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Spatial Assessment of Atmospheric Pollutants Load in a Palm Oil Processing Plant in Ubima, Ikwere Local Government Area, Rivers State, Nigeria

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Abstract

This study examined the spatial variations in atmospheric pollutant loads around a palm oil processing facility in Ubima, in the Ikwere Local Government Area of Rivers State. Data for air quality parameters (O_3, CH_4, CO, CO_2, $PM_{2.5}$ and PM_{10}) were collected for a period of three months (January to March, 2024), using multi-gas detectors. Analysis of Variance (ANOVA) was used to test the hypothesis of the study. The study found that Ozone (O_3) concentration decreased from 1.56 mg/m^3 at 50 meters from the company, to 0.56 mg/m^3 at 200 m. The concentration of methane decreased from 1.33 mg/m^3 at 50 m away from the company to 0.95 mg/m^3 at 200 m. CO was 1.15 mg/m^3 at 50 m and 0.78 mg/m^3 at 200 m. Similarly, CO_2 at 50 m was 2.10 mg/m^3 and at 200 m it was 1.04 mg/m^3. The same pattern could be reported for $PM_{2.5}$ and PM_{10}, in which the concentration decreased from the source of pollution to 200 meters away from the company. ANOVA showed that there was a significant spatial difference in Ozone ($P < 0.05$; F = 208.968, sig = 0.00); methane ($P < 0.05$; F = 214.864, sig = 0.00); CO ($P < 0.05$; F = 200.262, sig = 0.00); CO_2 ($P < 0.05$, F = 225.875, sig = 0.00); $PM_{2.5}$ ($P < 0.05$, F = 150.443, sig = 0.00) and PM_{10} ($P < 0.05$; F = 146.012, sig = 0.00). The study concluded that, except for the concentration of CO, the concentration of air quality parameters like O_3, CO_2, $PM_{2.5}$ and PM_{10} were above the WHO standard which could portend possible health challenges for people living around the company. Moreover, the air quality parameters experienced a gradual reduction in concentration with distance from the major operating zone of the palm oil processing facility. It was recommended among others that there is an urgent need to prioritize the transition to the use of clean energy in the operations of the palm oil processing facility.

Keywords

Atmospheric-Pollution, Pollutant-Concentration, Health-Challenges, Pollution-Variation

1. Introduction

There is a growing recognition of the deteriorating quality of air in heavily industrialized regions in developed and developing countries due to attendant ecological and health consequences. Ozabor & Obisesan (2015); Oyebanji et al. (2021) contend that air pollution is a major contributor to environmental and health disorders globally, but developing countries are more vulnerable due to the poor investment in research to ascertain the extent of susceptibility in urban and rural communities. It is recognized in the literature (Ozabor & Obaro, 2016; Invally et al., 2017; Famous & Adekunle, 2020) that cardiovascular disorder, asthma, premature death and impaired lung capacity are some of the deleterious manifestations of prolonged and sustained air pollution in the world. In spite of the enormity of empirical evidence on the reality of air pollution in Nigeria, there is still a recurring gap in the literature on the appropriate methodology to separate different sources of air pollutants (Ozabor et al., 2024a; Abulude et al., 2024). This is due to the fact that the natural and anthropogenic activity that contributes to air quality deterioration are numerous. Manufacturing, transportation, agriculture, and waste have been noted as some of the major contributors to air pollution in the world (Ogoro et al., 2020; Oyebanji et al., 2023; Nwaogu et al., 2025).

The southern part of Asia is the home of India, Pakistan, Bangladesh and Nepal which represent four of the five most populated countries in the world; the World Air Quality Report in 2020 revealed that 37 out of 40 top most populated countries in the cities of the world are in this region (Abdul Jabbar et al., 2022; Ozabor et al., 2023; Iyama et al., 2024). However, the case of Africa has also evoked considerable research in the literature as increasing manufacturing, transportation and diverse agricultural mechanization have equally contributed enormously to the pollutant loads in the lower atmosphere (Ushurhe et al., 2024a; Ozabor et al., 2024b). Harizanova-Bartos & Stoyanova (2018) recognized the major environmental consequences of mechanized agriculture and agro-allied processing in Bulgaria. Some of the effects are excessive deforestation without proportionate reforestation programs which also manifest in livelihood destruction in the rural communities, fragmentation of natural habitat, and air pollution from the use of fertilizers and pesticides and continuous emission of harmful gases into the atmosphere (Godspower et al., 2023). According to Waltner-Toews & Lang (2000), the interplay between agricultural processing and the environment is bilateral, they premised this argument on the understanding that agricultural processing tends to alter the quality of air within the catchment of the processing site through the emission of harmful gases such as methane, ammonia, carbon dioxide, and carbon monoxide into the atmosphere. However, the processing of agricultural products is also vulnerable to pollution from other natural and anthropogenic influences (Khatri & Tyagi, 2015; Famous et al., 2023).

Guan et al., (2023) posit that the emission of methane, ammonia and carbon dioxide represent the highest level of pollutants from mechanized agriculture and agro processing. According to Wyer et al., (2022); Ozabor & Ajukwu (2023) stated that estimated agricultural activities accounted for 83% of ammonia emitted into the atmosphere in 2015, and the immediate flora, fauna and the health of the populace in the immediate environment where ammonia is emitted are highly vulnerable (Ushurhe et al., 2023). The decomposition of manure under anaerobic conditions results in CH_4 and NO_2 emissions that contribute to the global warming effect. However, despite the enormous empirical evidence on the implications of agro-allied companies and mechanized agriculture on air quality, less attention has been devoted to the ambient air quality in the rural communities (Eyetan & Ozabor, 2021). The preference to site oil palm processing and agro allied processing industries, and huge investment in mechanized farming in rural communities can be attributed to the presence of raw materials, large expanse of land and access to cheap labour, but operations of the investors in the rural areas have not prioritized environmental integrity and the welfare of the people in their day-to-day operations (Yu et al., 2022). In recent years, the qualities of water, soil and air in rural places have witnessed serious pollution, and with huge investment in oil and gas, agriculture and manufacturing, such pollution has worsened (Okumagba & Ozabor, 2016; Nwagbara et al., 2017). Previous works have not considered the air quality in the context of oil palm plantation neighbourhoods; or at least none have been done in the area where this study was carried out. Yet, humans live within this neighbourhood who might have been suffering from pollutants that emanate from the activities of palm production (Ushurhe et al., 2024b). Many studies have been conducted in the region on pollution, although they focused on oil and gas pollution (Raimi et al., 2022), vehicular pollution (Emenike & Orjinmo, 2017), and domestic pollution (Umunnakwe et al., 2018) to the neglect of pollutions from sources such as oil palm production. Thus, this study examined the spatial variations in atmospheric pollutant load in the palm oil processing zone, Ubima, in Ikwere Local Government Area, Rivers State, Nigeria.

2. Materials and Methods

The study was carried out in a Palm oil processing plant in Ubima, Ikwerre LGA, Rivers State, Nigeria. The study area is located between 5˚07" and 10˚8"N of the equator and Longitude 6˚54" and 09˚4"E of the Greenwich meridian (**Figure 1** and **Figure 2(a)**, **Figure 2(b)**). The study adopted the cross-sectional research design. Data for this study were acquired from the primary source. The primary data were obtained from direct field measurements, while previous studies in journal articles were used to support the literature. Ojeh & Ozabor (2013) described primary data as raw data or original data collected specifically for a specific purpose. The sampling and monitoring were conducted within 8 hours daily for three months. The means of the eight-hourly period data were found and used for the data analysis. Each sample was obtained at 50, 100 and 200 m (**Table 1**) away from the facility in the study area (Awoke & Muche, 2013; Weli & Famous, 2018; Chukwudi et al., 2025). The intention of this exercise is to evaluate the in-situ concentration of O_3, CH_4, CO, CO_2, and $PM_{2.5}$ and PM_{10}. Therefore, the E6000 Portable Multi-gas Detector (6 gases maximum) was used for air quality data gathering. E6000 is a multi-gas detector designed to measure up to 6 gases at a time. Its smart sensor modules can combine various gases and measure them at a sweep. The Aeroset Met one particulate counter was used to monitor the particulate matter $PM_{2.5}$ and PM_{10}. The data was collected for a period of three months, between January and March at the calibrated distance mentioned above. Data collected from the field was collated, treated and presented in tables to express information quantitatively. Descriptive statistics were computed to provide a quantitative analysis of the data presented in tables. ANOVA was used to test the hypothesis, which states "there is no significant spatial variation in the pollutants load in the atmosphere in the neighbourhood of palm oil processing in Ubima". The basic principle of ANOVA is to test for the differences among the means of the populations by examining the variances (Sawyer, 2009; Ushurhe et al., 2024c; Famous, 2024).

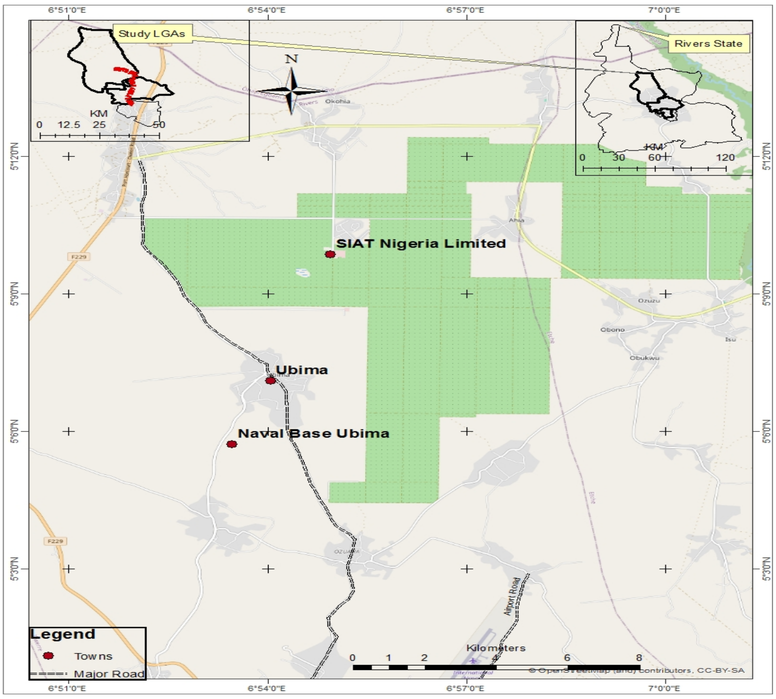
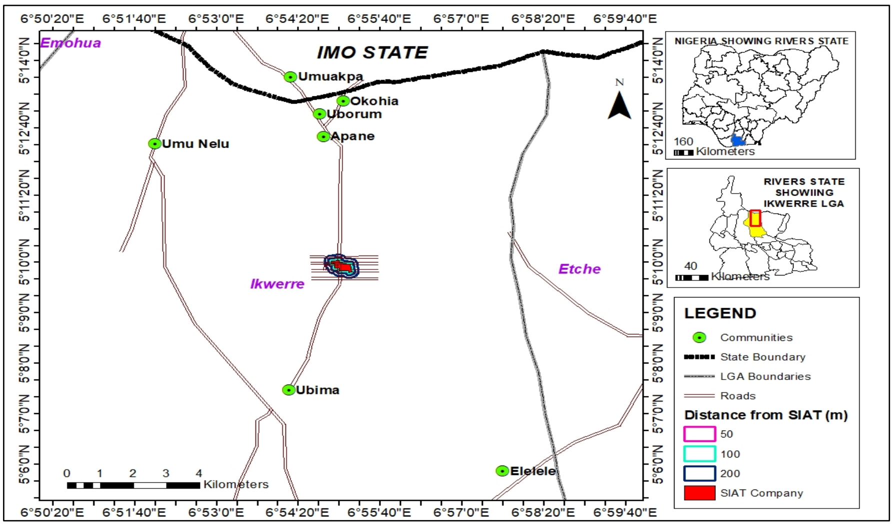
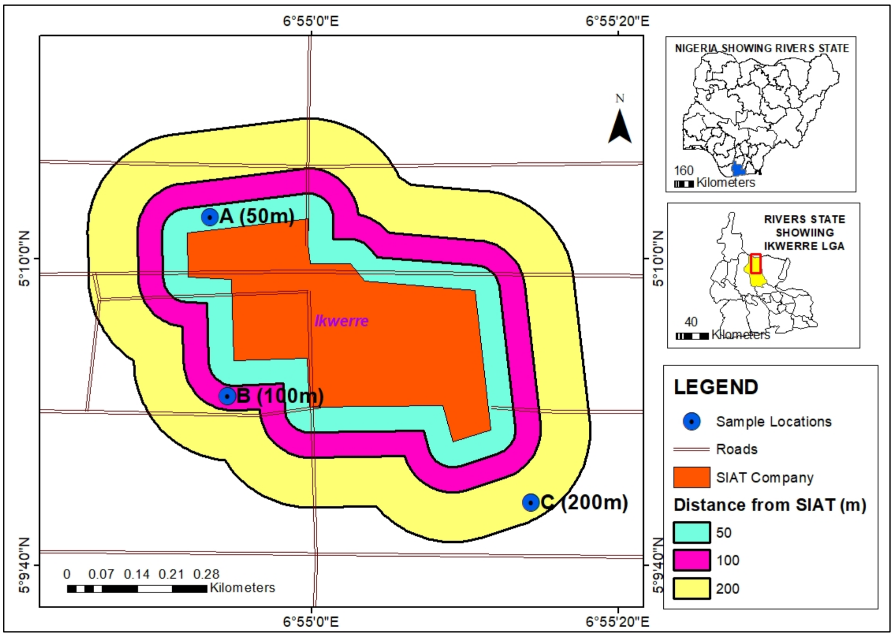


Figure 1. Showing study area, ubima. Source: Modified after Rivers State Ministry of Lands and Housing.



(a)



(b)

Figure 2. (a) Location of the study location; (b) Showing sample location.

Table 1. Geographical coordinates of the sample locations.

Distance (m)	Sample Locations	Longitudes	Latitudes
50	A	6.914822˚E	5.167421˚N
100	B	6.915137˚E	5.164173˚N
200	C	6.920641˚E	5.162248˚N

3. Results

The data presented in **Table 2** shows the spatial concentration of pollutant loads in the atmosphere within the neighbourhood of the palm oil processing facility. It is very evident that there is variation in the carbon footprint within the catchment of the palm oil processing plants at different intervals from the zone of operation and processing. The concentration and dispersion of Ozone (O_3) show concentrations of 1.56 mg/m^3, 1.03 mg/m^3 and 0.56 mg/m^3 at a distance of 50 m, 100 m and 200 m respectively. It is evident from the outcome of air sample analysis that the concentration of O_3 is higher than the permissible limit of the World Health Organization (WHO) which is 0.025 mg/m^3. The difference between the concentration of ozone and the background value permissible by WHO for human habitation and the safety of flora and fauna is more significant at 50 m from the zone of major activities of the company. The implication is that pollutant load decreases with distance away from the zone of oil palm processing which reinforces the argument that the activities of oil palm processing are a major contributor to the concentration of ozone in the study area. The case is also not different for methane that showed a gradual reduction in concentration with distance away from the zone of oil palm processing in the study area. The outcome of air samples collected showed that the concentration of methane at 50 m away from the zone of major processing is 1.33 mg/m^3, at 100 is 1.18 and 0.95 at 200 m.

Table 2. Average amount of gases measured in the study area at the calibrated distances.

Gas	50 m	51 - 100 m	101 - 200 m	WHO Standard (2021)
O_3	1.56	1.03	0.56	0.025 mg/m^3
CH_4	1.33	1.18	0.95	______
CO	1.15	1.01	0.78	4 mg/m^3
CO_2	2.10	1.63	1.04	0.015 mg/m^3
$PM_{2.5}$	1.46	1.28	1.11	0.005 mg/m^3
PM_{10}	2.25	2.18	1.83	0.015 mg/m^3

The data presented also show that the amount of carbon monoxide within the calibrated distance from the company is below the permissible limit of the world health organization. The data showed that at 50 m, the concentration of CO was 1.15, 1.01 at 100 m and 0.78 at 200 m. This connotes that the concentration of carbon monoxide does not portend very severe consequences for the residents within the calibrated distance from the major operating zone of the palm oil processing plant. The case is different in terms of the concentration of carbon dioxide which revealed that the amount of CO_2 in the environment exceeds the limits of the WHO in all the calibrated distance from the flare point. The outcome of air sample analysis shows that there is a gradual reduction in the concentration of CO_2 with distance from the major operating zone of palm oil processing plant. The permissible limit of the WHO for CO_2 is 0.005 mg/m^3, but at 50 m the concentration of CO_2 is 2.10, 1.68 at 100 m and 1.04 at 200 m. The implication is that palm oil processing plant contributes to the concentration of carbon dioxide in the study area. The case is also the same for $PM_{2.5}$ that showed a gradual decline in the concentration at different calibrated distances from the major operating zone of the palm oil processing facility. At the distance of 50 m, the concentration of $PM_{2.5}$ was 1.46, at the distance of 100 m, the concentration of $PM_{2.5}$ was 1.28, at the distance of 200, and the concentration of $PM_{2.5}$ was 1.11. In terms of the concentration of particulate matter (PM_{10}) (**Table 2**), the concentration of PM_{10} exceeds the permissible limits of the WHO in all the calibrated distance from the major operating zone of the oil palm processing facility. At a distance of 50 m from the processing zone, the amount of $PM_{2.5}$ was 2.25 mg/m^3, there was a slight reduction at the distance of 100 m with 1.28 mg/m^3 and 200 m with 1.83 mg/m^3. ANOVA (**Table 3**) showed that the mean difference for the concentration of ozone in the three zones (50 m, 50 - 100 m, 100 - 200 m) is significant at $P < 0.05$ level. F = 208.968, sig = 0.00. Since the significant value is 0.00 which is below 0.05 (*p* value), it indicates that there is a statistically significant difference in ozone pollution across the three calibrated distances from the operating zone of the Palm oil processing facility.

Table 3. Spatial variation in ozone pollution in the study area ANOVA.

Ozone					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	46.055	2	23.028	208.965	0.000
Within Groups	29.765	270	0.1102		
Total	75.8200	272			

Table 4. Duncan variation in ozone pollution in the study area ozone.

Duncan				
Identifiers	**N**	**Subset for Alpha = 0.05**		
		1	**2**	**3**
101 - 200 meters	91	0.5600		
51 - 100 meters	91		1.0300	
50 meters	91			1.5600
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a. Uses Harmonic Mean Sample Size = 91.000.

The Duncan variation analysis in **Table 4** shows that there is a significant difference between the first calibrated points of 50 m and 100 m. The case is also the same between 100 m and 200. The difference between the first point and the last point where air quality was analysed shows that there is a sharp decline in the concentration of ozone with distance from the zone of production. ANOVA shown in **Table 5** shows that the mean difference for the concentration of methane in the three zones (50 m, 50 - 100 m, 100 - 200 m) is significant at $P < 0.05$ level. F = 214.864, sig = 0.00. Since the significant value is 0.00 which is below 0.05 (p value), it indicates that there is a statistically significant difference in methane pollution across the three calibrated distances from the operating zone of the oil palm processing industry.

Table 5. Spatial variation in methane pollution in the study area (ANOVA).

Methane					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	50.751	2	25.3755	214.864	0.000
Within Groups	31.891	270	0.1181		
Total	82.642	272			

Table 6. (a) Duncan variation in methane pollution in the study area (Methane); (b) Duncan variation in carbon monoxide pollution in the study area.

(a)

Duncan				
Identifiers	**N**	**Subset for Alpha = 0.05**		
		1	**2**	**3**
101 - 200 meters	91	0.9500		
51 - 100 meters	91		1.1803	
50 meters	91			1.3301
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a. Uses Harmonic Mean Sample Size = 91.000.

(b)

Duncan				
Identifiers	**N**	**Subset for Alpha = 0.05**		
		1	**2**	**3**
101 - 200 meters	91	0.7800		
51 - 100 meters	91		1.0100	
50 meters	91			1.1502
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a. Uses Harmonic Mean Sample Size = 91.000.

Duncan analysis (Table 6) shows that the variation in the concentration of Carbon Monoxide between the first point at 50 m and the last point at 200 m is significant. The case is also the same between 100 m and 200 m. This connotes that distance is a critical factor in the dispersion and concentration of pollutants in the atmosphere.

ANOVA model in Table 7 showed the spatial variation concentration of carbon monoxide in the three zones (50 m, 50 - 100 m, 100 - 200 m) is significant at $P <$ 0.05 level. F = 200.262, sig = 0.00. Since the significant value is 0.00 which is below 0.05 (p value), it indicates that there is a statistically significant difference in carbon monoxide pollution across the three calibrated distances from the operating zone of the oil palm processing industry.

Table 7. Spatial variation in carbon monoxide pollution in the study area.

ANOVA					
Carbon Monoxides					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	31.321	2	15.6605	200.262	0.000
Within Groups	21.121	270	0.0782		
Total	52.442	272			

Duncan variation analysis in Table 7 shows that there is a remarkable difference between the first point at 50 m and the last point at 200 m in the concentration of carbon monoxide. ANOVA Table 8 showed that the mean difference for the concentration of carbon dioxide in the three zones (50 m, 50 - 100 m, 100 - 200 m) is significant at $P <$ 0.05 level. F = 225.875, sig = 0.00. Since the significant value is 0.00 which is below 0.05 (p value), it indicates that there is a statistically significant difference in carbon dioxide pollution across the three calibrated distances from the operating zone of the oil palm processing company.

Table 8. Spatial variation in CO_2 pollution in the study area (ANOVA).

CO_2					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	18.567	2	9.2835	225.875	0.000
Within Groups	11.123	270	0.0411		
Total	29.6900	272			

Table 9. Duncan variation in CO_2 pollution in the study area (CO_2).

Duncan				
Identifiers	**N**	**Subset for Alpha = 0.05**		
		1	**2**	**3**
101 - 200 meters	91	1.0401		
51 - 100 meters	91		1.6333	
50 meters	91			2.1011
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a. Uses Harmonic Mean Sample Size = 91.000.

The Duncan variation output (Table 9) shows that the difference in the concentration of carbon dioxide varies significantly between the first calibrated point of 50 m and 200 m. There is also a significant variation between the points of 50 m and 100 m. This connotes that distance is a critical factor in the dispersion and concentration of CO_2. ANOVA (Table 10) showed that the mean difference for the concentration of $PM_{2.5}$ in the three zones (50 m, 50 - 100 m, 100 - 200 m) is significant at $P < 0.05$ level. F = 150.443, sig = 0.00. Since the significant value is 0.00 which is below 0.05 (p value), it indicates that there is a statistically significant difference in $PM_{2.5}$ pollution across the three calibrated distances from the operating zone of the Palm processing facility. The Duncan variation output (Table 11) showed that the difference between the concentrations of $PM_{2.5}$ is more significant between 50 m and 100 m. Evidently, there is also a significant difference between the first calibrated point of 50 m and 200 m. This is a clear indication that the pollutant load decreases with distance from the major operating zone of the palm oil processing zone.

Table 10. Spatial variation in $PM_{2.5}$ pollution in the study area (ANOVA).

$PM_{2.5}$					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	19.347	2	9.6735	150.443	0.000
Within Groups	17.355	270	0.0643		
Total	36.702	272			

Table 11. Duncan variation in $PM_{2.5}$ pollution in the study area ($PM_{2.5}$).

Duncan				
Identifiers	**N**	**Subset for Alpha = 0.05**		
		1	**2**	**3**
101 - 200 meters	91	1.1112		
51 - 100 meters	91		1.2811	
50 meters	91			1.4601
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a. Uses Harmonic Mean Sample Size = 91.000.

ANOVA (Table 12) showed that the mean difference for the concentration of PM_{10} in the three zones (50 m, 50 - 100 m, 100 - 200 m) is significant at $P < 0.05$ level. F = 146.012, sig = 0.00. Since the significant value is 0.00 which is below 0.05 (p value), it indicates that there is a statistically significant difference in PM_{10} pollution across the three calibrated distances from the operating zone of the oil palm processing company.

Table 12. Spatial variation in PM_{10} pollution in the study area (ANOVA).

PM_{10}					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	16.441	2	8.2205	146.012	0.000
Within Groups	15.223	270	0.0563		
Total	31.664	272			

The Duncan variation output (Table 13) shows that the difference in the concentration of PM_{10} at 200 m from the major zone of operation is radically different from that of 50 m. The difference between the concentration of PM_{10} at 50 m and 100 m is not very significant. This connotes that the pollutant loads decrease with distance from the zone of production.

Table 13. Duncan variation in PM_{10} pollution in the study area (PM_{10}).

Duncan				
Identifiers	**N**	**Subset for Alpha = 0.05**		
		1	**2**	**3**
101 - 200 meters	91	1.8313		
51 - 100 meters	91		2.1834	
50 meters	91			2.2461
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a. Uses Harmonic Mean Sample Size = 91.000.

4. Discussion of Findings

The concentration of ozone (O_3) at different calibrated distances from the palm oil processing zone suggests severe environmental and health consequences for residents. The ozone pollution may be associated with nitrogen oxides (NOx) and volatile organic compounds (VOCs) emitted from biomass burning and combustion of engines used for milling. These consequences could also manifest in economic losses for the residents in the study location. Also, persons are employed by the palm oil processing company as either skilled or unskilled workers. Thus, working under polluted conditions exposes them directly to the nonstop emission of harmful substances (Haryati et al., 2022). This study revealed that the concentration of O_3 at different distances within the buffer off the industry was above the recommended limits of the World Health organization (Hoffmann et al., 2021). The concentration of ozone reduced with distance away from the industry which is strong evidence that the company is a major emitter of ozone in the community (Olaguer, 2012). Ozone is an important component of smog and it is highly pervasive and reactive and it has the potential to damage the living cells of humans and animals (Iriti & Faoro, 2008). Prolonged inhalation of ozone as reported in the study area could cause inflammation and irritation of the tissues along the human respiratory system for residents as corroborated by Chidiebere-Mark & Adikaibe (2025). These problems could be compounded by the absence of adequately equipped and staffed primary health care centres (PHC) in the community to meet the medical needs of the residents. Other studies like that of Wyner et al., have reported cough, tightness of the chest, pain upon breathing, and reduced lung function as some of the effects of long- and short-term exposure to ozone at the community level. The ARB approved 8 hours standard for 0.075 ppm exposure to ozone is slightly different from that of WHO (Filippidou et al., 2016). Ozabor et al., (2024b) posited that long term exposure to ozone could cause lung cancer, but many of the cases are never diagnosed and not linked to ozone exposure in developing countries due in part to poor health care system. Elijah et al. (2013) reported that the implication of short term exposure to ozone led to many medical issues, however, existing medical conditions such as diabetes mellitus and asthma could be aggravated. Continuous exposure to ozone reduces the amount of clean air that the lungs can breathe (Filippidou & Koukouliata, 2011). The implication is the shortness of breath and increase in the susceptibility to toxins for humans and animals (White & Martin, 2010). Adults and children who spend more time outdoor and participate in different occupational and recreational activities are highly vulnerable to health risk, this is in line with the reportage of Niyibigira et al. (2024). The argument is premised on the fact that children breathe more rapidly than adults. But beyond the health implication of high concentration of ozone in the lower atmosphere in the study area, there are implications for the physiological functioning of plants and habitability of animals within the circumference of the oil palm processing industry. The implication is that the amount of food stored as carbohydrate in roots and stems is reduced significantly (Janeček & Klimešová, 2014). The concentration of methane in the different calibrated distance from the palm oil processing facility was more than the permissible limits. This possibly resulted from the anaerobic decomposition of palm oil mill effluent (POME) and the empty fruit bunches which are known source of methane pollution associated with palm oil production. This study revealed that there is variation in the dispersion of methane at different levels from the palm oil processing facility as reported by Ogorure et al., (2024). The environmental and health implications of short- and long-term exposure to ozone have been widely reported. Methane is colourless, odourless and it is highly flammable. It is a primary component of nature and biogas in the environment and a major contributor to the global carbon footprint. Given that CH_4 can be generated from the decay of natural materials such as dead plants and animals, and industrial waste (Heilig, 1994). The operations of the oil palm processing company portend serious environmental hazards in the study area. The methods deployed by the company to dispose hazardous waste are not consistent with global best practices, and this mode of waste management can be linked to the footprint of methane concentration within 200 m circumference of the company. Studies (Fang et al., 2013; Ozabor & Nwagbara, 2018) have reported rising concentration of CH_4 in the lower atmosphere and some of the health and environmental implications have also elicited investigation in the literature. Visual impairment, slurred speech and mood changes are some of the health problems associated with exposure to methane (Prasad et al., 2011). Others are memory loss, nausea, vomiting and headache (Shusterman, 1992). Monteny et al. (2001) reported that CH_4 can be formed through human activities such as animal husbandry that increases the release of manure into the environment and through mechanized farming.

This study revealed that there is a gradual reduction in the amount of CO with distance from industry. This connotes that oil palm processing company contributes to the pollutant load in the place. The environmental and health implications of CO have been widely reported. CO may produce mild neurological effects but studies showing such correlation is still limited (Levy, 2015). But the effect of CO for oxygen for binding sites on haemoglobin is reported in the literature. Prolonged exposure to CO could cause reduction in both oxygen transport and release. Exposure to carbon monoxide could also lead to loss of consciousness intermittently, and this could lead to neurological damage (Townsend & Maynard, 2002). Rajput et al. (2022) asserts that short- and long-term exposure to CO portends health consequences, and the environmental implications are also very severe.

The concentration of CO_2 in study area is beyond the limits of the WHO. It is reported in this study that places close to the industry have more concentration of CO_2 in the lower atmosphere. The implication is that distance and climatic parameters is a major influencer of the dispersion of CO_2. Bietwirt (2024) complements the outcome of this study that exposure to CO_2 is expected in the future in developed and developing countries. Effects include the concentration of CO_2 in human blood due to occupational exposure, and other outdoor activities. Brainwaves have also been reported for CO_2 above 600 ppm for short term exposure.

The concentration of $PM_{2.5}$ and PM_{10} in the study area is more than the permissible limit of the World Health Organization WHO. It was revealed form analysis of data that there is a gradual decline in $PM_{2.5}$ with distance from the industry. This is a strong indication that the palm oil producing facility contributes to the concentration of $PM_{2.5}$ and PM_{10} in the study area, particulate matter is a widespread air pollutant and it consists of the mixture of solid and particles suspended in the atmosphere at different sizes, and quantity. The concentration of PM is influenced by different factors with climatic parameters laying a critical role. The case of Ubima is from anthropogenic sources due to the use of combustion engines by the palm oil processing facility and other activities that releases dust and other particles into the atmosphere. WHO recognized the health effects of inhaling $PM_{2.5}$ and PM_{10}. The short- and long-term exposure and its effects are well documented.

5. Conclusion and Recommendations

The study concluded that apart from the concentration of CO, the concentration of air quality parameters like O_3, CO_2, $PM_{2.5}$ and PM_{10} are above the WHO standard which could portend possible health challenge for people living around the company. Moreover, the air quality parameters were observed to gradually reduce in concentration with distance from the major operating zone of the oil palm processing company. Albeit, the study is limited due to the fact that it did not include meteorological parameters which could have explained the spatial patterns of the pollution. However, due to the findings the study recommended that there is an urgent need to prioritize transition to the use of clean energy in the operations of the oil palm processing company. Investment in clean energy such as solar energy would reduce the amount of harmful substances emitted into the environment. The global best farming practices should be adopted to stop the controlled burning of farms during site preparation for planting of oil palm seedlings. Also, there is a need to review the Environmental Impact Statement (EIS) of the Company in view of the expansion of the operations of the company and encroachment of residential settlements. The review of the EIS should be done concomitantly with the Social Impact Assessment (SIA) reports for the purposes of timely responses to the environmental and health consequences of oil palm production for the people. Relevant agencies should enforce more compliance to environmental laws and guidelines on oil palm processing to safeguard the integrity of the environment and to protect the environment that provides a support system for the local economy to thrive.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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