Asian Journal of Environment & Ecology

16(4): 63-73, 2021; Article no.AJEE.76321
ISSN: 2456-690X

Analysis of Temporal Variations of Air Pollutant Concentrations in Ogoni Area, Niger Delta Region, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEE/2021/v16i430260
Editor(s):
(1) Dr. Wen-Cheng Liu, National United University, China.
Reviewers:
(1) Chuanxi Yang, Qingdao University of Technology, China.
(2) Fikrat M. Hassan, The University of Baghdad, Iraq.
Complete Peer review History: http://www.sdiarticle4.com/review-history/76321

Original Research Article

Received 12 August 2021
Accepted 25 October 2021
Published 03 November 2021

ABSTRACT

This study investigated the temporal variations of air pollutant concentrations in Ogoni area, Niger Delta, Nigeria. The study used hourly data measured over 8 hours for 12 months at selected locations within the area. The analyses were based on time series and time variations techniques in Openair packages of R programming software. The variations of air pollutant concentrations by time of day and days of week were simulated. Hours of the day, days of the week and monthly variations were graphically simulated. Variations in the mean concentrations of air pollutants by time were determined at 95 % confidence intervals. Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), ground level Ozone (O_3) and fine particulate matter ($PM_{2.5}$) concentrations exceeded permissible standards. Air pollutant concentrations showed increase in January, February, November and December compared to other months. Simulation showed that air pollutants varied significantly by hours-of-the-day and days-of-the-week and months-of-the-year. Analysis of temporal variability revealed that air pollutant concentrations increased during weekdays and decreased during weekends. The temporal variability of air pollutants in Ogoni area showed that anthropogenic activities were the main sources of air pollution in the area, therefore further studies are required to determine air pollutant dispersion pattern and evaluation the potential sources of air pollution in the area.

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Keywords: R programming; time series; time variations; hours-of-the-day; days-of-the-week.

1. INTRODUCTION

Global atmospheric circulation patterns are capable of rapidly transporting air pollutants across boundaries around the world [1]. In recent times, the problems of air pollution have been on the increase worldwide, the World Health Organization (WHO) has ranked air pollution as the 13th major cause of mortality in the world today [2-3]. Several health effects have been associated with short-term (few hours, days, weeks and months) exposure to air pollution [4-6]. Short-term exposure to air pollution can cause damage to the lung function and respiratory infectious diseases such as wheezing, cough and shortness of breath [4-5, 7]. Study has shown that hourly or daily exposure to elevated levels of air pollutant concentrations above permissible can aggravate asthma symptoms and trigger respiratory or cardiovascular health problems [7]. Also, short-term exposure has been associated with reduced life expectancy and premature deaths [4]. The deterioration of air quality is believed to be more dangerous to human health compared to land and water pollution [8]. This is because it is absolutely very difficult to effectively clean a polluted ambient air as compared to polluted land and water. Therefore, it is necessary to carry out air pollution study in order to address its inherent danger to human being and the environment.

The analysis of the temporal variation of air pollutants is necessary to assess their potential effects on human health [6]. Providing scientific information on how air pollutants vary with time in the area will be useful in safeguarding human health [6]. Ropkins and Carslaw [9] have demonstrated the use of time series and time variation for temporal analysis of air quality. This method was used to determine the variations of ambient temperature with time at monitoring sites in Makkah, Saudi Arabia [6]. Also, a similar approach was used to analyze the spatial and temporal variation of air pollution in Makkah, Saudi Arabia [10]. Studies has shown that short-term changes in air quality can be revealed through the simulations of hourly, daily and weekly variations of air pollutants [6, 11, 12].

Currently there is an escalating problem of air pollution in the Niger Delta, especially with the appearance of *black carbon (BC)* commonly called *black soot (BS)* episodes in the atmosphere of the region. Also, United Nations Environmental Programmes [13] reported high levels of air pollution in Ogoni area and recommended the conduct of a comprehensive air quality monitoring across Ogoni area. Thus, it is widely known that Ogoni area is a hydrocarbon polluted area of the Niger Delta of Nigeria, which is of environmental and public health concern [13]. Air pollution in Ogoni area of the Niger Delta has been attributed mainly to oil and gas activities, vehicular emissions, industrial activities among others [13-16]. The analysis of the temporal variation of air pollutants in the area is necessary in order to provide scientific information on the variation of air pollutants by time of the day, which can help reveal useful information concerning their potential sources [12. Therefore, this study analyzed the temporal variations of air pollutant concentrations in Ogoni area, Niger Delta region, Nigeria using diurnal hourly measured data. It provided a useful way of characterizing air pollution for a wide range of pollutants [12,17]. The study attempted to provide significant understanding of air pollutants characteristics and temporal trends as well as potential sources in the area.

2. METHODOLOGY

The study was carried out in Ogoni area (Fig. 1) located between Latitude 4.7798^{0}N and Longitude 7.1528^{0}E in the Niger Delta region of Nigeria. The air quality data for this study were measured at selected locations within Ogoni area. Monthly measurement was conducted from January to December, 2019. Daily monitoring was carried out between 6:00am and 4:00pm and hourly values of measured air pollutants were averaged up to 8 hours to give 8-hour mean values. The air pollutants monitored in this study were Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), ground level Ozone (O_3), Ammonia (NH_3), Total volatile organic compounds (TVOC) Total suspended particulate matter (TSP), PM_{10} particulate matter and $PM_{2.5}$ particulate matter). Measured data were aggregated, processed and analyzed using time series and time variations techniques in Openair packages of R programming software [12]. Variations in the mean concentrations of air pollutants by time were determined at 95 % confidence intervals.

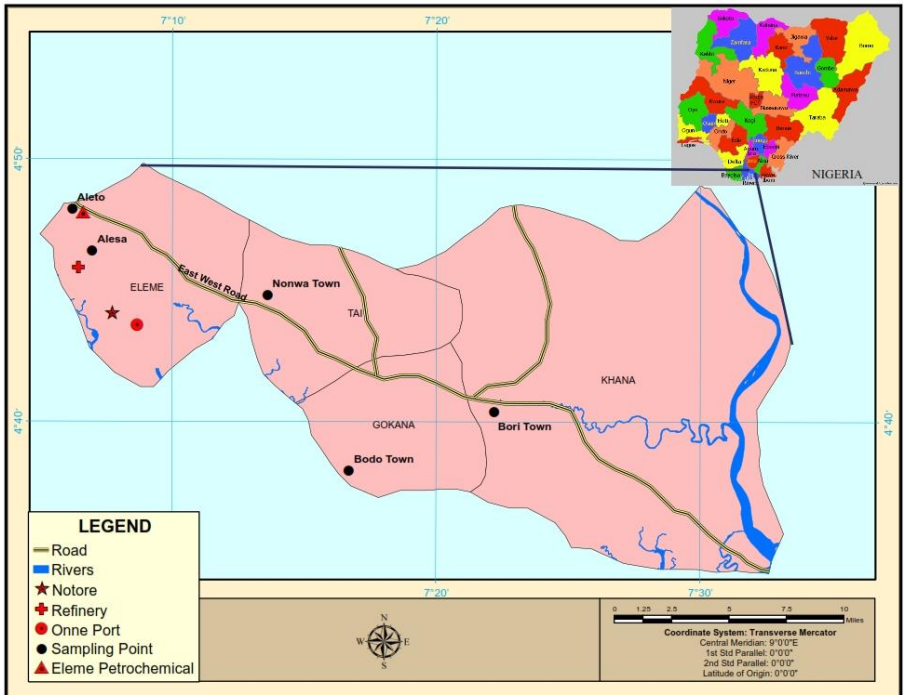


Fig. 1. Map of study area showing sampling locations

Code use to create time series plots in R programming language is:

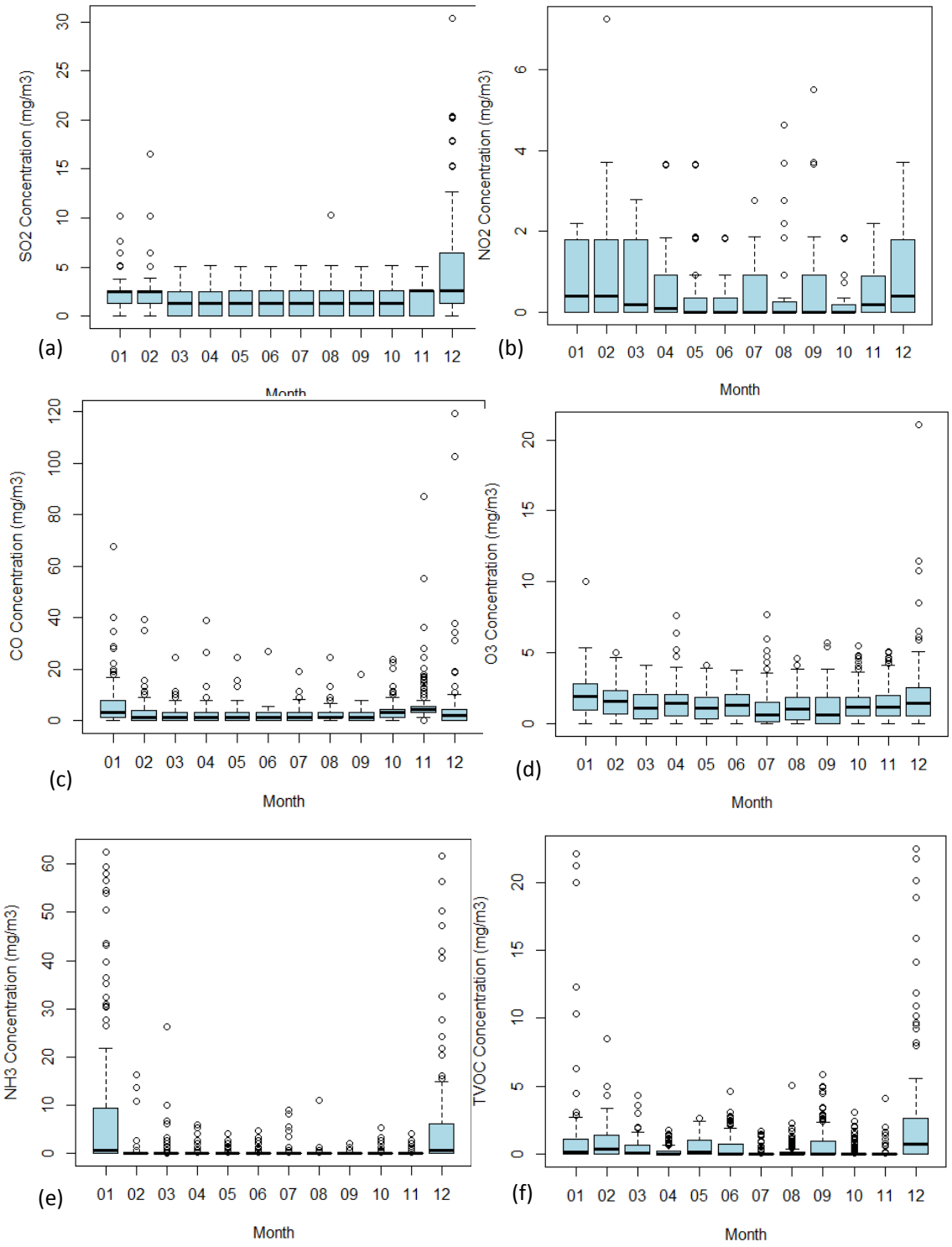
>timePlot(data.frame, pollutant = c("pollutant.name1",
> + "pollutant.name2", "pollutant.name3"))
Code used to create time variation plots is:
>timeVariation(data.frame, pollutant = c("pollutant.name1",
> + "pollutant.name2", "pollutant.name3"),
>normalise = TRUE)

3. RESULTS AND DISCUSSION

The statistical summary of measured pollutant concentrations in the study area is shown in Table 1. The minimum, maximum, mean and standard deviation in comparison with the Federal Ministry of Nigeria (FMEnv) air quality standards and the United States National Ambient Air Quality standards (NAAQS) are shown in Table 1. The result in Table 1 showed that the mean value of SO_2 exceeded FMEnv permissible limit by 592.3% and NAAQS permissible limit by 800%; mean NO_2 value exceeded FMEnv permissible limit by 445.5% and NAAQS permissible limit by 215.8%; while the mean value of CO is within both limits. Similarly, mean concentration of O_3 exceeded FMEnv permissible limit by 1,150% and NAAQS permissible limit by 900%; the mean concentration of PM_{10} falls within the NAAQS limit; while the mean value of $PM_{2.5}$ exceeded NAAQS permissible limit by 142.3%. These results showed that the area is polluted by SO_2, NO_2, O_3 and $PM_{2.5}$ (fine particles with aerodynamic diameter of 2.5μm or less).This level of air pollution observed in the area is capable of posing adverse health hazards to the public [7, 18].

The box-whisker plots (Fig. 2) were carried out to visually assess the monthly and seasonal variations of the air pollutant concentrations. Fig. 2 showed how air pollutant concentrations vary by month of the year. The lower and upper whisker lines indicate the lowest and highest concentration values. The bottom and top horizontal lines show the 25^{th} and 75^{th} quantiles of the air pollutant concentrations. The dark horizontal lines indicate the median values. It can be observed from Fig. 2(a) that SO_2 varied monthly with peak and maximum concentrations in December; NO_2 varied monthly with peaks in January, February, March and December and maximum concentrations observed in February and December; the variations of CO and O_3 showed monthly peaks in January with maximum concentrations in December. Similarly, the variation of NH_3 showed peak in January and

maximum concentrations in January and December; concentrations of TVOC varied with peak in December and maximum concentrations in January and December; while the variations of particulate matter showed monthly peaks in February and maximum concentrations in January.



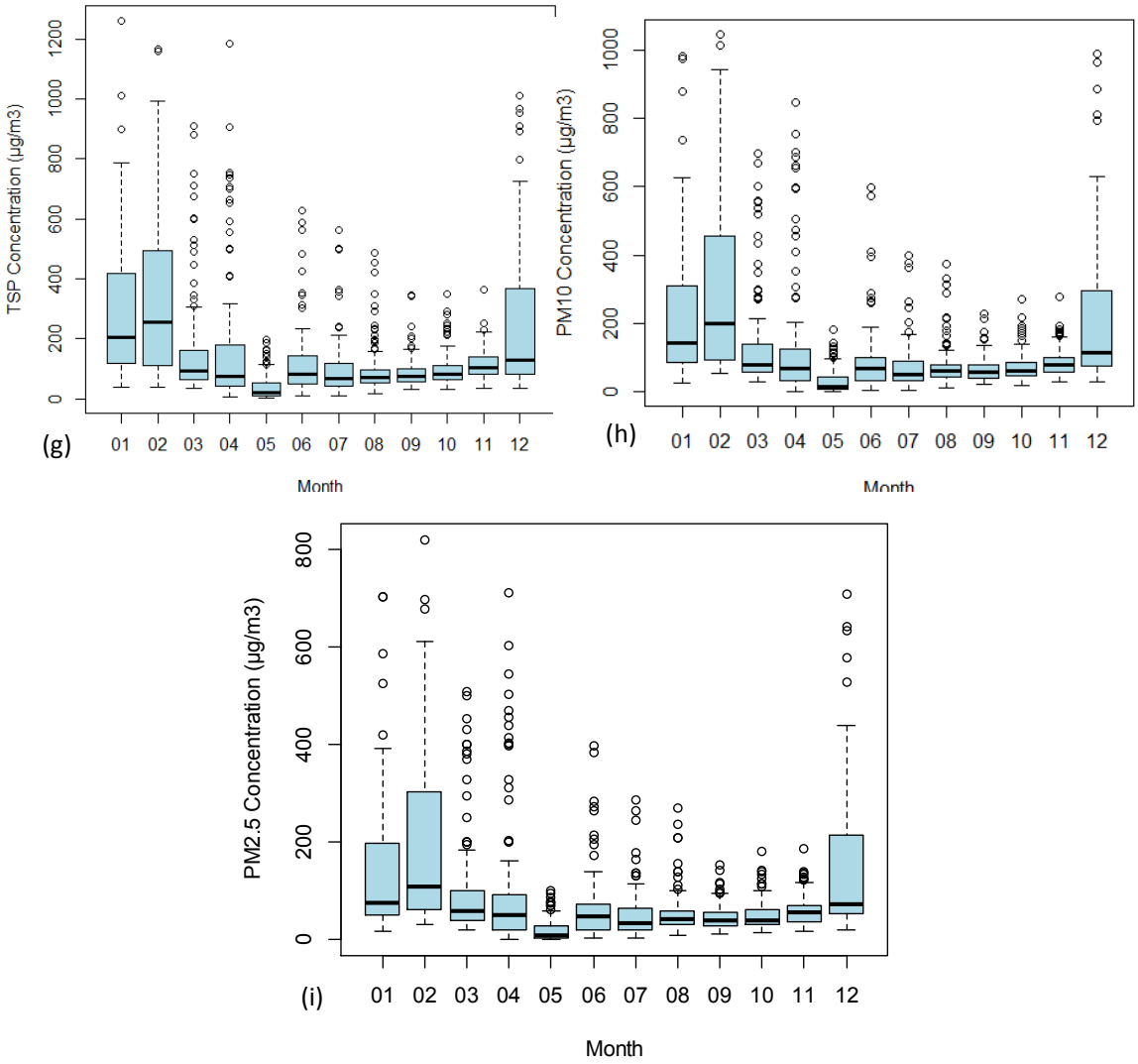


Fig. 2. Box-Whisker plot of Monthly air pollutants concentrations in the study area

The time series plots of air pollutant concentrations measured in the study area are shown in Figs. 3 to 5. It is clearly observed in Fig. 3 that the concentrations of SO_2 showed increase in January, February and December and varied steadily from March to November; NO_2 concentrations showed steady variation in all the months (from January to December). CO concentrations showed increase in January, February, November and December and varied steadily from March to October. Fig. 4 shows that NH_3 concentrations increased in January and December and showed slight increase in March; while O_3 and TVOC concentrations showed increase in January and December, and then varied steadily from February to November. Similarly, it can be observed in Fig. 5 that concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) showed increase in January to April and December. These findings on time series variations of air pollutants in the study area corroborated with similar studies carried out in parts of the area by [19-20].

It is clear from Figs. 2 to 5 that the concentrations of air pollutants showed increase in January, February, November and December, which are the months of dry season, and showed decrease in March to October, which are the months of rainy season [19]. Thus, air pollutant concentrations were higher in the months of dry season and lower in the months of rainy season. The high concentrations in the dry season can be attributed to the harmattan wind that transports

Table 1. Statistical summary of pollutants measured in the study area

Parameter	SO_2 (mg/m^3)	NO_2 (mg/m^3)	CO (mg/m^3)	O_3 (mg/m^3)	NH_3 (mg/m^3)	TVOC (mg/m^3)	TSP (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)
Min.	0.0	0.0	0.0	0.0	0.0	0.0	6.0	3.0	1.0
Max.	30.4	3.7	119.0	11.5	62.6	22.5	12.6	1045.0	818.0
Mean	1.8	0.6	3.5	1.5	1.5	0.7	154.2	126.2	84.8
Stdv.	2.3	0.8	7.0	1.4	6.4	2.0	180.7	156.4	109.9
FMEnv limit	**0.26**	**0.11**	**22.8**	**0.12**					
NAAQS limit	**0.2**	**0.19**	**10.0**	**0.15**				**150.0**	**35.0**

air pollutants from different sources around the area; while the low concentrations in the rainy season may be due to atmospheric wash-out of the air pollutants by precipitation during the monsoon season. This behavior of the air pollutants is in agreement with similar studies carried out in parts of the area by [19, 21].

3.1 Temporal Variability of Air Pollutant Concentrations in Study Area

The trends in the temporal variability of air pollutant concentrations in the study area are shown in Figs. 6 to 8. The shaded portions of the figures represent the 95 % confidence intervals of the mean concentrations. The figures show how the concentrations of air pollutants measured in the area vary by hours-of-the-day and days-of-the-week and months-of-the-year. The result (Fig. 6) indicates the concentrations of SO_2 show a steady increase from the morning hours to a peak around 10:00am and then decrease steadily toward evening time (around 4:00pm); NO_2 showed steady increase from 6:00am to around 4:00pm; while concentrations of CO increase from 6:00am to a peak around 10:00am, decrease till 3.00pm and then increases around 4:00pm. As observed

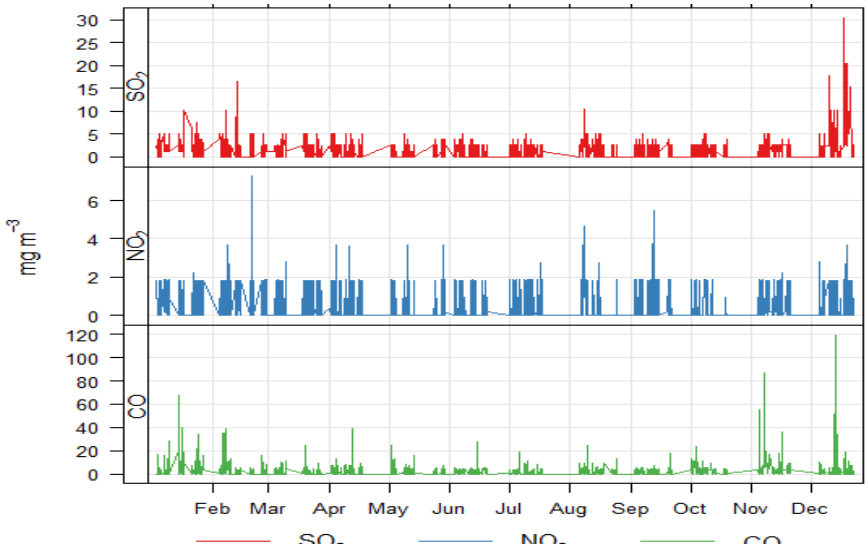


Fig. 3. Monthly variation of SO_2, NO_2 and CO measured in the study area

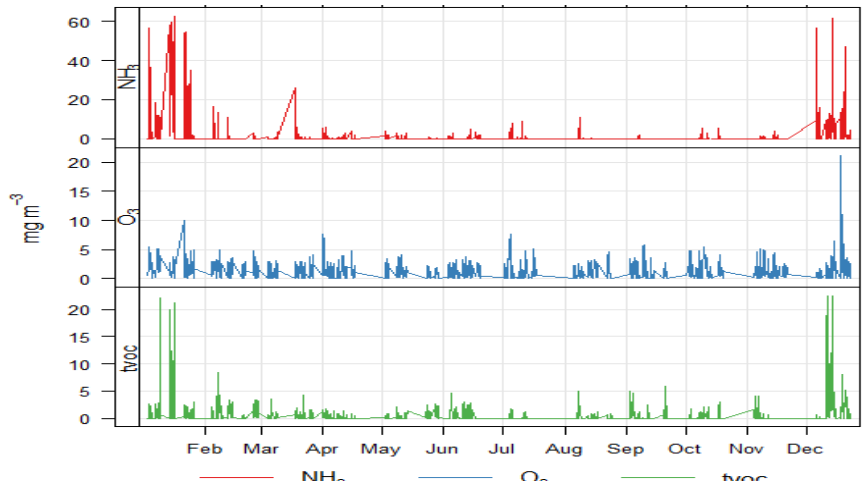


Fig. 4. Monthly variation of NH_3, O_3 and TVOC measured in the study area

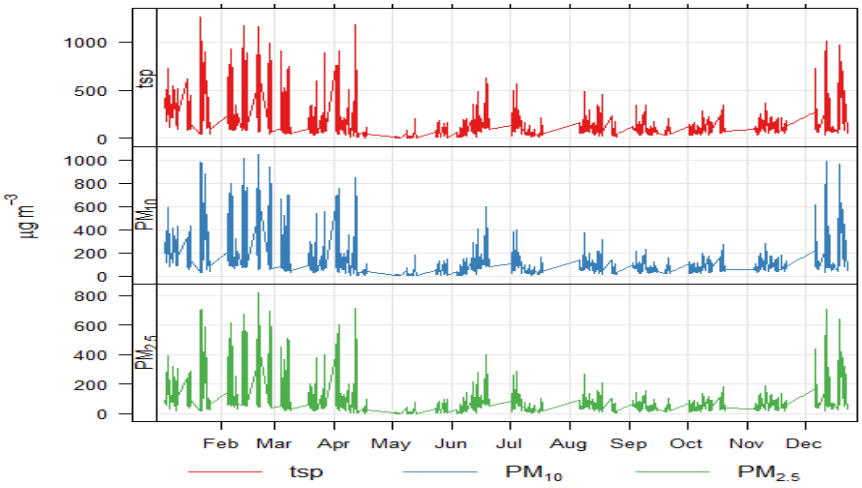


Fig. 5. Monthly variation of TSP, PM_{10} and $PM_{2.5}$ measured in the study area

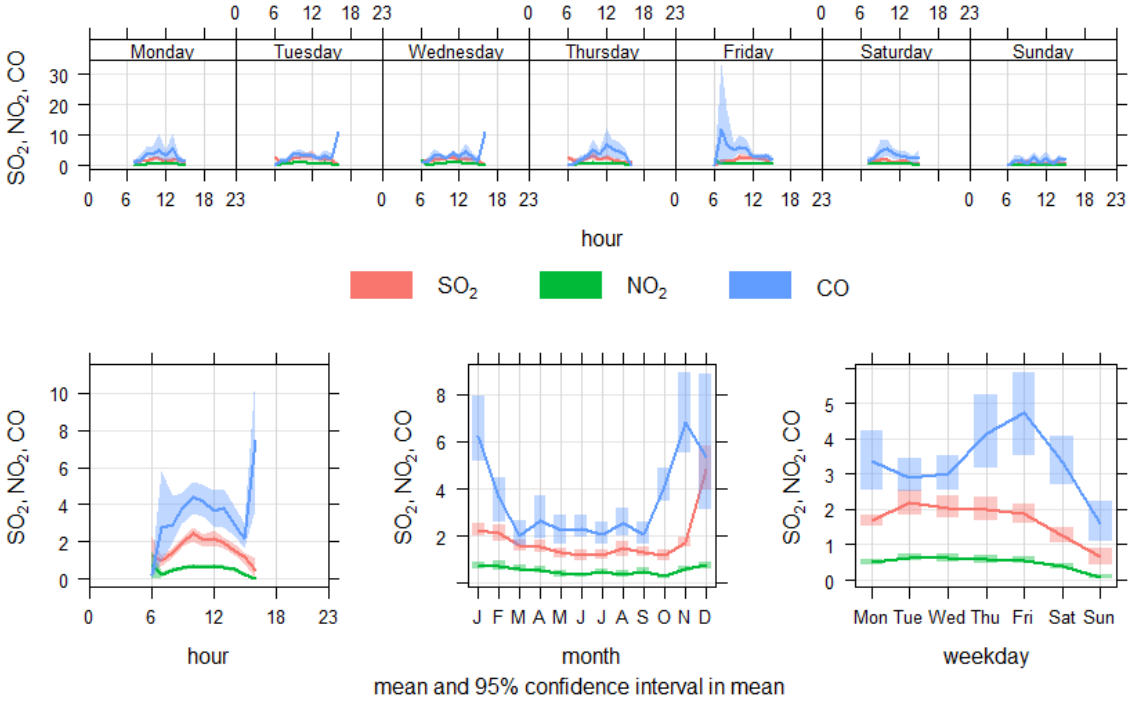


Fig. 6. Temporal variations of SO_2, NO_2 and CO concentrations

from Fig. 6, SO_2, NO_2 and CO show high concentrations in the months of dry season (January, February, March, November and December) compared to the months of rainy season. It can be seen from Fig. 7 that the concentrations of O_3 increase steadily from 6:00am in the morning to a peak around 1:00pm and then decreases towards 4:00pm in the evening; NH_3 concentrations increase from 6:00am peak around 8:00am and then decrease monotonically toward evening time. The concentrations of TVOC tend increase from 6:00am to a peak around 2:00pm and then decrease toward evening (around 4:00pm). O_3, NH_3, and TVOC show high concentrations in the months of January and December. Similarly, Fig. 8 shows that the concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) tend to increase to a peak around 7:00am and then decrease monotonically toward evening time (around

4:00pm). Particulate matter shows high concentrations in the months of dry season compared to the months of rainy season. This is expected because of the dry harmattan dust that dominates the dry season as well as atmospheric wash-out that occurs due to heavy precipitation in the rainy season period [19].

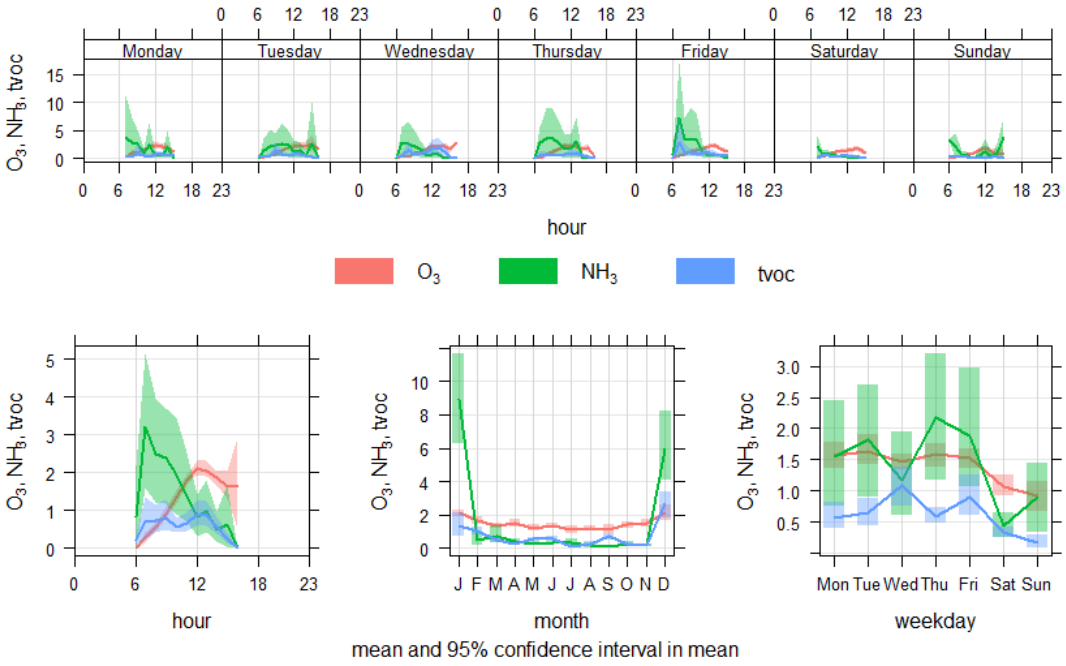


Fig. 7. Temporal variations of O_3, NH_3 and TVOC concentrations

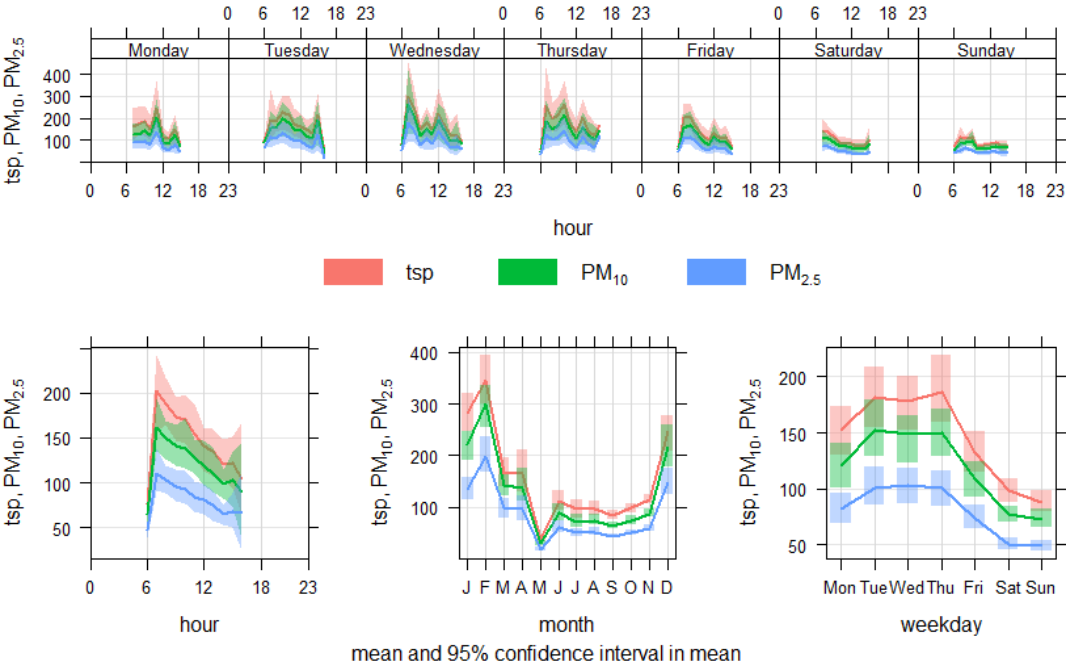


Fig. 8. Temporal variations of TSP, PM_{10} and $PM_{2.5}$ concentrations

The temporal variability plots in Figs. 6 to 8 indicated that the air pollutant concentrations show pronounced difference in temporal trends during the days of the week. Generally, the temporal variations of the air pollutants showed high concentrations from Monday to Friday and low concentrations on Saturday and Sunday. It can also be observed from the figures that concentrations of air pollutants tend to increase during the weekdays when human activities are high and decrease during weekends when human activities are low. This finding corroborated the finding of [22] in a study carried out in Krakow, Poland. This indicates that the concentrations of air pollutants in the study area are higher during weekdays compared to weekends, implying that human activities such as domestic, commercial, agricultural, transportation, industrial and artisanal oil refining taking place during week days are the potential sources of air pollution in Ogoni area [23-25].

4. CONCLUSION

The study found high level of air pollution in Ogoni area, which poses hazards to public health. This study provided a good understanding of the temporal variability and trend in air pollutants of Ogoni area. Air pollutant concentrations were found to be higher in the months of dry season and lower in the months of rainy season. The temporal variability of air pollutant concentrations showed a pronounced difference in temporal trends during the days of the week. Generally, concentrations of air pollutants showed increase during the weekdays when human activities are high and decrease during weekends when human activities are low. It is concluded that human activities are the potential sources of air pollution in the area. Therefore, further studies are required to determine air pollutant dispersion pattern based on the meteorological conditions of the area, and to evaluate the potential sources of air pollution in the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DOI:IJDS17071701

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/76321