2.5}$, PM_{10}, PM_1, TSP, and gaseous pollutants such as CO, NO_2, VOC, O_3, SO_2, H_2S etc which are also constituents of AGO-based fuel, were not analyzed. Therefore, to be certain of the overall safety of those who accesses the facility, it is recommended that further studies should be carried out to expand the scope on the power plant.

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