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# Evaluation of atmospheric methane concentrations and growth trends in selected locations of Rivers State, Nigeria

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## Abstract
The study addresses the increasing atmospheric methane mixing ratios in Rivers State, Nigeria, a pressing issue linked to global warming. The objective was to analyze the growth rate and sources of methane emissions in the region. Using a quantitative approach, ground-level methane measurements were collected from seven different locations between September 2021 and June 2022, complemented by data from the Tropospheric Monitoring Instrument satellite spanning January 2019 to June 2022. The methodology combined descriptive, comparative, and regression analyses with plume chemistry modeling using the U.S. EPA Atmospheric Dispersion Modeling System software. Results indicated significant spatial variance in methane concentrations, ranging from 9.76 ppm in Ogbogu to 21.5 ppm in Choba, with notable temporal fluctuations. Regression analysis revealed a correlation between atmospheric conditions and methane levels, while plume chemistry identified a landfill near Choba market as a major emission source, raising concerns about tropospheric ozone pollution and health risks. The study highlights the need for effective waste management in Rivers State and emphasizes the importance of continuous monitoring to address the challenges posed by methane emissions and tropospheric ozone pollution.

**Keywords:** Atmospheric methane mixing ratio, Tropospheric Monitoring Instrument, Rivers State, Nigeria, Plume chemistry analysis, Tropospheric ozone pollution.

## 1. Introduction

Methane, a potent greenhouse gas with a global warming potential far greater than carbon dioxide, is a significant contributor to climate change (Al Mazrouei *et al*., 2023; Howarth *et al*., 2011; U.S. Environmental Protection Agency, 2023). Wu *et al*. (2023) highlight its considerable impact over a 100-year horizon, emphasizing its role in the current climate crisis. Both natural and anthropogenic sources, including the fossil fuels, waste, and agriculture sectors, release methane into the atmosphere, with the oil and gas sector alone responsible for nearly 23% of emissions (Atkins *et al*., 2021; Cardoso-Saldaña & Allen, 2020; Kim *et al*., 2021; Malhi *et al*., 2021; Singh, 2023).

The pre-industrial atmospheric methane mixing ratio, once around 600 – 700 ppb, has risen significantly, posing threats to the Paris Agreement's goals (Nisbet *et al*., 2019; Tollefson, 2022; Xu *et al*., 2022). This increase, with contributions from regions like India, China, and tropical wetlands, has been observed and analyzed using satellite data (Maasakkers *et al*., 2019). Studies have emphasized the urgent need for scalable methane reduction strategies and the use of advanced technology for monitoring and mitigation (Dunn *et al*., 2023; Mohammadi & Akhoondzadeh, 2023; Ogbowuokara *et al*., 2023; Schuit *et al*., 2023).

In Rivers State, Nigeria, a region with diverse urban, agricultural, and hydrocarbon exploration activities, the dynamics of methane emissions are particularly complex (Egbueri *et al*., 2023; Suku *et al*., 2023). This study leverages satellite and ground-level data to comprehensively evaluate atmospheric methane mixing ratios in Rivers State, aiming to inform both local and global strategies for emission reduction (Roberts *et al*., 2023; Scarpelli *et al*., 2020; Zhang *et al*., 2020). The study aligns with the Sustainable Development Goals by seeking methods to reduce methane emissions, thereby curtailing its detrimental effects on health, agriculture, and ecosystems (United Nations, 2023; Worden *et al*., 2023). The purpose of this study is to provide a nuanced understanding of the methane scenario in Rivers State, contributing to both local policy formulation and global efforts in greenhouse gas mitigation.

## 2. Materials and Methods

### *2.1 Research design*

This study utilized a quantitative cross-sectional design to investigate the atmospheric methane mixing ratio in Rivers State. The primary objective was to ascertain the methane mixing ratio and its growth rate within the state. Data collection involved primary measurements and secondary data analysis. Primary data was collected from three types of sites: school premises, bush areas, and markets, spread across seven locations: Choba, Ahoada, Ogbogu, Omoku, Onne, Eleme, and Abonnema. Ground-level methane measurements were taken using specialized equipment monthly from September 2021 to June 2022. Secondary data was sourced from the Tropospheric Monitoring Instrument (TROPOMI) satellite, focusing on atmospheric methane mixing ratios from 2019 to June 2022. This data comprised 1,278 units, enabling a comprehensive evaluation of methane levels.

For analysis, descriptive statistics (mean, median, standard deviation, minimum, and maximum) were used to assess the atmospheric methane mixing ratio across the 21 sampling points. Comparative and trend analyses were conducted to identify variations and temporal changes in methane mixing ratios among the different locations.

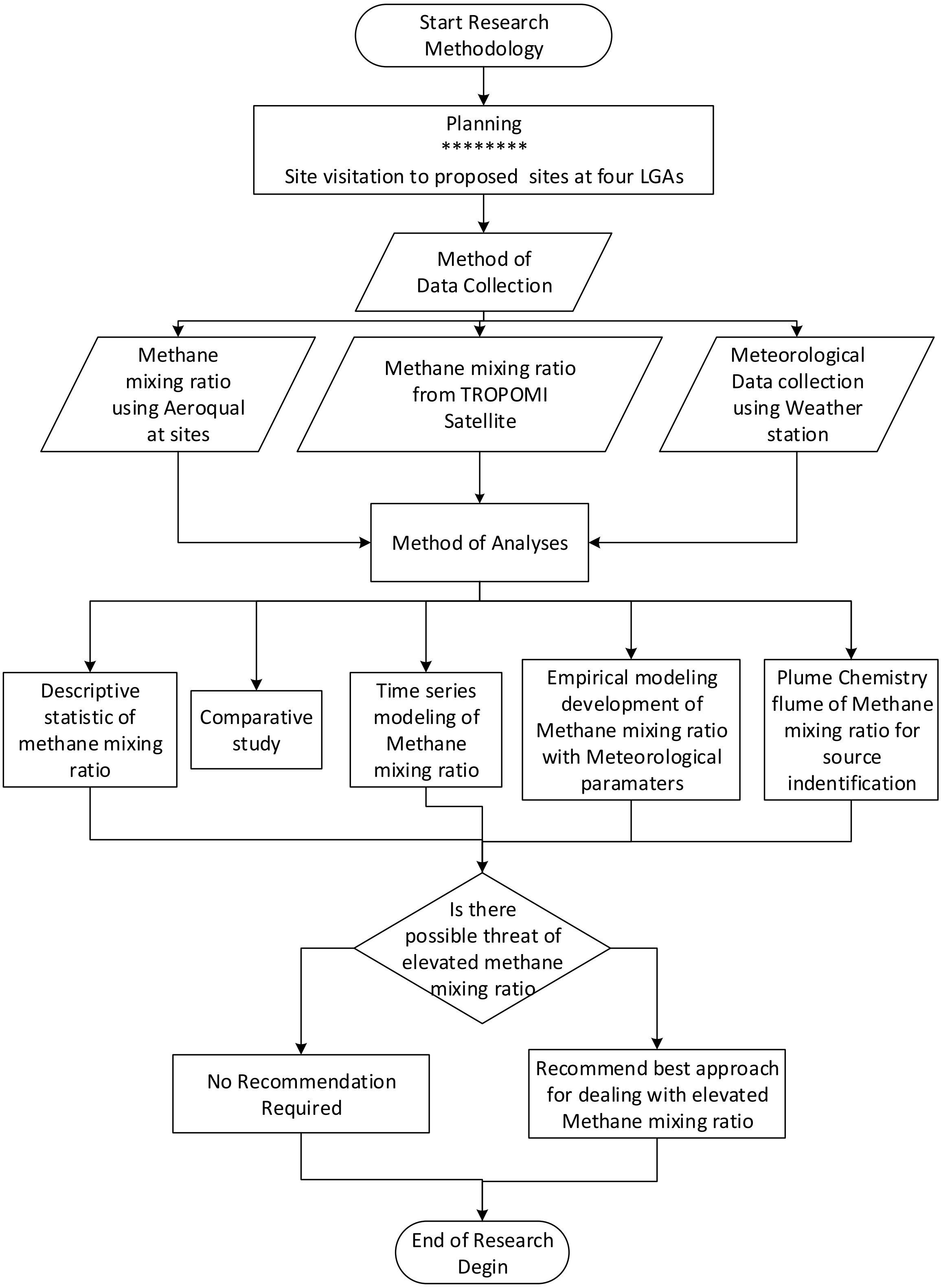


**Figure 1 – Research design flowchart.**

The ground-level measurements' reliability was gauged through a comparative analysis with data obtained from the TROPOMI satellite. Subsequently, an empirical model was formulated to examine the interplay between the atmospheric methane mixing ratio and other variables, notably temperature and humidity. A separate plume chemistry model was employed to pinpoint the sources of methane emissions in the region. The structured approach of the research is visually encapsulated in Figure 1.

*2.2 Study area*

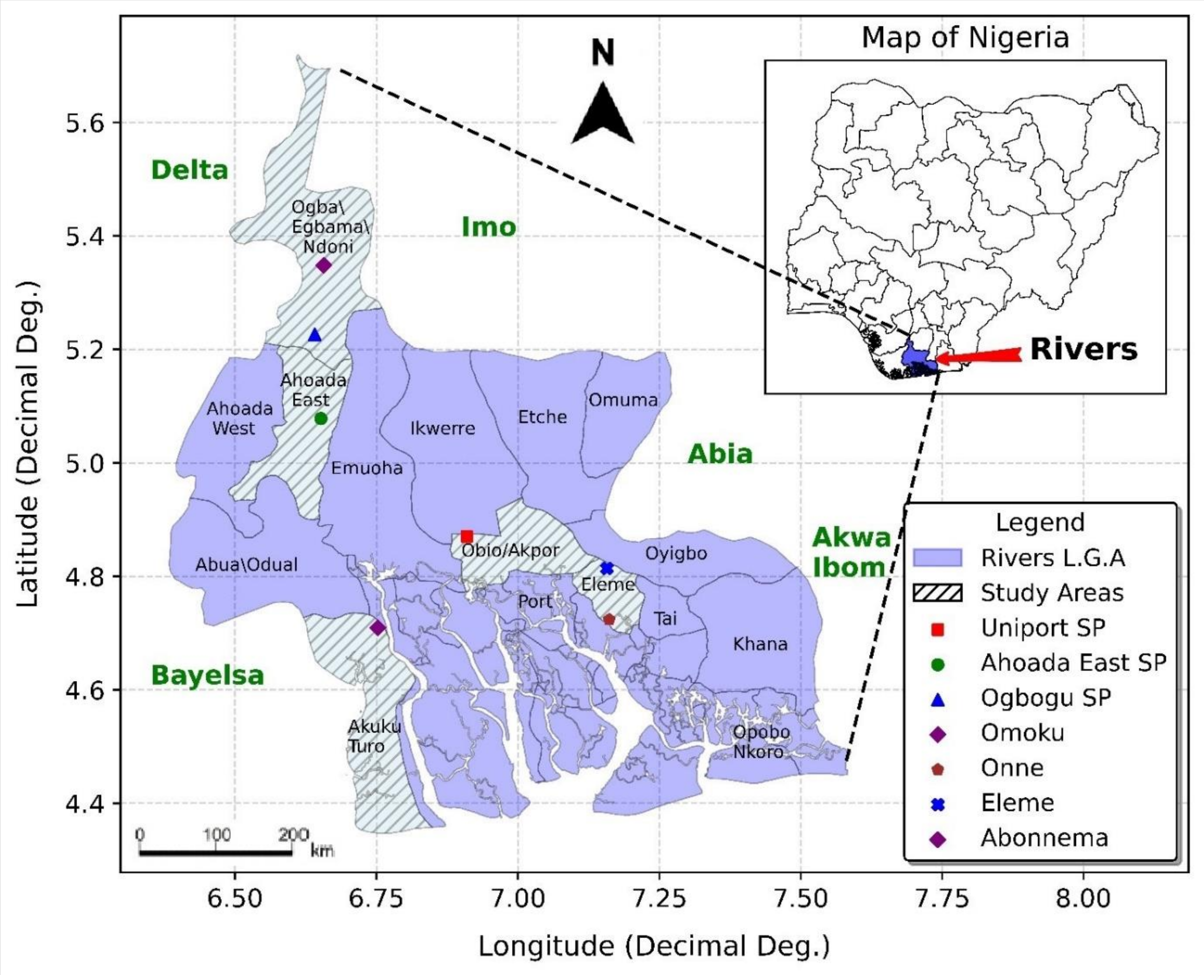


**Figure 2 – Geographical representation of sampling points and primary sampling locations in the study area.**

Rivers State, located in the southern part of Nigeria, covers an area of 11,077 square kilometres and has a population of approximately 7,476,800 (City Population, 2022). Geographically positioned between latitudes 4.74974 and 6.82766, it is bordered by Delta, Imo, Abia, Akwa Ibom, and Bayelsa States (Figure 2). The state capital, Port Harcourt, is a significant economic and educational centre, housing the University of Port Harcourt. The state's landscape is predominantly wetlands, making it a prime location for oil and gas production, which along with agriculture and commerce, drives its economy. Rivers State's infrastructure includes oil fields, pipelines, markets, educational institutions, and transportation systems like roads and river transport.

This study focuses on seven specific locations within Rivers State: Choba, Ahoada, Ogbogu, Omoku, Abonnema, Onne, and Eleme. These areas were chosen for their diverse characteristics, ranging from the urban environment of Port Harcourt in Choba to the agricultural and commercial areas in Ahoada and Eleme. Details of the geographical layout and coordinates of these sites are presented in Figure 2 and Table 1, respectively.

**Table 1 – Geospatial coordinates of the sampling points in the study area.**

| Locations | Sampling Points Coordinates | | | | | | |
|---|---|---|---|---|---|---|---|
| | Choba (Uniport) | Ahoada | Ogbogu | Omoku | Onne | Eleme | Abonnema |
| School | 4.8901°N<br>6.9092°E | 5.0776°N<br>6.6525°E | 5.2259°N<br>6.6414°E | 5.3481°N<br>6.6566°E | 4.7238°N<br>7.1617°E | 4.8139°N<br>7.1575°E | 4.7094°N<br>6.7527°E |
| Bush Area | 4.8906°N<br>6.9092°E | 5.0742°N<br>6.6551°E | 5.2356°N<br>6.6456°E | 5.3246°N<br>6.6685°E | ---<br>--- | ---<br>--- | ---<br>--- |
| Market | 4.8987°N<br>6.9058°E | 5.0765°N<br>6.6536°E | 4.8901°N<br>6.9092°E | 5.3451°N<br>6.6563°E | ---<br>--- | ---<br>--- | ---<br>--- |

*2.3 Population of the Study*

This study was conducted to investigate the atmospheric methane mixing ratio in Rivers State, Nigeria. The population of the study encompasses all the local government areas (LGAs) in Rivers State. There are twenty-three (23) LGAs in Rivers State. The state is renowned for its rich natural resources and its diverse ecosystem. The population of Rivers State is estimated as 7,476,800 people, as reported by City Population (2022).

*2.4 Sample and sampling techniques*

The study's sample comprised atmospheric methane mixing ratio data from seven locations in Rivers State: Choba, Ahoada, Ogbogu, Omoku, Onne, Eleme, and Abonnema. A purposeful sampling approach was employed, selecting areas with high potential for methane generation. In Choba, Ahoada, Ogbogu, and Omoku, three distinct sampling points were chosen – school premises, bush areas, and markets – based on their likelihood of higher methane concentrations due to human activity and waste disposal. In contrast, only one point (school premises) was sampled in Abonnema, Onne, and Eleme.

A total of 150 data points on atmospheric methane mixing ratios were collected monthly over the period from September 2019 to June 2022. The Aeroqual air monitoring equipment was utilized to gather data from all 21 sampling points. The collected data were then recorded in a Microsoft Excel sheet for subsequent analysis.

*2.5 Sources of data*

The study utilized both primary and secondary data sources. Primary data were obtained through ground measurements of atmospheric methane mixing ratios at various locations in Rivers State from September 2021 to June 2022. These measurements were conducted using the Series 500 Portable Air Quality Monitor, positioned 1 metre above the ground. The monitor, equipped with interchangeable sensors and an active fan sampling system, provided accurate, real-time data. The Garmin 10 model GPS was initially used to geo-reference the locations, with subsequent visits for data collection using a methane meter.

Secondary data comprised atmospheric methane mixing ratio readings from the Tropospheric Monitoring Instrument (TROPOMI) satellite, covering a time series from 2019 through June 2022. This data was retrieved using the Sentinel-5 (S5) measurements in the Near Infra-Red (NIR) and Short Wave Infra-Red (SWIR) spectral range. TROPOMI, detailed in the Sentinel User Guides (2021) and by Zhang *et al*. (2020), is a spectrometer on the Sentinel-5P spacecraft, providing regular, consistent measurements of solar radiation reflected from the Earth.

*2.6 Methods of data collection/instrumentation*

For ground-level measurements, a GPS reading was first taken at each location. The atmospheric methane mixing ratio was then measured using a Methane Meter, positioned 1 meter above the ground. Readings were taken monthly from September 2021 to June 2022, typically around 8:00 a.m., with some variations in timing. This bottom-up approach was essential for verifying the national scale Greenhouse Gas Inventory (GHGI), as per the National Academies Press of Sciences Engineering Medicine (2018).

For top-down atmospheric data, the Tropospheric Monitoring Instrument (TROPOMI) satellite was utilized. This Dutch-Finnish instrument, part of the ESA's Sentinel-5 Precursor satellite, detects trace gases including methane. Methane data from 2019 to 2021 for Rivers State, Nigeria, were accessed and downloaded from the TROPOMI website and the ONDA Horizon Cloud Web Portal. The process involved creating a user account, requesting data for specific coordinates, and downloading the required information from the ONDA catalogue.

### 2.7 *Analytical methods of atmospheric methane mixing ratio*

This study employed several analytical methods to assess atmospheric methane mixing ratios over a 10-month period. Descriptive statistics (mean, median, standard deviation, minimum, and maximum values) were calculated for each location to provide an overview of methane variations and data dispersion. A comparative analysis was conducted to identify significant differences in methane ratios among school, bush area, and market sites. Due to non-normal data distribution, the non-parametric Kruskal-Wallis test was used, with ANOVA applied in cases where normality assumptions were met. Additionally, ground-level measurements were compared with TROPOMI satellite data through correlation analysis to evaluate consistency and discrepancies. Trend analysis was performed using the Mann-Kendall test and Sen-slope method. An ARIMA time series model was developed for future methane ratio forecasting, ensuring data stationarity and addressing any autocorrelation with trend-free pre-whitening. An empirical model was also developed to explore the relationship between atmospheric methane and environmental factors like temperature and humidity. This model assumed normal distribution of residual errors and consistent residual variance. Finally, methane emission sources were investigated using a plume chemistry model, employing AERMOD software. This involved steps from data collection on additional variables (VOCs, NOx, $CH_4$, ozone) and meteorological conditions, through model execution, to sensitivity analyses and interpretation of results (Figure 3). The model's outputs were compared to observed methane concentrations to draw conclusions about emission sources and impacts.

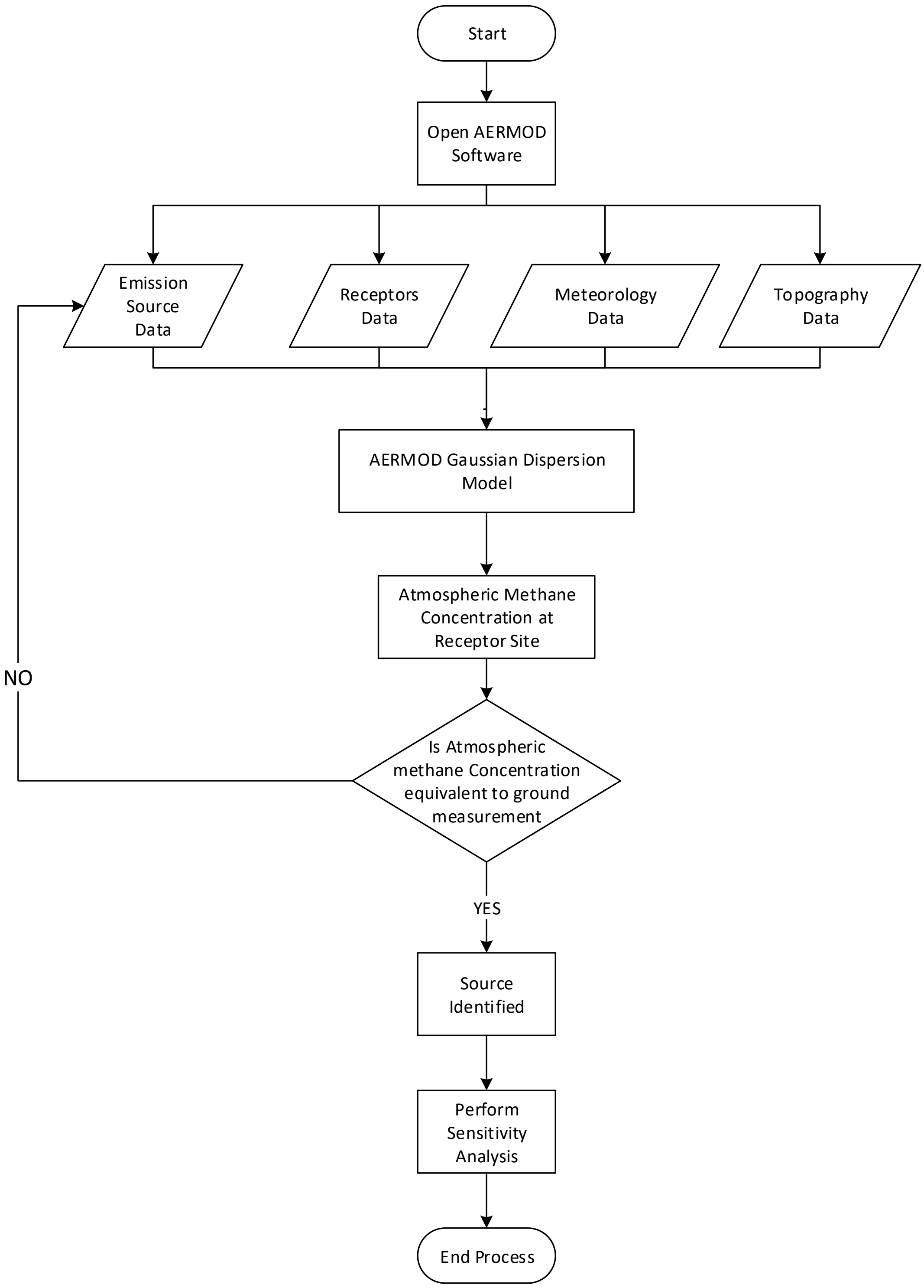


**Figure 3 – Flowchart for plume chemistry analysis.**

## 3. Results

The ground-level atmospheric methane mixing ratios were plotted to understand the monthly variations of the atmospheric methane mixing ratio. Subsequently, descriptive statistics such as mean, median, and skewness were used to quantitatively understand the variations of methane mixing ratios across the sampling points and locations. The results of the ground-level monthly atmospheric methane mixing ratios at the school, bush, and market sampling points for four sampling locations are presented in Figure 4. The ground-level monthly atmospheric methane mixing ratios were collected over a duration of 10 months, starting from September 2021 to June

2022. For the Ahoada sampling location, the result of the atmospheric methane mixing ratio for the 10-month duration is shown in Figure 4b. For the Omoku location, the atmospheric methane mixing ratio's monthly trend is presented in Figure 4d.

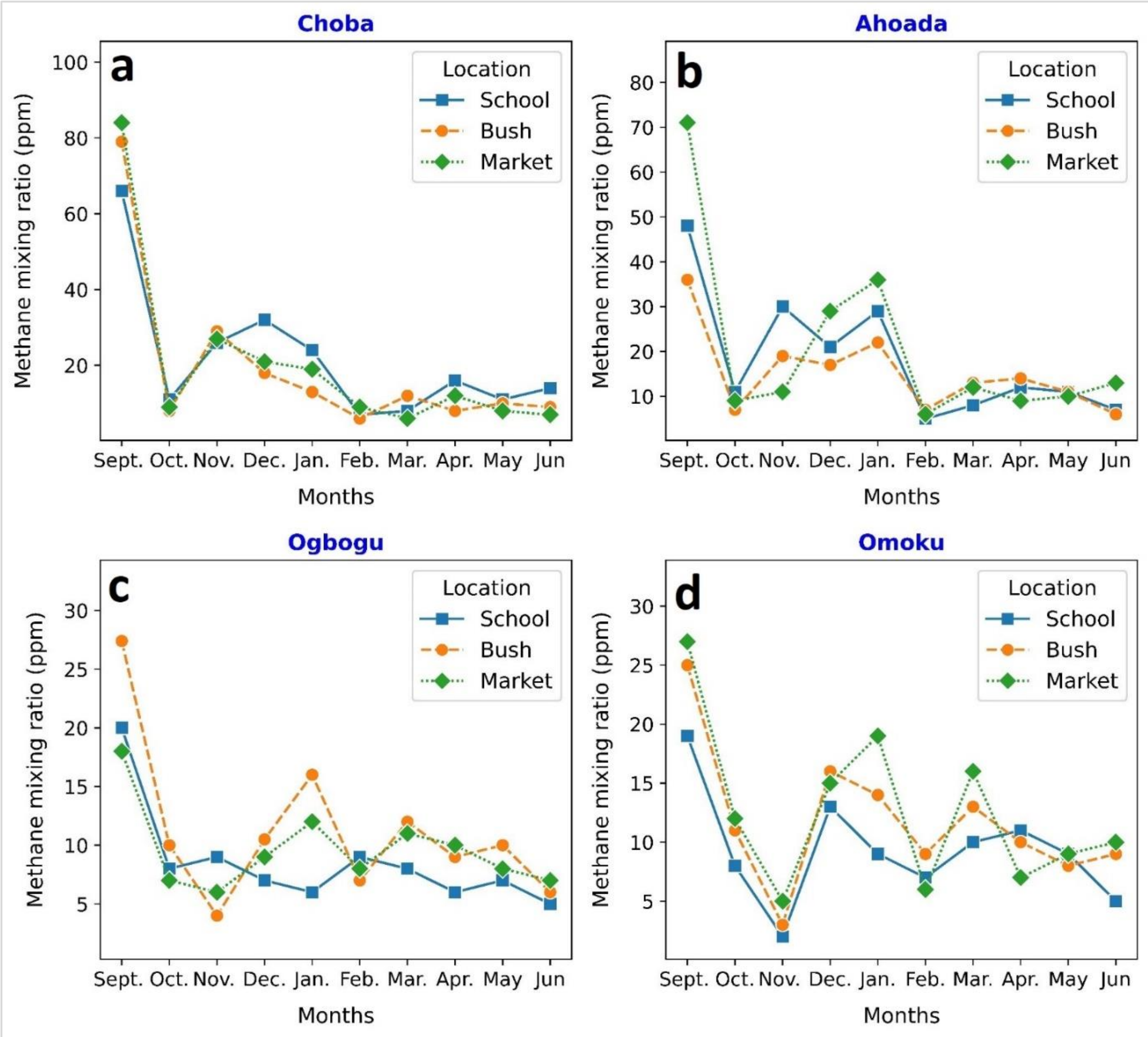


**Figure 4 – Plot of atmospheric methane mixing ratio for the 10 months observation period at the different sampling locations.**

Figure 5 presents the atmospheric methane mixing ratio measurements for three sampling locations (Onne, Eleme, and Abonnema) over a period of six months (September to February). The results indicate variations in the atmospheric methane mixing ratio across the three sampling locations.

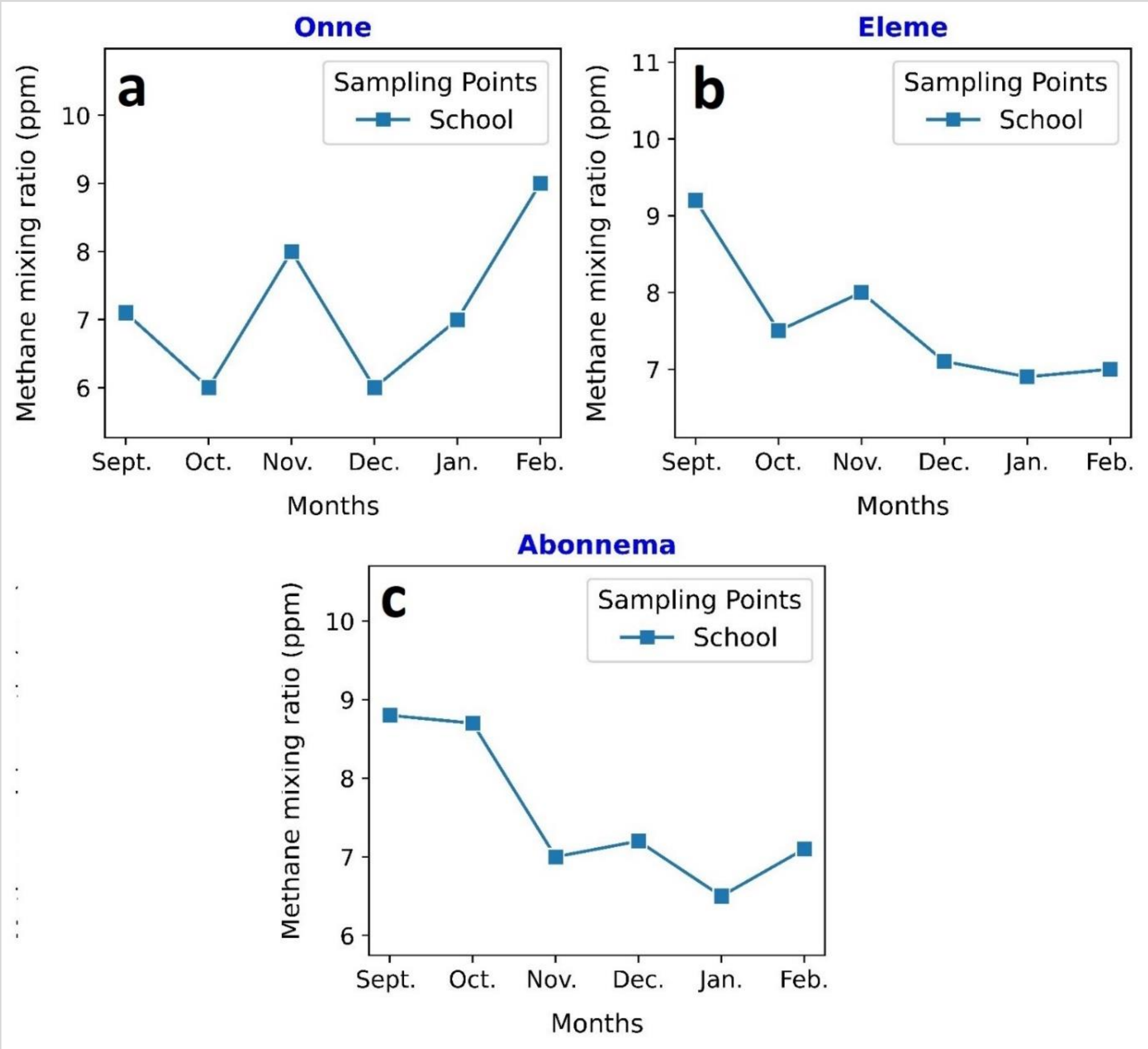


**Figure 5 – Plot of Atmospheric methane mixing ratio for the 10 months observation period at the different sampling locations.**

The results from the descriptive statistics presented in Table 2 shows the average monthly atmospheric methane mixing ratios for the sampling points at the four sampling locations.

**Table 2 – Monthly average of ground level atmospheric methane mixing ratio at the three sampling points for the seven sampling locations.**

| Sampling Locations | Sampling Points | Concentration (ppm) | | | | |
|---|---|---|---|---|---|---|
| | | mean | median | Min | Max | skew |
| Choba | Bush | 19.20 | 11.00 | 6.00 | 79.00 | 2.68 |
| | Market | 20.20 | 10.50 | 6.00 | 84.00 | 2.68 |
| | School | 21.50 | 15.00 | 7.00 | 66.00 | 2.03 |
| Ahoada | Bush | 15.20 | 13.50 | 6.00 | 36.00 | 1.38 |
| | Market | 20.60 | 11.50 | 6.00 | 71.00 | 2.08 |
| | School | 18.20 | 11.50 | 5.00 | 48.00 | 1.27 |
| Ogbogu | Bush | 11.19 | 10.00 | 4.00 | 27.40 | 1.83 |
| | Market | 9.60 | 8.50 | 6.00 | 18.00 | 1.68 |
| | School | 8.50 | 7.50 | 5.00 | 20.00 | 2.61 |
| Omoku | Bush | 11.80 | 10.50 | 3.00 | 25.00 | 1.10 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Market | 12.60 | 11.00 | 5.00 | 27.00 | 1.02 |
| | School | 9.30 | 9.00 | 2.00 | 19.00 | 0.69 |
| Onne | School | 7.18 | 7.05 | 6.00 | 9.00 | 0.61 |
| Abonnema | School | 7.55 | 7.15 | 6.50 | 8.80 | 0.68 |
| Eleme | School | 7.62 | 7.30 | 6.90 | 9.20 | 1.47 |

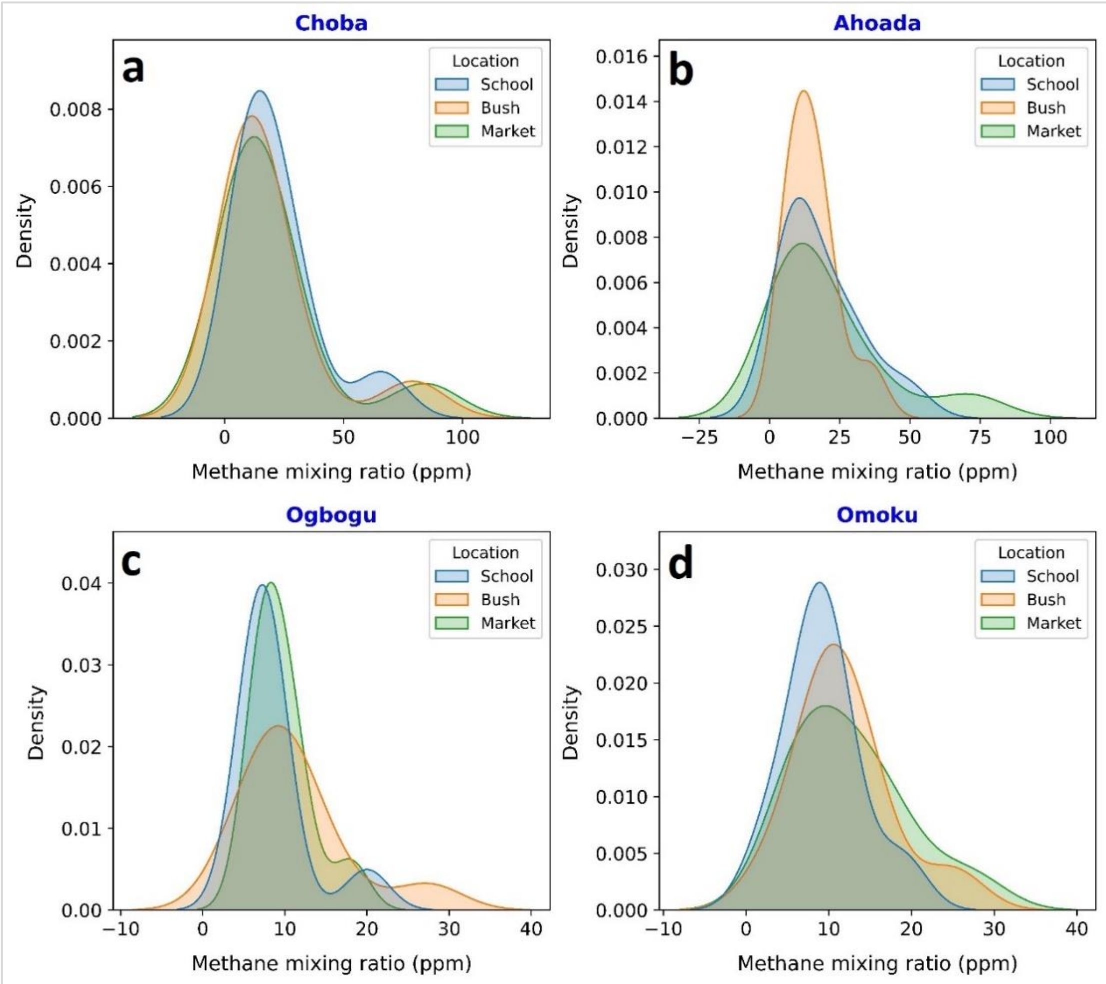


**Figure 6 – Distribution plot of atmospheric methane mixing ratio for the 10 months observation period at the different sampling locations.**

The result of the average atmospheric methane mixing ratio at the four sampling locations, namely: Choba, Ahoada, Ogbogu, and Omoku, is shown in the boxplot in Figure 7, while the descriptive statistic for the atmospheric methane mixing ratio is shown in Table 4.

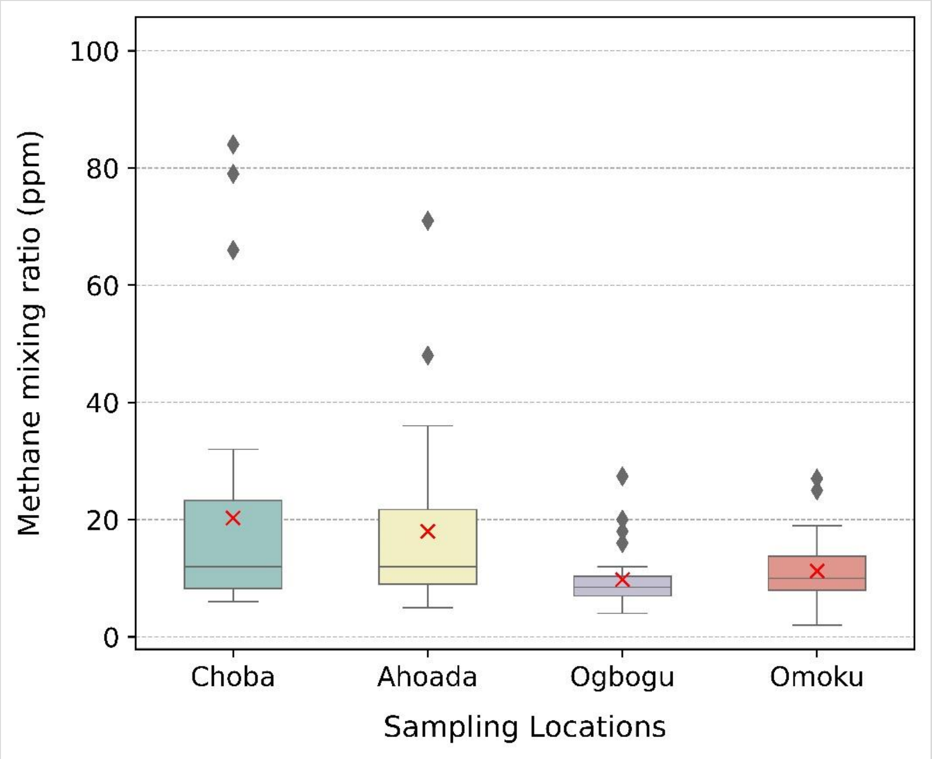


**Figure 7 – Boxplot of atmospheric methane mixing ratio at the four sampling locations.**

**Table 3 – Monthly average of ground level atmospheric methane mixing ratio for the seven sampling locations.**

| Sampling Locations | Concentration (ppm) | | | | |
|---|---|---|---|---|---|
| | mean | Median | Min | max | skew |
| Choba | 20.30 | 12.00 | 6.00 | 84.00 | 2.28 |
| Ahoada | 18.00 | 12.00 | 5.00 | 71.00 | 2.07 |
| Ogbogu | 9.76 | 8.50 | 4.00 | 27.40 | 2.10 |
| Omoku | 11.23 | 10.00 | 2.00 | 27.00 | 1.04 |
| Onne (School) | 7.18 | 7.05 | 6.00 | 9.00 | 0.61 |
| Abonnema (School) | 7.55 | 7.15 | 6.50 | 8.80 | 0.68 |
| Eleme (School) | 7.62 | 7.30 | 6.90 | 9.20 | 1.47 |

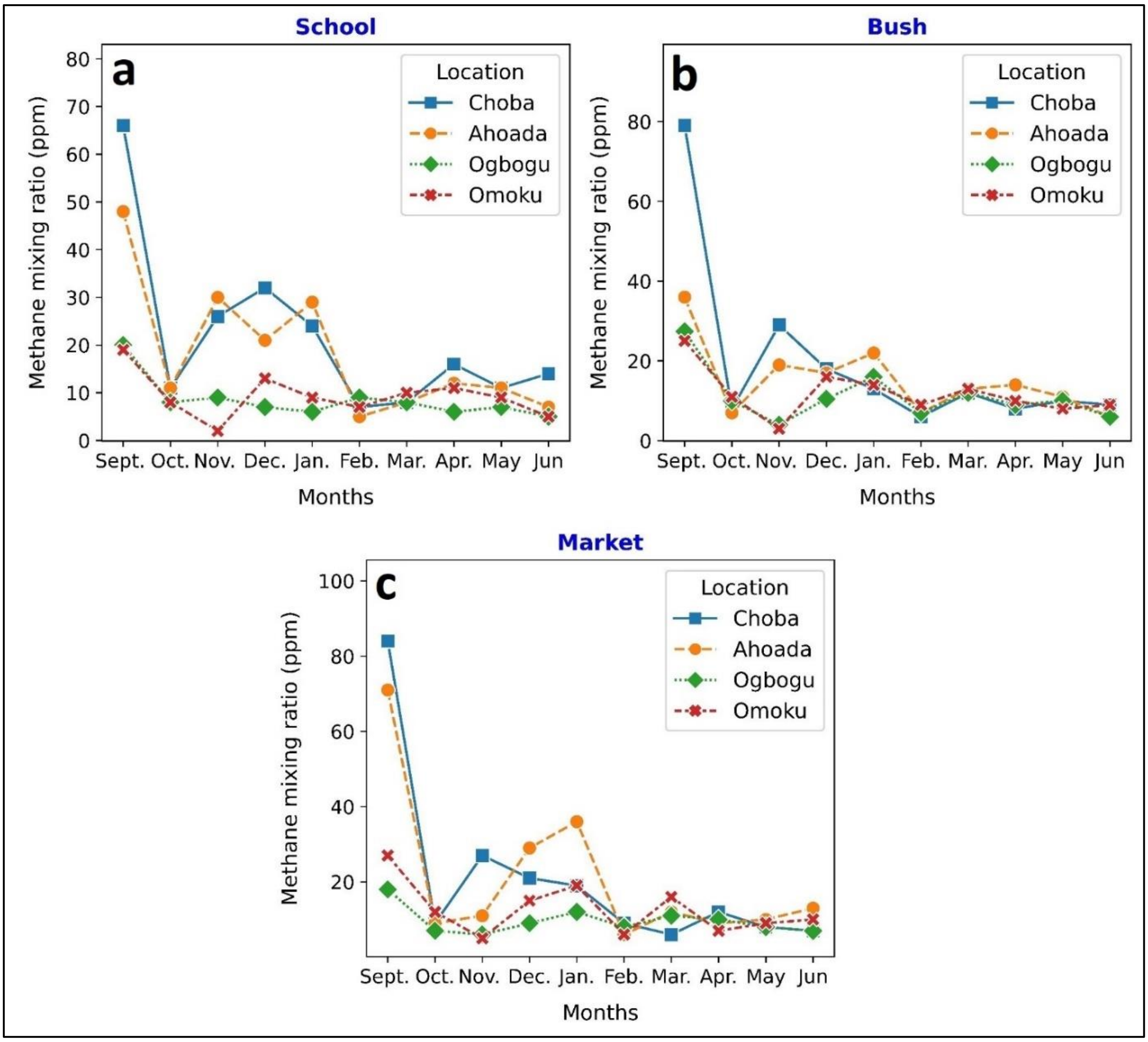


**Figure 8 – Plot of atmospheric methane mixing ratio for the 10 months observation period for a sampling location for the four sampling towns.**

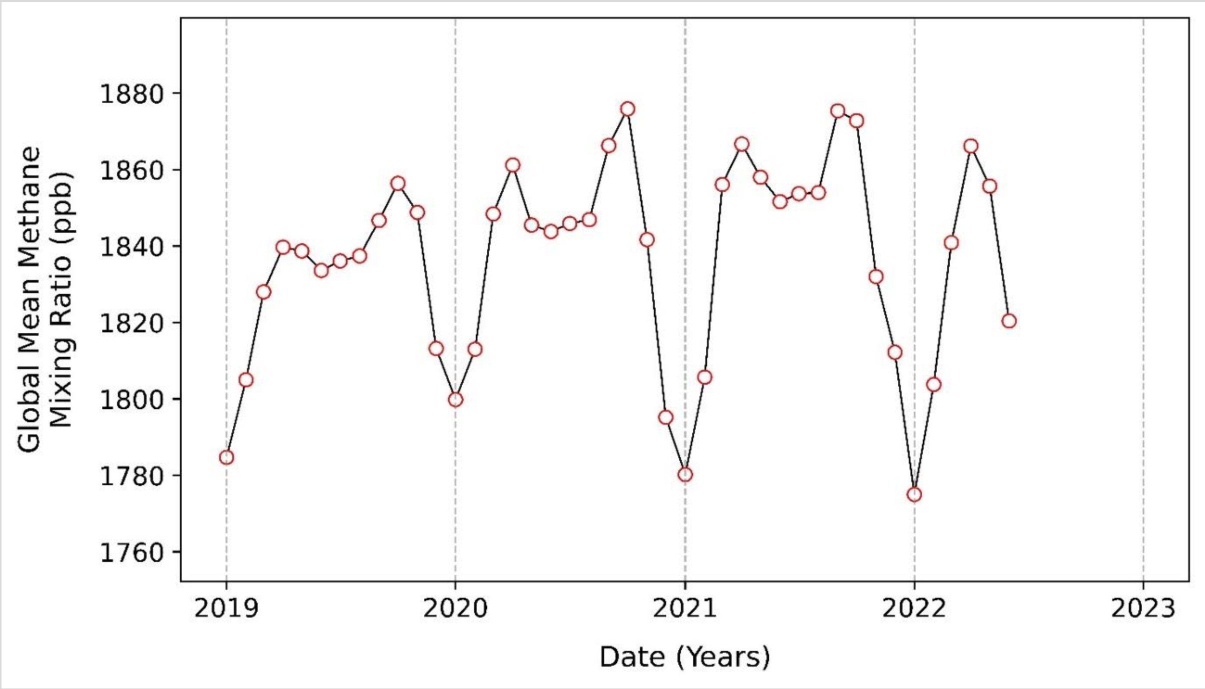


**Figure 9 – Global mean atmospheric methane mixing ratio (ppb).**

**Table 4 – Test of significance of the ground level atmospheric methane mixing ratio for the sampling points (market, bush, and school) at Choba location using Kruskal Wallis test.**

| Statistic | Values |
|---|---|
| K (Observed value) | 0.858 |
| K (Critical value) | 5.991 |
| DF | 2 |
| p-value (Two-tailed) | 0.651 |
| Alpha | 0.05 |

**Table 5 – Test of significance of the ground level atmospheric methane mixing ratio for the sampling points (market, bush, and school) at Ahoada location using Kruskal Wallis test.**

| | |
|---|---|
| K (Observed value) | 0.010 |
| K (Critical value) | 5.991 |
| DF | 2 |
| p-value (Two-tailed) | 0.995 |
| Alpha | 0.05 |

**Table 6 – Test of significance of the ground level atmospheric methane mixing ratio for the sampling points (market, bush, and school) at Ogbogu location using Kruskal Wallis test.**

| | |
|---|---|
| K (Observed value) | 2.528 |
| K (Critical value) | 5.991 |
| DF | 2 |
| p-value (Two-tailed) | 0.282 |
| Alpha | 0.05 |

**Table 7 – Test of significance of the ground level atmospheric methane mixing ratio for the sampling points (market, bush, and school) at Omoku location using ANOVA test.**

| Source | DF | Sum of squares | Mean squares | F | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 59.267 | 29.633 | 0.871 | 0.430 |
| Error | 27 | 918.100 | 34.004 | | |
| Corrected Total | 29 | 977.367 | | | |

*Computed against model Y=Mean(Y)*

**Table 8 – Test of significance of the ground level atmospheric methane mixing ratio for the sampling locations (market, bush, and school) using Kruskal Wallis test.**

| Statistic | Values |
|---|---|
| K (Observed value) | 12.490 |
| K (Critical value) | 7.815 |
| DF | 3 |
| p-value (Two-tailed) | 0.006 |
| Alpha | 0.05 |

**Table 9 – Dunn multiple comparison test for atmospheric methane mixing ratio at sampling location. Values with Different superscripts (a, b, c) were significantly different from each other (p < 0.05) and those with the same superscripts were not significantly different.**

| Sampling Location | Frequency | Sum of ranks | Mean of ranks | Groups | |
|---|---|---|---|---|---|
| Atm. mix. ratio \| Ogbogu | 30 | 1332.500 | 44.417 | A | |
| Atm. mix. ratio \| Omoku | 30 | 1669.500 | 55.650 | A | B |
| Atm. mix. ratio \| Choba | 30 | 2125.500 | 70.850 | | B |
| Atm. mix. ratio \| Ahoada | 30 | 2132.500 | 71.083 | | B |

**Table 10 – Pearson correlation between the atmospheric methane ($CH_4$) mixing ratio from TROPOMI satellite and Ground level methane atmospheric mixing ratio.**

| Variables | $CH_4$ (Tropomi) | $CH_4$ (Ahoada) | $CH_4$ (Choba) | $CH_4$ (Ogbogu) | $CH_4$ (Omoku) |
|---|---|---|---|---|---|
| $CH_4$ (Tropomi) | **1** | | | | |
| $CH_4$ (Ahoada) | 0.088 | **1** | | | |
| $CH_4$ (Choba) | 0.208 | **0.930** | **1** | | |
| $CH_4$ (Ogbogu) | 0.437 | **0.733** | **0.817** | **1** | |
| $CH_4$ (Omoku) | 0.354 | 0.497 | **0.684** | **0.646** | **1** |

Values in bold are different from 0 with a significance level alpha=0.05

**Table 11 – Scaling factor for atmospheric methane mixing ratio to be applied to the TROPOMI data.**

| Date | Scaling Factor (Ahoada) | Scaling Factor (Choba) | Scaling Factor (Ogbogu) | Scaling Factor (Omoku) | Monthly Average Scaling Factor |
|---|---|---|---|---|---|
| 9/1/2021 | 25.59 | 35.19 | 10.66 | 10.13 | 20.40 |
| 10/1/2021 | 5.87 | 5.87 | 4.27 | 4.27 | 5.07 |
| 11/1/2021 | 16.00 | 13.86 | 4.80 | 1.07 | 8.93 |
| 12/1/2021 | 11.20 | 17.06 | 3.73 | 6.93 | 9.73 |
| 1/1/2022 | 15.46 | 12.80 | 3.20 | 4.80 | 9.06 |
| 2/1/2022 | 2.67 | 3.73 | 4.80 | 3.73 | 3.73 |
| 3/1/2022 | 4.27 | 4.27 | 4.27 | 5.33 | 4.53 |
| 4/1/2022 | 6.40 | 8.53 | 3.20 | 5.87 | 6.00 |
| 5/1/2022 | 5.87 | 5.87 | 3.73 | 4.80 | 5.07 |
| 6/1/2022 | 3.73 | 7.47 | 2.67 | 2.67 | 4.13 |
| | | | | **Average** | 7.67 |

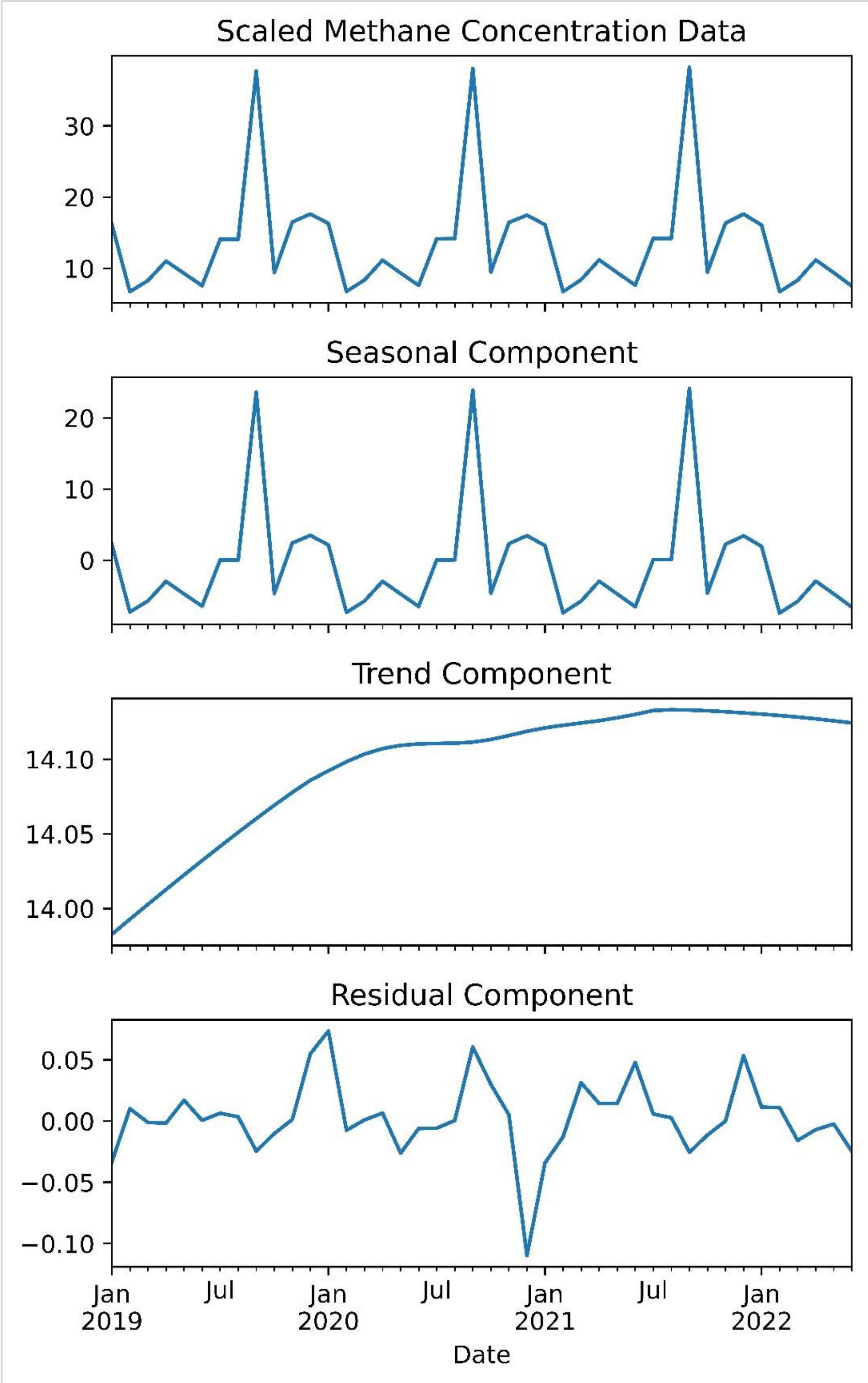


**Figure 10 – Decomposition of the atmospheric methane mixing ratio to detect trend, and seasonality.**

## 4. Discussion

The study's comprehensive analysis of atmospheric methane mixing ratios in Rivers State offers valuable insights into the complex dynamics of methane emissions. These insights are informed by variations in local activities, environmental conditions, and the interplay between ground-level observations and global satellite data.

Across different locations in Rivers State, notably Choba, Ahoada, Ogbogu, and Omoku, a common trend emerges. September typically records the highest atmospheric methane mixing ratios at various sampling points, as shown in Figures 4a-d and detailed in Table 2. This peak is followed by a decline in October and a subsequent rise towards the end of the year. The school area in Choba consistently shows higher methane ratios, indicating significant emissions likely due to increased human activity. The distribution of methane mixing ratios at Choba (Figure 6) further underscores the presence of outliers and the usefulness of median values over means in these analyses.

The comparative analysis of methane mixing ratios across various locations, as depicted in Figure 7 and Table 3, highlights Choba as having the highest average methane ratio. This could be attributed to a combination of industrial, educational, and urban activities. The median values suggest Choba and Ahoada as significant emission areas, indicating a spatial variability in emission intensity.

The monthly methane mixing ratios for various sampling points, presented in Figure 8, reveal that school areas in Choba and Ahoada generally exhibit higher methane levels. This observation points towards these locations as notable contributors to regional methane emissions. The inconsistencies observed at market sampling points across locations reflect the complexity and variability in methane emission sources.

The analysis of global atmospheric methane mixing ratios, derived from TROPOMI satellite data (Figure 9), shows a gradual increase over the study period, interspersed with periodic dips, particularly in January each year. This pattern indicates the influence of seasonal factors on methane emissions. The Pearson correlation analysis between TROPOMI satellite data and ground-level measurements (Table 10) suggests a positive correlation, although not statistically significant. This finding implies a potential alignment in broader trends between global and local methane levels.

The statistical tests, including Kruskal-Wallis and ANOVA as shown in Tables 3 to 5, reveal no significant differences in methane ratios among sampling points within each location. However, significant differences were noted across the four sampling locations (Table 8), suggesting localized variability in methane emissions.

The Seasonal and Trend decomposition using Loess (STL) on the scaled TROPOMI data (Figure 10) reveals clear seasonal patterns in methane emissions. The Mann-Kendall test applied to the de-seasonalized data indicates no significant long-term trend, underscoring the importance of considering both local and global factors in understanding methane emission patterns.

In summary, this study elucidates the multifaceted nature of methane emissions in Rivers State, impacted by local factors such as human activities, land-use patterns, and meteorological conditions, as well as global trends. The findings highlight the importance of continuous monitoring and analysis at both local and global scales to develop a comprehensive understanding of methane emissions, which is crucial for effective environmental policy-making and climate change mitigation strategies.

## 5. Conclusion

This study underscores the critical importance of understanding atmospheric methane mixing ratio fluctuations, particularly in regions like Rivers State. Methane's significant role as a potent greenhouse gas and its impact on climate dynamics necessitates a thorough examination of its sources and the factors influencing its variability. This is crucial considering methane's global warming potential and its interaction with other atmospheric components like ozone.

Key findings from the study include the observation that the Choba sampling site exhibited a notably higher atmospheric methane mixing ratio compared to other areas. This highlights potential environmental vulnerabilities, especially when considering the combined effects of methane and ozone. The spatial variations in methane mixing ratios point to the need for tailored strategies that address the unique emission characteristics of each area. The study identified September as a critical month with elevated methane levels, suggesting a need for targeted interventions during this period.

Environmental factors such as temperature and humidity, along with human activities, were found to significantly influence methane levels. Landfills, particularly those near markets, emerged as major sources of methane, calling for improved waste management practices to mitigate emissions.

Based on these insights, the study recommends several strategies for addressing methane emissions in Rivers State. Continuous and detailed monitoring of methane levels is essential for informed policy-making. Enhancing global research partnerships can aid in consistent data collection and analysis. Converting flared gas to Liquefied Natural Gas (LNG) presents an opportunity to reduce emissions while capitalizing on the region's natural gas reserves. The oil and gas sectors, major contributors to methane emissions, require strict regulation and oversight. Efficient waste management near markets and residential areas is also crucial.

The study acknowledges certain limitations. Using global average values for atmospheric methane mixing ratios may not fully capture the specific emission characteristics of Rivers State. Additionally, potential inaccuracies from the instrumentation, such as the Aeroqual Methane Meter and the GPS device, must be considered. The finding that landfills slightly surpassed oil and gas production areas as methane sources was unexpected, highlighting the complex and varied origins of methane emissions. This emphasizes the need for a multifaceted approach to effectively mitigate methane emissions and address their environmental impacts.

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