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Dry Season Concentration of Selected Air Pollutants in Yenagoa, Bayelsa State, Nigeria

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Abstract
This study assessed the air pollutants concentration around Yenagoa, Bayelsa State, Nigeria. Purposive sampling was used to select three sampling locations (Igbogene, Tombia-Edepie and Swali market) based on identified land use and socio-economic activities, and a control location of fifteen kilometers away from the study area. The study carried out field measurement of air pollutants (SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$) and meteorological parameters (temperature, humidity, wind speed and direction). North-easterly wind was found to control the overall concentration of air pollutants in the study area. Mean SO_2, NO_2 PM $_{2.5}$ and PM $_{10}$ exceeded permissible limits. The differences in the concentrations of CO, PM $_{2.5}$ and PM_{10} at the locations were significant (p-value < 0.05), but no significant differences in the concentrations of SO_2 and NO_2 across the locations (p-value > 0.05). Air pollutant concentrations decreased progressively from December to March. Monthly concentrations of air pollutants showed no significant differences (p-value > 0.05). However, significant difference was observed in monthly air pollutant concentration between the study area and the control location (p-value < 0.05). In order to reduce air pollution and mitigate its potential environmental health effects in the study area the study recommends the use of sustainable transport systems, especially mass transit. In addition, power supply in the study area should be improved to reduce the use of power generating sets by businesses and households. This can be supported by improving access to renewable energy sources for businesses and households.

Keywords: *Sulphur dioxide, Nitrogen dioxide, Carbon monoxide, Particulate matter, Hazardous, Human health*

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1. Introduction

Air pollution emanates from natural or anthropogenic sources and has been defined by Dockery et al. (1993) as the presence in the outdoor or indoor atmosphere of one or more gaseous or particulate contaminants in quantities, characteristics and of duration such as to be injurious to human, plant or animal life or to property, or which unreasonably interferes with the comfortable enjoyment of life and property. Air pollutants can be solid particles, liquid droplets, or gases (WHO, 2003).

Suleiman (2013) and Ojo (2012) noted that air pollution was an acute problem in urban centres of developing countries, and was largely sourced from transportation activities, industrial emission, use of gasoline generators as a result of unstable power supply and use of fuel wood for domestic use and energy for small industries. At both global and local levels, anthropogenic actions have been linked to environmental pollution and the consequential health effects (Obisesan and Weli, 2019).

Air pollution from both outdoor and indoor sources represents the single largest environmental risk to health globally. It is estimated that more than 6 million premature deaths were caused by air pollution exposure in 2012 (WHO, 2016). Air pollution is a key risk factor for non-communicable diseases (NCDs) including chronic obstructive pulmonary disease, asthma, lung disease, and cardiovascular diseases (WHO, 2020) and is the second leading cause of NCD-related deaths after tobacco smoking (WHO, 2021).

Studies indicate that there has been progressive increase in air pollution in the Niger Delta, driven by urbanization, oil exploration activities, increase in transportation, industrial and commercial activities as well as population expansion (Tawari and Abowei, 2012; Akuro, 2012; Zagha and Nwaogazie, 2015; Verere and Oluwagbenga, 2015; Ajayi et al., 2017; Abaje et al., 2020). Yenagoa is a fast developing urban area in the Niger Delta with visibly polluted environment (Olutunde et. al. 2017). Prior to the creation of Bayelsa State in 1996, Yenagoa was a rural settlement with minimal socio-economic activity. At the creation of the State and subsequent attainment of capital city status, there has been a rapid expansion of roads and massive increase in transport activities.

With the absence of an efficient transport system, private ownership of vehicle by the well-to-do is encouraged. This increases private motorist related externalities such as noise pollution, traffic delays, congestion and air pollution in the study area. Since becoming the capital of Bayelsa State in 1996, the city has experienced rapid population and infrastructural growth. This is driven by the influx of human population, industrial activities and increase in traffic/transport activities with the corresponding increase in other anthropogenic activities (Katato et al. 2019). This situation is worsened by uncontrolled urban expansion due to the non-implementation of the Yenagoa master plan. Yenagoa is located in the Niger Delta where major oil exploration activities and other ancillary industrial activities take place. This is also an important source of air pollution in the study area.

Increasing transport and other socio-economic activities in all parts of the city has increased energy use and environmental pollution (Alfred, 2020). Heaps of refuse are left unattended to in most cases in the streets of Yenagoa due to either disagreement on issues of payment between refuse evacuators and waste management contractors or poor access road to uncontrolled refuse dumps. This gives rise to burning of refuse especially during the dry season by the residents and businesses, which is an important source of air pollution.

Extant literature indicates that some studies have been carried out on air quality in the study area and environs such as those of Abulude et al. (2022), Angiamowei et al. (2019) and Njoku et al. (2019) Binaebiye et. al. (2018), Ajayi et. al. (2017). However, these studies did not assess gaseous pollutants, were carried out in different locations in Bayelsa State and were focused on play grounds and the oil and gas industry. The aim of this study is to assess dry season air quality in Yenagoa, Bayelsa State, Nigeria.

2. Materials and methods

2.1 Study area

Yenagoa, the capital of Bayelsa State in the Niger Delta region of Nigeria is geographically located between latitudes 4º51'36" and 5º01'23" North, and between longitudes 6º12'25" and 6º27'34" East (Figure 1). It is situated in the low-lying coastal area of the Niger Delta South-South zone. According to Angiamawei et. al. (2019) the study area is predominately dominated by the South-East and North-East wind during the wet season while the dry season is predominately dominated by the North-West and North-East wind direction. The vegetation of the study area falls within the fresh water swamp forest. The climate is tropical with alternating wet and dry seasons. The mean monthly temperature ranges from 25ºC to 38ºC with a range of 2ºC between wet and dry seasons (Obafemi and Omiunu, 2014).

The soil is mainly deltaic in nature composing mainly of loamy and alluvial soil close to the River Bank (Nwankwoala et al. 2014). It is endowed with the sedimentary rocks which are characteristic of the Niger Delta. The detailed geology of the area has been described by Udom et al. (1998). Drainage system of the study area is characterized by creeks and swamps crisscrossing each other as they flow through the Epie Creek and finally empties into the Atlantic Ocean through river Nun. Epie creek runs from Orashi River up North to Ekole River down South.

The study area is hub for various socio-economic activities, ranging from fishing, agricultural activities at the bank of the creek, commercial and business activities and recreational activities. According to Tawari and Abowei (2012) and Akuro (2012) almost half of the population engages in agricultural activities. Because of its well-endowed natural oil and gas resource deposits, the area also plays host to multi-national companies.

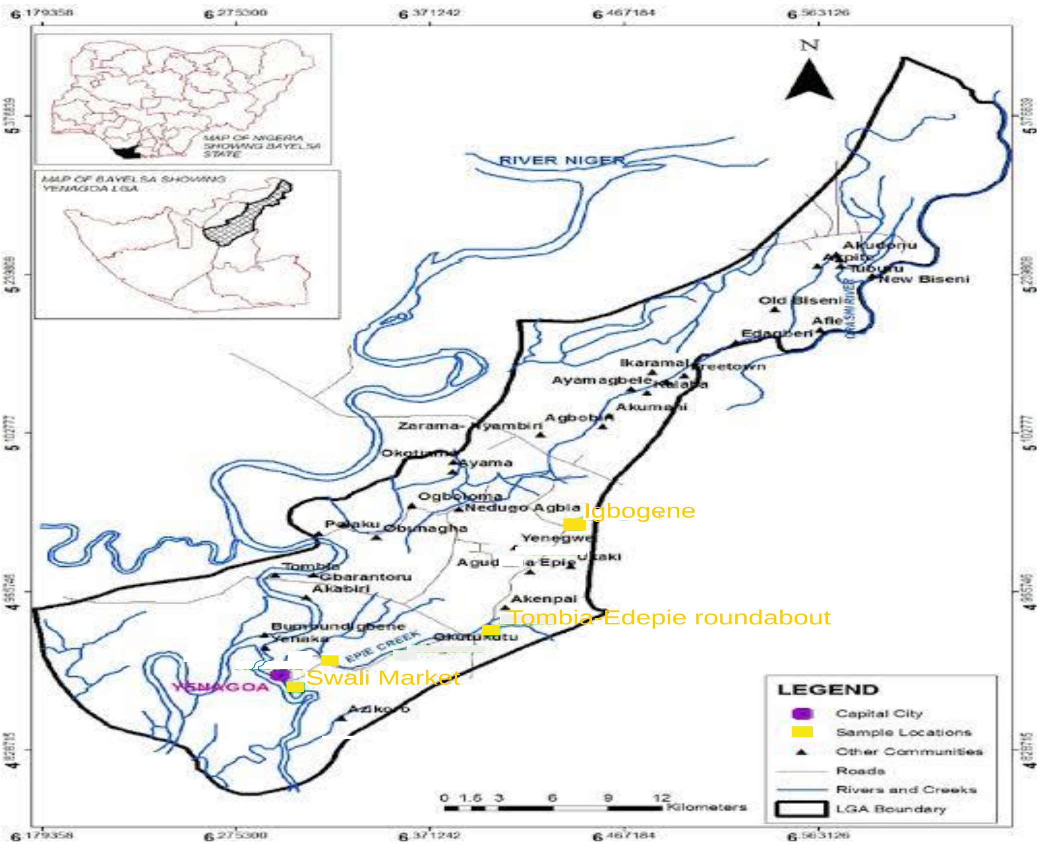


Fig. 1: Yenagoa showing study locations

2.2 Data collection procedure

Purposive sampling was employed in the selection of sampling locations based on observed land use within the study area. Three major commercial districts in the study area namely, Igbogene, Tombia- Edepie and Swali were selected, and within each of these commercial areas a major road junction (Igbogene junction, Tombia-Edepei junction and Swali market junction) was selected as a sampling location for this study. Otuogori, fifteen kilometers away from the study area was used as a control (Table 1).

Sample collection was carried out during the daytime, six days in every month from December, 2021 to March, 2022. Samples were taken simultaneously at all sampling locations. Readings were taken from 9am to 5pm at the sampling locations; recording of readings for each pollutant were taken at intervals of one hour (1hr) in order to generate eight sets of data from which, the average mean was taken. The air pollutants investigated in this study were sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), PM_{10}, $PM_{2.5}$ and particulate matter.

Atmospheric pollutants in the study area were measured using Aeroqual series 200 multi-sensors instrument and BoseanK-600 portable multi-gas detector (Bosean Electronic Technology, China, 2019). A 3 cup Scholab digital anemometer weather instrument was used to measure meteorological parameters, while a BHCnav NAVA 600 Global Positioning System (GPS) was used to take coordinates of the sampling locations.

The air monitoring instruments were placed at 1.5 meters above ground level and measurements were taken simultaneously across the four samplings locations. Before readings were taken the instruments were allowed to stabilize for at least three minutes in order to ascertain reliability and provide real time reading of parameters.

Table 1: Sampling location

	Sampling location	Coordinates	
		Latitude (N)	Longitude (E)
1	Igbogene	5°2'15.87"	6°24'16.23"
2	Tombia-edepie roundabout	4°57'15.60"	6°21'29.60"
3	Swali market	4°55'7.69"	6°16'1.56"
4	Otuogori (control)	4°49'18"	6°16'00"

2.3 Data analysis

Data analysis was carried out using Statistical Package for Social Sciences (SPSS) version 26.0. Descriptive statistics (range, mean, standard deviation and coefficient of variation) were determined. Analysis of variance (ANOVA) was performed to test for differences in air pollutant levels between sampling locations. In addition, monthly differences were also compared using ANOVA. The statistical tests were carried out in Microsoft Excel at 95% confidence level, in which the p-values were determined ($p\text{-value} \leq 0.05$). The concentrations of the gaseous air pollutants were compared with the Federal Ministry of Environment (FMEnv) and the United States National Ambient Air Quality Standards (NAAQS); while particulate pollutants were compared with NAAQS and World Health Organization (WHO) standards.

3. Results and discussion

3.1 Meteorological conditions in the study area

Result of the meteorological conditions in the study area is shown in Table 2. The plot of wind direction distribution, indicating the dominant wind directions is indicated in Fig. 2. Table 2 shows that at Tombia-Edepie, wind speed ranged from 0.6m/s to 4.1m/s with a mean of 2.1±0.63m/s while ambient temperature ranged from 26.0°C to 41.1°C with a mean deviation of 32.96±2.61°C. Relative humidity ranged from 43.7% to 84.6% with a mean deviation of 60.59±6.74%. At Swali Market Junction, Table 2 indicates that wind speed ranged from 0.8m/s to 4.2m/s with a mean deviation of 2.3±0.7m/s. Ambient temperature ranged from 26.5°C to 33.6°C with a mean deviation of 32.98±2.1°C. Relative humidity ranged from 42.3% to 82.1% with a mean deviation of 67.22±8.46%.

At Igbogene, wind speed ranged from 0.8m/s to 4.0m/s with a mean deviation of 2.08±0.6m/s while ambient temperature ranged from 26.1°C to 33.8°C with a mean deviation of 33.02±2.12°C. Relative humidity ranged from 41.9% to 82.2% with a mean deviation of 65.09±9.13%. At the control location, wind speed ranged from 0.7m/s to 4.0m/s with a mean deviation of 2.14±0.51m/s. Ambient temperature ranged from 20.2°C to 33.6°C with a mean deviation of 30.22±4.43°C while relative humidity ranged from 42.3% to 87.2% with a mean deviation of 64.52±9.79%. The wind direction distribution (Fig. 2) indicates that the prevailing wind direction in the area is northeast (NE) with a frequency of occurrence of 53.0%, followed by northwest (NW) and southwest (SW) with frequencies of occurrence of 18.0% each, while southeast has a frequency of occurrence of 11.0%.

Table 2: Meteorological conditions in the study area

Location	Parameter/ Statistic	Wind speed (m/s)	Temp. (°C)	Relative humidity (%)	Wind direction (deg.)
Tombia-Edepie	Min	0.6	26.0	43.7	SE
	Max	4.1	34.1	84.6	NE
	Mean	2.1	32.96	60.59	NW
	SD	0.63	2.61	6.74	
Swali Market Junction	Min	0.8	26.5	42.3	SW
	Max	4.2	33.6	82.1	NE
	Mean	2.3	32.98	67.22	NE
	SD	0.7	2.1	8.46	
Igbogene	Min	0.8	26.1	41.9	SE
	Max	4.0	33.8	82.2	NE
	Mean	2.08	33.02	65.09	NW
	SD	0.6	2.12	9.13	
Control	Min	0.7	20.2	42.3	SE

Max	4.0	33.6	87.2	NE
Mean	2.14	30.22	64.52	NW
SD	0.51	4.43	9.79	

SD = standard deviation

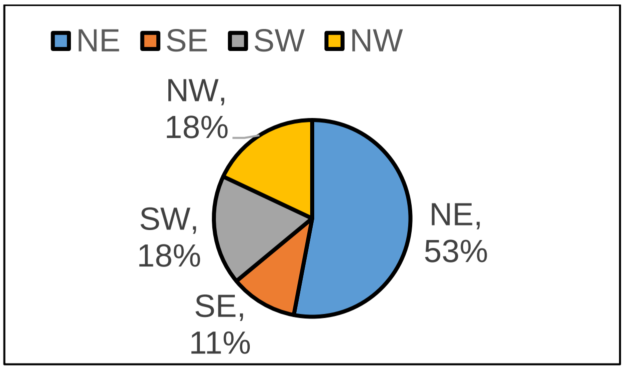


Fig. 2: Summary of wind direction in the study area during the study

3.2 Air quality of the study area

Concentration of air pollutants in the study area is shown in Table 3, while the daily variation of air pollutants is shown in Figure 3. The plots of the mean concentration of air pollutants are shown in Fig. 4 (a – e), while the plots of the monthly concentration of air pollutants are shown in Figure 5 (a – e).

Table 3: Concentration of air pollutants during dry season

Location	Parameter/statistic	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)
Tombia-Edepie	Min	0.00	0.00	0.00	65.00	12.00
	Max	2.00	2.00	8.00	532.00	226.00
	Mean	0.60	0.36	2.17	220.39	77.69
	SD	0.66	0.53	1.88	76.62	41.53
	COV (%)	110.00	147.22	86.64	34.77	53.46
Swali Market Junction	Min	0.00	0.00	0.00	15.00	3.00
	Max	2.00	3.00	7.00	356.00	268.00
	Mean	0.63	0.48	1.15	177.49	60.01
	SD	0.69	0.67	1.44	75.01	29.24
	COV (%)	109.52	139.58	125.22	42.26	48.73
Igbogene	Min	0.00	0.00	0.00	21.00	8.00
	Max	2.00	1.00	5.00	313.00	99.00
	Mean	0.42	0.39	1.14	175.3	59.43
	SD	0.52	0.49	1.22	58.4	20.04
	COV (%)	123.81	125.64	107.02	33.31	33.72
Control	Min	0.00	0.00	0.00	19.00	5.00
	Max	1.00	1.00	4.00	86.00	32.00
	Mean	0.018	0.021	0.58	44.29	17.28
	SD	0.038	0.04	0.76	22.4	10.93
	COV (%)	211.11	190.48	131.03	50.59	63.25
	FMEnv limit	0.1	0.06	10		
	NAAQS limit	0.14	0.1	9	150	35
	WHO limit				50	25

SD = standard deviation

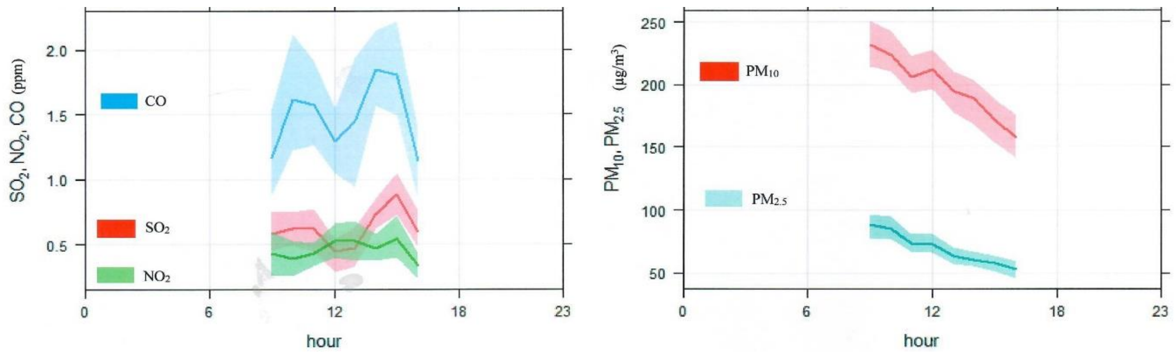
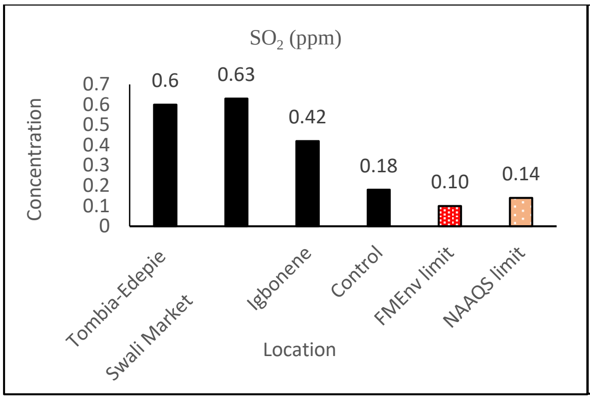
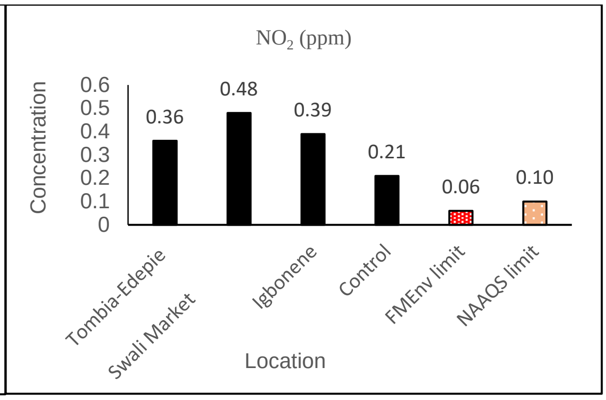
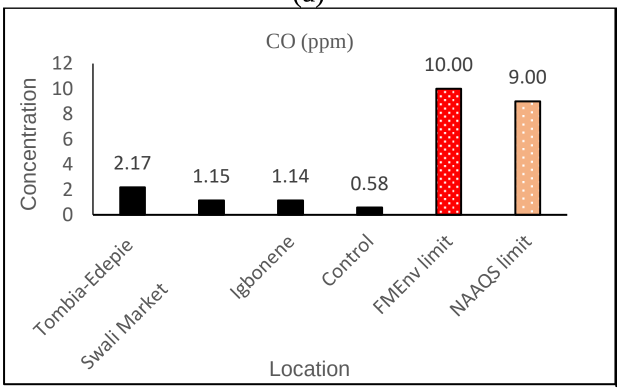


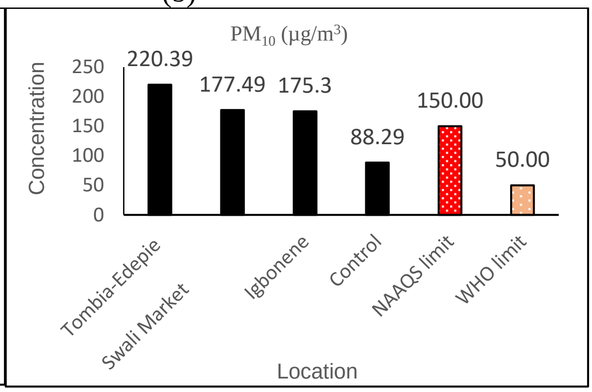
Fig. 3: Trend in daily variation of air pollutants



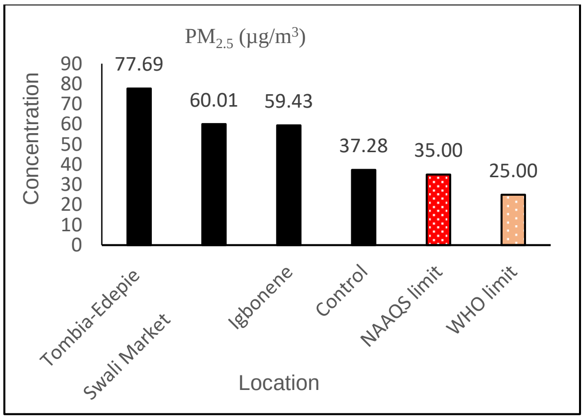


(a) (b)





(c) (d)



(e)

Fig. 4 (a – e): Mean concentration of air pollutants in the study area

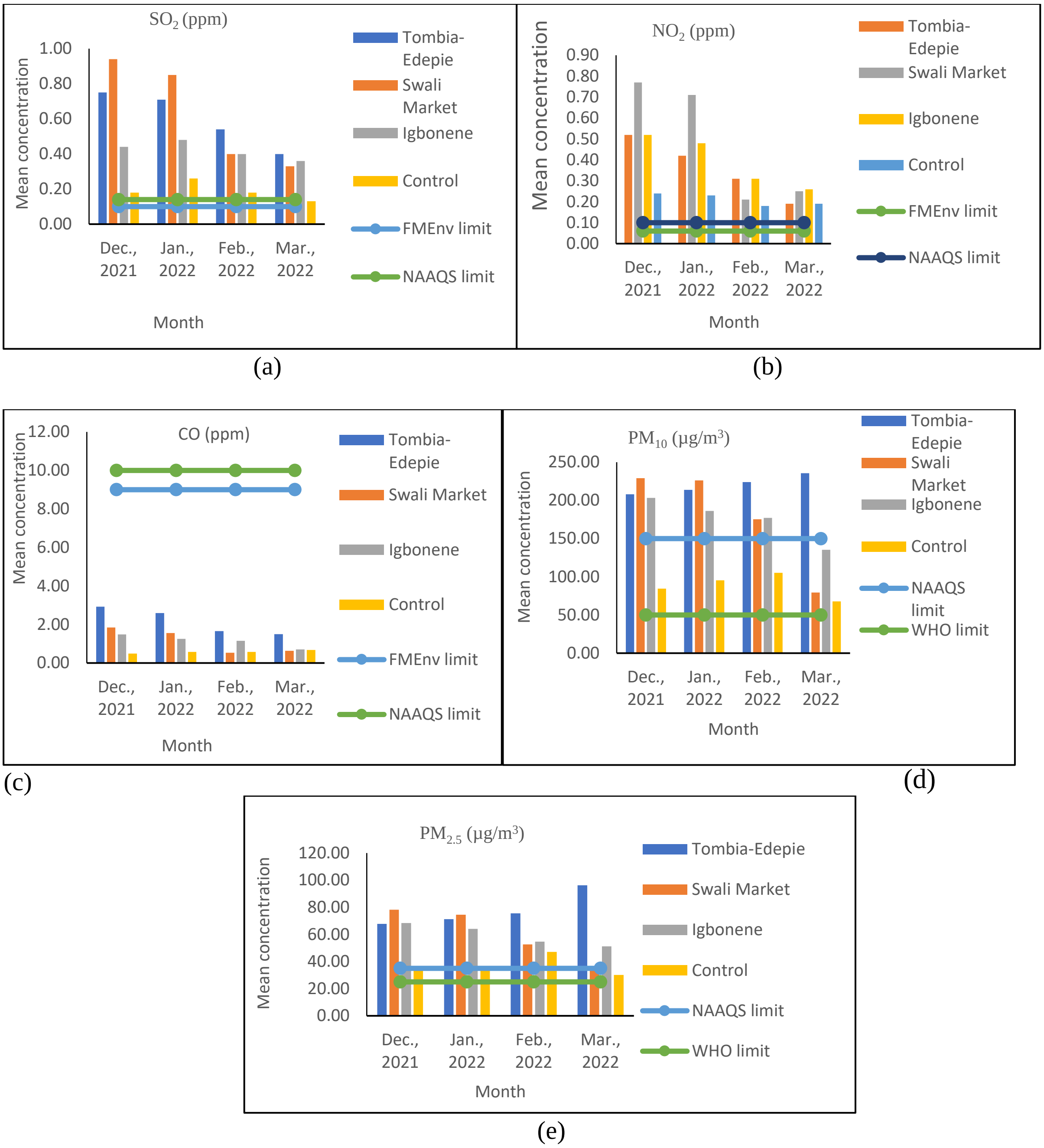


Fig. 5 (a – e): Monthly variation of air pollutants in the study area

Table 3 shows that at Tombia-Edepie, concentration of sulphur dioxide ranged from 0.0ppm to 2.0ppm with a mean deviation of 0.6±0.66ppm, while nitrogen dioxide ranged from 0.0 to 2.0ppm with a mean deviation of 0.36±0.53ppm. Carbon monoxide ranged from 0.0 to 8.0ppm with a mean deviation of 2.17±1.88ppm. PM_{10} ranged from 65.00µg/m^3 to 532.00µg/m^3 with a mean deviation of 220.39±76.62µg/m^3, while $PM_{2.5}$ ranged from 12.00µg/m^3 to 226.00µg/m^3 with a mean deviation of 77.69±41.53µg/m^3.

At Swali Market Junction, sulphur dioxide ranged from 0.0.0ppm to 2.0ppm with a mean deviation of 0.63±0.69ppm while nitrogen dioxide ranged from 0.0ppm to 3.0ppm with a mean deviation of 0.48±0.67ppm. Carbon monoxide ranged from 0.0 to 7.0ppm with a mean deviation of 1.15±1.44ppm. PM_{10} ranged from 15.00µg/m^3 to 356.00µg/m^3 with a mean deviation of 177.49±75.09µg/m^3. $PM_{2.5}$ ranged from 3.00µg/m^3 to 268.00µg/m^3 with a mean deviation of 60.01±29.24µg/m^3.

Table 4 further shows that at Igbogene, sulphur dioxide ranged from 0.0.0ppm to 2.0ppm with a mean deviation of 0.42±0.52ppm. Nitrogen dioxide ranged from 0.0ppm to 1.0ppm with a mean deviation of 0.39±0.49ppm while carbon monoxide ranged from 0.0 to 5.0ppm with a mean deviation of

1.14±1.22ppm. PM_{10} ranged from 21.00μg/m^3 to 313.00μg/m^3 with a mean deviation of 175.30±58.40μg/m^3 while $PM_{2.5}$ ranged from 8.00μg/m^3 to 99.00μg/m^3 with a mean deviation of 59.43±20.04μg/m^3.

At the control location, sulphur dioxide ranged from 0.0.0ppm to 1.0ppm with a mean deviation of 0.018±0.38ppm while nitrogen dioxide ranged from 0.0ppm to 1.0ppm with a mean deviation of 0.021±0.4ppm. Carbon monoxide ranged from 0.0 to 4.0ppm with a mean deviation of 0.58±0.76ppm. PM_{10} ranged from 19.00μg/m^3 to 86.00μg/m^3 with a mean deviation of 44.29±22.40μg/m^3. $PM_{2.5}$ ranged from 5.00μg/m^3 to 32.00μg/m^3 with a mean deviation of 17.28±10.93μg/m^3.

Meteorological conditions of the study area were characteristic of the tropical region where this study was carried out (Yorkor et. al. 2017). Despite being the dry season, high levels of wind speed, ambient temperature and relative humidity were observed in the coastal area (Table 3). Angiamowei et. al. (2019) also observed similar meteorological conditions in parts of Yenagoa, Bayelsa State. This can be attributed to the highly humid sea breeze that blows in the area.

The plot of wind direction (Figure 2) shows the prevalence of northeast wind direction in the study area. The northeast wind direction is associated with the dry season period in the study area. Wind speed and wind direction play important roles in the dispersion of air pollutants in the study area. The dominance of the north-easterly wind controls the overall dispersion of air pollutants concentration in the study area. This finding agrees with studies by Yorkor (2017), Angiamowei et. al. (2019), Njoku et. al. (2019), Antia et al. (2020) and Abulude et. al. (2022).

Trends in the daily variations of air pollutants in the study area (Figure 4) indicate that the concentration of SO_2, NO_2 and CO were elevated during the morning hours (8:00am – 11:30am), decreased towards afternoon (11:30am – 2:00pm), and then rose between 2:30pm and 4:00pm before decreasing toward evening time. Similarly, particulate air pollutants (PM_{10} and $PM_{2.5}$ showed similar trend. This trend could be attributed to high transportation activities during these peak periods. In addition, the trend in the daily variations of air pollutants in the study area suggests the influence of the harmattan wind which is stronger during morning hours compared to other times of the day.

Mean concentration of SO_2 at Tombia-Edepie location exceeded FMEnv limit by 500.0% and NAAQS limit by 328.57%; mean concentration of SO_2 at Swali Market Junction location exceeded FMEnv limit by 530.0% and NAAQS limit by 350.0%; mean concentration of SO_2 at Igbogene location exceeded FMEnv limit by 320.0% and NAAQS limit by 200.0%; while mean concentration of SO_2 at the control location exceeded FMEnv limit by 80.0% and NAAQS limit by 28.57%. Mean concentration of NO_2 at Tombia-Edepie location exceeded FMEnv limit by 500.0% and NAAQS limit by 260.0%; mean concentration of NO_2 at Swali Market Junction location exceeded FMEnv limit by 700.0% and NAAQS limit by 380.0%; mean concentration of NO_2 at Igbogene location exceeded FMEnv limit by 550.0% and NAAQS limit by 290.0%; while mean concentration of NO_2 at the control location exceeded FMEnv limit by 250.0% and NAAQS limit by 110.0%.

Mean concentration of PM_{10} at Tombia-Edepie location exceeded NAAQS limit by 46.93% and WHO limit by 340.78%; mean concentration of PM_{10} at Swali Market Junction location exceeded NAAQS limit by 18.23% and WHO limit by 254.98%; mean concentration of PM_{10} at Igbogene location exceeded NAAQS limit by 16.87% and WHO limit by 250.0%; while mean concentration of PM_{10} at the control location falls below NAAQS limit but exceeded WHO limit by 76.58%. Mean concentration of $PM_{2.5}$ at Tombia-Edepie location exceeded NAAQS limit by 121.97% and WHO limit by 210.76%; mean concentration of $PM_{2.5}$ at Swali Market Junction location exceeded NAAQS limit by 71.46% and WHO limit by 140.04%; mean concentration of $PM_{2.5}$ at Igbogene location exceeded NAAQS limit by 69.80% and WHO limit by 137.72%; while mean concentration of $PM_{2.5}$ at the control location exceeded NAAQS limit by 6.5% and WHO limit by 49.12%. The mean values of carbon monoxide were below the permissible limits around all the sampling locations, including the control location.

The highest value of SO_2 was obtained at Swali Market Junction followed by Tombia-Edepie and Igbogene and the lowest at control location. The concentration of NO_2 in the study area was also found to be high (Table 4). The highest value was also obtained at Swali Market Junction, followed by Igbogene, Tombia-Edepie and the lowest at the control location. The concentration of carbon monoxide in the study area were generally low (Table 4), with the highest value obtained at Tombia-Edepie followed by Swali Market Junction, Igbogene and the lowest at the control location. Angiamowei et. al. (2019) and Njoku et. al. (2019) also reported lower concentration of CO relative to SO_x and NO_X in their studies.

Table 4 indicates that the concentration of PM_{10}in the study area was high. The highest value was obtained at Tombia-Edepie, followed by Swali Market Junction and Igbogene. Also, $PM_{2.5}$ particulate shows high concentration in the study area (Table 4). The highest value of $PM_{2.5}$ was obtained at Tombia-Edepie, followed by Swali Market Junction and Igbogene. The concentration of carbon monoxide were generally low (Table 3), with the highest value obtained at Tombia-Edepie followed by Swali Market Junction, Igbogene and the control location. Angiamowei et. al. (2019) and Njoku et. al. (2019) in previous studies, reported low concentration of CO in parts of Yenagoa, Bayelsa State.

Coefficient of variation (Table 4) indicate that the concentration of SO_2 vary widely at the control location, followed by Igbogene, Tombia-Edepie and Swali market Junction. The concentration of NO_2 varied widely around the control location, followed by Tombia-Edepie, Swali Market Junction and Igbogene. The concentration of CO varied widely around the control location, followed by Swali Market Junction, Igbogene and Tombia-Edepie. Concentration of particulate matter (PM_{10} and $PM_{2.5}$) varied moderately at all the sampling locations in the study area but varied less at the control location.

It is evident from Figure 4 that SO_2, NO_2, PM_{10} and $PM_{2.5}$ in the study area exceeded permissible limits. This finding agrees with Angiamowei et. al. (2019), who obtained high values of these air pollutants in part of Yenagoa, Bayelsa State. The CO mean value was below permissible limit, which also agrees with the study of Angiamowei et. al. (2019) and Njoku et. al. (2019). Mean concentration of air pollutants obtained in the study area were higher than the control location. As has been observed by Tawari and Abowei (2012) and Yorkor et. al. (2021), high volume of vehicular traffic, commercial activities, medium scale industrial activities, the use of generators, burning of refuse and cow skin may be the potential sources of air pollutants at Swali Market Junction and account generally for the high concentration of air pollutants in the study area. The low concentration of CO in the study area could be attributed to high dispersion by wind speed.

Fig. 5 (a – e) show that at Tombia- Edepie, SO_2, NO_2 CO and PM_{10} levels decreased from December 2021 to March 2022. However, concentration of $PM_{2.5}$ particulate decreased in value from December 2021 to March 2022. At Swali Market, Igbogene and the control location all the pollutants assessed showed decreasing trend from December 2021 to March 2022. This trend demonstrated that the concentration of air pollutants decreased from the core dry season months of December, January and February to the transition month of March when the rains begin to set in. The concentration of gaseous pollutants, were varied significantly widely at the control location compared to the study area. PM_{10} and $PM_{2.5}$ concentrations did not vary significantly at the study area. This may be attributed to the dusty harmattan wind that blows steadily across the study area during the dry season period.

Significant differences were not found in the levels of SO_2 and NO_2 at Tombia-Edepie, Swali Market Junction and Igbogene (p-value > 0.05). However, significant difference was observed in the levels of CO, PM_{10} and $PM_{2.5}$ at Tombia-Edepie, Swali Market and Igbogene (p-value < 0.05, 95% CI). The study found significant difference in the concentration of air pollutants in the study area and the control location (p-value < 0.05). Suggesting that study area is more polluted compared to the control location. This finding corroborated the study of Angiamowei et al., (2019). The study showed no significant differences in monthly air pollutants in the study area (p-value > 0.05). However, a significant difference was observed in monthly air pollutant concentration between the study area and the control location (p-value < 0.05).

5. Conclusion

The findings of this study indicated that meteorological conditions in the study area were a characteristic of the tropical region with the dominant of north-easterly wind which controls overall dispersion of air pollutants during the period of study. The result indicated that mean values of SO_2, NO_2, PM_{10} and $PM_{2.5}$ exceeded permissible limits in the study area. A significant difference was found between the concentration of air pollutants in the study area and the control location (p-value < 0.05), suggesting that study area is more polluted compared to the control location. The trend in daily air pollutants indicated higher concentrations in the morning and evening periods. The study identified anthropogenic activities such as transportation, commercial activities, medium scale industrial activities, burning of fossil fuels, refuse and cow skin as the potential sources of air pollution in the area during the dry season period. High levels of air pollutants in the study area pose a serious threat to the health of the exposed public. Long-time exposure may have detrimental health effects on the exposed population, particularly, sensitive groups such as the elderly and children. In order to reduce air pollution and mitigate its potential environmental health effects in the study area, the study recommends the use of sustainable transport systems, especially mass transit. In addition, power supply in the study area should be improved to reduce the use of power generating sets by businesses and households. This can be supported by improving access to renewable energy sources for businesses and households.

Conflict of interest

The authors have declared that no competing interests exist.

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